

The Jar That Warmed Up: What Are the Seeds Doing in the Dark?

Investigation question: Three sealed jars of pea seeds sit in a dark cupboard overnight. Which jar changes the indicator, warms up and grows, and what hidden process explains all three changes at once?

Evidence-based mystery

Groups of 4

2 sessions

Setup 10 · Activity 60 · Cleanup 10 min

MS-LS1-7 · assesses

MS-LS2-3 · supports

Scientific purpose

Students set up living, dry and boiled seeds in sealed jars with a carbon dioxide indicator, read the jars a day later, and reason from color, temperature and growth evidence to the process responsible. The mystery format makes them propose and rule out explanations (water, light, air, something alive) before the name cellular respiration is attached, and the plant setting makes the point that producers respire too.

Why this helps students with this chapter

Students readily believe animals release energy from food and plants get energy from light. Watching a plant part grow, warm and give off carbon dioxide with no light forces the idea that the seed is running on stored food the same way a squirrel runs on an acorn. The boiled and dry controls let students rule out 'the water did it' and 'the air did it' themselves instead of being told.

Standards connections

MS-LS1-7 (assesses, evidence that food molecules are rearranged in an organism to release energy and that products leave): Students use their own observations of a product (carbon dioxide), released energy (warmth) and growth from stored food to build and defend a model of what the seeds are doing. The reaction's details are not asked for, which respects the assessment boundary.

MS-LS2-3 (supports, defining a system boundary and tracking matter into and out of it): The sealed jar is a closed system for matter; students must decide what crossed into the indicator and what the seeds' stored starch became, which is the organism-scale version of ecosystem matter tracking in Lesson 6.

Roles (rotate each session)

- **Jar manager:** Loads the seeds, places the indicator cup, seals each lid and labels the jar. Opens jars on day 2 only when the group is ready to record.
- **Indicator reader:** Compares the indicator cup against the printed color key on day 1 and day 2 and records the color and the match number.
- **Measurer:** Measures five seeds or sprouts from each jar with a ruler on day 2 and reads the class vacuum flask thermometers when asked.

- **Recorder and reporter:** Keeps the recording sheet, writes the group's predictions, and reports the group's day 2 results to the class table.

Materials

Item	Quantity	Per	Note
Dried whole peas (grocery store), soaked 24 h by the teacher	about 40 g (a small handful)	group	Lentils or mung beans also work and sprout faster.
Dried whole peas, unsoaked	about 40 g	group	
Soaked peas boiled 10 minutes and cooled (teacher-prepared)	about 40 g	group	
Clear jars with tight lids, 250-500 mL	3	group	Clean recycled jam or sauce jars are fine.
Small cups or vials for indicator (bottle caps or 30 mL medicine cups)	3	group	
Bromothymol blue indicator, 0.04% solution	about 30 mL	group	Red cabbage juice (blue-purple, turns pink-red with carbon dioxide) is a food-safe substitute.
Paper towels, damp	3 sheets	group	
Ruler marked in millimeters	1	group	
Printed indicator color key (blue, green, yellow swatches numbered 1-3)	1	group	
Vacuum flasks (thermoses) with a thermometer through a cotton plug	2	class	One holds living soaked seeds, one holds boiled seeds, for the class temperature comparison.
Thermometers, 0-50 °C or digital probe	2	class	
Masking tape and marker for labels	1	group	
Safety goggles	1	student	

Estimated cost: 12 to 18 per class (an estimate; One pound of dried peas (about \$2) supplies every group; a 500 mL bottle of 0.04% bromothymol blue is \$8 to \$12 and lasts many classes; jars are recycled; two thermoses and thermometers are usually in the science closet.)

Safety

- Bromothymol blue is a mild skin and eye irritant and stains clothing. Wear goggles while pouring or opening jars, wipe spills with a wet towel and wash hands afterward. Use red cabbage juice if any student has a known sensitivity.

