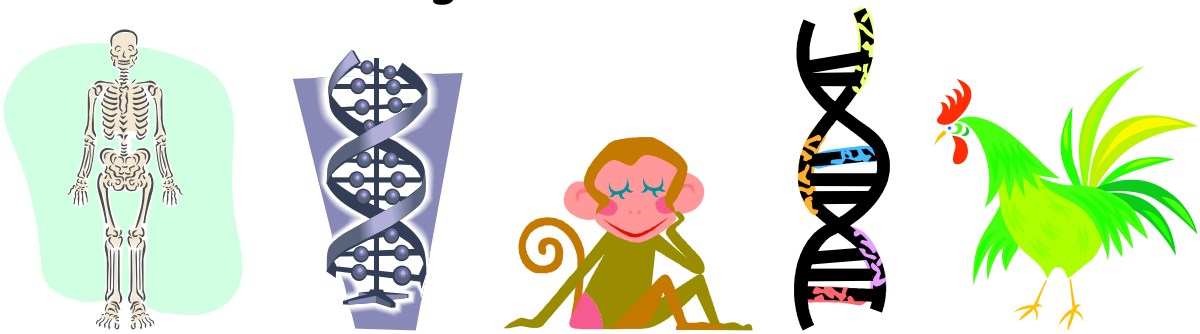
Name:_____Date:_____Block:__

Cladograms and Genetics



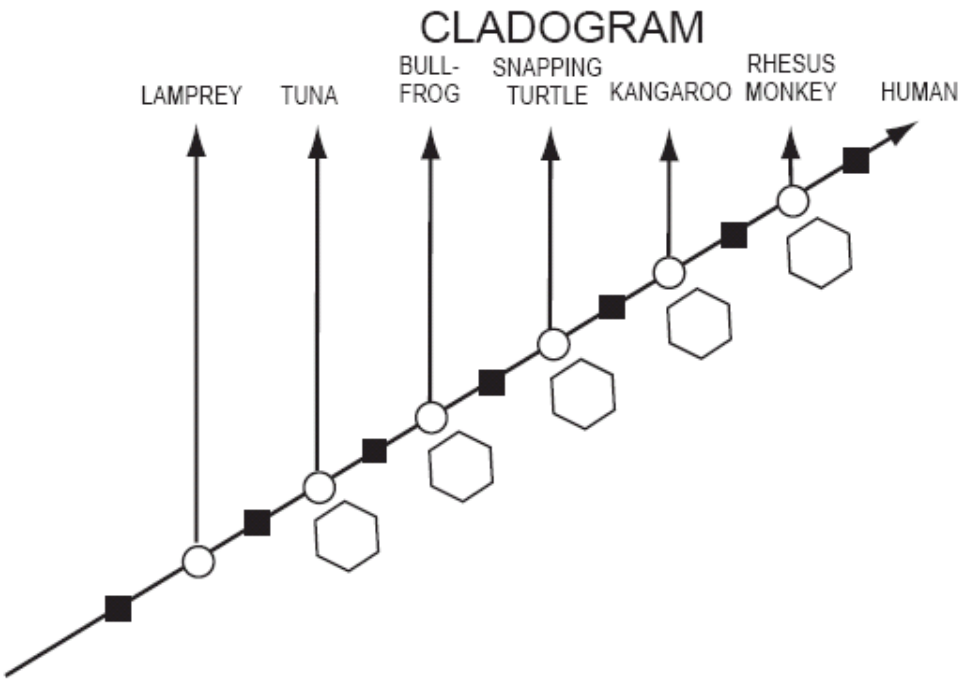
1. Find the human, rhesus monkey, kangaroo, snapping turtle, bullfrog, and tuna on the "Amino Acid Sequences in Cytochrome-C Proteins from 20 Different Species" chart provided. Highlight their entire protein sequences.

2. Compare the human amino acid sequence with each of these five animals. Do this by counting the number of times an amino acid in that animal's protein is different from the same amino acid position of the human sequence. Write that information in the table below.

