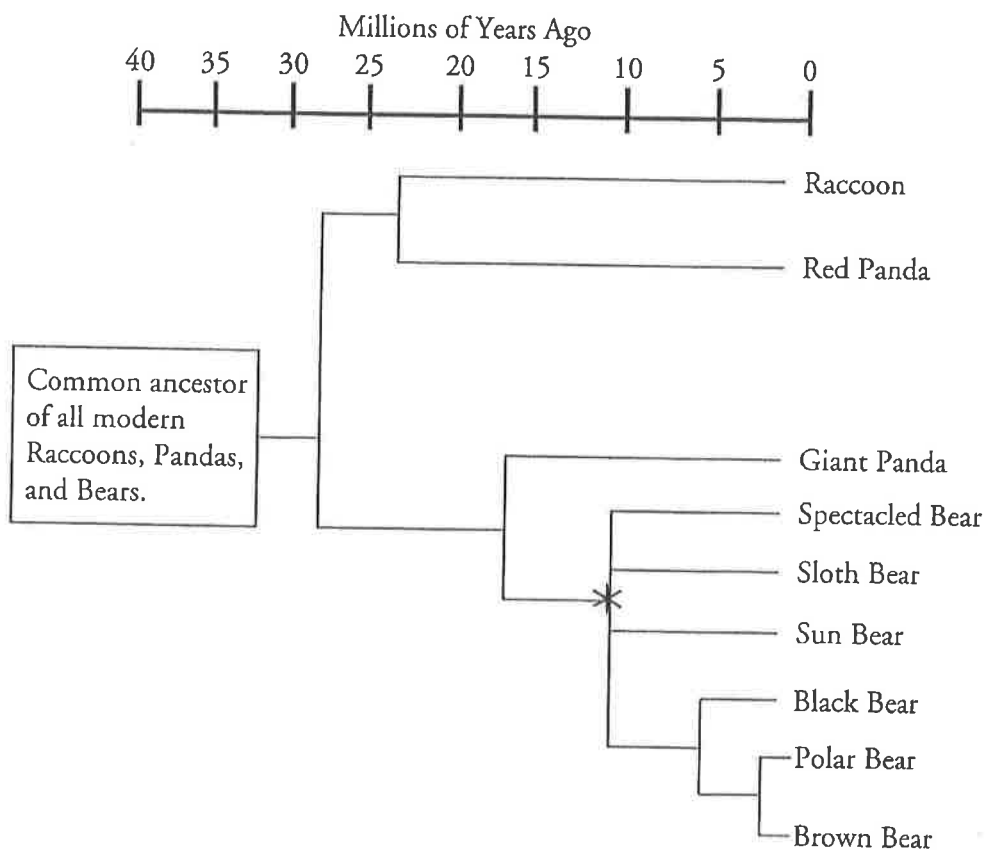# Phylogenetic Trees

How do the changes in gene sequences allow us to reconstruct
the evolutionary relationships between related species?

Why?

The saying "Don't judge a book by its cover." could be applied to the topic of evolution. For example, humans share 75% of their DNA with chickens. Biologists point to this as evidence that humans and chickens once shared a common ancestor. The advent of DNA technology has given scientists the tools with which to examine how closely related certain species are. DNA analysis allows scientists to construct phylogenetic trees whose branches link together the relatedness of different organisms.

Model 1 – Phylogenetic Trees

1. Refer to Model 1.

   a. How long ago did the common ancestor of all the organisms on this phylogenetic tree exist?

   40 million years ago.

   b. Which two lines diverged 30 million years ago?

   The Raccoon and Red Panda line diverged from the Bear line about 30 million years ago.

   c. List all modern descendants of the organism that was alive at the point indicated by the asterisk.

   Spectacled, Sloth, Sun, Black, Polar, and Brown bears.

2. According to Model 1, when did the Giant Panda line diverge from the line that led to modern bears?

15–20 million years ago.

3. According to Model 1, what animal shares the most recent common ancestor with the Brown Bear?

The Polar Bear.

4. In a complete sentence, describe what the branch points and lines in a phylogenetic tree represent.

The branch points are the most recent common ancestor and the lines represent the species that diverged from the common ancestor and how long ago the divergence occurred.

5. Which of the two branches from the common ancestor in Model 1 has the most living descendants?

The branch that leads to the bears.

