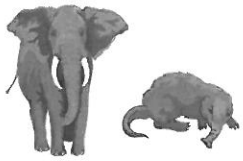
Name: _____ Date: _____

Molecular Clocks and Classification



In the 21st century, the way scientists classify animals is a bit more involved than it was during Linnaeus' time. Though Carl Linnaeus was not wrong to group organisms by their anatomy or appearance, he was lacking one valid piece of information: DNA. With this new and critical piece, we have found that sometimes looks can be deceiving.

Recall that divergence is an event in which one species accumulates genetic differences, which if drastic enough will lead to speciation: the formation of a new species. Accumulated molecular differences in the DNA of two species can indicate how long they have been separate species. Species that have recently diverged share a recent common ancestor. Species that diverged from one another long ago share a more distant common ancestor. Two ways that scientists can indicate the closeness of a relationship is by comparing the DNA base sequences of two groups, or the amino acid sequence of a specific protein among two groups.

Comparisons of DNA can also be used to mark the passage of evolutionary time in a model known as a **molecular clock**. This model relies on mutations to mark certain events. Mutations happen frequently, and cause slight changes in DNA. Some mutations can have a positive effect on the organism's phenotype; some mutations can have a negative effect, while others have no effect. These "neutral" mutations that have no effect occur at about equal rates among different species. When comparing these neutral mutations, we can reveal how dissimilar the genes are. The more dissimilar the genes are, the longer amount of time it has been since the two species shared a common ancestor. Whereas if the genes are still relatively similar, the two species most likely shared a more recent common ancestor.

Comparing DNA One way to compare the DNA of two species is a method known as DNA-DNA hybridization. Recall that DNA is a double stranded molecule that is held together with hydrogen bonds between the complementary base pairs. Double-stranded DNA from each species is heated to separate the complementary strands. Then a single strand from each species are mixed and allowed to cool. As DNA cools, the single strand from each species begins to bond, or hybridize. The more of a genetic match the two species are, the more DNA base pairs will match, and the more strongly their DNA strands will bond.

Protein Clocks Recall that proteins are made up of sequences of amino acids. A specific protein can be assumed to evolve at about the same rate in all species that contain the protein. Comparing the amino acid sequences of the protein in several species can give us clues as to how long ago the two species diverged.

1. What is speciation?

   _____.

2. What is divergence?

   _____.

3. Species that have recently diverged share a _____;
   species that diverged long ago share a _____.

4. What is a molecular clock? _____

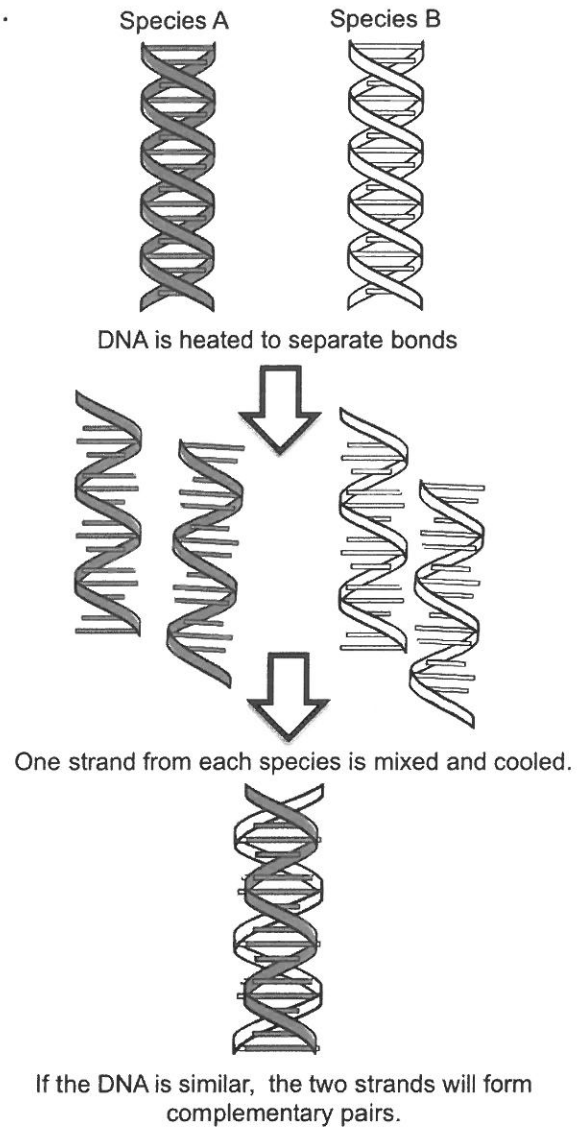
_____.

