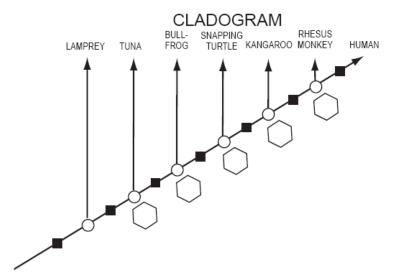
Cladograms and Genetics

- 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 ...

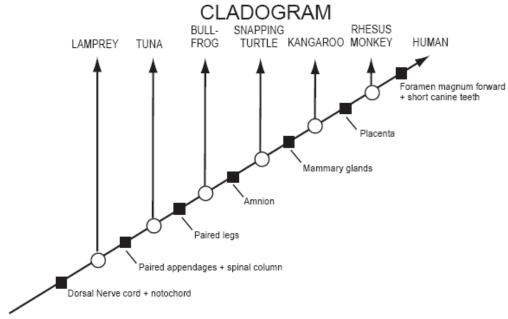
Rhesis Monkey	
Kangaroo	
Snapping Turtle	
Bull Frog	
Tuna Fish	

3. Record the total number of amino acid differences between humans and each animal shown on the cladogram below. Write your answer in the hexagons 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.	
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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

	9 8 2	YTAA	YTAA	YTDA	YTDA	YTDA	YTDA	YTDA	YTDA	YTDA	YTDA	YTDA	Y T E A	YTDA	Y T D A	YTNA	Y S N A	YSAA	YTDA	YTDA	ATDA
	3456	G Y S	PGYS	T I	S F	G F S	G F S	VGFS	PGFT	EGFS	BGFS	EGFS	EGFS	AGFS	EGYS	G F A	PGFS	G Y S	GYA	G Y S	S V S
20	9012	GQAP	GOA	GOAP	GOAP	GQAP	GQAV	G Q A	G Q A	G Q A	G Q A	G Q A	Q Q	G Q A	G Q A	GQAA	G Q A	GTTA	GSVD	GOAQ	4 0
	5678	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GRKT	GROS	GRKT	GRHS	OHOO
	234	H G L F	H G L F	H G L F	H G L F	н съ	H G L F	H G L F	NGIF	H G L F	H G I F	H G L F	NGLI	YGLI	WGLF	H G L F	н G Р Y	H G L F	H G L F	H G I F	0 T
40	8901	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PNL	PAL	PNL	D M T. H
	4567	HKTG	HKTG	HKTG	HKTG	HKTG	HKTG	HKTG	HKTG	HKTG	HKTG	HKTG	HKTG	HKVG	HKVG	HKVG	HKVG	HKQG	QKIG	HKVG	DAMAR
30	0 1 2 3	K G G K	KGGK	K G G K	KGGK	K G G K	K G G K	K G G K	K G G K	KGGK	K G G K	KGGK	K G G K	KGGK	NGGK	A G G K	AGGK	AGAG	GNLT	K G G P	0 0 0
e	7 8 9	TVE	HTVE	TVE	HTVE	HTVE	HTVE	HTVE	HTVE	HTVE	HTVE	HTVE	HTVE	HICE	HTVE	HTVE	HTVE	TVD	HGEG(TVE	Ε Ε
	3456	SQCH	SQC	AQCH	AQCE	AQCE	AQCE	AQC	AQC	0 0 8	000	S	AQC	AQC	AQC	AQC	AQC	AQCH	AECE	BLCH	0 0 0
20	9012	IMKC	IMKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQKC	VQRC	VQRC	KTKC	KTRC	KTRC	0 11 14
	5678	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKIF	KKTF	KKIF	KKIF	AKIF	ANLF	ATLF	E + E
	901234		GDVEKG	GDVEKGI	EK	EKG	GDVEKGI	EKG	B K G	E K	BKG	FKG	K G	Ö	AKG		AENG	Ü	KKG	KKG	
10	8901	- GDVEKG	- G D 1	- G D V	- G D V	- G D V	- G D V	- G D V	- G D V	- G D I	- G D 1	- G D 7	- GDVE	- GDVEK	- G D V	GVPAGDVEKG	A G N	BAPPGNPDA	AGDS	AGSA	6000
t	4567															- G V P	- G V P		- GFS	TEFK	
	123	:			1 1						1			1				ASFS	!		6
	ober>		ұе	:	neep	:	:	:	:	rkey	:	:	rtle	:	:	Y	тр	:	spora)	yeast)	301
	Amino Acid Number> 1 2 3 4 5 6 7 8	Human	Rhesus monkey	Horse	Pig, cow, sheep	Dog	Gray whale	Rabbit	Kangaroo	Chicken, Turkey	Penguin	Pekin duck	Snapping turtle	Bullfrog	Tuna	Screwworm fly	Silkworm moth	Wheat	Fungus (Neurospora)	Fungus (baker's yeast)	Throng (Candida)
	Amino	Human	Rhesu	Horse	Pig,	Dog	Gray	Rabbi	Kanga	Chick	Pengu	Pekin	Snapp	Bullf	Tuna.	Screw	Silkw	Wheat	Fungus	Fungus	5

