Name _____ Class _____ Date _____

Making a Model Molecular Clock

Concepts such as evolution and natural selection have been applied to many areas of biology. One relatively new area to which these concepts are being applied is protein molecules. In this activity you will compare the various structures of a protein in four organisms. You will also make a model of a molecular clock and use it to determine when divergent evolution might have occurred in these organisms.

By comparing the structures of organisms, scientists discover evolutionary relationships. Recently, many studies have been made of certain protein molecules, such as cytochrome *c*. This protein plays a key role in respiration and is found in organisms ranging from yeasts to human beings.

When human cytochrome *c* is compared to the cytochrome of other organisms, many similarities and a few differences are found. When the amino acids of the cytochromes are compared, those sequences that are the same or very similar are called homologies. Those that are different are called amino acid "substitutions." Figure 1 shows that the twelfth amino acid in human cytochrome is methionine, but the twelfth amino acid in a turtle is glutamine.

Figure 1

First 50 Amino Acids in Cytochrome *C*

	1 5 10 15 20 25 30 35 40 45 50
Human ...	GDVEKGKKI F I MKCSQCHTVEKGGKHKTGPNLHGLFGRKTGQAP GYS YTA
Turtle	GDVEKGKKI FVQKCAQCHTVEKGGKHKTGPNLNGLI GRKTGQAE GF S YTE
Shark	GDVEKGKKVFVQKCAQCHTVENGGKHKTGPNLS GLFGRKTGQAQGF S YTP
Fruit fly ...	GDVEKGKKLFVQRCAQCHTVEA GGKHKVGPNLHGLI GRKTGQAA GF AYTN

Amino acid key:
G—Glycine; A—Alanine; V—Valine; L—Leucine; I—Isoleucine;
M—Methionine; F—Phenylalinine; W—Tryptophan; P—Proline; S—Serine;
T—Threonine; C—Cysteine; Y—Tyrosine; N—Asparagine; Q—Glutamine;
K—Lysine; R—Arginine; H—Histidine; D—Aspartic acid; E—Glutamic acid

The number of differences between each of the proteins shows the degree of difference between the organisms. The greater the difference between the cytochromes of two organisms, the further in the past it was that those two organisms diverged from a common ancestor. Many scientists believe that cytochrome *c* has evolved at a fairly constant rate. The constant rate of change for cytochrome *c* may be the basis for a molecular "clock." The molecular clock can be a helpful tool in trying to determine when various organisms may have diverged from a common ancestor.

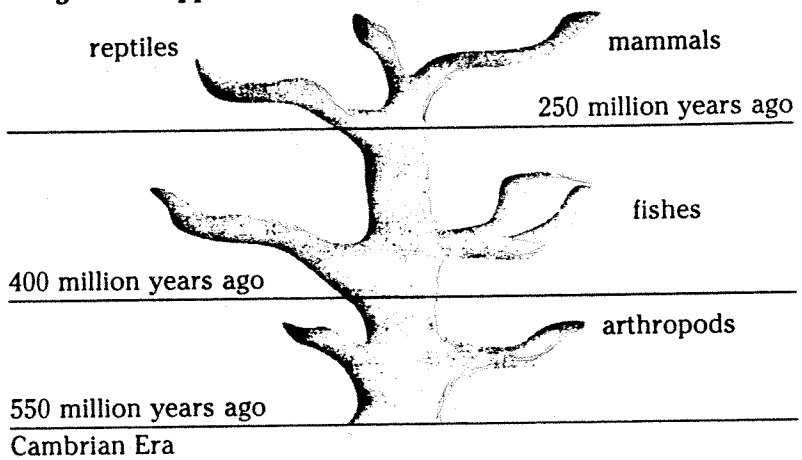
1. Compare each organism's cytochrome to human cytochrome. Record the positions of amino acid substitutions and the total number of substitutions for each on Figure 2.
2. To calculate the percentage of difference for each cytochrome from human cytochrome, divide the number of substitutions for each organism by the total number of amino acids in the sequence (50). Enter the percentages on Figure 2. You may use a calculator or computer to do your computations.

Figure 2

Human vs.	Positions of Substitutions	Number of Substitutions	Percentage of Difference
Turtle			
Shark			
Fruit fly			

Figure 3 shows the approximate time of divergent evolution of reptiles, fishes, and insects. These data are based on the fossil record. The divergent evolution of fungi, plants, and animals is believed to have occurred during the Precambrian Era, but there is no fossil record of this.

Figure 3 Approximate Dates of Divergence Before Present



Use the percentage of difference from Figure 2 to calculate the average percentage of change of cytochrome *c* for each million years of Earth history. To do this, divide the percentage (the whole-number value for the percentage difference shown in column 4 of your table) of change for each organism—turtle (reptile), shark (fish), and fruit fly (arthropod)—by the number of million years from that organism's point of divergence (from Figure 3). Then average the three quotients together. This number is the average amount of change in cytochrome *c* that has occurred over each 1 million years of the last half billion years. Now fill in the chart below.

Figure 4

Percentage of Change per 1 Million Years

Reptiles	
Fishes	
Insects	
Average percentage	

Use the average percentage you found to answer the following questions.

3. If plants diverged 740 million years ago, what percentage of the cytochrome would be different from human cytochrome? _____

4. What percentage of change should be expected if yeast diverged 800 million years ago?

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