

# Biochemical Evidence for Evolution

One method scientists use to help determine the evolutionary relationships between organisms is to analyze and compare the molecular structure of proteins. Recall that proteins are made up of chains of amino acids. There are 20 amino acids used to make proteins. The particular type and order of the amino acids in a protein are determined by the DNA code.

To make a given protein, this information is first transcribed into a messenger RNA (mRNA) code, which is “read,” or translated into protein, three nucleotides at a time. With a few exceptions, each triplet, called a codon, codes for a certain amino acid. For example, the mRNA codon UCA (that is uracil, cytosine, and adenine) codes for the amino acid serine. The code is also somewhat flexible. The amino acid glycine will be brought into the sequence of a protein if any of the following codons appear: GGU, GGC, GGA, or GGG.

To better understand ancestral relationships between organisms, scientists compare the amino acid sequences of the same proteins in different organisms. Scientists have concluded that the more a sequence from one organism matches the sequence from another organism, the more closely related the two organisms are. For example, scientists determined that light-sensing proteins in the brain of an ancient marine worm are very similar to those found in the vertebrate eye. This evidence supports the idea that worms and vertebrates share a common ancestor.

Scientists have examined the amino acid sequences of proteins such as hemoglobin and myoglobin in many organisms and compared them to the corresponding sequences in humans. Hemoglobin is the protein in red blood cells that binds to oxygen and carbon dioxide. Myoglobin is a protein found in muscle tissue. Scientists have used the information from these analyses to strengthen conclusions drawn from other evidence of the ancestral relationships between certain organisms.

**In this lab, you will compare the amino acid sequences of hemoglobin from several vertebrate organisms with the amino acid sequence for human hemoglobin.**

**PROBLEM:** How do the amino acid sequences of vertebrate organisms compare?

## **PROCEDURE:**

1. **Table 1** shows part of the amino acid sequence for hemoglobin in several different vertebrates, including humans. A single-letter abbreviation has been used to represent each amino acid in the sequences. **Table 2** shows which amino acid each abbreviation stands for.
2. Look at the amino acid sequence of hemoglobin for each organism listed in **Table 1** and compare it to the sequence of amino acids in human hemoglobin. Count the number of amino acids that match the human amino acids in the same position. Record this number in **Table 3**.
3. Count the number of amino acids that do not match the human amino acids in the same position. Record in **Table 3**.
4. Calculate the percent similarity between the amino acid sequence of humans and each of the other organisms using the formula below. Record your results in **Table 4**.

$$\text{Percent Similarity} = \frac{\text{number of matching amino acids}}{\text{total number of amino acids}} \times 100$$

5. Calculate the percent difference between the amino acid sequence of humans and each of the other organisms by subtracting the percent similarity from 100%. Record your results in **Table 2**.

$$\text{Percent Similarity} = 100\% - \text{Percent Similarity}$$

**OBSERVATIONS:**

TABLE 2. Abbreviations for Amino Acids			
Abbreviation	Amino Acid	Abbreviation	Amino Acid
A	Alanine	L	Leucine
R	Arginine	K	Lysine
N	Asparagine	M	Methionine
D	Aspartic Acid	F	Phenylalanine
C	Cysteine	P	Proline
E	Glutamic Acid	S	Serine
Q	Glutamine	T	Threonine
G	Glycine	W	Tryptophan
H	Histidine	Y	Tyrosine
I	Isoleucine	V	Valine

