

The Molecular Connection

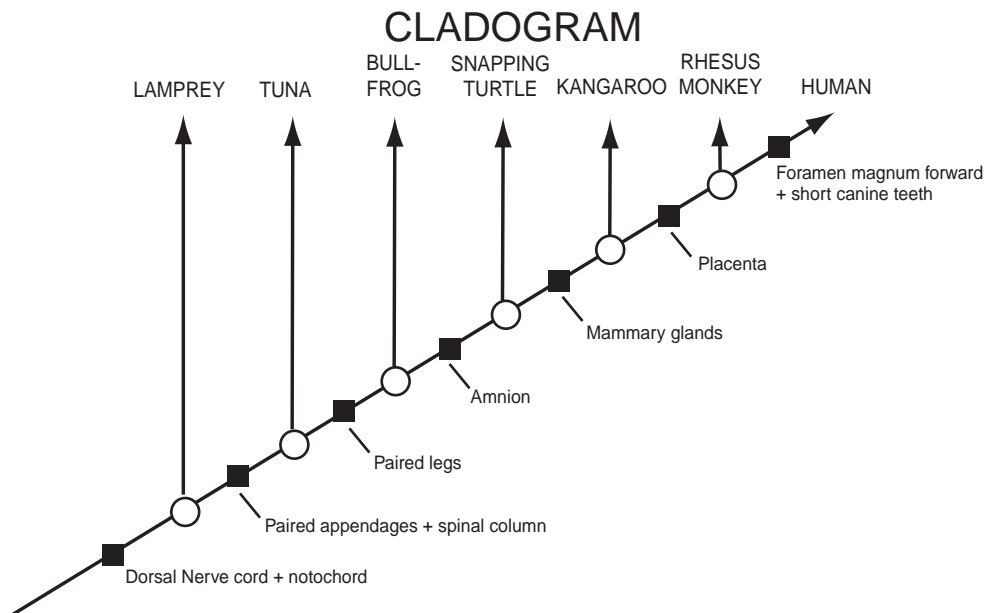
1. Find the human, rhesus monkey, kangaroo, snapping turtle, bullfrog, and tuna on the "Amino Acid Sequences in Cytochrome-C Proteins from 20 Different Species" chart provided and underline their names.
2. Compare the human amino acid sequence with each of these five animals by counting the number of times an amino acid in that animal's cytochrome c is different from the amino acid in that same position of the human sequence. For example, the number of differences between human and dog=10.

Write that information below:

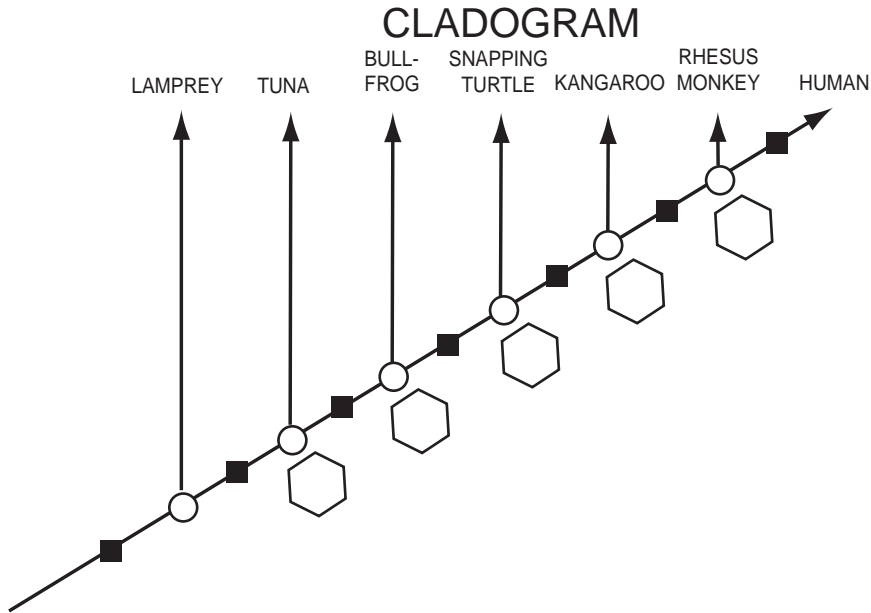
Number of amino acid differences between human and

- Rhesus monkey=
- Kangaroo=
- Snapping turtle=
- Bullfrog=
- Tuna=

3. The cladogram diagram below shows the relationship of selected animals based on their shared anatomical features. For example, out of seven key traits, all of these animals have a dorsal nerve cord, but only humans, monkeys and kangaroos have mammary glands.



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



4. Does the data from the amino acid sequence generally agree with the anatomical data that was used to make the cladogram?

5. Do organisms with fewer shared anatomical traits also have more amino acid differences?

6. Based on the molecular data, how does the "human-monkey" relationship compare to the "duck-chicken" relationship (which shows three amino acid differences)?

7. If the molecular data, the structural 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?

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

	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 Y S 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 Y 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 Y 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 P G Y 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 P G Y 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 H G L F G R K T G Q A P G Y S 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 L 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 H G L F 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 L 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 K T G 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 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				

[CONTINUED FROM ABOVE]

	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					
Human	...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 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 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 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 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 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 K 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 K 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 K 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 K 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 K A C S K					
Tuna	...N K S K G I V 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 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 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 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 (bakers yeast)	N I 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 A K D R N D L V T Y M L E A S K -					

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 = Methionine
N = Asparagine
P = Proline
Q = Glutamine
R = Arginine
S = Serine
T = Threonine
V = Valine
W = Tryptophan
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)