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Amino Acid Sequences and Evolutionary Relationships

**(November 18, 2013)**

**Homologous structures** are structures believed to have a common origin but not necessarily a common function. These structures 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.

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 believe 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. Furthermore, biologists have found that such biochemical evidence compares favorably with other lines of evidence for evolutionary relationships.

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.

**Part A. Comparing Amino Acid Sequences**

1. **Figure 1** compares corresponding portions of hemoglobin molecules in humans and

five other vertebrate animals. Hemoglobin 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 Figures 1 indicate the position of a particular amino acid in the chain.

1. In **Data Table 1**, notice that the abbreviated names of the amino acids **in human**

**hemoglobin** are printed. In the appropriate spaces in Data Table 1, write the abbreviated name of each amino acid in chimpanzee hemoglobin that is *different* from that in human hemoglobin. **If there are no differences, leave the spaces blank.**

1. For the remaining organisms, write the abbreviated names of the amino acids that

do not correspond to those in human hemoglobin. 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.*

1. Then, count the number of differences in data table 1 (for each organism) and

complete **Data Table 2 (**which summarizes the data).

**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 | ASP | VAL | LEU | VAL | CYS | VAL | LEU | ALA | HIS |
| Chimpanzee | ASN | PHE | ARG | LEU | LEU | GLY | ASP | VAL | LEU | VAL | CYS | VAL | LEU | ALA | HIS |
| Gorilla | ASN | PHE | LYS | LEU | LEU | GLY | ASP | VAL | LEU | VAL | CYS | VAL | LEU | ALA | HIS |
| Rhesus monkey | ASN | PHE | LYS | LEU | LEU | GLY | ASP | VAL | LEU | VAL | CYS | VAL | LEU | ALA | HIS |
| Horse | ASN | PHE | ARG | LEU | LEU | GLY | ASP | VAL | LEU | ALA | LEU | VAL | VAL | ALA | ARG |
| Kangaroo | ASN | PHE | LYS | LEU | LEU | GLY | ASP | ILE | ILE | VAL | ILE | CYS | LEU | ALA | GLU |

**Data Table 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 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gorilla |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Rhesus  monkey |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Horse |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kangaroo |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **102** | **103** | **104** | **105** | **106** | **107** | **108** | **109** | **110** | **111** | **112** | **113** | **114** | **115** | **116** |
| Human | ASN | PHE | ARG | LEU | LEU | GLY | ASP | VAL | LEU | VAL | CYS | VAL | LEU | ALA | HIS |
| Chimpanzee |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gorilla |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Rhesus monkey |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Horse |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Kangaroo |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Data Table 2**:

|  |  |  |
| --- | --- | --- |
|  | **Number of Amino Acid**  **Differences (From Table 1)** | **Positions Where They Vary** |
| Human and Chimpanzee |  |  |
| Human and Gorilla |  |  |
| Human and Rhesus monkey |  |  |
| Human and Horse |  |  |
| Human and Kangaroo |  |  |

**Part B. Inferring Evolution Relationships from Differences in Amino Acid Sequences**

1. 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. In **Figure 2**, using cytochrome *c* as a standard, the amino acid differences between humans and a number of other organisms are shown.
2. **Using Figure 2**, construct a bar graph on **Graph 1** to show the amino acid differences between humans and other organisms.

**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** |

**0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50**

**Graph 1**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Example** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Fruit Fly** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Chimpanzee** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Horse** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Pigeon** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Rattlesnake** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Red bread mold** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Rhesus monkey** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Screwworm fly** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Snapping turtle** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Tuna** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Human-Wheat** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

1. In **Figure 3** the **cytochrome *c*** of a fruit fly is used as a standard in comparing amino acid differences among several organisms. Using the data in **Figure 3**, 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 hornworm moth** | **14** |
| **Fruit fly-Wheat** | **47** |

**0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50**

**Graph 2**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Example** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Fruit fly-Dogfish shark** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Fruit fly-Pigeon** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Fruit fly-Screwworm fly** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Fruit fly-Silkworm moth** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Fruit fly-Tobacco hornworm moth** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Fruit fly-Wheat** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Analysis and Conclusions**

1. On the basis of the hemoglobin similarity

(looking at Data Table 2), which organism

appears to be **most closely related** to humans?

2. On the basis of the hemoglobin similarity

(looking at Data Table 2), which organism

appears to be the **least closely related** to humans?

3. On the basis of differences in their

cytochrome c, (looking at Figure 2), which

organism appears to be **most closely**

**related** to humans?

4. On the basis of differences in their

cytochrome c, (looking at Figure 2), which

organism appears to be **least closely**

**related** to humans?

5. After examining Figure 2, **circle the pair** of organisms that you would infer to be the most closely related to each other.

Snapping turtle-tuna Snapping turtle-rattlesnake Snapping turtle-pigeon

6. **Agree or disagree** with the following statement **AND** **give reason** to support your answer. “Fruit flies appear to be more closely related to silkworm moths than they

are to screwworm flies.”

7. After examining Figure 2, which two organisms appear to be equally related to each other? Explain your answer.

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

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