AP BIOLOGY · UNIT 7 · TOPIC 7.6

Evidence of Evolution

Learning objective 7.6.A Describe the types of data that provide evidence for evolution, and 7.6.B explain how morphological, biochemical, and geological data provide evidence that organisms have changed over time.

Name: Date: Period:

Use the tool **Four Kinds of Evidence, One Answer**. Parts 1 and 2 use **Dating a fossil**, Parts 3 and 4 use **Reading a protein**, and Part 5 uses **Same bones, different jobs**. The case for evolution does not rest on any single line of evidence, and this handout is built so that you can see why. Each part uses a method that has **nothing in common** with the others: measuring radioactive decay, counting differences between protein sequences, or comparing skeletons. The last part asks whether they agree.

Part 1 · Dating something with carbon-14

Carbon-14 has a half-life of **5,730 years**: half of whatever is present decays in that time, whatever else is happening. Fill in the Years and Carbon-14 remaining columns from the half-life before you use the specimen buttons, then check them against the graph.

Half-lives elapsed	Years	Carbon-14 remaining
0		
1		
2		
3		
4		
5		

1. Explain how a radioactive isotope can be used to date a fossil.

2. For each specimen, the tool calculates an age from the carbon-14 remaining. It then runs the decay law forward from that age and checks that it returns the starting fraction (the Check: decay law run forward readout). Explain why this check is useful.

Part 2 · Where the method stops working

Click each of the four specimen buttons, from 79.5% left to 6.1% left, and record the carbon-14 left and the age. Then fill in each isotope's half-life and what it dates from the table Where carbon-14 stops working, in the second panel. The isotope columns are a separate list; they do not match the specimen in the same row.

Specimen	C-14 left	Age	Isotope	Half-life	What it dates
Charred wood from a hearth			Carbon-14		
Bone from a burial site			Uranium-235		
Plant material in a peat bog			Potassium-40		
Charcoal beneath a volcanic ash layer			Uranium-238		

3. (a) Explain why a dinosaur fossil cannot be dated using carbon-14.

(b) Describe how a dinosaur fossil is dated instead.

4. Identify four different types of data that provide evidence for evolution.

Part 3 · Counting differences in a protein

Go to **Reading a protein**. Cytochrome c is present in every aerobic eukaryote. The tool compares each species' sequence with the human one, position by position, and counts the mismatches. It does not know anything about evolutionary relationships; it only counts letters.

Organism	Differences from human	Positions compared	Identity
Chimpanzee			
Rhesus monkey			
Horse			
Chicken			
Rattlesnake			
Tuna			
Yeast			

5. Using the Part 3 table, explain how comparing the amino acid sequences of a protein in different species provides evidence for evolution.

6. Human and chimpanzee cytochrome c are identical at every position compared. (a) Explain why this identity is evidence that humans and chimpanzees share a common ancestor.

(b) Describe what an explanation without common ancestry would have to claim about the two sequences.

Part 4 · The molecular clock, and where it strains

Open the panel headed **A molecular clock, calibrated on one point**. A single divergence date (the chicken, 320 million years ago) sets the rate, and every other date is then predicted from sequence differences alone. Calculate each ratio as the clock estimate divided by the fossil date.

Organism	Divergence	Clock estimate (My)	Fossil date (My)	Ratio
Rhesus monkey				
Horse				
Chicken				
Rattlesnake				
Tuna				
Yeast				

7. The chicken lineage and the rattlesnake lineage separated from the human lineage at the same time, about 320 million years ago, yet their cytochrome c differs from human cytochrome c by different amounts. Explain what this observation indicates about molecular clocks.

8. The molecular clock ranks the organisms in the same order as the fossil record, although some of its dates differ from the fossil dates by a factor of two or more. Explain why the agreement in order supports common ancestry, even though the dates do not match exactly.

Part 5 · Same bones, different jobs, and four methods agreeing

Go to **Same bones, different jobs**. Then read the table Homologous or analogous? and the panel Four methods, one answer, beneath it.

Pair of structures	Homologous or analogous?	How you can tell
Bat wing and insect wing		
Whale flipper and fish fin		
Whale flipper and bat wing		
Human arm and cat foreleg		

9. (a) Describe what homologous structures are.

(b) Describe what analogous structures are.

(c) Explain how homologous structures can be distinguished from analogous structures.

10. Using one vestigial structure from the tool as an example, explain why vestigial structures are evidence of common ancestry.

11. Using the four lines of evidence about whales in the tool, explain why independent lines of evidence that agree provide stronger support for evolution than any one line of evidence alone.

What the model simplifies

The cytochrome c sequences are a 104-position fragment aligned without gaps except at the very end, and the comparison is a plain count of differing positions. Real molecular phylogenetics uses full sequences, many genes, an explicit model of which substitutions are likely, and a correction for the same site changing twice, which is one reason the clock estimates here are rough.

The molecular clock is calibrated on a single point and applied to every other comparison. Real clocks are calibrated on several fossil dates at once and allow the rate to differ between lineages, precisely because it does, as the chicken and rattlesnake rows show.

Carbon-14 ages are computed from a clean exponential with no correction for the fact that atmospheric carbon-14 has varied over time. Real dates are calibrated against tree rings and other records, which shifts them by up to a few percent.

The forelimb diagram shows 6 bone groups; a real forelimb has many individual carpals and phalanges whose numbers differ between species, and those differences are themselves evidence.

The divergence dates used to check the clock are approximate figures from the fossil record and the rocks around it, and different sources give somewhat different values. They are used here as an independent comparison, not as exact truth.