5. Which type of mutations are used to gage time on a molecular clock?

_____.

6. When comparing DNA among two species, if the genes are dissimilar, then what does that suggest about the two species? _____

_____.



7. When comparing DNA among two species, if the genes are alike, then what does that suggest about the two species?

_____

_____

_____.

8. The figure at left is a depiction of a process known as

_____.

9. Summarize the process of DNA-DNA hybridization:

_____

_____

_____

_____.

10. Which conclusions can be reached if the DNA is similar in DNA-DNA hybridization? _____

_____.

11. Proteins are made up of sequences of _____

_____.

12. What clues can be revealed from comparing the amino acid sequence of a specific protein found in different species? _____

_____.

13. The process of using proteins or amino acids to give clues about evolutionary time is known as a _____ clock.

For example, the protein cytochrome c is an essential protein found in our mitochondria. Cytochrome c is found in the cells of aerobic organisms (organisms that require oxygen).

The chart on the next page compares the amount of differences in amino acids in cytochrome c to humans.

Organism	Number of Amino Acid Differences in Cytochrome c Compared to Humans
Chimpanzees	0
Dogs	13
Rattlesnake	20
Tuna	31

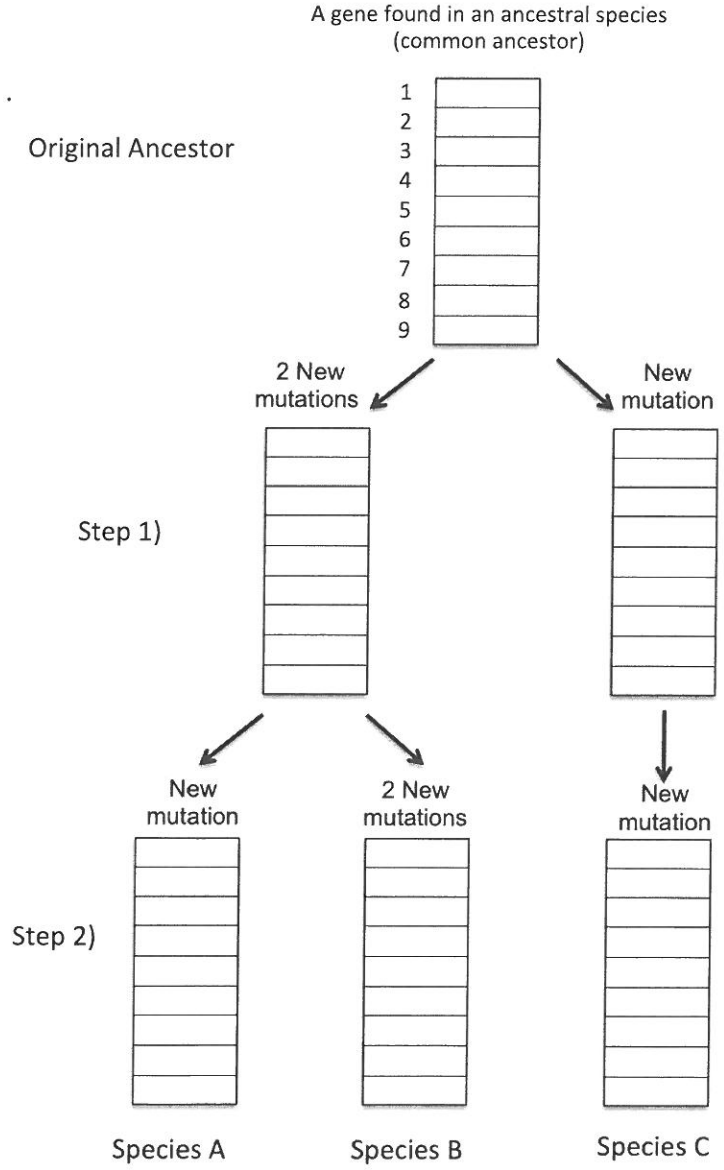
14. What does this indicate about the relationship between humans and chimpanzees?

_____

_____.

15. Which animal has the most distant ancestor in common with humans according to this chart?

_____.



16. The figure at left depicts how mutations among can drive divergence over time. The bars represent a single gene with 9 different sequences. The ancestral gene is numbered for reference.

Using colored pencils, choose 5 different colors to represent each mutation. Leave the ancestral gene blank, as it is the starting point. For each new mutation, color in one of the bars to represent the difference as time goes on using the text below.

Be sure to carry any of the mutations on to the next segment of time.

Step 1: Two populations of the same species experienced a mutation in the gene pool. One population had a two new mutations at number 1 and 6. The other population had one new mutation at number 4.

Step 2: Many years later, species A was formed when an additional mutation occurred at number 9. Species B formed from 2 separate new mutations: one at number 5 and one at number 8. Species C was formed due a mutation at number 7.

17. What does the diagram involving mutations represent?

_____

_____.

18. Which species (A, B, or C) is most related to the original ancestor? Why do you think so?

_____

_____.

19. In the space below, create a Cladogram based on the diagram, using the common ancestor as a starting point, and branching out to the 3 species.

20. **Summary:** How do biological molecules such as DNA and proteins play a role in modern classification?

_____

_____

_____

_____.

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