Amino Acid Sequences and Evolutionary Relationships

Introduction:

_____(analogous or homologous) structures are believed to have a common origin but not necessarily a common function. They provide some of the most significant evidence supporting the theory of evolution. For example, the forelimbs of vertebrates often have different functions and outward appearances, yet the underlying similarity of the bones indicates a common origin. Although these structures can be used to demonstrate relationships between similar organisms, they are of little value in determining evolutionary relationships among those structures that are dissimilar.

Another technique used to determine evolutionary relationships is to study the biochemical/molecular similarity of organisms. Though molds, aardvarks, and humans appear to have little in common physically, a study of their proteins reveals certain similarities. Biologists have perfected the techniques for determining the sequences of amino acids that make up _____(carbohydrates or proteins or nucleic acids). By comparing these sequences, some evolutionary relationships that might otherwise go undetected can be determined (the close relationship of the elephant and hyrax for example). Further, biologists have found that such biochemical evidence compares favorably with the other lines of evidence for evolutionary relationships.

You would never guess it from looking at them, but this tiny rock hyrax (about 10 inches tall and weighs 6 pounds) is the closest living relative to the elephant. They are also closely related to manatees.

Problem: How do amino acid sequences provide evidence for evolution?

Methods/Procedure:

Part A. Comparing Amino Acid Sequences

1. Examine Figure 1, which compares corresponding portions of hemoglobin molecules in humans and 5 other vertebrate animals. Hemoglobin, a protein composed of several long chains of amino acids, carries _____ in _____ blood cells. The sequence shown is only a portion of a chain made up of 146 amino acids. The numbers in Figure 1 indicate the position of a particular amino acid in the long chain.

2. Use Figure 1 to **complete Data Table 1**. You will be indicating the amino acids that are *different* only. **Using a highlighter can help. Note**: *Always be sure that you compare the amino acid sequence of each organism with that of the human and not the organism on the line above!*

Figure 1

	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101
Human	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
chimpanzee	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Gorilla	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Rhesus monkey	GLN	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Horse	ALA	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Kangaroo	LYS	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU

	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116
Human	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
chimpanzee	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Gorilla	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Rhesus monkey	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Horse	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	ALA	LEU	VAL	VAL	ALA	ARG
Kangaroo	ASN	PHE	LYS	LEU	LEU	GLY	ASN	ILE	ILE	VAL	ILE	CYS	LEU	ALA	GLU

*Human hemoglobin is being used as the standard for comparison.

Data/Results

Data Table 1

Organisms	Number of Amino Acid Differences
Human & Chimpanzee	
Human & Gorilla	
Human & Rhesus Monkey	
Human & Horse	
Human & Kangaroo	

Part B. Inferring Evolutionary Relationships from Differences in amino Acid Sequences

1. Now examine Figure 2. In this figure the cytochrome *c (a liver enzyme)* of a fruit fly is used as the standard in comparing amino acid differences among several organisms. Which animal is the fruit fly's closest relative? _____ Are humans closer related to birds or fish? _____

2.

Figure 2

Species Pairings	Number of Differences
Fruit fly-dogfish shark	26
Fruit fly-pigeon	25
Fruit fly-screwworm fly	2
Fruit fly-silkworm moth	15
Fruit fly-tobacco hornworm moth	14
Fruit fly-wheat	47

Species Pairings	Number of Differences
Human - chimpanzee	0
Human - fruit fly	29
Human - pigeon	12
Human - red bread mold	48
Human - rhesus monkey	1
Human - snapping turtle	15
Human - tuna	21
Human - wheat	43

Discussion –

1. There is a difference of only one amino acid in one chain of the hemoglobin of humans and gorillas. What caused this difference? _____

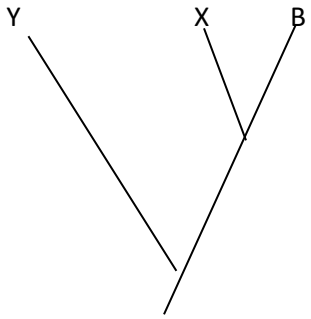
2. If the amino acid sequences in the proteins of 2 organisms are similar, why will their DNA also be similar?

   _____

3. Many biologists believe that the number of differences between the proteins of different species indicates how long ago the species diverged from common ancestors. Why do these biologists believe that humans, chimpanzees, and gorillas diverged from a common ancestor only a few million years ago (relatively recently)?

   _____

4. Species X and Y have 25 amino acid differences. Species X and B have 10 amino acid differences in the same protein. Species Y and B have 27 amino acid differences. A phylogenetic tree/cladogram would look like this:



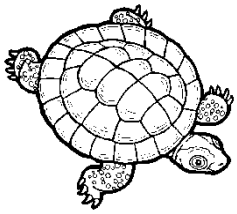
Y and B diverged first because they have the most differences. X and B diverged more recently because they have fewer differences.

You are a scientist trying to determine the relationship between the organisms below. Fill out the cladogram on the last page that depicts how these animals are related. Use #1-8 below to help you.

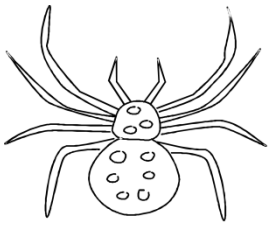
Consider the following characteristics when designing your cladogram. The terms in bold should be included on your cladogram. Those terms below on the lines, and indicate that all organisms after the point when the characteristic evolved have that characteristic and all organisms to the left/below the point, do not have that characteristic. One has been completed for you. Be sure all of your animals are arranged at the top of the cladogram and the distinguishing characteristics are listed.