6. According to the phylogenetic tree in Model 1, the Red Panda is most closely related to which animal?
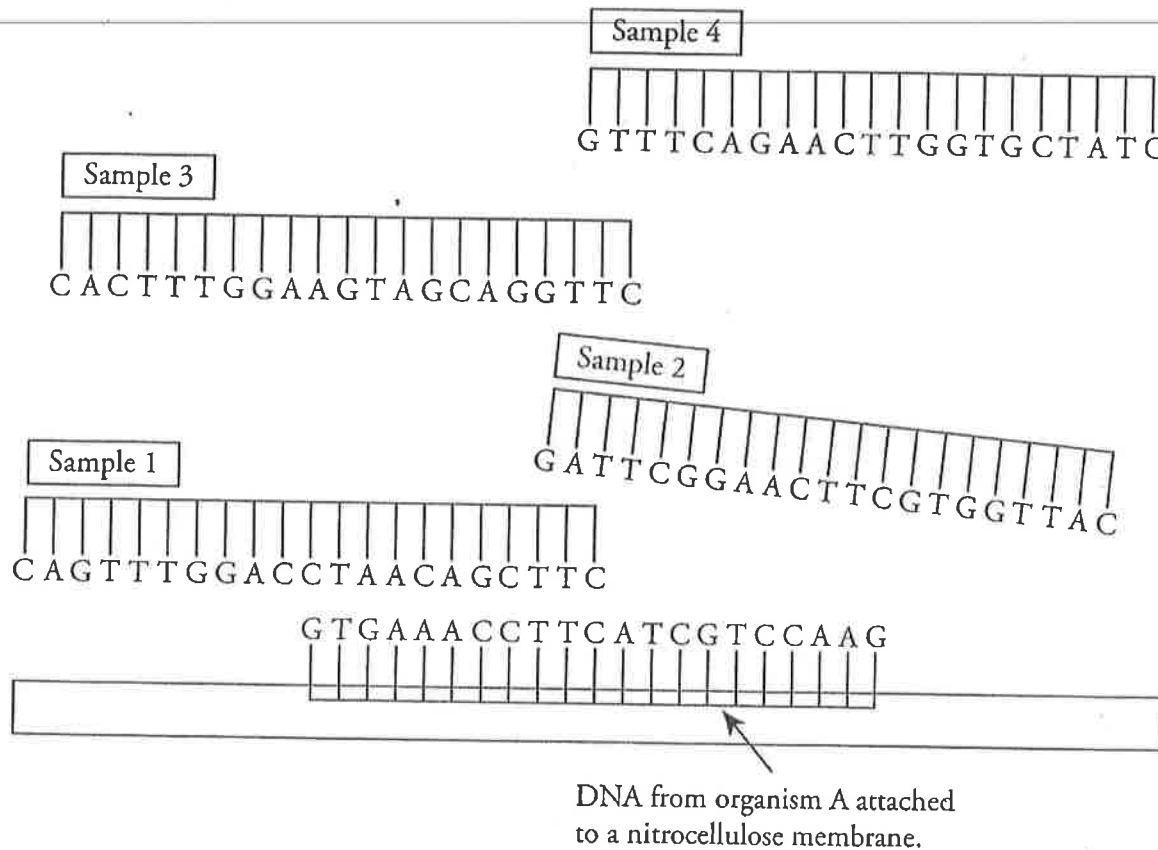
The Raccoon.

7. Which are more closely related, the Giant Panda and the Red Panda or the Giant Panda and the Polar Bear? Justify your answer using grammatically correct sentences.

The Giant Panda and Polar Bear because they share a more recent common ancestor (~20 million years ago) compared to the Giant Panda and Red Panda (~35 million years ago).

STOP

Model 2 – DNA Sample Comparison

Sample 4

GTTTCAGAACTTGGTGCTATC

Sample 3

CACTTTGGAAGTAGCAGGTTC

Sample 2

GATTCGGAACTTCGTGGTTAC

Sample 1

CAGTTTGGACCTAACAGCTTC

GTGAAACCTTCATCGTCCAAG

DNA from organism A attached
to a nitrocellulose membrane.

8. How many bases are found in each of the DNA samples 1–4 as well as in the DNA from organism A in Model 2?

   21.

9. Using your knowledge of base-pairing, which DNA sample in Model 2 will be 100% complementary to organism A?

   Sample 3.

10. Which other DNA sample in Model 2 is likely to pair with one of the strands from organism A?

    Sample 1.

11. How many of the total number of base pairs in the sample you chose in Question 10 are noncomplementary between the strands?

    Five.

