

Passport of a Carbon Atom: Where Do the Atoms Pile Up?

Investigation question: When carbon atoms move among the air, water, living things, soil and fossil fuels by chance at each step, which reservoirs end up holding the most atoms, and what changes when people start burning fossil fuels?

Collaborative systems modeling

Groups of 3

1 session

Setup 8 · Activity 35 · Cleanup 5 min

MS-LS2-3 · assesses

MS-LS1-6 · supports

Name _____

Group _____

Date _____

Your role today

- ☐ **Atom (every student):** Rolls the die at each station, reads the rule, records the round in their own passport and moves to the next station. Every student is an atom; the group roles below are extra jobs.
- ☐ **Station keeper:** One member of each group also keeps a station: reads the rule aloud for anyone unsure, keeps the die at the station, and counts the atoms present at the end of each run.
- ☐ **Tally recorder:** One member of each group collects the group's three passports after each run, checks they have ten rounds, and reports the group's final stations to the class tally on the board.
- ☐ **Grapher:** One member of each group copies the class tally into the recording sheet and draws the two bar charts for the group to analyze.

Safety

- Students walk between stations; clear bags and chairs from the paths and set a walking-only rule. Mark station areas with tape so groups do not crowd a corner.
- Foam or large plastic dice only; no throwing dice across the room.
- No chemicals, heat or sharp tools are used.

Procedure

1. Stand at your starting station and write it in round 0 of your passport. The class should be spread evenly across all six stations. Agree on the boundary of the model: the six stations are the whole system, and no atom may leave the room or join from outside.
2. Round 1: roll the die at your station once. Read the rule for your roll on the station card. In your passport write the round number, the station you are at, the number you rolled, the process named on the card and the station you are going to. If the card says stay, write 'stays' as the process and your current station as the destination.
3. Move to your destination station only after you have written the row. Wait there until the teacher calls the next round. Everyone rolls once per round.

4. Repeat for ten rounds. At the end of round 10 stay where you are. Station keepers count the atoms at their station and report the count; the tally recorder writes the group's three final stations on the board tally. Check that the class total equals the number of students.
5. Return to your run 1 starting station. The teacher flips every station card to the fossil-fuel-era side. The only rule that changes is at the Fossil fuels station, where rolls of 4, 5 or 6 now send the atom to the Atmosphere by combustion. Run ten more rounds exactly as before and record them in the run 2 passport table.
6. At the end of run 2, count and tally again. Check the total.
7. In your group, copy both tallies into the recording sheet and draw two bar charts, one per run, with the same vertical scale so they can be compared by eye.
8. Count how many rounds of your own passport you spent in each reservoir across both runs and fill in the personal summary table.
9. Answer the analysis questions on your own, then compare answers in your group and revise anything you now disagree with.

Record your observations

Lab 1 recording sheet: Passport of a carbon atom

You are a carbon atom. At each station, roll once, find your number on the station card, write the row, and only then move. The rules below are a model: the chances are invented for teaching, but every arrow is a real process in the carbon cycle.

Station rules (reference). Run 1 natural rules; run 2 changes only the Fossil fuels row.

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Station (reservoir)	Roll 1	Roll 2	Roll 3	Roll 4	Roll 5	Roll 6
Atmosphere (carbon dioxide in air)	Producers: photosynthesis	Producers: photosynthesis	Producers: photosynthesis	Water: dissolves into the ocean or pond	Stays in the air	Stays in the air
Water (carbon dioxide dissolved)	Producers: photosynthesis by algae	Producers: photosynthesis by algae	Atmosphere: escapes to the air	Stays dissolved	Stays dissolved	Stays dissolved
Producers (plants, algae)	Atmosphere: cellular respiration	Atmosphere: cellular respiration	Consumers: eaten	Consumers: eaten	Soil and decomposers: dies or drops a leaf	Stays, stored in wood
Consumers (animals)	Atmosphere: cellular respiration	Atmosphere: cellular respiration	Atmosphere: cellular respiration	Soil and decomposers: wastes	Soil and decomposers: dies	Stays in the body
Soil and decomposers	Atmosphere: decomposers' cellular respiration	Atmosphere: decomposers' cellular respiration	Atmosphere: decomposers' cellular respiration	Stays stored in soil	Stays stored in soil	Fossil fuels: buried under sediment for millions of years
Fossil fuels, run 1 (natural)	Stays buried	Stays buried	Stays buried	Stays buried	Stays buried	Stays buried
Fossil fuels, run 2 (fossil-fuel era)	Stays buried	Stays buried	Stays buried	Atmosphere: dug up and burned (combustion)	Atmosphere: dug up and burned (combustion)	Atmosphere: dug up and burned (combustion)

Run 1 passport (natural rules). Starting station for round 0: _____

Round	Station I am at	Roll	Process on the card	Station I go to
1				
2				
3				
4				
5				

Round	Station I am at	Roll	Process on the card	Station I go to
6				
7				
8				
9				
10				

