

Fixing Marco's Cycle Poster: Seven Claims That Break the Rules

Learning target: I can find the mistaken idea behind a wrong claim about matter cycling, explain what rule it breaks, and rewrite the claim so that it is accurate.

Error analysis

About 40 min

Individual

MS-LS2-3 · practice

MS-LS1-6 · supports

writing

independent practice

Standards connections

MS-LS2-3 (practice): Each of Marco's claims misreads a cycle model: matter destroyed, a single required route, plants built from soil, Earth closed to energy. Diagnosing and repairing them sharpens the understanding students need to build and defend accurate cycling-of-matter models.

MS-LS1-6 (supports): Two claims concern where a plant's mass comes from. Correcting them relies on the role of photosynthesis in bringing carbon from the air into organisms, which is the heart of this PE, though the sheet does not ask for a full explanation.

Purpose: practice · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

Marco's seven claims — **1.** A big oak tree can weigh several tons. Almost all of that mass came up out of the soil through its roots. **2.** When firewood burns, the wood is destroyed. Its matter turns into heat and light. **3.** Plants pull nitrogen gas straight out of the air through their leaves and use it to make protein. **4.** The water molecules in your glass are the exact same water molecules a dinosaur drank. Water molecules never change. **5.** Decomposers get rid of dead matter. Once they finish, that matter is gone from the ecosystem. **6.** The carbon cycle is one loop: air → plant → animal → decomposer → air. Every carbon atom takes those steps, in that order. **7.** Earth is a closed system, so nothing comes in from space. Not even energy.

Part A: Which rule does each claim break?

Here are the five rules a good cycle model follows. **Rule A:** Atoms are never created or destroyed; they change form and reservoir (conservation of matter). **Rule B:** Producers build most of their mass from carbon dioxide and water, not from soil. **Rule C:** Only nitrogen fixation (mostly by bacteria) makes nitrogen gas usable; plants and animals cannot use it directly. **Rule D:** Atoms persist, but molecules are taken apart and rebuilt; a cycle diagram shows possible routes, not one required track. **Rule E:** Earth is closed for matter but open for energy.

1. For each claim, write the letter of the rule it breaks and copy the few words from the claim that show the error. One rule is broken by more than one claim.

Answer: Claim 1: Rule B ('came up out of the soil'). Claim 2: Rule A ('wood is destroyed', 'turns into heat and light'). Claim 3: Rule C ('nitrogen gas straight out of the air'). Claim 4: Rule D ('exact same water molecules', 'never change'). Claim 5: Rule A ('gone from the ecosystem'). Claim 6: Rule D ('one loop', 'in that order'). Claim 7: Rule E ('not even energy').

Why: Rules A and D are each broken by two claims. The quoted words should point at the exact error, not the whole claim.

Also acceptable: Accept Rule A for Claim 2 even if the student also mentions Rule E (energy-matter confusion); accept Rule D or Rule A for Claim 4 if the explanation says atoms persist but molecules do not.

- All seven rules correctly assigned
- Words quoted from each claim point to the error

Part B: What went wrong, and the fix

2. **Claim 1** (the oak tree's mass came from the soil). (a) What went wrong? (b) Write the fix. Include where most of the tree's mass actually came from and what process brought it in.

Answer: (a) What went wrong: Marco assumed that because roots are in the soil, the tree's material comes from soil. In fact a tree takes only water and small amounts of dissolved minerals from the soil; the soil under a tree does not shrink by tons. (b) Fix: 'A big oak tree can weigh several tons. Most of that mass came from the air: the tree's leaves took in carbon dioxide and, using sunlight, combined it with water from the soil to build sugar, and the tree built the sugar into wood. Only a small part of the tree's mass is minerals from the soil.'

Why: The accurate picture: the carbon in wood comes from carbon dioxide via photosynthesis; water contributes hydrogen and oxygen; soil minerals are a small fraction. Students need not give the chemical reaction.

Also acceptable: A fix that says 'from carbon dioxide and water' without the word photosynthesis is acceptable if the process is described.

- Identifies the soil assumption as the error
- Fix names carbon dioxide from the air and photosynthesis
- Fix keeps soil's real but small role (water, minerals)

3. **Claim 2** (burning destroys the wood and turns it into heat and light). (a) What went wrong? (b) Write the fix. Your fix must say where the wood's atoms are after the fire and must keep energy and matter separate.

Answer: (a) What went wrong: Marco confused matter with energy. Burning releases energy as heat and light, but the wood's atoms do not become energy; the loss of visible wood made him think matter was destroyed. (b) Fix: 'When firewood burns, the wood is not destroyed. Its carbon and hydrogen atoms combine with oxygen from the air and leave as carbon dioxide and water vapor, and a little stays behind as ash. The fire gives off heat and light, which is energy that was stored in the wood, not the wood's matter.'