Number of amino acid differences between human and …

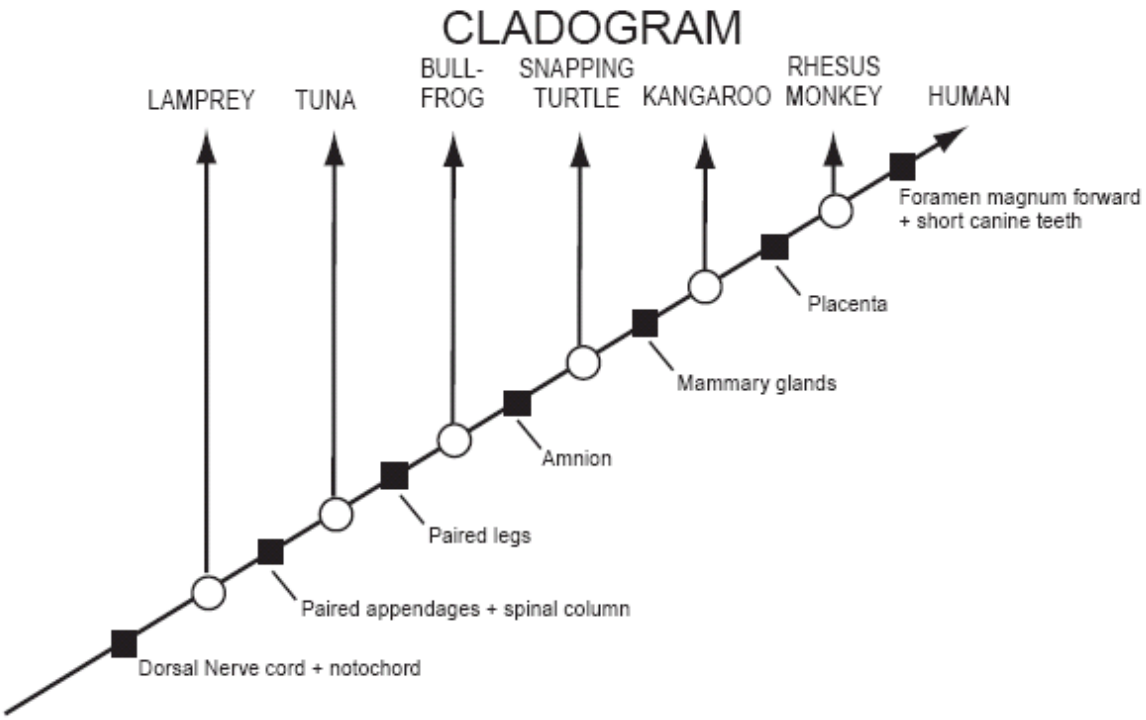
Rhesis Monkey	
Kangaroo	
Snapping Turtle	
Bull Frog	
Tuna Fish	

3. Record the total number of amino acid differences between humans and each animal shown on the cladogram on the next page. Write your answer in the hexagon below the arrow pointing to the name of that animal.



This cladogram is organized using genetic information.

4. Are these organisms in the correct order according to the genetic information?



This cladogram is organized using anatomical (body) features.

5. Does the cladogram organized by genetic information agree with the cladogram organized by anatomical features? Why or why not?

6. Do organisms with fewer anatomical traits in common also have fewer amino acids in common?

7. Based on the cladogram organized by genetic information, how does the "human-monkey" relationship compare to the "duck-chicken" relationship (which shows more amino acid differences)?

8. If the genetic information, the anatomical similarities, and the fossil record all support the same pattern of relationships, can we be fairly confident that the pattern is accurate? Why or why not?

9. Chickens and turkeys are both birds and have the same sequence of amino acids in their cytochrome-c protein. Explain how two species can have identical cytochrome-c and still be different species.

10. Neurospora (bread mold) and Saccharomyces (bakers yeast) are both fungi. Chickens and turkeys are both birds. Who is more closely related, both fungi or both birds? Use the cladograms to explain your reasoning.

11. Write a short paragraph summarizing the important information that can be obtained from cladograms (not the information used to make them).

AMINO ACID SEQUENCES IN CYTOCHROME-C PROTEINS FROM 20 DIFFERENT SPECIES

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                                        10        20        30        40        50
Amino Acid Number----> 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
Human ..... - - - - - - - - - G D V E K G K K I F I M K C S Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A P G Y S Y T A A
Rhesus monkey..... - - - - - - - - - G D V E K G K K I F I M K C S Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A P G Y S Y T A A
Horse ..... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A P G F T Y T D A
Pig, cow, sheep... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A P G F S Y T D A
Dog..... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A P G F S Y T D A
Gray whale ..... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A V G F S Y T D A
Rabbit..... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A V G F S Y T D A
Kangaroo..... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T V E K G G K H K T G P N L N G I F G R K T G Q A P G F T Y T D A
Chicken, Turkey... - - - - - - - - - G D I E K G K K I F V Q K C S Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A E G F S Y T D A
Penguin..... - - - - - - - - - G D I E K G K K I F V Q K C S Q C H T V E K G G K H K T G P N L H G I F G R K T G Q A E G F S Y T D A
Pekin duck..... - - - - - - - - - G D V E K G K K I F V Q K C S Q C H T V E K G G K H K T G P N L H G L F G R K T G Q A E G F S Y T D A
Snapping turtle... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T V E K G G K H K T G P N L N G L I G R K T G Q A E G F S Y T E A
Bullfrog..... - - - - - - - - - G D V E K G K K I F V Q K C A Q C H T C E K G G K H K V G P N L Y G L I G R K T G Q A A G F S Y T D A
Tuna..... - - - - - - - - - G D V A K G K K T F V Q K C A Q C H T V E N G G K H K V G P N L W G L F G R K T G Q A E G Y S Y T D A
Screwworm fly..... - - - - G V P A G D V E K G K K I F V Q R C A Q C H T V E A G G K H K V G P N L H G L F G R K T G Q A A G F A Y T N A
Silkworm moth..... - - - - G V P A G N A E N G K K I F V Q R C A Q C H T V E A G G K H K V G P N L H G F Y G R K T G Q A P G F S Y S N A
Wheat ..... A S F S E A P P G N P D A G A K I F K T K C A Q C H T V D A G A G H K Q G P N L H G L F G R Q S G T T A G Y S Y S A A
Fungus (Neurospora) - - - - G F S A G D S K K G A N L F K T R C A E C H G E G G N L T Q K I G P A L H G L F G R K T G S V D G Y A Y T D A
Fungus (baker's yeast) - - - T E F K A G S A K K G A T L F K T R C E L C H T V E K G G P H K V G P N L H G I F G R H S G Q A Q G Y S Y T D A
Fungus (Candida) - - P A P F E 0 G S A K K G A T L F K T R C A E C H T I E A G G P H K V G P N L H G I F S R H S G Q A Q G Y S Y T D A
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[CONTINUED FROM ABOVE]