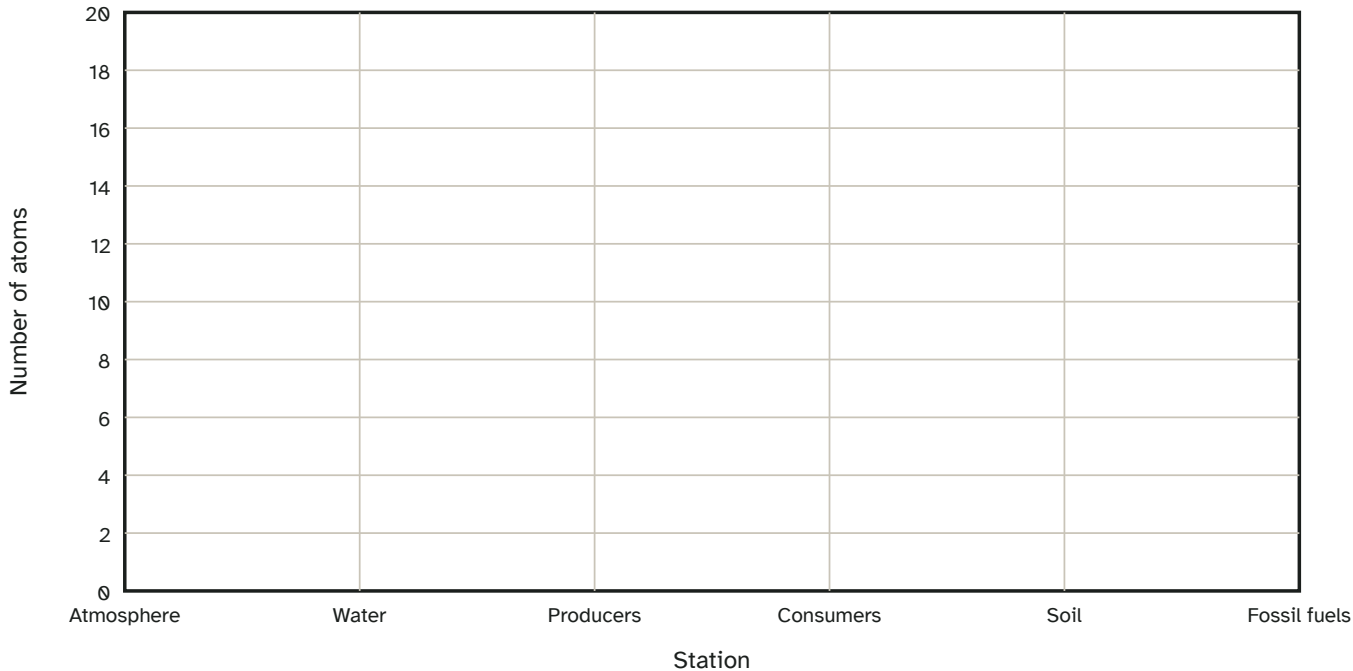
Run 2 passport (fossil-fuel era). Starting station for round 0: _____

Round	Station I am at	Roll	Process on the card	Station I go to
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Class tally: atoms at each station after round 10

Station	Run 1 count (natural)	Run 2 count (fossil-fuel era)	Change (run 2 minus run 1)
Atmosphere			
Water			
Producers			
Consumers			
Soil and decomposers			
Fossil fuels			
Total (must equal the class size)			

Atoms at each station after ten rounds, run 1 and run 2 (draw two bars per station,



My own journey: rounds spent in each reservoir (count rows from both passports, 20 rounds total)

Reservoir	Rounds in run 1	Rounds in run 2	Total rounds
Atmosphere			
Water			
Producers			
Consumers			
Soil and decomposers			
Fossil fuels			

1. Which reservoir held you for the most rounds, and which card rule explains why it was hard to leave?
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2. Compare your run 1 passport with a groupmate's. Name one reservoir you visited that they did not, and one process that moved you that never moved them.

Analysis questions

3. Look at the class tally for run 1. Which reservoir had the most atoms after ten rounds? Use the station rules to explain why atoms pile up there.

4. In run 1, what fraction of the Soil and decomposers rolls send an atom to Fossil fuels, and what fraction of the Fossil fuels rolls let an atom leave? Show the two fractions and explain what they mean for how long an atom stays buried.

5. Compare the run 2 tally with run 1. Which station changed the most, in which direction, and which single rule caused it? Use numbers from the class tally.

6. Add the counts in each run column. What do you notice about the totals, and which law does that illustrate? Explain why the total could not have changed no matter how the dice fell.

- 7.** State the boundary of the system this model represents. Name one real flow of carbon that crosses the boundary of a real ecosystem but could not happen in the model.

- 8.** The die gives each arrow a fixed chance. Name two ways this is different from how carbon really moves, and say whether each difference makes the model's answer to our question better, worse or unchanged.

- 9.** Propose a rule change for a run 3 that models a large reforestation project. Say which station's rule you would change, how, and what you predict would happen to the Atmosphere count after ten rounds.