- Do not eat the seeds; soaked and boiled seeds in a sealed jar can grow mold within a day or two. Open day 2 jars at arm's length, not near the face, and discard contents in the trash, not the sink.
- Glass jars can break: carry one at a time with two hands, keep them off the edge of the desk, and tell the teacher about any crack. Plastic jars are an acceptable substitute. Screw lids on snugly, not wrenched tight, and if a lid bulges the teacher loosens it at arm's length.
- The boiled seeds are prepared by the teacher; students never handle hot water in this lab.
- Keep the indicator cup upright inside the jar; it must not touch the seeds or be swallowed by the sprouts' water.

Teacher preparation and setup

1. Two days before: soak enough peas for the living jars and the living thermos in tap water for 24 hours, then drain and rinse. Soak a second batch for the boiled jars, boil it for 10 minutes, cool and rinse. Keep the batches labeled.
2. Mix or buy 0.04% bromothymol blue. Pour a small amount into one cup and blow into it through a straw yourself to see the blue-green-yellow change and to calibrate the printed color key.
3. Fill the two class thermoses: one with about 200 g of living soaked seeds, one with about 200 g of boiled seeds, each with a thermometer pushed through a loose cotton plug. Record both starting temperatures on the board.
4. Run one group set yourself 24 hours ahead so you know how strongly the living jar changes with your seeds and room temperature; cold rooms slow the change.
5. Print the recording sheet and the color key; set the dark cupboard or a box aside with room for every group's three jars.

Investigation design

Independent variable	Condition of the seeds: living and soaked (A), dry (B), or soaked and then boiled (C)
Dependent variable	Indicator color number (carbon dioxide evidence), average root or shoot length (growth), and the temperature change in the class thermoses (energy released as heat)
Controlled	Same mass of seeds in each jar; Same jar size and lid; Same depth of indicator in the same size cup; Same dark cupboard and the same 24 hours; Same damp towel in every jar, so water is present in B as well as A
Trials	Each group runs one set of three jars; the class pools the indicator numbers and lengths so that about eight independent jar A results can be compared.
Comparison	Jar A against jars B and C, which share everything with A except living, activated seeds.

Student procedure

1. Day 1. Look at a few seeds from each of the three batches (living soaked, dry, boiled). Record what you see and feel on the recording sheet, then write your group's prediction for each jar: will the indicator change, will the jar warm, will the seeds grow?

2. Line each jar with a damp paper towel. Put about 40 g of one batch of seeds on the towel in each jar, keeping the batches separate. Label the jars A (living soaked), B (dry) and C (boiled).
3. Pour indicator into three small cups to the same depth (about 1 cm). Compare each cup to the color key and record the starting color number. Stand one cup upright on the towel in each jar, away from the seeds.
4. Seal each lid tightly. Record the time. Place all three jars in the dark cupboard. Read and record the two class thermos temperatures on the board.
5. Day 2 (about 24 hours later). Before opening anything, look through the glass: record the indicator color number for each jar and any visible change in the seeds (roots, swelling, color, moisture on the glass).
6. Read and record the two class thermos temperatures. Compute the change for each since day 1.
7. Open each jar at arm's length with goggles on. Remove five seeds or sprouts, lay them on a paper towel and measure the longest root or shoot on each in millimeters. Record all five and the average.
8. Report your group's indicator numbers and average lengths to the class table on the board. Compare your jar A with other groups' jar A.
9. Answer the recording-sheet questions, draw the matter-movement diagram, then work through the analysis questions individually before comparing in your group.

Expected observations

- Jar A: indicator moves from blue (1) to green (2) or yellow (3) within 24 hours at room temperature; seeds swell further and most show a root 3 to 15 mm long; droplets of water on the glass.
- Jar B: indicator stays blue or barely shifts; dry seeds look unchanged, perhaps slightly swollen from the towel's moisture.
- Jar C: indicator stays blue or shifts slightly toward green if microbes have started on the dead seeds; seeds are soft and pale with no roots. A sour smell may be present by day 2.
- Class thermoses: the living-seed flask reads about 2 to 6 °C above its day 1 value and above the boiled flask; the boiled flask stays near room temperature.