12. From your answer to Question 11, convert the number of noncomplementary pairs into a percentage of the total base-pairs. This is called the **sequence divergence.**

   5/21 = 23.8%

13. Calculate the sequence divergence for the remaining two samples. Check your calculations within your group.

   Sample 2 = 12/21 = 57%

   Sample 4 = 14/21 = 66.7%

14. Use the calculations from the previous questions to fill in the table below.

Most Homologous		Sample	Sequence Divergence
		3	0%
		1	23.8
		2	57
Least Homologous		4	66.7

15. Based on your previous knowledge of DNA, which sample from Model 2 is from an organism that is most closely related to Organism A?

   Sample 3.

16. With your group, describe how DNA sequence divergence can give scientists information about relatedness.

   Answers should include some reference to the greater the sequence divergence, then the less DNA sequence they have in common so the organisms are not as related. Those with low divergence share a lot of DNA in sequence and are more closely related.

17. Fill in the phylogenetic tree below with Samples 1 through 4 to summarize the relatedness of the organisms that supplied the samples.

```
                                    ───────────────── Sample 3
  ┌──────────┐        │
  │ Common   │────────┤
  │ Ancestor │        │           ───────── Sample 1
  └──────────┘        └───────────┤
                                  │         ──── Sample 2
                                  └─────────┤
                                            ──── Sample 4
```
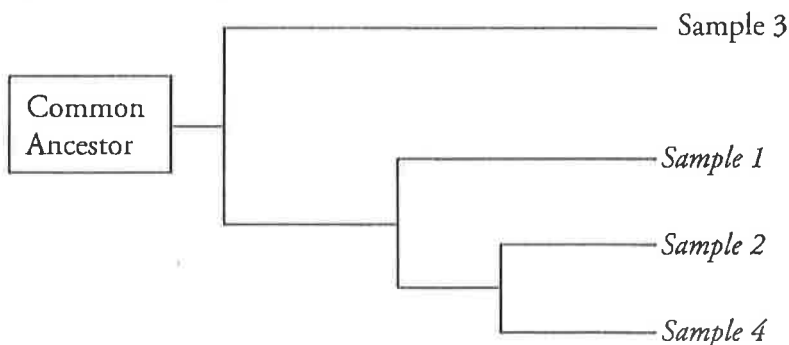
Model 3 – Comparing the Cytochrome *c* Gene

Amino Acid Position 1–40

Species	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
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
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	H	K	V	G	P	N	L
Whale	•	•	•	•	•	•	•	•	G	D	V	E	K	G	K	K	I	F	V	Q	K	C	A	Q	C	H	T	V	E	N	G	G	K	H	H	K	V	G	P	N	L
R. 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
Chicken	•	•	•	•	•	•	•	•	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
Pig	*	*	*	*	*	*	*	*	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
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
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

Amino Acid Position 41–77

Species	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
Human	H	G	L	F	G	R	K	T	G	Q	A	P	G	Y	S	Y	T	A	A	N	K	N	K	G	I	I	W	G	E	D	T	L	M	E	Y	L	E
Tuna	W	G	L	F	G	R	K	T	G	Q	A	E	G	Y	S	Y	T	D	A	N	K	S	K	G	I	V	W	N	N	D	T	L	M	E	Y	L	E
Whale	H	G	L	F	G	R	K	T	G	Q	A	V	G	F	S	Y	T	D	A	N	K	N	K	G	I	T	W	G	E	E	T	L	M	E	Y	L	E
R. Monkey	H	G	L	F	G	R	K	T	G	Q	A	P	G	Y	S	Y	T	A	A	N	K	N	K	G	I	T	W	G	E	E	T	L	M	E	Y	L	E
Chicken	H	G	L	F	G	R	K	T	G	Q	A	E	G	F	S	Y	T	D	A	N	K	N	K	G	I	T	W	G	E	D	T	L	M	E	Y	L	E
Pig	H	G	L	F	G	R	K	T	G	Q	A	P	G	F	S	Y	T	D	A	N	K	N	K	G	I	T	W	G	E	D	T	L	M	E	Y	L	E
Yeast	H	G	I	F	G	R	H	S	G	Q	A	Q	G	Y	S	Y	T	D	A	N	I	K	K	N	V	L	W	D	E	N	N	M	S	E	Y	L	T
Fly	H	G	L	F	G	R	K	T	G	Q	A	A	G	F	A	Y	T	N	A	N	K	A	K	G	I	T	W	Q	D	D	T	L	F	E	Y	L	E

Amino Acid Position 78–112

Species	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	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	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	*
Whale	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	S	A	T	S	*
R. Monkey	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	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	N	E
Pig	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	D	A	T	S	K
Yeast	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	*
Fly	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	*

*No amino acid at this position

18. Cytochrome *c* is a protein used in cellular respiration in many species. Refer to Model 3 to answer the following questions about cytochrome *c*.

   a. How many different species are represented in the cytochrome *c* amino acid sequences?

