

Origins of Life on Earth

Learning objective 7.12.A Describe the scientific evidence that supports models of the origin of life on Earth.

Name:Date:Period:

Use the tool **Four Billion Years, One Window**. Parts 1 and 2 use **The window**, Part 3 uses **Four steps**, and Parts 4 and 5 use **Why RNA**. The objective for this topic asks you to describe **the evidence**, not to tell the story — and the two are different things. Some of what follows is as firm as anything in biology, and some of it is a set of partially supported hypotheses that working scientists argue about. Being able to say which is which is the point of this handout, so as you go, keep asking: how would anyone know that?

Part 1 · What the rocks bracket

Five dates, and only one of them comes from a fossil. Record each one and where it comes from. Then work out the **window** — the interval between the moment the Earth's surface became survivable and the moment there is already evidence of life on it. Everything this topic is about happened inside it.

Event	Billion years ago	Geological or fossil?	What the evidence is
Earth forms			
Oldest surviving minerals			
Oldest surviving rocks			
Conditions become survivable			
Earliest widely accepted evidence of life			

1. Describe the geological evidence that brackets when life began on Earth.

2. These dates say when life began but nothing about how. Explain why that makes them the firmest claims in the topic.

Part 2 · Five clocks, one rock

A single date from a single measurement would not be worth much. Fill in what each decay system says about the same **4.55-billion-year-old** sample. Look at the fourth column before you look at the fifth, and notice how little the five measurements have in common.

Decay system	Half-life (billions of years)	Half-lives elapsed	Parent isotope left	Age it gives
Uranium-238 → Lead-206				
Uranium-235 → Lead-207				
Potassium-40 → Argon-40				
Thorium-232 → Lead-208				
Rubidium-87 → Strontium-87				

3. Explain why the agreement between several different radiometric clocks is stronger evidence than any single measurement.

4. Someone objects that radiometric dating cannot be trusted because carbon dating only works back about 50,000 years. Explain what is wrong with the objection.

5. Describe the fossil evidence for the earliest life, and state roughly how old it is.

Part 3 · Four steps, and how well each is supported

Go to **Four steps**. Every model of the origin of life has to get from simple chemistry to something that reproduces and inherits, and the route is usually drawn as four steps. They are **not** equally well supported. Record the evidence and the open question for each, and pay attention to which one is marked weakest.

Step	What it produces	Strength of evidence	What is still open
1. Small organic molecules form from inorganic precursors			
2. Small molecules join into polymers			
3. Polymers become enclosed in membranes			
4. A molecule appears that can both store information and be copied			

6. Describe the Miller-Urey experiment and state what it demonstrated.

7. Describe what protobionts are and why they are evidence about one of the four steps.

8. Identify the step supported by the weakest evidence, and explain why it is also the step that matters most.

Part 4 · Three requirements, three candidates

Go to **Why RNA**. Whatever the first genetic material was, it had to do three things. Score the three molecules against the three requirements. Only one of them survives, and that is the entire argument for the RNA world — it is a matter of chemistry, not of preference.

	Stores information in a sequence	Can be copied from a template	Can catalyze chemical reactions	Total
DNA				
Protein				
RNA				

9. Explain the RNA world hypothesis, and state the property of RNA that neither DNA nor protein has.

10. Explain the “chicken and egg” problem with DNA and proteins, and how RNA resolves it.

11. Describe one piece of evidence from living organisms — not from rocks — that supports the RNA world hypothesis.

Part 5 · The objection, and the arithmetic

The commonest objection to any of this is a probability calculation, and it deserves to be done properly rather than waved away. Fill in the second panel of that tab. Read the third column carefully: the first calculation is **correct**, and that is exactly why the reply to it has to be about something other than the arithmetic.

The calculation	Result	Is the arithmetic correct?
A specific 100-residue protein in one random draw		
Random trials available in the whole window		
The same target reached by cumulative selection		

12. Someone argues that life cannot have arisen by chance because the odds against a specific protein forming are astronomical. Explain what is right and what is wrong about that argument.

13. State what the reply to that argument does not explain, and connect your answer to Part 3.

What the model simplifies

The dates are rounded to the nearest hundred million years, which is roughly the precision at which they are usefully quoted rather than the precision of any individual measurement. The age of the Earth is

known considerably more precisely than the date at which the surface became survivable, and the date of the earliest fossil life is the least secure of the three.

The five decay systems are used to make one point — that independent clocks with very different rates agree — and the arithmetic assumes a closed system with no initial daughter isotope. Real dating corrects for both, and the correction is most of what the technique consists of. The isochron method, which handles initial daughter isotope without assuming it away, is beyond this course but is the reason the assumption is not a weakness.

The four steps are presented as a sequence because that is how the models present them. There is no requirement that they happened in that order, and some proposals reverse steps 2 and 3 — compartments first, chemistry inside them afterwards. The ordering is a convenience for teaching rather than a finding.

The Miller-Urey experiment is described as it was performed. The gas mixture it used is no longer thought to be a good match for the early atmosphere, and later repeats with more realistic mixtures produce smaller yields. This does not undo the result, because organic monomers are also found in meteorites, which settles the point independently of any assumption about Earth's atmosphere.

Scoring DNA as unable to catalyze is a simplification. Catalytic DNA molecules have been made in the laboratory; none is known to occur in nature, and DNA's catalytic range is far narrower than RNA's. The scoring reflects the biological situation, not an absolute chemical impossibility.

The cumulative-selection simulation uses a fixed target sequence, which is a real weakness in it: evolution has no target. It is used only for one comparison — how many trials a step-by-step process needs against how many a single draw needs — and that comparison does not depend on the target being fixed. If anything a fixed target makes the problem harder than the real one, in which very many different sequences would do.

The 2025 course framework asks students to describe the scientific evidence that supports models of the origin of life. This handout therefore marks how strong the evidence for each step is, and states what is unresolved, rather than presenting the four steps as a single settled account. That is a deliberate choice about how to teach the topic, and it is worth being explicit with students that it is one.