

# What is Molecular Evolution?

## Worksheet

Molecular evolution is the accumulation of changes in DNA, RNA and protein sequences over generations; comparing these sequences between species, using the molecular clock, lets scientists estimate divergence times and build phylogenetic trees.

$$K = \frac{d}{2t}$$

## Questions

- Two sequences differ by 20 substitutions and diverged 5 million years ago. What is the substitution rate?
  - 4 differences/Myr
  - 2 differences/Myr
  - 20 differences/Myr
  - 0.5 differences/Myr
- The neutral theory of molecular evolution states that most mutations are:
  - Strongly beneficial
  - Strongly harmful
  - Neutral, fixed mainly by drift
  - Always lethal
- Orthologous genes arise through:
  - Gene duplication within one genome
  - Speciation events separating lineages
  - Horizontal gene transfer only
  - Random mutation with no ancestry
- The molecular clock is mainly used to:
  - Measure an organism's metabolic rate
  - Estimate divergence times between species
  - Count chromosomes
  - Determine an organism's diet
- Two species' cytochrome c proteins differ by 12 amino acids, and fossil evidence puts their divergence at 60 million years ago. Estimate the substitution rate.
- A gene's molecular clock rate is known to be 0.5 substitutions per million years. Two living species differ by 5 substitutions in that gene. Estimate when they diverged.
- Human and chimpanzee beta-globin genes differ by about 5 substitutions, with a fossil-calibrated divergence time of roughly 6.5 million years. Estimate the substitution rate.
- Define: What is molecular evolution?
- Define: What is the molecular clock?
- Define: Neutral theory of molecular evolution

## Answer Key

1. B) 2 differences/Myr -  $r = K/(2T) = 20/(25) = 2$  differences per million years.
2. C) Neutral, fixed mainly by drift - Kimura's neutral theory holds most molecular changes are neutral and fixed by genetic drift, not selection.
3. B) Speciation events separating lineages - Orthologs are copies of a gene in different species that trace back to a speciation event.
4. B) Estimate divergence times between species - By comparing sequence differences and an assumed mutation rate, the molecular clock estimates when lineages split.
5.  $K = 12$  differences,  $T = 60$  Myr  $r = K / (2T) = 12 / (2 \cdot 60)$   $r = 12 / 120 = 0.1$  differences per million years
6. Rearrange:  $T = K / (2r)$   $T = 5 / (2 \cdot 0.5) = 5 / 1$   $T = 5$  million years ago
7.  $K = 5$ ,  $T = 6.5$  Myr  $r = K / (2T) = 5 / (2 \cdot 6.5)$   $r = 5 / 13$  0.38 differences per million years
8. The study of how DNA, RNA and protein sequences change over evolutionary time.
9. A method that assumes mutations accumulate at a roughly constant rate, used to estimate divergence times between species.
10. Kimura's theory that most molecular-level mutations are neutral and fixed by genetic drift, not selection.

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