Likely difficulties

- Cold classrooms or a short interval (less than 18 hours) give a weak indicator change in jar A; leave the jars longer or move them somewhere warmer, and compare against jar C rather than demanding full yellow.
- Jar C may show a slight color shift because bacteria and fungi on the dead seeds also respire. Treat it as a teaching moment: something alive is still there, just not the pea; this is why jar C may not stay perfectly blue.
- Students may read the indicator through colored or dirty glass; have the reader hold the color key against the jar in the same light for every jar.
- Students confuse water droplets on the glass with the water product of respiration. The towel was damp, so condensation is expected in every jar; the water product cannot be separated here (q6 asks exactly this).
- Some students will say the seeds 'woke up because of the water' and stop there; press them on where the energy for growth came from, since water carries no usable chemical energy.

Structured debrief

1. Pool every group's jar A indicator number and average sprout length on the board. Ask why the results agree even though groups used different jars: the cause is in the seeds, not the container.
2. Walk the elimination together: jar B rules out 'the water made the gas' (water was present, seeds were dry inside); jar C rules out 'the air or the towel did it' (same air, same towel, dead seeds, no change). What is left is a process that only living, activated seeds carry out.
3. Name it: cellular respiration. Write the word equation under the class data and have students match each product and the energy to an observation (yellow indicator, warmth, growth from stored starch). Point out that water is the one product the jar could not show because the towel was already damp.
4. Ask the big question: the seed is part of a plant, a producer. If a producer releases energy from stored sugar in the dark, exactly like a consumer, what does that say about the textbook claim that plants get all the oxygen they need from photosynthesis? Lead to q8 and flooded roots.
5. Close on the system boundary: the jar was sealed, so the mass inside did not change, but the seeds got lighter and the air got heavier in carbon dioxide. Matter moved; it was not lost.

Recording sheet: what students fill in

Lab 1 recording sheet: The jar that warmed up

Fill in the day 1 sections before the jars go into the cupboard. Fill in the day 2 sections before and after opening the jars, in the order the procedure gives. Use the color key numbers: 1 = blue, 2 = green, 3 = yellow.

Day 1: what we see and what we predict

Jar	What the seeds look and feel like now	Will the indicator change? (yes/no, and why)	Will the jar warm up? (yes/no)	Will the seeds grow? (yes/no)
A: living soaked				
B: dry				
C: boiled				

Day 2: observations

Jar	Indicator color number, day 1	Indicator color number, day 2	Changes seen through the glass	Lengths of five seeds or sprouts (mm)	Average length (mm)
A: living soaked					
B: dry					
C: boiled					

Class thermos temperatures

Thermos	Temperature day 1 (°C)	Temperature day 2 (°C)	Change (°C)
Living soaked seeds			
Boiled seeds			

-  Draw jar A as a system. Show the seeds, the indicator cup and the air. Use labeled arrows to show what you think moved from where to where during the 24 hours, and mark where energy was released.

Answer: A jar containing seeds, an indicator cup and air. Arrows: oxygen from the air into the seeds; carbon dioxide from the seeds into the air and into the indicator cup; a label or symbol on the seeds showing energy released as heat (and used for growth); optionally water from the seeds into the air.

Why: The drawing is a system model of what crossed between the parts. Oxygen in and carbon dioxide out are the minimum; energy marked at the seeds shows the student locates the process in the living organism.

- Seeds, indicator cup and air all shown
- Carbon dioxide arrow from seeds to indicator or air
- Energy released marked at the seeds
- Oxygen arrow into the seeds (full credit) or at least a sign that something from the air was used

1. Which of your predictions were right and which were wrong? For one wrong prediction, say what evidence changed your mind.

Answer: Group-specific. Common wrong predictions: that jar C would change because the seeds were wet, or that jar B would grow because it had a damp towel. The evidence that changes minds is jar C staying blue and cool with no roots, and jar B staying unchanged.

Why: The question rewards honest revision. Full credit requires naming a specific observation, not just 'we were wrong'.

- Identifies at least one prediction as right and one as wrong
- Names the specific observation that overturned the wrong one

2. List every difference you recorded between jar A and jar C. Then name the one thing that is different about the seeds themselves in those two jars.

