

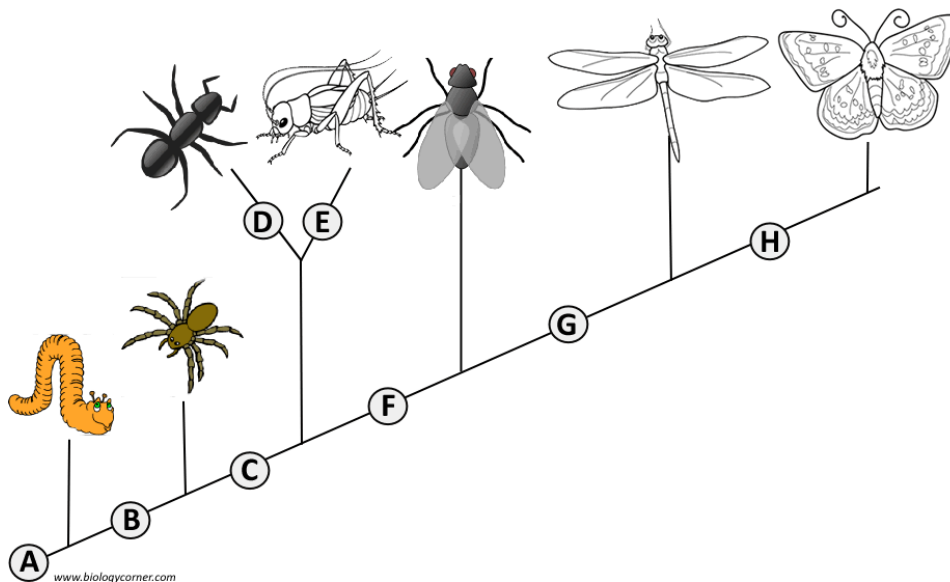
What is a cladogram? It is a diagram that depicts evolutionary relationships among groups. It is based on **PHYLOGENY**, which is the study of evolutionary relationships. Sometimes a cladogram is called a phylogenetic tree (though technically, there are minor differences between the two).

In the past, biologists would group organisms based solely on their physical appearance. Today, with the advances in genetics and biochemistry, biologists can look more closely at individuals to discover their pattern of evolution, and group them accordingly - this strategy is called **EVOLUTIONARY CLASSIFICATION**

CLADISTICS is form of analysis that looks at features of organisms that are considered "innovations", or newer features that serve some kind of purpose. (Think about what the word "innovation" means in regular language.) These characteristics appear in later organisms but not earlier ones and are called **DERIVED CHARACTERS**.

PART I - Analyze the Cladogram

Examine the sample cladogram, each letter on the diagram points to a derived character, or something different (or newer) than what was seen in previous groups. Match the letter to its character. *Note: this cladogram was created for simplicity and understanding, it does not represent the established phylogeny for insects and their relatives*



1. ____ Wings
2. ____ 6 Legs
3. ____ Segmented Body
4. ____ Double set of wings
5. ____ Jumping legs
6. ____ Crushing mouthparts
7. ____ Legs
8. Curly antennae

PART II - Create Your Own Cladogram

To make a cladogram, you must first look at the animals you are studying and establish characteristics that they share and ones that are unique to each group. For the animals on the table, indicate whether the characteristic is present or not. Based on that chart, create a cladogram like the one pictured above

	Cells	Backbone	Legs	Hair	Opposable Thumbs
Slug					
Catfish					
Frog					
Tiger					
Human					

DRAWING OF YOUR CLADOGRAM

Convert the following data table into a Venn diagram, and then into a cladogram:

Characters	Sponge	Jellyfish	Flatworm	Earthworm	Snail	Fruitfly	Starfish	Human
Cells with flagella	X	X	X	X	X	X	X	X
Symmetry		X	X	X	X	X	X	X
Bilateral symmetry			X	X	X	X	(X)	X
Mesoderm				X	X	X	X	X
Head develops first				X	X	X		
Anus develops first							X	X
Segmented body				X		X		
Calcified shell					X			
Chitinous exoskeleton						X		
Water-vascular system							X	
Vertebrae								X

