

Global Cycles of Matter: Mastery Check

Learning target: I can show that I understand how water, carbon and nitrogen move between reservoirs, why the total amount of matter stays the same, and how people change and repair the carbon cycle.

Retrieval and mastery check

About 35 min

Individual

MS-LS2-3 · assesses

MS-ETS1-1 · practice

independent practice

writing

Standards connections

MS-LS2-3 (assesses): Items ask students to trace matter between living and nonliving reservoirs, apply conservation of matter inside a defined boundary, and draw a small cycling model. Together they produce evidence toward the PE without requiring chemical equations.

MS-ETS1-1 (practice): One item asks students to sort statements from a reforestation brief into criteria and constraints, a quick check of the precision idea in this PE.

Purpose: assess · **Time:** about 35 minutes · **Format:** individual

Answers with reasoning

Part A: Retrieval

1. Scientists model Earth as a closed system. What does that mean?

Answer: B. Almost no matter enters or leaves Earth, although energy flows in and out.

Why: The closed-system model applies to matter; sunlight enters and heat leaves. Option A reverses the energy point; C treats energy as trapped; D contradicts conservation of matter.

Also acceptable: None.

2. True or false: A tree builds most of its mass from matter it takes in from the soil through its roots.

Answer: False. Most of a tree's mass comes from carbon dioxide taken in from the air (and water), built into sugar by photosynthesis and then into wood. Soil supplies water and a small amount of minerals.

Why: This is the most persistent misconception in the chapter; the correction is the carbon-from-air idea.

Also acceptable: Accept 'false' with 'from the air' as the reason.

3. Which process moves carbon from a **nonliving** reservoir into a **living** one?

Answer: C. Photosynthesis.

Why: Photosynthesis builds carbon dioxide (nonliving) into sugar inside a producer (living). Respiration, combustion and decomposition all move carbon toward the nonliving world.

Also acceptable: None.

4. Name two **nonliving** reservoirs that store carbon, and for one of them name the process that moves carbon out of it.

Answer: Any two of: the air (carbon dioxide), ocean or pond water (dissolved carbon dioxide), soil (dead organic matter), fossil fuel deposits (coal, oil, gas), carbon-containing rock such as limestone. Processes out: photosynthesis takes carbon out of the air or water; combustion takes carbon out of fossil fuels; decomposers' cellular respiration takes carbon out of soil organic matter.

Why: Both reservoirs must be nonliving (not 'trees' or 'animals'), and the process must match the reservoir named.

Also acceptable: Accept 'the atmosphere' for air and 'burning' for combustion.

- Two nonliving reservoirs
- A correct process for one of them

5. A sealed glass jar containing water, a water plant, a snail and mud has a total mass of 1,240.0 g on day 1. By day 60 the plant has grown and some leaves have rotted. Predict the total mass on day 60 and explain your prediction in one sentence.

Answer: 1,240.0 g. The jar is sealed, so no matter can enter or leave; by the law of conservation of matter the plant's growth and the leaves' decay only move atoms between the water, the plant, the snail, the mud and the air inside the jar, and the total mass stays the same.

Why: Light energy enters, but energy has no measurable mass on a classroom balance; the point is that matter is conserved inside a closed boundary.

Also acceptable: Accept 'about 1,240 g' with the conservation explanation.

6. Fill each blank with the right kind of bacteria. _____ bacteria change nitrogen gas into ammonia. _____ bacteria change ammonium into nitrate. _____ bacteria change nitrate back into nitrogen gas.

Answer: Nitrogen-fixing bacteria; nitrifying bacteria; denitrifying bacteria.

Why: Three bacterial groups run the entry, conversion and exit of the nitrogen cycle.

Also acceptable: Accept 'nitrogen fixers' and 'denitrifiers'.

7. Lightning makes nitrogen gas react with oxygen in the air. In what form does that nitrogen reach the soil?

Answer: B. As nitrate carried down in rain.

Why: Lightning produces nitrogen oxides that dissolve in rain and reach the ground as nitrate (the textbook says ammonia; nitrate is the accurate form). Nitrogen gas dissolving in rain would not be fixed; protein and pellets are not natural products.

Also acceptable: None.

8. A classmate says, 'When I eat a bean, I use its nitrates to build my muscle protein.' Correct the statement: what form of nitrogen does your body actually use from food, and how does it get it?

Answer: Animals do not use nitrates. The bean's nitrogen is in its proteins; digestion breaks those proteins into amino acids, and the body links the amino acids into its own muscle proteins. Plants are the ones that absorb nitrate and ammonium.

Why: The correction separates the plant route (absorb nitrate or ammonium) from the animal route (digest protein to amino acids).

Also acceptable: Accept 'protein building blocks' for amino acids.

- Says animals use amino acids from protein, not nitrates
- Describes digestion as the way they get them

9. Which statement best describes what burning fossil fuels does to the carbon cycle?

Answer: B. It moves carbon that was stored underground for millions of years into the air within moments.

Why: Combustion releases carbon dioxide from a very slow reservoir into the fast cycle; no atoms are created (A) or destroyed (C), and the direction is ground to air, not air to ground (D).

Also acceptable: None.

10. A farmer spreads 100 kg of nitrogen on a field. The crop takes up 55 kg, and denitrifying bacteria return 15 kg to the air as nitrogen gas. If nothing else happens to it, how much nitrogen is left to wash into nearby water? Show your work and name the law that lets you be sure.