Answer: Differences: indicator color (A yellow or green, C blue or barely green), growth (A has roots, C none), temperature in the thermoses (living warmer), appearance (A firm and sprouting, C soft and pale). The one difference in the seeds themselves: A's seeds are alive; C's were killed by boiling.

Why: Students must separate the many observed differences from the single cause. Boiling changed nothing about the water, air or towel, only whether the seeds were living.

- Lists at least three recorded differences
- States that the only difference in the seeds is living versus boiled (dead)

Analysis questions: answer key

3. The indicator turns from blue toward yellow when carbon dioxide dissolves in it. What does the day 2 color in jar A tell you, and why is the day 2 color in jar C important for that conclusion?

Answer: Jar A's yellow or green indicator shows carbon dioxide built up in the jar's air, so the living seeds gave off carbon dioxide. Jar C matters because it had the same air, towel and indicator but dead seeds, and it stayed blue (or shifted far less). So the carbon dioxide in A came from the living seeds, not from the air that was sealed in, the towel or the cup.

Why: A control is what turns 'the indicator changed' into 'the seeds caused it'. Students should state both halves.

Also acceptable: Credit a student who notes that a slight shift in C could be microbes on the dead seeds, still a living source.

- Reads the A color as carbon dioxide from the seeds
- Explains that C rules out non-living sources because everything else was the same

4. No light reached any jar. Where did the energy to warm the living-seed thermos and push out roots come from? Trace it back as far as you can.

Answer: From chemical energy stored in the seeds. The parent pea plant captured light energy by photosynthesis, built sugar, and stored it in the seed as starch. When the seed took up water and became active, its cells broke starch into sugar and carried out cellular respiration, releasing the stored energy. Part of that energy built roots; part escaped as heat and warmed the thermos. So the energy came from sunlight, but from sunlight that reached the parent plant last season, not from any light in the cupboard.

Why: The full chain is sun → parent plant → starch in seed → sugar → respiration → heat and growth. The key move is that light energy was stored as chemical energy earlier.

- Identifies stored chemical energy (starch or sugar) in the seed as the source
- Names cellular respiration as the process that released it
- Traces the stored energy back to the parent plant's photosynthesis

5. Jar B had a damp towel just like jar A, but its dry seeds changed almost nothing. What does that tell you about what the water does, and what the water does not do, for the seeds?

Answer: Water is needed to activate the seed: a dry seed's cells cannot run reactions until water enters, so jar B's seeds stayed inactive even though water was nearby on the towel. But water does not supply the energy or the gas; jar A's warmth and carbon dioxide came from the seeds' stored sugar reacting with oxygen. Water is a switch, not a fuel.

Why: Students often credit water with the energy. Jar B (water present, no change inside dry seeds) separates activation from fuel.

- Water is needed to start the seed's reactions
- Water is not the source of energy or carbon dioxide

6. Write the word equation for cellular respiration. Next to each product and the energy, write the observation from this lab that is evidence for it. Which product did you have no evidence for, and how could you get some?

Answer: sugar + oxygen → carbon dioxide + water + energy. Carbon dioxide: the indicator in jar A turned yellow or green. Energy: the living-seed thermos warmed and the seeds grew roots. Water: no evidence, because the towel was already damp and every jar had condensation. To get evidence, start with dry seeds given a measured amount of water in a dry jar with no towel, or use a dry indicator paper that changes color with moisture, and compare living against boiled seeds.

Why: Matching each product to an observation is the model-building core of MS-LS1-7. The water gap is real and students should see that a good design would need a dry control.

- Correct word equation
- Carbon dioxide matched to the indicator
- Energy matched to warmth and/or growth
- Water identified as unsupported with a sensible way to test it

7. If the sprouts kept growing in the dark, would the total dry mass of seed-plus-sprout go up, stay the same or go down? Explain where any missing mass would go.

Answer: Down. The sprouts are growing by rearranging the seed's stored starch into root and shoot, and some of that stored matter is respired: its carbon leaves as carbon dioxide and its hydrogen leaves in water. Nothing new comes in except oxygen and water, and in the dark there is no photosynthesis to add sugar, so the dry mass of seed-plus-sprout falls until leaves reach light.

