

Two Jars, One Lid: Does a Closed System Keep Its Mass?

Investigation question: If seeds sprout, leaves rot and water droplets form inside a sealed jar, does the jar's mass change, and how does an identical open jar behave over the same two weeks?

Physical model

Groups of 4

3 sessions

Setup 10 · Activity 65 · Cleanup 10 min

MS-LS2-3 · assesses

MS-LS1-6 · supports

Scientific purpose

Students build two identical miniature ecosystems in clear containers, seal one and leave the other open, and track the mass and the visible changes in both over about two weeks. The sealed jar is a physical model of Spaceship Earth: closed to matter, open to light. Students use their own mass data to argue that matter was conserved while it changed form inside, that the open jar lost matter across its boundary as water vapor, and that even the sealed jar was open to energy.

Why this helps students with this chapter

Students will accept 'Earth is a closed system' as a slogan but rarely believe that a sprouting plant or a rotting leaf adds or removes nothing from a sealed container. Weighing the jar before and after visible change makes conservation a measurement rather than a rule, and the open twin jar shows what crossing a boundary looks like on a balance. The droplets on the lid give the water cycle in miniature, and the need for a windowsill makes 'open to energy' concrete.

Standards connections

MS-LS2-3 (assesses, describing conservation of matter in an ecosystem and defining the boundaries of the system): Students define the boundary of each jar system, record what can and cannot cross it, and use measured masses to describe conservation of matter among the living and nonliving parts (seeds, leaves, soil, water, air). This is the conservation-and-boundary emphasis named in the PE's clarification statement, without chemical reactions.

MS-LS1-6 (supports, photosynthesis and respiration moving matter into and out of organisms): Students reason that a seedling's new mass came from the jar's air and water rather than from nothing, which uses the role of photosynthesis as background without requiring the full explanation.

Roles (rotate each session)

- **Builder:** Measures and adds the soil, water, seeds and leaves to both containers in identical amounts and seals jar A with the lid and tape.
- **Mass recorder:** Zeroes the balance, masses each jar at every session, reads the display aloud to 0.1 g and records it. Masses each jar twice and records both.

- **Observer:** Writes the observations for both jars at every session: droplets, sprouts, color changes, mold, smell (open jar only), and takes or sketches a picture.
- **Checker:** Confirms the jars are labeled, returned to the same spot and not opened; checks each table row is complete before the group leaves.

Materials

Item	Quantity	Per	Note
Clear plastic deli containers with tight lids, about 500 mL to 1 L	2	group	Plastic, not glass; both must be the same size and model.
Potting soil (not garden soil)	about 1 cup (240 mL) per container, 2 cups	group	
Grass seed or radish seed	about 20 seeds per container	group	Radish sprouts in 3 to 5 days and is easy to see.
Dead leaves, crumbled	2 per container	group	
Water in a measuring cup or graduated cylinder	30 mL per container	group	
Clear packing tape	about 30 cm	group	To seal the lid seam of jar A.
Digital balance reading to 0.1 g (capacity at least 500 g)	1	class	Two balances halve the queue; always use the same balance for a given jar.
Labels or masking tape and marker	2	group	
Recording sheet	1	student	
Disposable gloves	4 pairs	group	For building and for the final opening.

Estimated cost: 15 to 25 per class, mostly reusable (an estimate; Deli containers about \$8 for 16, a small bag of potting soil about \$6, radish seed about \$3, tape and gloves from stock; the balance is standard equipment.)

Safety

- Mold will probably grow on the leaves. Do not open the sealed jar near your face; open it at the end only, at arm's length, and let any student with a mold allergy or asthma observe from a distance rather than handle the jars. Wear gloves and wash hands after every handling.
- Use plastic containers only; a dropped glass jar on a windowsill is a cut hazard.
- Potting soil can carry bacteria and fungi; keep it off faces, do not eat or drink during the lab, and wipe the bench afterward.
- Do not place a sealed jar in direct hot sun; heat can bulge the lid and the contents can spoil quickly.

Teacher preparation and setup

1. Choose a spot that gets daylight but not direct hot sun for hours (direct sun can cook a sealed jar) and that stays at a steady temperature; a north- or east-facing windowsill or a lit shelf works.