Why: Energy and matter must be kept separate; the atoms are accounted for (gases plus ash). This is the combustion arrow of the carbon cycle.

Also acceptable: Accept 'smoke and gases' if carbon dioxide is named.

- Names the matter-energy confusion
- Fix locates the atoms (carbon dioxide, water vapor, ash)
- Fix keeps heat and light as energy, not matter

4. **Claim 3** (plants pull nitrogen gas from the air through their leaves). (a) What went wrong? (b) Write the fix, naming who actually makes nitrogen usable and the form plants take in.

Answer: (a) What went wrong: Marco assumed that because the air is full of nitrogen, plants can use it the way they use carbon dioxide. But nitrogen gas is locked in pairs of atoms that plants cannot split. (b) Fix: 'Plants cannot use nitrogen gas from the air. Nitrogen-fixing bacteria in the soil and in root nodules of plants like peanuts and clover change nitrogen gas into ammonium, and other bacteria change that into nitrate. Plant roots absorb ammonium and nitrate from the soil and use them to build protein.'

Why: This is the fixation rule. Lightning and fertilizer factories are additional fixers and may be mentioned.

Also acceptable: Accept 'ammonia' for ammonium. A fix that adds lightning or factories is more complete.

- Identifies the assumption that plants can use nitrogen gas
- Fix names nitrogen-fixing bacteria
- Fix names ammonium or nitrate absorbed by roots

5. **Claim 4** (the same water molecules a dinosaur drank; water molecules never change). (a) What went wrong? Hint: think about what photosynthesis does to water and what cellular respiration produces. (b) Write the fix so that it is still a surprising fact but a true one.

Answer: (a) What went wrong: Marco treated molecules as permanent. Atoms persist, but water molecules are split apart during photosynthesis (their oxygen leaves as oxygen gas) and new water molecules are built during cellular respiration. So many of the water molecules in a glass are not the same molecules that existed in dinosaur times; what persists is the atoms. (b) Fix: 'The hydrogen and oxygen atoms in your glass of water have been on Earth for billions of years, and some were surely once inside a dinosaur. But water molecules are taken apart and rebuilt by living things all the time, so the molecules in your glass are a mix of very old ones and ones that were made recently by cells.'

Why: This corrects the textbook's dinosaur-water statement at the atomic level. The surprising fact survives (ancient atoms); the inaccurate part (unchanging molecules) is removed.

Also acceptable: Accept a fix that says 'some of the water molecules' instead of 'the exact same.'

- States that atoms persist but molecules are split and rebuilt
- Names at least one process that breaks or makes water (photosynthesis or cellular respiration)
- Fix keeps the ancient-atoms idea

6. **Claim 5** (decomposers make dead matter disappear from the ecosystem). (a) What went wrong? (b) Write the fix, naming at least two reservoirs the matter actually goes to.

Answer: (a) What went wrong: Marco thought 'break down' means 'make disappear.' Decomposers change dead matter's form and move it, but every atom is still in the ecosystem. (b) Fix: 'Decomposers break dead matter into simpler substances and move its atoms to new reservoirs. Carbon leaves as carbon dioxide into the air or water through the decomposers' cellular respiration; nitrogen is released into the soil as ammonium; some matter becomes dark organic material in the soil; and some is built into the decomposers' own bodies. Nothing is gone; it is ready to be used again.'

Why: The fix must name at least two destination reservoirs: air (carbon dioxide), soil (ammonium, organic matter), water, or the decomposers themselves.

Also acceptable: Accept 'into the soil and the air' as the two reservoirs with the forms named.

- Identifies 'break down equals disappear' as the error
- Fix names at least two reservoirs
- Fix states that atoms remain in the ecosystem

7. **Claim 6** (the carbon cycle is one loop every atom follows in order). (a) What went wrong? (b) Write the fix, and give one example of a carbon atom skipping a step and one example of a carbon atom staying in a reservoir for a very long time.

Answer: (a) What went wrong: Marco read the diagram as a schedule rather than a map of possibilities. Arrows show routes an atom can take; most atoms skip steps, loop back, or sit in one reservoir for a long time. (b) Fix: 'The carbon cycle shows many routes a carbon atom can take between the air, water, living things, soil and rocks. An atom might go from the air into a plant and straight back to the air when the plant respire, never passing through an animal. Another might be buried in mud and stay there for millions of years, becoming coal or oil, before burning returns it to the air.' Skipping example: plant respiration returning carbon without a consumer. Long-stay example: fossil fuel deposits, deep ocean water, or limestone.