1. Divide the animals into two groups depending on if they possess **vertebrae**.
2. Divide the vertebrates into groups according whether they have an **amniotic egg** or not. (Hint: Reptiles, birds, and mammals have amniotic eggs. Keep the animals who give live birth with the amniotic egg animals.)
3. Divide those with endoskeleton according to whether or not they give **live birth**.
4. Divide those not giving live birth into **calcium egg** or **leathery egg** laying.
5. Divide those with live birth depending on if they possess **opposable thumbs**.
6. Return to your invertebrates. Divide them according to the presence of an **exoskeleton**.
7. Divide those with exoskeletons according to whether they possess **wings**.
8. Add the label "humans" in the correct location. What derived character (trait) might we use to differentiate us from the clade line nearest us?

Owl

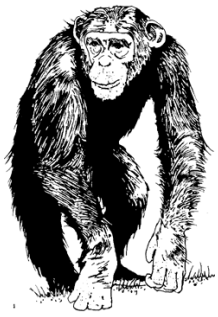


Turtle

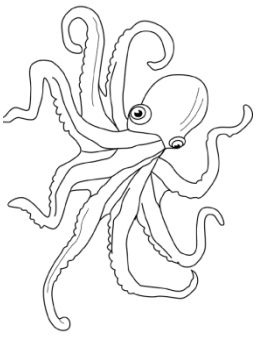


Spider

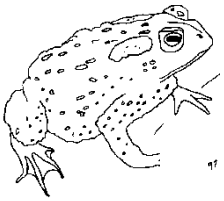
Butterfly



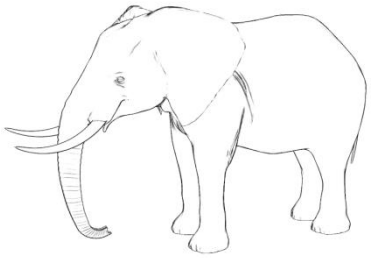
Chimpanzee



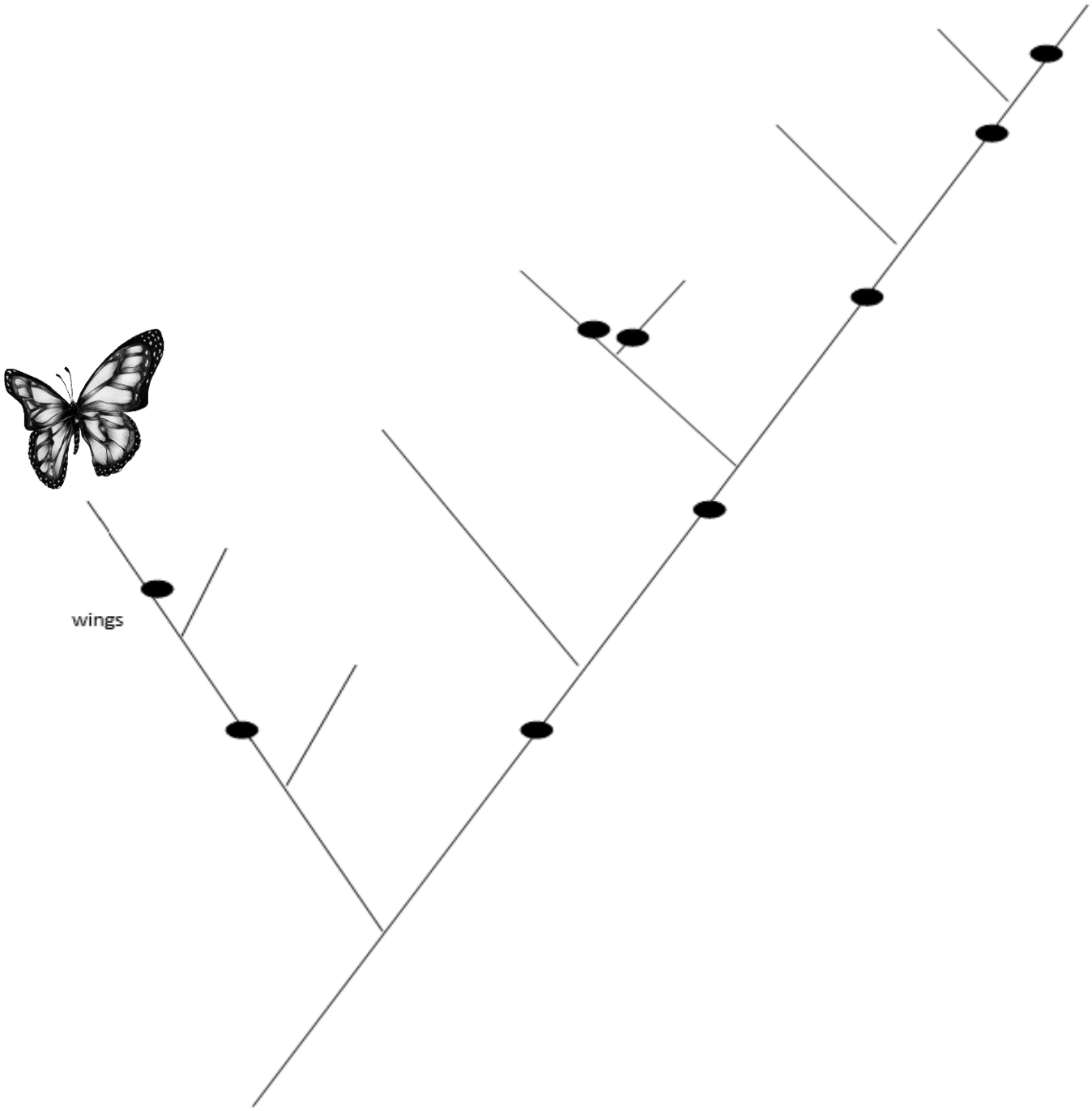
Octopus



Toad



Elephant


wings