2. Pre-measure soil in cups so building goes fast. Check that your balance can take the full jar (a 1 L container with a cup of moist potting soil and the added water is usually 150 to 400 g, depending on how damp and dense the soil is).
3. Run one pair of jars yourself a week ahead so you know what your seeds and leaves will do in your room, and keep it as a demonstration pair.
4. Plan the three sessions on the calendar: day 0 (build and mass, about 30 minutes), day 3 to 5 (mass and observe, about 10 minutes), day 10 to 14 (mass, observe, open and conclude, about 25 minutes).

Investigation design

Independent variable	Whether the container is sealed (jar A) or open to the room (jar B)
Dependent variable	Change in the mass of each jar from day 0 to the final day, plus the visible changes inside
Controlled	Same container type and size; Same amounts of soil, water, seeds and leaves; Same spot, light and temperature; Same balance and the same handling at every session; Same number of days between sessions
Trials	Each group runs one pair; the class pools all groups' mass changes so that balance noise averages out.
Comparison	Jar A (closed to matter) versus jar B (open to matter); both are open to energy.

Student procedure

1. Label the containers A (sealed) and B (open) with your group name. Before adding anything, mass each empty container with its lid and record the values; this lets you check that the two jars start alike.
2. Build both jars exactly the same way: 1 cup of potting soil pressed level, 30 mL of water poured evenly over it, 20 seeds pressed lightly into the surface, and 2 crumbled dead leaves laid on top.
3. Put the lid on jar A and run tape around the seam so no air or water can leave. Put the lid on jar B only while carrying it, and remove it once the jar is in place; jar B stays open for the whole experiment.
4. Mass each finished jar twice (jar B with its lid off, the same way every time) and record both readings as day 0. Write the time of day. Record the first observations and make the day 0 drawing.
5. Fill in the boundary table: for each jar, decide what can cross its boundary (matter, energy, both, neither) and write a prediction with a reason for what each jar's mass will do over two weeks.
6. Place both jars side by side in the chosen spot. Nobody opens jar A, moves either jar to a different place, or adds anything to jar B until the last session.
7. Session 2 (day 3 to 5): mass each jar twice on the same balance, record, and write observations: droplets on the lid or walls, sprouts and their height, leaf color, mold, dryness of the soil surface in jar B.
8. Session 3 (day 10 to 14): mass each jar twice and record. Observe and make the final drawing. Compute the change in mass for each jar from day 0 to the final day using the average of the two readings each time.
9. With gloves on and the jar held at arm's length, open jar A over the bench. Note any smell, the wetness of the soil and the condition of the sprouts and leaves. Empty both jars into the compost or trash, wash the containers and your hands.

10. Answer the analysis questions on your own, then compare in your group and revise what you now disagree with.

Expected observations

- Jar A: droplets form on the lid and upper walls within a day; radish seeds sprout in 3 to 5 days and reach 2 to 5 cm; leaves darken and may grow white or gray mold; the soil surface stays moist; mass stays within about 0.1 to 0.3 g of day 0 across all sessions.
- Jar B: the soil surface dries and lightens in color; sprouts appear but may wilt if the soil dries out; little or no droplet formation; mass falls by several grams over two weeks, typically 5 to 15 g for a 1 L container with 30 mL of water added, depending on room humidity.
- Empty-container masses for A and B agree within a gram, and the built jars agree within a few grams; small differences do not affect the change comparison.

Likely difficulties

- A poorly sealed lid lets jar A lose a gram or two over two weeks. Tape the seam, mass it immediately, and treat a small steady loss as evidence of a leak rather than of matter being destroyed; it is a good discussion in itself.
- Balance drift and handling: students press on the pan or mass jar B with its lid on at one session and off at the next. Insist on the same balance, the same lid rule and two readings every time.
- Jar B's sprouts may die if the soil dries fully. Do not add water; the drying is the point, and the dead sprouts are a chance to discuss decomposers.
- Students expect the sealed jar to lose mass because 'the plants are using things up' or to gain mass because 'the plants grew.' Both predictions are worth writing down on day 0 so the data can test them.