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                                        60        70        80        90        100       110
Amino Acid Number----> 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2
Human .....N K N K G I I W G E D T L M E Y L E N P K K Y I P G T K M I F V G I K K K E E R A D L I A Y L K K A T N E
Rhesus monkey.....N K N K G I T W G E D T L M E Y L E N P K K Y I P G T K M I F V G I K K K E E R A D L I A Y L K K A T N E
Horse .....N K N K G I T W K E E T L M E Y L E N P K K Y I P G T K M I F A G I K K K T E R E D L I A Y L K K A T N E
Pig, cow, sheep...N K N K G I T W G E E T L M E Y L E N P K K Y I P G T K M I F A G I K K K G E R E D L I A Y L K K A T N E
Dog.....N K N K G I T W G E E T L M E Y L E N P K K Y I P G T K M I F A G I K K T G E R A D L I A Y L K K A T K E
Gray whale.....N K N K G I T W G E E T L M E Y L E N P K K Y I P G T K M I F A G I K K K G E R A D L I A Y L K K A T N E
Rabbit.....N K N K G I T W G E D T L M E Y L E N P K K Y I P G T K M I F A G I K K K D E R A D L I A Y L K K A T N E
Kangaroo.....N K N K G I I W G E D T L M E Y L E N P K K Y I P G T K M I F A G I K K K G E R A D L I A Y L K K A T N E
Chicken, Turkey...N K N K G I T W G E D T L M E Y L E N P K K Y I P G T K M I F A G I K K K S E R V D L I A Y L K D A T S K
Penguin.....N K N K G I T W G E D T L M E Y L E N P K K Y I P G T K M I F A G I K K K S E R A D L I A Y L K D A T S K
Pekin duck.....N K N K G I T W G E D T L M E Y L E N P K K Y I P G T K M I F A G I K K K S E R A D L I A Y L K D A T A K
Snapping turtle...N K N K G I T W G E E T L M E Y L E N P K K Y I P G T K M I F A G I K K K A E R A D L I A Y L K D A T S K
Bullfrog.....N K N K G I T W G E D T L M E Y L E N P K K Y I P G T K M I F A G I K K K G E R Q D L I A Y L K S A C S K
Tuna.....N K S K G I V W N N D T L M E Y L E N P K K Y I P G T K M I F A G I K K K G E R Q D L V A Y L K S A T S -
Screwworm fly.....N K A K G I T W Q D D T L F E Y L E N P K K Y I P G T K M I F A G L K K P N E R G D L I A Y L K S A T K -
Silkworm moth.....N K A K G I T W G D D T L F E Y L E N P K K Y I P G T K M V F A G L K K A N E R A D L I A Y L K E S T K -
Wheat .....N K N K A V E W E E N T L Y D Y L L N P K K Y I P G T K M V F P G L K K P Q D R A D L I A Y L K K A T S S
Fungus 1 (Neurospora) N K Q K G I T W D E N T L F E Y L E N P K K Y I P G T K M A F G G L K K D K D R N D I I T F M K E A T A -
Fungus 2 (bkrs yeast) N I K K N V L W D E N N M S E Y L T N P K K Y I P G T K M A F G G L K K E K D R N D L I T Y L K K A C E -
Fungus 3 (Candida) N K R A G V E W A E P T M S D Y L E N P K K Y I P G T K M A F G G L K K A K D R N D L V T Y M L E A S K -
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AMINO ACID SYMBOLS

- A = Alanine
- C = Cysteine
- D = Aspartic acid
- E = Glutamic acid
- F = Phenylalanine
- G = Glycine
- H = Histidine
- I = Isoleucine
- K = Lysine
- L = Leucine
- M = Methicnine
- N = Asparagine
- P = Proline
- Q = Glutamine
- R = Arginine
- S = Serine
- T = Threonine
- V = Valine
- W = Tryptohpan
- Y = Tyrosine

Symbols in light blue or gray represent amino acids which show NO differences in any organism on the list, so you can ignore them.

(adapted from Strahler, Arthur, *Science & Earth History*, 1987, p. 348)