   Eight.

   b. What do the individual letters represent?

   Amino acids.

   c. What do the asterisks represent?

   No amino acid at this position.

19. Circle the pairing of organisms from Model 3 that you predict would have the most divergence in their DNA. Support your choices with a group discussion about morphology (observable characteristics and structure), ecology, and lifestyles of the animals.

a. whale and human   or   whale and tuna

b. pig and rhesus monkey   or   pig and chicken

c. tuna and fly   or   tuna and chicken

Answers will vary. Look for students to support their choices with specific examples of morphology, ecology, and lifestyle. For example, many students will choose "whale and human" for part a because a whale lives in the ocean and a human on land. This may lead students to believe that a whale and tuna share more DNA.

Read This!

Cytochrome *c* is a protein that is shared by many organisms due to its vital role in cellular respiration. Over time (billions of years) mutations have occurred in the cytochrome *c* gene that do not affect the function of the cytochrome *c* protein. These mutations are called **neutral mutations**. By looking at these mutations scientists can predict when the organisms diverged from a common ancestor and from each other.

20. Refer to Model 3. Write down the number of differences between the amino acid sequence of cytochrome *c* in a human and each of the following organisms.

a. Tuna   *21*   e. Pig   *10*

b. Whale   *10*   f. Yeast   *45*

c. Rhesus monkey   *1*   g. Fly   *27*

d. Chicken   *13*

21. Based on the differences in amino acid sequences, to which organism from the list are humans
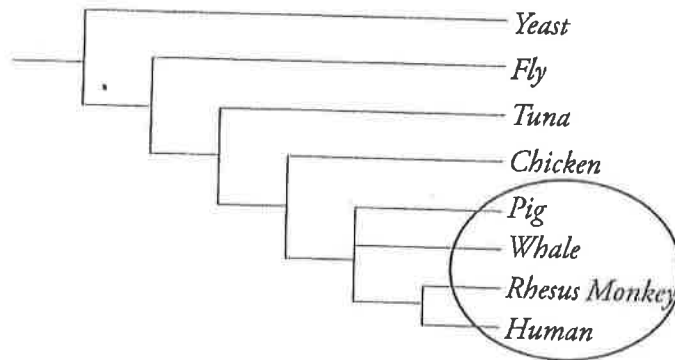
a. Most closely related to?

Rhesus monkey.

b. Most distantly related to?

Yeast.

22. Enter the names of the seven organisms in Model 3 into the tree below, to illustrate a phyloge-
netic relationship between these organisms and humans, as suggested by the cytochrome *c* data.

(Note that the position of whale and pig can be reversed, since they have the same "distance" from humans.)

```
                                          ──── Yeast
                                     ──── Fly
                                  ──── Tuna
                              ──── Chicken
                          ┌──── Pig
                          ├──── Whale
                          ├──── Rhesus Monkey
                          └──── Human
```

23. How do your predictions about relatedness based on morphology, ecology, and lifestyle in Ques-
tion 19 compare to the relatedness information in the phylogenetic tree developed from DNA
data in Question 22?

*Answers will vary. Students should see that predictions based on outward appearance and behavior can
be misleading. For example, whales and tuna, although they both have fins and live in the water, are
only distantly related.*

24. Circle all of the mammals in the phylogenetic tree in Question 22. How does the tree illustrate
the fact that those animals are all members of the same class?

*See Question 22. The animals are all members of the same class because they all diverged from a com-
mon ancestor at the same point.*

25. Compare the differences in amino acid sequences among the mammals with differences in other
animal classes. Is there a pattern?

*All the mammals have few differences between them, compared to between the groups, so there is more
relatedness within a taxonomic group.*

26. Should scientists infer evolutionary relationships based on data from a single protein? Justify your
answer in complete sentences.

*No. These animals each have thousands of genes and the fact that one gene is similar at certain loca-
tions says nothing about the other genes. It is better to look at multiple proteins or other sources of
DNA evidence to support any evolutionary relationship.*

(STOP)

Phylogenetic Trees