

Do Plants Run on Oxygen Too? A Claim-Evidence-Reasoning Case

Learning target: I can use gas measurements and field observations to argue whether plants carry out cellular respiration, and explain my reasoning with the idea that cells release energy from sugar by reacting it with oxygen.

Claim, evidence, reasoning

About 45 min

Individual

MS-LS1-7 · practice

MS-LS1-6 · supports

writing

data analysis

Standards connections

MS-LS1-7 (practice): Students use evidence to argue that producers, like consumers, rearrange sugar and oxygen into carbon dioxide and water to release energy. Writing the argument builds the understanding that the model in the PE applies to every organism, including plants.

MS-LS1-6 (supports): The lamp-on data show photosynthesis removing carbon dioxide while respiration continues, so students must keep both processes in mind at once; this connects the two lessons' explanations of matter and energy.

Purpose: practice · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

The scenario

Two students disagree. Nadia says, 'Plants make their own food with photosynthesis, so they don't need cellular respiration. They don't even take in oxygen.' Tomas says, 'Every living cell has to release energy from food, so plants must do cellular respiration too, even if they also photosynthesize.' Their teacher gives them three pieces of evidence to settle it. Study each one carefully.

Evidence 1: carbon dioxide inside a sealed box

A small basil plant was potted in sand that had been rinsed and heated so that no soil microbes were living in it. The pot was sealed inside a clear plastic box with a carbon dioxide sensor. A second, identical box held a pot of the same sterile sand with no plant. A lamp shone on both boxes for the first three hours, then was switched off for the next three hours. The sensor reports carbon dioxide in parts per million (ppm); ordinary air is about 420 ppm.

Carbon dioxide inside two sealed boxes (teaching dataset)

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

Hour	Lamp	Box with basil plant (ppm)	Box with sand only (ppm)
0	on	420	420
1	on	385	421
2	on	350	419
3	on	315	420
4	off	365	422
5	off	415	420
6	off	465	421

Simulated data for teaching. Lamp on from hour 0 to hour 3; lamp off from hour 3 to hour 6. Both boxes stayed at 23 °C.

Evidence 2: oxygen in a dark jar of sprouting seeds

Oxygen in two sealed jars kept in a dark cupboard for 24 hours (teaching dataset)

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

Jar	Oxygen at start (% of air)	Oxygen after 24 h (% of air)	What the seeds looked like after 24 h
Living sprouting seeds	20.9	17.6	white root tips about 1 cm long
Boiled seeds	20.9	20.9	swollen, no roots

Simulated data for teaching. Each jar held 50 radish seeds that had been soaked overnight. One batch was boiled first to kill the seeds.

Evidence 3: a field note

From a community garden logbook — After the creek overflowed, the low bed stayed under water for nine days. When it drained, the tomato plants in that bed were wilted even though the soil was soaking wet. We pulled one up: the roots were brown, soft and smelled sour. The tomatoes in the raised bed next to it, which drained within a day, were fine, with white, firm roots. Soil that stays flooded has almost no air left in the spaces between its grains.

Warm-up: organize the evidence

1. In Evidence 1, describe what the carbon dioxide in the plant box did while the lamp was on and what it did after the lamp went off. What did the sand-only box do the whole time?

Answer: Lamp on: carbon dioxide in the plant box fell steadily from 420 to 315 ppm. Lamp off: it rose steadily from 315 to 465 ppm, ending higher than it started. The sand-only box stayed at about 420 ppm the whole time (419 to 422).

Why: The reversal at hour 3 and the flat control are the two key observations.

Also acceptable: Accept 'dropped about 35 ppm an hour, then climbed about 50 ppm an hour.'

- Fall in the light with numbers
- Rise in the dark with numbers
- Sand-only box flat

2. Calculate the rate at which carbon dioxide rose in the plant box in the dark (hours 3 to 6), in ppm per hour. Then calculate the rate at which it fell in the light (hours 0 to 3). If the plant was releasing carbon dioxide at the dark rate the whole time, at what rate was photosynthesis removing carbon dioxide while the lamp was on? Show your work.