Structured debrief

1. Collect every group's change in mass for A and B on the board and compute the two class averages. Jar A changes should scatter around zero within balance noise; jar B changes should be clearly negative. Ask: what does a change of 0.0 g in jar A prove, and what does it not prove? It proves no matter crossed the lid; it does not prove nothing happened inside, because everyone watched things happen.
2. Ask where jar B's lost grams went. Students should say the room's air, as water vapor, by evaporation, and should notice that the room is now part of jar B's system if you want to conserve matter. Drawing the boundary bigger restores conservation, which is the point of defining the boundary first.
3. Return to the sprouts: a seedling that grew inside a sealed jar added mass to the plant reservoir, so some other reservoir inside the jar lost it, mostly the seed's own stored food at first, then the jar's air and water. Nothing came from the lid. Connect to the tree-and-soil misconception: a tree's wood comes mostly from the air.
4. Finish on energy: jar A would have died in a dark closet with the same lid on. Closed to matter, open to energy, is exactly Earth's situation, and the droplets on the lid are the water cycle running on windowsill light.

Recording sheet: what students fill in

Lab 2 recording sheet: Two jars, one lid

Mass each jar twice at every session and use the average. Jar B is always massed with its lid off. Record the date and time, because balances drift and so does the room.

Boundary table: what can cross?

System	Where is the boundary?	Can matter cross? (how)	Can energy cross? (how)	My prediction for its mass over two weeks, and why
Jar A (sealed)				
Jar B (open)				

Mass record (grams, to 0.1 g)

Session and date	Jar A reading 1	Jar A reading 2	Jar A average	Jar B reading 1	Jar B reading 2	Jar B average
Empty containers with lids, day 0						
Built jars, day 0						
Session 2, day ____						
Session 3, day ____						
Change, day 0 to final (final minus day 0)						

Observation record

Session	Jar A: droplets on lid or walls?	Jar A: sprouts (number, height), leaves, mold	Jar B: soil surface wet or dry?	Jar B: sprouts (number, height), leaves, mold
Day 0				
Session 2				
Session 3				

-  Draw jar A twice, side by side: on day 0 and on the final day. Label the soil, seeds or sprouts, leaves, water droplets and the air space, and draw the boundary as a heavy line. Add an arrow for each thing that crosses the boundary (light in, heat out) and write 'no matter crosses' on the lid.

Answer: Two labeled panels of jar A. Day 0: level soil, seeds on the surface, two leaf pieces, clear air space, dry lid. Final day: sprouts 2 to 5 cm tall, darkened or moldy leaf pieces, droplets on the lid and upper walls, soil still moist. Both panels show the boundary as a heavy line around the whole container, an arrow for light entering through the side, an arrow for heat leaving, and the words 'no matter crosses' on the lid.

Why: The drawing is the student's model of a closed system with its boundary defined, which is the MS-LS2-3 emphasis. Energy arrows show the student separates matter from energy at the boundary.

Also acceptable: Accept labeled photographs with the boundary and arrows drawn on them.

- Both panels present with soil, seeds or sprouts, leaves, air space and droplets labeled where present
- Boundary drawn as a closed line around the container
- Energy arrows for light in and heat out, and a statement that no matter crosses

1. Did the two jars start with the same mass within 1 g? If not, what might have differed, and does it matter for comparing the changes?

Answer: Usually yes, within 1 g, because the containers are the same model and the contents were measured. If they differ, the cause is usually a different amount of soil pressed in or a different lid. It does not matter for the comparison, because each jar's change is computed from its own day 0 reading.

Why: Students should see that a change is a difference within one jar, so a small offset between jars cancels out.

- States whether the day 0 masses agreed
- Explains that the change is computed within each jar, so an offset does not affect the comparison

2. Describe the first change you could see in jar A and the first change you could see in jar B. Which cycle (water, carbon or nitrogen) does each belong to?

Answer: Jar A: droplets on the lid and walls, usually within a day (water cycle: evaporation then condensation). Jar B: the soil surface drying (water cycle: evaporation into the room). Sprouting in either jar is the carbon cycle (photosynthesis beginning, and respiration of stored seed food); darkening or mold on the leaves is decomposition, part of the carbon and nitrogen cycles.

Why: Any correctly matched change and cycle earns credit; the common first change in both jars is water moving.

