

Name: _____

Date: _____

Amino Acid Sequences and Evolutionary Relationships

Introduction

Homologous structures—those structures thought to have a common origin but not necessarily a common function—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 homologous 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 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 techniques for determining the sequence of amino acids in proteins. By comparing the amino acid sequences in homologous proteins of similar organisms and of diverse organisms, evolutionary relationships that might otherwise go undetected can be determined. Biologists claim that the greater the similarity between the amino acid sequences of two organisms, the closer their relationship. Conversely, the greater the differences, the more distant the relationship. Further, biologists have found that such biochemical evidence compares favorably with other lines of evidence for evolutionary relationships.

An interesting additional line of evidence supporting evolution involves sequences of DNA known as "pseudogenes." Pseudogenes are remnants of genes that no longer function but continue to be carried along in DNA as excess baggage. Pseudogenes also change through time, as they are passed on from ancestors to descendants, and they offer an especially useful way of reconstructing evolutionary relationships.

With functioning genes, one possible explanation for the relative similarity between genes from different organisms is that their ways of life are similar—for example, the genes from a horse and a zebra could be more similar because of their similar habitats and behaviors than the genes from a horse and a tiger. But this possible explanation does not work for pseudogenes, since they perform no function. Rather, the degree of similarity between pseudogenes must simply reflect their evolutionary relatedness. The more remote the last common ancestor of two organisms, the more dissimilar their pseudogenes will be.

The evidence for evolution from molecular biology is overwhelming and is growing quickly. In some cases, this molecular evidence makes it possible to go beyond the paleontological evidence. For example, it has long been postulated that whales descended from land mammals that had returned to the sea. From anatomical and paleontological evidence, the whales' closest living land relatives seemed to be the even-toed hoofed mammals (modern cattle, sheep, camels, goats, etc.). Recent comparisons of some milk protein genes (beta-casein and kappa-casein) have confirmed this relationship and have suggested that the closest land-bound living relative of whales may be the hippopotamus. In this case, molecular biology has augmented the fossil record.

In this investigation, you will compare amino acid sequences in proteins of several vertebrates. You will also study amino acid differences and infer evolutionary relationships among some diverse organisms.

Problem

How do amino acid sequences provide evidence for evolution?

Procedure

Part A: Comparing Amino Acid Sequences

1. Examine Figure 1, which compares corresponding portions of hemoglobin molecules in humans and five other vertebrate animals. Hemoglobin, a protein composed of several long chains of amino acids, is the oxygen-carrying molecule in red 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 chain.

DATA TABLE 2		
Organisms	Number of Amino Acid Differences	Positions in Which They Vary
Human and chimpanzee		
Human and gorilla		
Human and rhesus monkey		
Human and horse		
Human and kangaroo		

Part B: Inferring Evolutionary Relationships from Differences in Amino Acid Sequence

- Another commonly studied protein is cytochrome *c*. This protein, consisting of 104 amino acids, is located in the mitochondria of cells. There it functions as a respiratory enzyme. Examine Figure 2. Using human cytochrome *c* as a standard, the amino acid differences between humans and a number of other organisms are shown.

FIGURE 2	
Species Pairings	Number of Differences
Human-chimpanzee	0
Human-fruit fly	29
Human-horse	12
Human-pigeon	12
Human-rattlesnake	14
Human-red bread mold	48
Human-rhesus monkey	1
Human-screwworm fly	27
Human-snapping turtle	15
Human-tuna	21
Human-wheat	43

- Using Figure 2, construct a bar graph on Graph 1 to show the amino acid differences between humans and other organisms.
- Now examine Figure 3. In this figure the cytochrome *c* of a fruit fly is used as a standard in comparing amino acid differences among several organisms. Construct a bar graph on Graph 2 to show these differences.

FIGURE 3	
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 moth	14
Fruit fly-wheat	47

Analysis and Conclusions

Part A: Use the data from **Part A** to answer questions 1 and 2. As always, use complete sentences when needed.

1. On the basis of hemoglobin similarity, what organisms appear to be most closely related to humans? Explain your answer.
2. Among the organisms that you compared, which one appears to be least closely related to humans? Explain your answer.

Part B: Use the data from **Part B** to answer questions 3 through 7.

3. On the basis of differences in their cytochrome *c*, which organisms appear to be most closely related to humans? Explain your answer.

4. Which organisms appear to be least closely related to humans? Explain your answer.

5. Check the pair of organisms that appears to be most closely related to each other.

_____ snapping turtle-tuna
_____ snapping turtle-rattlesnake
_____ snapping turtle-pigeon

Give a reason for your answer.

6. Agree or disagree with the following statement and give reasons to support your answer. "Fruit flies appear to be more closely related to silkworm moths than they are to screwworm flies."

7. Agree or disagree with the following statement. "Fruit flies and humans have about the same evolutionary relationship to wheat." Explain your answer.

Critical Thinking and Application

1. There is a difference of only one amino acid in one chain of hemoglobin of humans and gorillas. What might have caused this difference?
2. If the amino acid sequences in the proteins of two organisms are similar, why will their DNA also be similar? If the amino acid sequences are identical, does this mean that the DNA must be identical?
3. Many biologists think that the number of differences between the proteins of different species indicates how long ago the species diverged from common ancestors. Explain how the data in this investigation supports the idea that humans, chimpanzees, and gorilla diverged from a common ancestor only a few million years ago.
4. Other proteins can be used to establish degrees of evolutionary relatedness between organisms. Would you expect to find roughly the same number of differences in different amino acid chains when comparing organisms? Explain your answer.