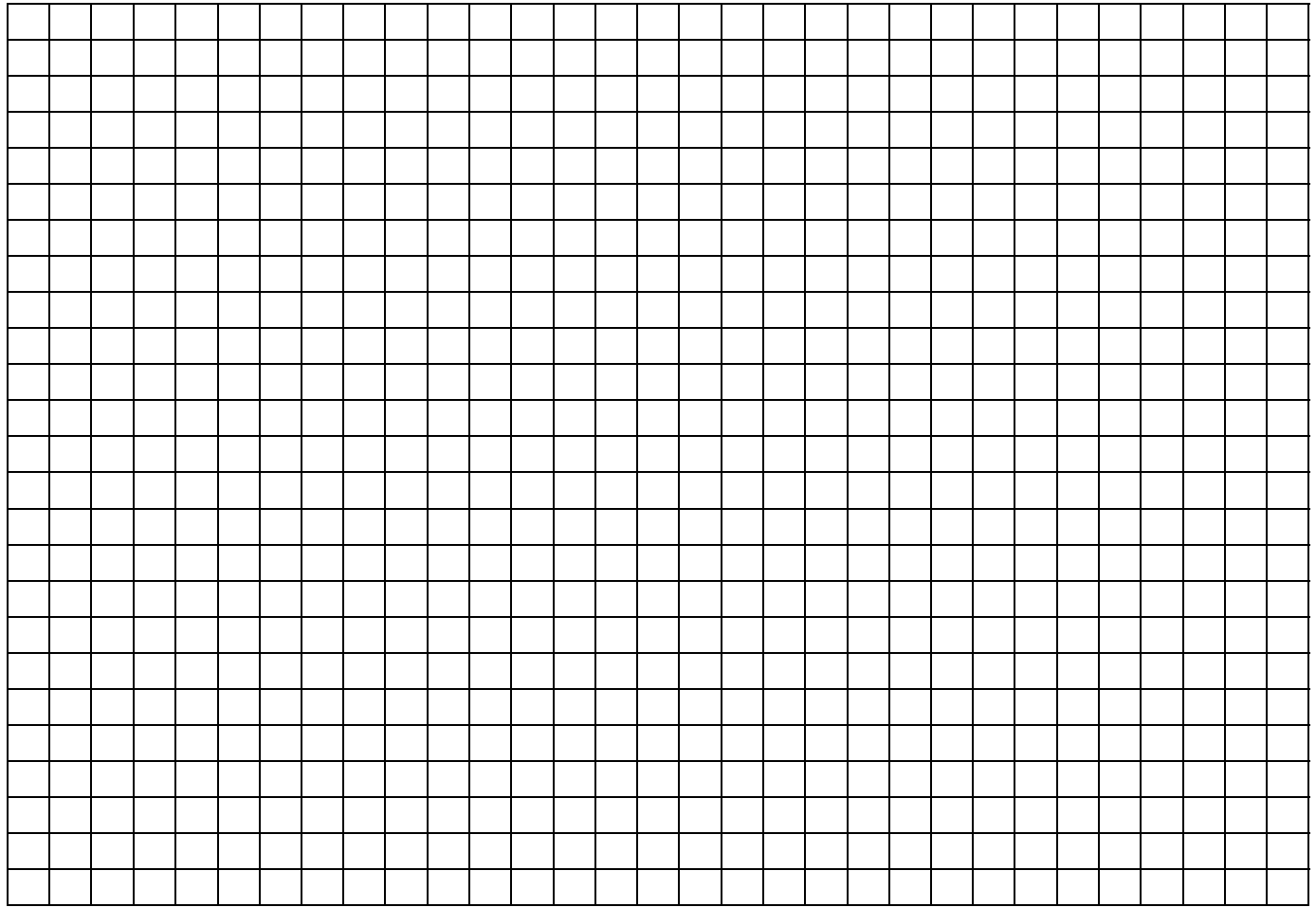
TABLE 3. Matching & Nonmatching Amino Acids		
Organism	Number of Matching Amino Acids	Number of Nonmatching Amino Acids
Chimpanzee		
Fish		
Mouse		

TABLE 4. Percent Similarity and Difference in Amino Acid Sequences Compared with Human Sequence		
Organism	Number of Matching Amino Acids	Number of Nonmatching Amino Acids
Chimpanzee		
Fish		
Mouse		

TABLE 1. Hemoglobin Amino Acid Sequence for Various Vertebrates	
Chimpanzee	VLSPADKTN VKAAWGKVG AHAGEYGAE ALERMELSF PTTKTYFPFH ALSALSDIH AHKLRVDPV NFKLLSHCL LVTLAAHLP AEFTPAVHA SLDKF
Fish	SLSDKDKAV VKAIWAKIS PKADEIGAE ALARMLTVY PQTKTYFSHW GLAALSEIH AFKLRVDPA NFKILSHNV IWVIAMLFP ADFTPEVHV SVDKF
Human	VLSPADKTN VKAAWGKVG AHAGEYGAE ALERMELSF PTTKTYFPFH ALSALSDIH AHKLRVDPV NFKLLSHCL LVTLAAHLP AEFTPAVHA SLDKF
Mouse	VLSGEDKSN IKAAWGKIG GHGAEYGAE ALERMELSF PTTKTYFPFH ALSTLSDIH AHKLRVDPV NFKFLSHCL LVTLASHHP GDFTPAMHA SLDKF

**ANALYZE & CONCLUDE:**

1. **Construct** Choose whether a line graph or bar graph best represents the percent similarity data from **Table 4**. Construct the graph, showing the rank of the organisms from least to greatest in terms of percent similarity to the amino acid sequence of human hemoglobin.



2. **Analyze** Based on the amino acid sequences for hemoglobin, which organism is most closely related to humans? Which organism is the least closely related to humans?

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3. **Calculate** Use the information in **Table 1** to calculate the percent similarity and the percent difference between the amino acid sequence in fish and mice.

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4. **Sequence** Use **Table 2** to determine the amino acids in the following sequence from a strand of human hemoglobin: AHAGEYGAE

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5. **Calculate** The total number of amino acids in the hemoglobin beta-chain is 146. When compared to a human, a lamprey (jawless fish) has 21 matching amino acids and 125 nonmatching amino acids. Calculate the percent similarity and percent difference between humans and lampreys.

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6. **Assess** Myoglobin is a protein found in the muscle tissue of vertebrates. The following table contains information about the percent similarity and difference between the myoglobin of various organisms and human myoglobin.

	Organism	% Similarity	% Difference	Organism	% Similarity	% Difference
Baboon	Baboon 	96.0	4.0	Gorilla	99.3	0.7
Lemur	Lemur 	85.6	14.4	Squirrel Monkey	88.8	11.2

Which of these organisms is most closely related to humans? Which is least closely related to humans?

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7. **Infer** How would you expect the mRNA codons that code for the amino acids that make up hemoglobin to compare between humans and chimpanzees? Explain how you got your answer.

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