Why: Students connect growth with gaining mass; in the dark, growth is reorganization plus loss. Dry mass is specified so water uptake does not confuse the answer.

- Says dry mass goes down
- Explains that respired carbon leaves as carbon dioxide
- Notes that no new sugar is made without light

8. A gardener overwaters a potted plant until the soil is soaked for a week, and the plant dies even though it sits in a sunny window. Use what the jars showed to explain what happened to the roots.

Answer: Roots respire all the time and need oxygen, which they normally take from air spaces in the soil. Soaked soil fills those spaces with water, so the roots cannot get oxygen and cannot release energy from the sugar the leaves send down. The root cells die, the plant can no longer take up water and minerals, and it dies even in full sun. Sunlight reaches the leaves, not the roots; the leaves' oxygen does not reach the roots fast enough through the plant.

Why: This is the transfer that corrects the textbook: plants need oxygen for respiration in cells that are not photosynthesizing. The jars showed that living plant tissue in the dark uses oxygen and releases carbon dioxide.

- Roots respire and need oxygen
- Waterlogging removes oxygen from the soil
- Explains why sunlight on the leaves does not save the roots

Individual evidence of learning

Each student submits their own completed recording sheet (both tables, the thermos table, the system drawing) and written answers to q1 through q8. The drawing and q6 are the primary evidence for the model-

building target; q4 and q8 are the evidence for understanding that plants release stored energy and need oxygen.

Assessment criteria

Criterion	Proficient looks like
Observations and data	All three jars recorded on both days with color numbers, five lengths and an average, and the thermos changes computed correctly.
Reasoning from controls	Uses jar B and jar C to rule out water and air as the cause and identifies a process in living, activated seeds as the explanation.
Model of the process	Writes the respiration word equation, matches carbon dioxide, energy and growth to specific observations, and identifies water as the product the jar could not show.
Transfer to plants and oxygen	Explains that roots and seeds respire without light and need oxygen from their surroundings, and applies this to the flooded plant.

Accessibility adaptations

- Provide the color key with large numbered swatches and allow the indicator reader to describe the color aloud for the recorder; a color-blind student can take the measurer or recorder role and compare a photographed cup to the key with a partner.
- Pre-fill the day 1 observation column for students who need more support and provide sentence frames for q3 and q6 ('The indicator in jar A turned ___, which means ___; jar C stayed ___, so ___').
- Accept the system drawing as a labeled photograph of the real jar with arrows added, or as a spoken explanation recorded on a device.
- Offer a multilingual glossary card for indicator, seed, sprout, living, boiled and carbon dioxide, and pair students so the day 2 readings are discussed before they are written.

Low-cost alternative

Replace bromothymol blue with red cabbage juice (boil chopped red cabbage, cool, strain), which turns from blue-purple toward pink with carbon dioxide. Skip the thermoses and instead have one group's jar A sit inside a foam cup with a thermometer; or simply feel the two seed piles by hand on day 2, since a large living pile is noticeably warm. Zip bags can replace jars if the indicator cup is taped upright inside.

Model limitations

The jar shows the products and the released heat but cannot show the reaction's steps, the mitochondria, or the water product, because water was already present. The living seeds use oxygen from the air in the jar; in a small sealed jar that oxygen runs low within hours, and the seeds then switch to a different, less complete way of releasing energy that still gives off carbon dioxide, which is beyond this lesson. The indicator result stands either way, but the jar cannot show how much oxygen the seeds used; Worksheet 5 and Worksheet 6 supply that evidence. Jar C can shift slightly because microbes on dead seeds respire, which is a limitation of the control and worth discussing. This activity has not been physically tested by the authors; the 24-hour indicator change and the 2 to 6 °C thermos rise are estimates for room-temperature peas.

Teacher notes

Accept green as a positive result for jar A if the room was cool; the comparison with jar C is what matters. If jar C shifted noticeably, discuss microbial respiration on dead seeds rather than treating the control as failed. Keep one group's jar A sprouts to show the dry-mass task on the presentation; weighing a dried sprout sample against dried unsprouted seeds is a strong extension if a drying oven or a warm windowsill and a 0.1 g balance are available.