Predicting Evolutionary Relationships

On the surface, mushrooms and monkeys don't seem to have much in common. But at the genetic level, these two organisms aren't so different after all. Monkeys, mushrooms, and just about all other living creatures have a gene that codes for a protein called Cytochrome C, which plays a central role in releasing energy from food. Genes and proteins that govern such basic survival functions tend to be shared by many organisms, making them an ideal tool for scientists who want to learn more about relationships among species. In this activity, you will use Cytochrome C data to predict evolutionary relationships between humans and six other species.

Procedure

1 Brainstorm some of the similarities and differences between humans and each of the organisms below. What are some of the criteria scientists might use to determine how closely related, in evolutionary time, two organisms are? Discuss with a partner and share your ideas with the class.

2 Predict how recently humans shared a common ancestor with each organism listed below. Write your predictions in a paragraph and explain your reasoning, including the criteria you discussed in Step 1 above. Consider features that humans share with each organism, as well as ways in which humans differ from each one.

3 Compare the Cytochrome C amino acid sequence in humans to each of the organisms listed below. You will find amino acid data on the *Amino Acids in the Protein Cytochrome C* table on the next page. For each organism, circle each amino acid that differs from the human sequence.

   Note: "*" indicates an amino acid that is missing in some species. In places where one species has "*" and the other has a letter, count that as a difference.

4 Write down the number of differences between a human and a:

   tuna _____

   gray whale _____

   snapping turtle _____

   rhesus monkey _____

   chicken/turkey _____

   Neurospora (a type of bread mold) _____

Questions

Write your answers on a separate sheet of paper.

1 Based on the amino acid sequence data you collected, which organism are humans most closely related to? Which organisms are humans most distantly related to? Explain your reasoning.

2 What additional data or information might help you confirm the statement you made above?

3 Does your answer to Question 1 above match the prediction you made in Step 2 of the Procedure? Explain your answer.

4 Explain how amino acid sequence data can help scientists infer patterns of evolutionary relationships between species.

WHO'S MY CLOSEST RELATIVE?

According to evolutionary theory, species that recently shared a common ancestor have more similarities in their DNA than ones that last shared a common ancestor long ago. By comparing the order of amino acids that make up the protein Cytochrome C and noting the differences in the arrangement, scientists can infer relationships among species. In general, the more amino acids two species share, the more closely related they are in evolutionary time.

Amino Acids in the Protein Cytochrome C

Note: letters in boldface represent amino acids that are identical in all species. Asterisks represent positions that do not have an amino acid present, so when comparing two species' sequences, count as a difference any position in which one species has a letter and the other has an asterisk.

Amino Acid Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56 →
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**
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**
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**
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**
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**
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**
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**
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**
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**
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**
Candida	*	*	P	A	P	F	E	O	**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**
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**

→	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
Human	T	A	**A**	**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
Tuna	T	D	**A**	**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	*
Gray whale	T	D	**A**	**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
Snapping turtle	T	E	**A**	**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
Rhesus monkey	T	A	**A**	**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
Chicken, Turkey	T	D	**A**	**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
Neurospora	T	D	**A**	**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	*
Pig, cow, sheep	T	D	**A**	**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
Baker's yeast	T	D	**A**	**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	*
Silkworm moth	S	N	**A**	**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	*
Candida	T	D	**A**	**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	*
Screwworm fly	T	N	**A**	**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	*

Amino Acid Symbols

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