Venn diagram

Cladogram

The Molecular Connection

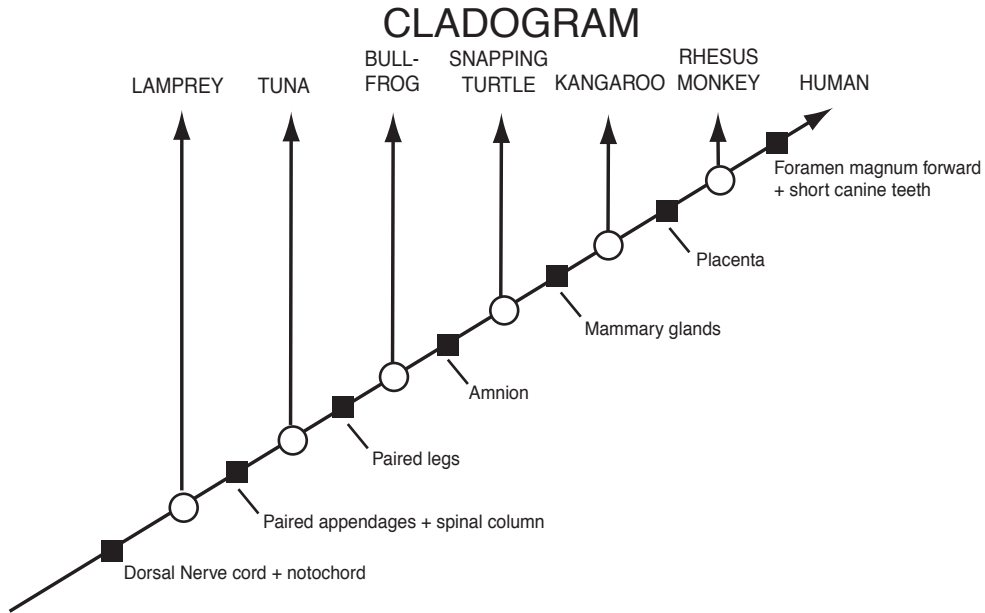
1. Find the human, rhesus monkey, kangaroo, snapping turtle, bullfrog, and tuna on the "Amino Acid Sequences in Cytochrome-C Proteins from 20 Different Species" chart provided and underline their names.
2. Compare the human amino acid sequence with each of these five animals by counting the number of 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:

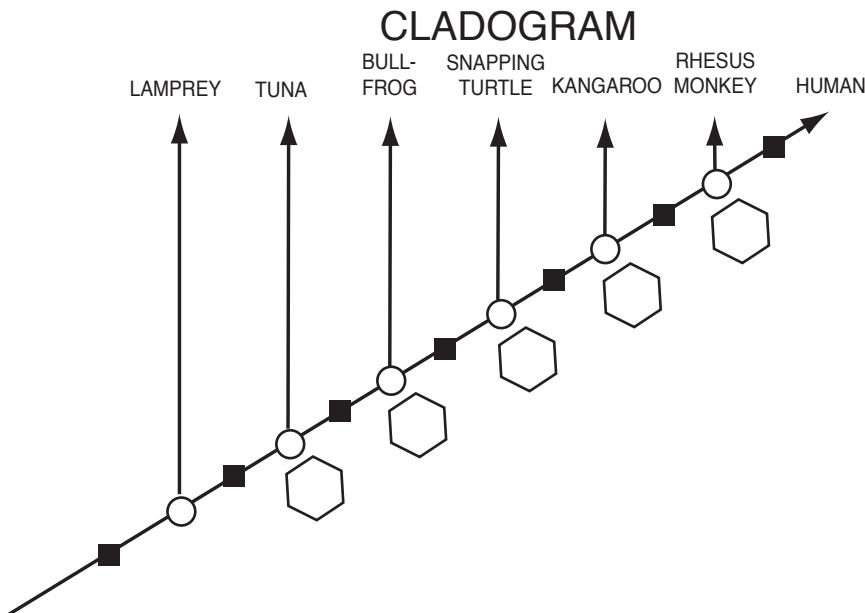
Number of amino acid differences between human and

- 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)?

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 K H K T G P N L H G L F G R K T Q A 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 K H K T G P N L H G L F G R K T Q A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A A				
Bullfrog.....	--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 K H K T G P N L H G L F G R K T Q A A P G Y S Y T A A				
Tuna.....	--G D V A K G K K T F V Q K C A Q C H T V E A G G K K H K V G P N L H G L F G R K T Q A A P G Y S Y T A 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 K H K V G P N L H G L F G R K T Q A A P G Y S Y T A A				
Silkworm moth.....	--G V P A G A E N G K K I F V Q R C A Q C H T V E A G G K K H K V G P N L H G L F G R K T Q A A P G Y S Y T A 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 Q Q G P N L H G L F G R K T G S V D G Y A Y T D A				
Fungus (Neurospora)	--G F S A G D S K K G A T L F K T R C A E C H G E G N L T Q 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 L F G R H S G Q A A 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 L F S R H S G Q A 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 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 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 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 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 K D A T S K					
Pekin duck.....	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 S E R A D L I A Y L K 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 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 Q 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 P 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 L K K D K D R N D I I T F M K E A T A -					
Fungus 2 (baks 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 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 L K K A K D R N D L V T Y M L E A S K -					

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)

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