Answer: Dark rise: $(465 - 315) \text{ ppm} \div 3 \text{ h} = 150 \div 3 = 50 \text{ ppm per hour}$. Light fall: $(420 - 315) \text{ ppm} \div 3 \text{ h} = 105 \div 3 = 35 \text{ ppm per hour}$. If the plant was still releasing 50 ppm per hour in the light, photosynthesis must have been removing $50 + 35 = 85 \text{ ppm per hour}$ to produce a net fall of 35 ppm per hour.

Why: This is the central calculation: the net change in the light is the difference between carbon dioxide removed by photosynthesis and carbon dioxide released by respiration. Students need not assume respiration was exactly 50 ppm/h in the light; the point is that the net drop hides a continuing release.

Also acceptable: Accept 'about 85 ppm per hour' with the reasoning shown; accept an answer that says photosynthesis removed at least 35 ppm per hour and more if respiration continued.

3. Why did the teacher include the sand-only box and the boiled seeds? What claim of Nadia's does Evidence 2 test most directly?

Answer: The sand-only box shows that the sand, the box and the sensor do not change the carbon dioxide on their own, so any change in the plant box comes from the plant. The boiled seeds show that the oxygen loss in the living jar comes from the seeds being alive, not from the jar or the water. Evidence 2 most directly tests Nadia's claim that plants 'don't even take in oxygen': the living seeds, which are plant tissue in the dark, used 3.3 percentage points of oxygen.

Why: Each comparison removes an alternative explanation; naming the specific claim being tested shows the student is reading the evidence as an argument.

Also acceptable: Accept 'the controls prove it is the living plant doing it.'

- Explains the control boxes as ruling out non-living causes
- Identifies the oxygen-intake claim as the one Evidence 2 tests

Your argument

Answer: Claim: Plants do carry out cellular respiration, and they do take in oxygen when and where they are not photosynthesizing. Tomas is right. Nadia is partly right that plants make their own food, but wrong that they skip respiration or never take in oxygen. Evidence: (1) In the dark, carbon dioxide in the sealed plant box rose from 315 to 465 ppm, about 50 ppm per hour, while the sand-only box stayed at 420 ppm, so the plant was releasing carbon dioxide. (2) In the light, carbon dioxide fell 35 ppm per hour; if respiration kept releasing 50 ppm per hour, photosynthesis was removing about 85 ppm per hour, so the drop was a net result of two processes. (3) In the dark jar, living sprouting seeds used oxygen (20.9% to 17.6%) and grew roots; boiled seeds used none, so living plant tissue takes in oxygen. (4) Roots in soil flooded for nine days, where the air spaces were full of water, died and rotted, while roots in drained soil stayed firm and white, so roots need oxygen from the soil air to stay alive. Reasoning: Cellular respiration is the reaction in which sugar and oxygen (reactants) are rearranged into carbon dioxide and water (products), releasing energy the cell uses to live and grow. A plant that respire must take in oxygen and release carbon dioxide wherever its cells cannot get those from photosynthesis: in the dark, in seeds and in roots. The dark-box rise and the seed-jar oxygen loss are exactly the gas pattern the reaction predicts, and the controls show the plant tissue caused them. In the light, the leaves' photosynthesis used carbon dioxide faster than respiration released it, so the reading fell even though respiration continued; the rate calculation shows the release was hidden, not stopped. Flooded roots died because they are plant cells with no light and no photosynthesis; without oxygen from soil air they could not release energy from sugar and could not stay alive. Together the evidence shows the model of cellular respiration applies to producers as well as consumers.

Why: This is the solved model response. Full credit requires a claim that names who is right and the partial truth in Nadia's view; at least three evidence items with numbers; reasoning that uses reactant and product, explains the net drop in the light, and explains the flooded roots.

Also acceptable: A student who claims that plants respire only at night has used the evidence but missed the q2 calculation; award partial credit on the claim and full credit on evidence if the numbers are correct. A student who argues the seeds are 'not really plants' should be reminded that a sprouting seed is a young plant.