[CONTINUED PROM ABOVE]				
60 70	08	90 100	110	AMINO ACID SYMBOLS
Amino Acid Number> 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4	567890123456	78901234567890123	456789012	A = Alanine
HumanNKNKGIIWGEDTLMBYLE	LENPKKYIPGT	KMIFVGIKKKBBRADLI	AYLKKATNE	C = Cysteine
Rhesus monkeyNKNKGITWGEDTLME	YLENPKKYIPGT	KMIFVGIKKKBBRADLI	AYLKKATNE	D = Aspartic acid
HorseNKNKGITWKEETLME	YLENPKKYIPGT	KMIFAGIKKKTEREDLI	AYLKKATNE	E = Glutamic acid
Pig, cow, sheepNKNKGITWGERTLME	YLENPKKYIPGI	KMIFAGIKKKGBRBDLI	AYLKKATNE	F = Phenylalanine
DogN KNKGITWGEETLME	YLENPKKYIPGI	KMIFAGIKKTGERADLI	AYLKKATKE	G = Glycine
Gray whale NKNKGITWGEETLME	YLENPKKYIPGT	KMIFAGIKKKGERADLI	AYLKKATNE	H = Histidine
RabbitNKNKGITWGEDTLME	YLENPKKYIPGT	KMIFAGIKKKDERADLI	AYLKKATNE	I = Isoleucine
KangarooNKNKGIIWGEDTLME	Y L E N P K K Y I P G T	KMIFAGIKKKGERADLI	AYLKKATNE	K = Lysine
Chicken, TurkeyNKNKGITWGEDTLME	YLENPKKYIPGT	KMIFAGIKKKSBRVDLI	AYLKDATSK	L = Leucine
PenguinNKNKGITWGEDTLME	YLENPKKYIPGT	KMIFAGIKKKSERADLI	AYLKDATSK	M = Methionine
Pekin duckNKNKGITWGEDTLME	YLENPKKYIPGT	KMIFAGIKKKSBRADLI	AYLKDATAK	N = Asparagine
Snapping turtleNKNKGITWGEETLME	YLENPKKYIPGT	KMIFAGIKKKAERADLI	AYLKDATSK	P = Proline
BullfrogNKNKGITWGEDTLME	YLENPKKYIPGT	KMIFAGIKKKGBRQDLI	AYLKSACSK	Q = Glutamine
TunaNKSKGIVWNDTLME	YLENPKKYIPGT	KMIFAGIKKKGERQDLV	AYLKSATS -	R = Arginine
Screwworm flyNKAKGITWQDDTLPE	YLENPKKYIPGT	KMIFAGLKKPNERGDLI	AYLKSATK-	S = Serine
Silkworm mothN KAKGITWGDDTLFE	YLENPKKYIPGT	KMVFAGLKKANERADLI	AYLKESTK -	T = Threonine
WheatNKNKAVEWEENTLYD	YLLNPKKYIPGT	KMVFPGLKKPQDRADLI	AYLKKATSS	V = Valine
Fungus 1 (Neurospora) N K Q K G I T W D B N T L F B	YLENPKKYIPGT	KMAFGGLKKDKDRNDII	TFMKBATA -	W = Tryptohpan
Fungus 2 (bkrs yeast) NIKKNVLWDENNMSE)	YLTNPKKYIPGT	KMAFGGLKKEKDRNDLI	TYLKKACE -	Y = Tyrosine
Fungus 3 (Candida) NKRAGVEWABPTMSD	YLENPKKYIPGT	KMAFGGLKKAKDRNDLV	TYMLBASK-	

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)