- Names a specific first change for each jar
- Assigns each change to the correct cycle

Analysis questions: answer key

3. Compute the change in mass for each jar from day 0 to the final session using the averages. Show the subtraction and state each result with its sign and unit.

Answer: Group-specific. Example: jar A day 0 average 352.4 g, final 352.3 g, change = $352.3 - 352.4 = -0.1$ g. Jar B day 0 average 351.9 g, final 343.6 g, change = $343.6 - 351.9 = -8.3$ g. Jar A: about 0 g (within balance noise); jar B: a loss of several grams.

Why: Check that the student subtracted final minus day 0 using averages and kept the sign. A jar A result within about ± 0.3 g should be interpreted as no change.

Also acceptable: Accept a small positive jar A change with the comment that it is within the balance's noise.

4. Jar B's mass changed. Where did that matter go, in what form, and which process in the water cycle moved it across the boundary?

Answer: Into the room's air, as water vapor, by evaporation from the wet soil surface. The water molecules left through the open top, so the jar lost mass; the matter still exists, now outside the jar's boundary.

Why: The student must name the form (vapor), the destination (room air) and the process (evaporation), and should say the matter was moved, not destroyed.

- Names water vapor and the room air
- Names evaporation
- States the matter was not destroyed

5. Inside jar A, seeds sprouted and leaves changed, yet its mass stayed within about 0.3 g of the start. Explain where the new sprout matter came from and where the leaf matter went, using the names of reservoirs inside the jar.

Answer: The sprouts' new matter came from inside the jar: first from the food stored in the seed itself, then from carbon dioxide in the jar's air and water from the soil, taken in by photosynthesis once the leaves opened. The leaf matter went to decomposers (mold and bacteria) that fed on it and released carbon dioxide and water back into the jar's air and soil by cellular respiration. Matter moved among the reservoirs air, water, soil, seeds and sprouts, leaves and decomposers, but none crossed the lid, so the total mass stayed the same.

Why: This is the core MS-LS2-3 evidence: internal cycling with conservation and a defined boundary. Equations are not expected or wanted.

- Sources the sprout mass from reservoirs inside the jar (seed food, air, water), not from nothing or from the soil alone
- Sends the leaf matter to decomposers and then to the jar's air and soil
- States that the total stayed the same because nothing crossed the boundary

6. Is jar A a closed system for energy? Use the fact that the seedlings needed the windowsill, and the droplets on the lid, to support your answer.

Answer: No. Light energy came in through the plastic (the seedlings grew green and would have died in a dark closet), and heat left the jar at night (the lid cooled, which is why droplets formed on it). So jar A was closed to matter but open to energy, like Earth.

Why: Both pieces of evidence point to energy crossing a boundary that matter could not cross.

- Answers no
- Uses the windowsill or light as evidence of energy in
- Uses the droplets or cooling as evidence of heat out

7. Pool the class data: compute the average change in mass for all the A jars and for all the B jars. Why is the class average more trustworthy than your group's single pair?

Answer: Class-specific. Example with six groups: A changes -0.1 , $+0.2$, -0.3 , 0.0 , -0.2 , $+0.1$ give an average of -0.05 g, about zero; B changes -8.3 , -6.9 , -11.2 , -7.5 , -9.0 , -5.8 give an average of -8.1 g. The class average is more trustworthy because random errors (balance drift, a slightly leaky lid, a nudge of the pan) push different groups in different directions and partly cancel, while a real effect shows up in every group.

Why: Students should add the changes and divide by the number of groups, then explain averaging as canceling random error.

Also acceptable: Accept a median with the same reasoning.

8. Earth is like jar A, and the room is like the rest of the universe. Name two ways jar A is a good model of Earth as a system and two ways it is a poor one.

Answer: Good: (1) matter cannot cross the boundary, so everything inside must be reused, just as on Earth; (2) energy does cross, light in and heat out, so the cycles inside keep running; (3) the water cycle, the carbon cycle and decomposition all run inside it. Poor: (1) the jar is tiny, so its air and nutrients can run out in weeks while Earth's reservoirs are enormous; (2) the jar has no rocks, ocean, weather or seasons; (3) the jar loses heat to a warm room, not to cold space; (4) the jar's seal can leak, and Earth's small leaks (space dust in, gas out) are different in kind.