Answer: $100 \text{ kg} - 55 \text{ kg} - 15 \text{ kg} = 30 \text{ kg}$ left to wash into nearby water. The law of conservation of matter: the nitrogen atoms cannot disappear, so whatever the crop and the denitrifiers did not take must still be somewhere, and with nothing else happening, that somewhere is the water.

Why: A simple budget; the law is what justifies treating the remainder as real nitrogen that went somewhere.

Also acceptable: Accept 30 kg with 'conservation of matter' or 'conservation of mass'.

11. A county is choosing a reforestation site. Label each statement as a **criterion** (a goal to judge plans by) or a **constraint** (a limit plans must stay within).

Answer: At least 200 tons per year: criterion. Cannot cost more than \$80,000: constraint. No one moved off their land: constraint. Carbon stored at least 30 years: criterion.

Why: Criteria describe how good a plan is (how much, how long); constraints are limits that rule plans out (money, people).

Also acceptable: Accept 'constraint' for the 200-ton line if the student explains it as a minimum that must be met; the money and people statements must be constraints.

- All four labeled correctly

12. Draw a model of carbon moving inside the sealed jar from q5. Include at least three reservoirs (boxes) and three labeled process arrows, and draw a dashed boundary around the system. Label one thing that crosses the boundary and say whether it is matter or energy.

Answer: A drawing with at least three boxes (for example: carbon dioxide dissolved in the water; water plant; snail; dead leaves and mud; decomposers), at least three labeled arrows (photosynthesis from carbon dioxide to plant; feeding from plant to snail; cellular respiration from snail, plant or decomposers back to carbon dioxide; death or wastes to the mud; decomposition from mud to decomposers), a dashed boundary around the jar, and 'light' or 'sunlight' crossing the boundary labeled as energy (heat leaving is also acceptable).

Why: Score for correct arrow directions, correct process labels, a drawn boundary, and the crossing item correctly identified as energy, not matter.

Also acceptable: A model whose return arrow comes from the decomposers in the mud rather than the snail is correct. An arrow labeled 'oxygen' crossing the boundary is an error, since the jar is sealed.

- Three or more reservoirs
- Three or more correctly labeled and directed arrows
- Dashed boundary drawn
- Light (or heat) crossing the boundary, labeled as energy

Part B: Synthesis

13. A classmate says: 'If we keep burning coal and oil, Earth will eventually run out of carbon.' Write a response in five to eight sentences. Use the law of conservation of matter and the carbon cycle to explain what actually happens to the carbon in burned fuel, where it goes, and why that is still a serious problem even though no carbon is lost. End with one way people can move carbon back out of the air and one limit of that method.

Answer: Model response: Earth will not run out of carbon, because the law of conservation of matter says atoms are not destroyed when fuel burns. Burning coal and oil combines their carbon with oxygen and releases it as carbon dioxide, so the carbon moves from a reservoir underground, where it had been stored for millions of years, into the air. From the air it can dissolve in the ocean or be taken into plants by photosynthesis, but those routes are slow compared with how fast we are burning, so carbon dioxide builds up in the atmosphere. That is the problem: the carbon is not gone, it is in the wrong reservoir, and extra carbon dioxide in the air traps heat and changes the climate. One way to move carbon back out of the air is reforestation, because growing trees pull carbon dioxide in through photosynthesis and store it as wood. The limit is that the storage lasts only as long as the forest: if it burns, is cut or rots, the carbon returns to the air, and trees take years to grow and need land and water.

Why: Full credit requires the conservation argument, the correct destination (the air), the 'wrong reservoir, too fast' explanation of why it matters, a named method of removal and a genuine limit of that method.

Also acceptable: Other removal methods (capturing carbon dioxide at a power plant, protecting existing forests, restoring wetlands) are acceptable with a correct limit. A student who says 'we will run out of fossil fuels, not carbon' has made a valid distinction and should still address where the carbon goes.

- States that carbon is not destroyed (conservation of matter)
- Says burned carbon goes to the air as carbon dioxide from a long-term underground reservoir
- Explains why building up in the air is a problem despite no loss of matter
- Names a method such as reforestation with photosynthesis
- Names a real limit of the method

Teacher notes

Suggested points: q1 to q3, q6, q7, q9 and q11 one point each; q4, q5, q8 and q10 two points each; q12 four points; q13 six points (one per criterion plus one for clarity). Items q2, q7 and q8 deliberately test the accurate versions of statements the textbook gets wrong or simplifies: a tree's mass comes mostly from the air, lightning's fixed nitrogen arrives as nitrate, and animals use amino acids rather than nitrates. Item q5 is the conservation core of MS-LS2-3; students who answer 'more than 1,240 g because the plant grew' have not yet separated growth (matter moving between reservoirs) from the total (which cannot change inside a sealed boundary), and should revisit Worksheet 6. The extension can double as a make-up or enrichment task.

Scaffold offered to students: A starter for the drawing

For q12, begin with three boxes: 'carbon dioxide dissolved in the water', 'water plant', and 'snail' (or 'dead leaves and mud'). Draw an arrow from the carbon dioxide box to the plant labeled 'photosynthesis', an arrow from the plant to the snail labeled 'feeding', and an arrow from the snail (or from the decomposers in the mud) back to the carbon dioxide box labeled 'cellular respiration'. Then draw the dashed line around everything and write 'light' with an arrow crossing it from outside, labeled 'energy'.

Extension: Three cycles, one sandwich

Choose a simple meal, such as a cheese sandwich, and write a short account of how the carbon, the nitrogen and the water in it got there from the air, the soil and the sky, and where each will be one year after you eat it. Name every reservoir and process, and point out at least one place where two cycles share a single process.