Why: Both examples are required. The long-stay example should be a real slow reservoir (fossil fuels, deep ocean, carbonate rock, old soil organic matter).

Also acceptable: Accept 'carbon dioxide dissolving in the ocean and staying for centuries' as the long-stay example.

- Identifies the 'one required order' error
- Gives a skip-a-step example
- Gives a long-storage example

8. **Claim 7** (closed system means no energy comes in). (a) What went wrong? (b) Write the fix, naming what enters Earth and what leaves.

Answer: (a) What went wrong: Marco applied 'closed' to everything. In the Earth model, 'closed' refers to matter only; energy crosses the boundary constantly. (b) Fix: 'Earth is nearly a closed system for matter: almost no atoms arrive from space or leave, apart from a little dust coming in and a little gas and spacecraft going out. But Earth is open for energy. Sunlight pours in every day and heat radiates out to space, and that flow of energy is what drives the cycles of matter.'

Why: Students should name both what enters (sunlight) and what leaves (heat). Mentioning the small matter exceptions is a bonus that matches the textbook's own caveat.

Also acceptable: Accept 'light in, heat out' with the matter-closed statement.

- Separates matter from energy
- Names sunlight entering and heat leaving

Part C: Step back

9. Two of Marco's claims make the **same** underlying mistake even though they are about different things (wood and dead matter). Which two, and what is the shared mistake?

Answer: Claims 2 and 5. Both assume that when something stops being visible (burned wood, decomposed remains), its matter is gone. The shared mistake is breaking the law of conservation of matter: in both cases the atoms moved to other reservoirs, mostly the air as gases.

Why: Both claims rest on the 'invisible means gone' intuition. Claims 4 and 6 also share Rule D, so a student who pairs those with a correct explanation (treating molecules or routes as fixed) should also receive credit, but the prompt's hint (wood and dead matter) points to 2 and 5.

Also acceptable: Accept claims 4 and 6 with the explanation that both treat a model's parts as permanent or fixed.

- Pairs claims 2 and 5
- Names the shared error as matter 'disappearing' (conservation)

10. Marco says: 'But the log in the cage really did get lighter. Doesn't that prove matter can disappear?' Describe one measurement or experiment that would convince Marco that the matter went somewhere instead of vanishing.

Answer: Seal a log (or leaves and soil) in a container on a balance for weeks or months: the leaves will visibly break down while the total mass stays the same and a carbon dioxide sensor inside shows the gas rising. Other acceptable designs: weigh a candle and the air in a sealed jar before and after burning; collect the gases from a small burning sample and show they have mass; measure the mass of a sealed, planted terrarium while the plants grow.

Why: Any closed-system measurement that pairs a visible change with an unchanged total mass answers Marco's objection.

Also acceptable: A student who proposes capturing and weighing the gases from the open cage has the right idea even if it is harder to do.

- Describes a sealed (closed) system
- Pairs a visible change with a mass measurement that stays constant

Teacher notes

The seven claims are the chapter's most common misconceptions, several of which the textbook itself nudges toward: it says every water molecule has been cycling since early Earth (molecules are rebuilt; atoms persist), presents the cycles as single tracks to 'follow,' and calls Earth closed without saying it is open to energy. Accurate points for the debrief: a tree's dry mass is mostly carbon from carbon dioxide plus hydrogen and oxygen from water; soil minerals are a small fraction (van Helmont's willow experiment is a good story). Burning wood leaves ash, which is the mineral part. Lightning fixes nitrogen to nitrate, not ammonia. In q9, claims 2 and 5 share the conservation error, while claims 4 and 6 share the 'model parts are fixed' error; accept either pairing with its reason. The extension's eighth claim: decomposers release ammonium; nitrifying bacteria make nitrate.

Scaffold offered to students: Ask the atom

For every claim, ask one question: 'Where is the atom now?' If the claim's answer is 'nowhere' or 'it became energy,' Rule A is broken. If the answer is 'in the plant, from the soil,' check Rule B. If the answer is 'in the plant, straight from nitrogen gas,' check Rule C. If the claim says an atom must take one exact path or that a molecule lasts forever, check Rule D. If the claim is about energy rather than atoms, check Rule E. Then write the fix by answering the question correctly.

Extension: Write the eighth claim

Marco's poster also says: 'Decomposers break down proteins and leave nitrates in the soil for plants.' This is close but not accurate. Find out which form of nitrogen decomposers actually release and which organisms make nitrates from it, then write a (a) and (b) for this claim as you did in Part B. Finally, explain why a claim that is 'almost right' can be harder to catch than one that is clearly wrong.