Why: Two of each with a reason earns full credit; the student should show they can evaluate a model, not just use it.

- Two valid ways the jar matches Earth as a system (closed to matter, open to energy, cycles inside)
- Two valid differences (size, missing reservoirs, how energy leaves, leaks)

9. Suppose jar A were left sealed on the windowsill for a whole year. Predict what would happen to the sprouts, the leaves and the mass, and explain each prediction with a cycle.

Answer: Sprouts: most would die once the small amount of nitrogen and other nutrients in the soil and the seed ran low and as they crowded each other; a few might persist if decomposers recycled nutrients fast enough. Leaves and dead sprouts: decomposers would break them down into dark soil material, carbon dioxide and water, so the leaf shapes would disappear (carbon and nitrogen cycles). Water: it would keep evaporating and condensing, so droplets would come and go daily but the total water would stay (water cycle). Mass: unchanged, because the lid still blocks matter; only energy crosses.

Why: Predictions must be tied to cycles and to conservation. Credit a prediction that the system reaches a slow balance of decomposers and a little plant growth, which is what long-sealed terrariums do.

- Predicts the fate of sprouts and leaves using decomposition and nutrient limits
- Predicts no change in mass with the boundary reason
- Links at least two predictions to named cycles

Individual evidence of learning

Each student submits their own boundary table, complete mass and observation records, the two-panel drawing of jar A with the boundary and energy arrows, and written answers to q1 through q9. The drawing plus q5 and q6 are the primary evidence for a model that describes conservation of matter with a defined boundary; q4 and q8 show the student can reason about what crosses a boundary.

Assessment criteria

Criterion	Proficient looks like
Measurement and records	All masses recorded twice per session with averages and the change computed correctly with sign and unit; observations specific and dated.
Boundary and conservation reasoning	States the boundary of each jar, explains the near-zero change in jar A as conservation of matter within a closed system and jar B's loss as water vapor crossing an open boundary.
Model of internal change	Drawing and q5 show reservoirs inside the jar (air, water, soil, seeds or sprouts, leaves, decomposers) with matter moving between them while the total stays the same.

Matter versus energy

Explains that the sealed jar is open to energy, citing light in and heat out and the need for the windowsill.

Accessibility adaptations

- Let a partner handle the balance while the student reads the display aloud and records; a talking balance or a phone camera zoomed on the display helps low-vision students.
- Provide the mass table with the day 0 row already averaged as an example, and a word bank (evaporation, condensation, photosynthesis, cellular respiration, decomposition) for q2, q4 and q5.
- Students with mold allergies or asthma can run the Checker role, observe through the plastic, and skip the final opening; their group reports the smell and texture to them.
- Accept the two-panel drawing as a labeled photograph pair, and allow q8 and q9 as a recorded spoken response.

Low-cost alternative

Use two clear zip bags instead of containers: tape one shut and leave the other open at the top, clipped upright in a cup. Garden soil from the school grounds and birdseed work in place of potting soil and radish seed. One class balance is still needed; if only a 1 g balance is available, use larger containers and more water so that jar B's loss is clearly measurable.

Model limitations

A deli container is closed to matter only as long as the seal holds, and plastic lets a tiny amount of water vapor through over weeks, so a loss of a few tenths of a gram is not evidence against conservation. The jar has far less air than a real ecosystem, so carbon dioxide and oxygen inside can swing to levels no pond or forest reaches, and the sprouts will eventually run out of nutrients. The jar is also open to energy in a simpler way than Earth, which radiates heat to space rather than to a room. This activity has not been physically tested by the authors; the expected mass changes are estimates for a 1 L container with 30 mL of water in an ordinary classroom.

Teacher notes

Grade q3 and q7 on the arithmetic and the interpretation of noise, not on hitting a particular number. If several A jars lost more than 0.5 g, check for leaks and discuss the difference between a leaky model and a broken law. Keep your demonstration pair for the misconception slide: a sealed jar that rotted and sprouted at constant mass is the strongest reply to 'decay destroys matter.' Compost the contents; do not let students take sealed jars home.