- Claim says plants respire and take in oxygen; identifies Tomas as right and Nadia as partly right
- At least three evidence items with numbers from the data
- Each evidence item states which gas moved in or out
- Reasoning names sugar and oxygen as reactants and carbon dioxide and water as products and says the reaction releases energy
- Reasoning explains the light-period drop as photosynthesis outpacing respiration
- Reasoning explains root death as lack of oxygen for respiration

4. Suppose the lamp had been left on for a full 24 hours. Predict what the carbon dioxide reading in the plant box would have done, and explain why that result would **not** mean the plant had stopped cellular respiration.

Answer: The carbon dioxide would keep falling, more and more slowly, and then level off at a low value when it became too scarce for photosynthesis to keep up with respiration. It would not mean respiration stopped: the leveling off happens when the carbon dioxide removed by photosynthesis equals the carbon dioxide released by respiration, so both are running. The dark-period rise is the proof that respiration never switched off.

Why: Students should recognize a steady reading as a balance between two processes, not the absence of one.

Also acceptable: A student who predicts the reading falls toward zero and stays there has the first idea; the balance explanation should still be present for full credit.

- Predicts a continued fall then a leveling off (or a low steady value)
- Explains the steady value as photosynthesis removal balancing respiration release

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	States that plants carry out cellular respiration and take in oxygen, names Tomas as right, and identifies the part of Nadia's statement that is true.	States that plants respire and take in oxygen; does not address who is partly right.	Claim is partly correct (for example, plants respire only at night) or contradicts part of the evidence.	No claim, or a claim that plants do not respire.
Evidence	Three or more specific pieces of evidence with numbers or observations from at least two of the three sources, each stating which gas moved in or out.	Three pieces of evidence, but one lacks a number or does not say what it shows about gases.	One or two pieces of evidence, or evidence listed without connecting it to gases going in or out.	Evidence missing, invented, or contradicting the data.
Reasoning	Uses reactant and product correctly, explains the net drop in the light as two processes at once, and explains the flooded roots as lack of oxygen for respiration.	Uses the model of cellular respiration to connect evidence to the claim but leaves out the light-period explanation or the roots.	Restates the evidence without the model, or states the model without linking it to the evidence.	No reasoning, or reasoning that confuses photosynthesis with respiration.
Scientific language and accuracy	Uses cellular respiration, photosynthesis, reactant, product and oxygen correctly; distinguishes breathing from cellular respiration; no scientific errors.	Terms mostly correct; one minor slip (for example, 'plants breathe' without explanation).	Several terms used loosely (for example, 'plants make oxygen so they don't need it').	Scientific language absent or consistently wrong.

Teacher notes

All three sources are teaching data, but the patterns are real: a plant in a sealed container lowers carbon dioxide in the light and raises it in the dark; germinating seeds consume oxygen; and roots in waterlogged soil die from lack of oxygen. The sterile sand is specified so that soil microbes cannot be blamed for the dark rise; if a student raises that objection anyway, it is a good one and the extension answers it. This sheet

corrects the textbook's claim that producers do not need to take in oxygen because photosynthesis supplies it; that is true only for a sunlit leaf, not for roots, seeds or any plant cell at night. The q_2 calculation (net change = photosynthesis removal minus respiration release) is the most demanding step; work one example on the board if needed. Keep the discussion at the level of inputs, outputs and energy release; the steps of the reactions are beyond the assessment boundary.

Scaffold offered to students: An evidence grid before writing

On scrap paper, make three rows (Evidence 1, 2, 3) and three columns: 'What changed?', 'Which gas, in or out?', and 'What would Nadia have to say about it?'. Fill the grid before you write. For Evidence 1, use two rows: lamp on and lamp off. Each filled cell becomes one sentence of your Evidence section, and the third column gives you your Reasoning: if Nadia's idea cannot explain a cell, say so.

Extension: Design the fourth piece of evidence

Nadia now agrees that plants release carbon dioxide in the dark but says it might come from the sand after all. Design an experiment that would settle this using the sealed boxes, and say exactly what readings would support her and what readings would support Tomas. Then explain why the plant box and the sand box being at the same temperature mattered, and what you would expect to happen to the dark rate if both boxes were warmed to 33 °C.