

The Willow, the Mint and the Jars: Finding Out What Plants Are Made Of

Learning target: I can explain, with evidence from a passage, how a series of experiments over 160 years showed that a plant's matter comes mostly from air and water and that light is required.

Reading with evidence

About 35 min

Individual

MS-LS1-6 · practice

reading

writing

Standards connections

MS-LS1-6 (practice): Students trace the evidence that matter enters a plant from carbon dioxide and water, with light as the energy source. They practice building an explanation from historical evidence, the same move the PE asks for, without the biochemical mechanism.

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

Answers with reasoning

The Willow, the Mint and the Jars

[1] A tree can have a mass of many tons, yet it begins as a seed you can hold in your palm. Where does all that new material come from? For centuries the obvious answer was the soil. The first person to test the obvious answer with a balance was a Flemish physician, Jan Baptist van Helmont. His experiment was published in 1648, a few years after his death.

[2] Van Helmont dried a batch of soil in an oven, weighed out 200 pounds of it, and planted a willow sapling with a mass of 5 pounds. He covered the pot with a pierced metal plate so that dust could not fall in, and for five years he added nothing but rainwater. After five years he weighed everything again. The willow had a mass of 169 pounds and 3 ounces, about 76 kilograms. The soil, dried again, had lost only about 2 ounces, roughly 57 grams. Van Helmont concluded that the wood had been made from water alone. He was half right: he had ruled out the soil, but he had not thought to weigh the air.

[3] The air entered the story in 1772, when an English chemist, Joseph Priestley, reported that a candle sealed in a glass jar soon went out, and a mouse sealed in a jar could not survive. But if a sprig of mint grew in the jar for several days, the candle would burn again and a mouse could breathe. The plant had somehow 'restored' the spoiled air. Priestley did not know what the plant was adding; today we call that gas oxygen. His was the first evidence that plants change the air around them, not just the soil beneath them.

[4] Priestley's results were hard to repeat, and a Dutch physician, Jan Ingenhousz, wanted to know why. In 1779 he published hundreds of trials. Green leaves held under water in bright sunlight released a stream of tiny bubbles, and the collected gas made a glowing splint burst into flame. The same leaves in the shade or in the dark released almost nothing. Roots, flowers and the non-green parts of plants never produced the bubbles. Ingenhousz had added two conditions to Priestley's discovery: the gas came only from green parts and only in light. Priestley's mint had sometimes failed because his jars had sometimes sat in the shade.

[5] That left van Helmont's question open. The willow had gained 164 pounds, and water could not be the whole answer if plants were also taking something from the air. The Swiss chemist Nicolas-Théodore de Saussure took up the problem in 1804. He grew plants in sealed containers holding known amounts of carbon dioxide and measured what disappeared. Plants supplied with carbon dioxide grew; plants in air with the carbon dioxide removed barely grew at all. More telling, the plants gained more mass than the mass of the carbon dioxide they took in. The extra mass, he argued, had to come from water joining the carbon dioxide inside the plant.

[6] Put the four experiments together and a picture appears. A plant's new matter comes mostly from carbon dioxide in the air, with water contributing a smaller share and the soil only a few percent of minerals. Making that matter requires light, and the process gives off oxygen. Modern measurements agree: dry a plant completely and about 45 percent of its mass is carbon and about 45 percent is oxygen, both traceable to carbon dioxide; about 6 percent is hydrogen from water; and only around 4 percent is minerals from the soil.

[7] No single experiment settled the question. Van Helmont ruled out the soil but drew the wrong conclusion. Priestley found that plants change the air but could not explain his own failures. Ingenhousz fixed the conditions. Saussure weighed the gas. Each scientist kept what held up in the earlier work and corrected what did not. That is how a scientific explanation is built: not in one stroke, but by measurement after measurement, each one narrowing the places the answer could hide.

Questions: cite the passage

1. According to paragraph 2, what three things did van Helmont measure, and what did he do to make sure nothing besides rainwater got into the pot?

Answer: He measured the dried soil (200 pounds), the sapling (5 pounds) and, after five years, the tree (169 pounds 3 ounces) and the re-dried soil (about 2 ounces lighter). He covered the pot with a metal plate with small holes so dust could not fall in, and added only rainwater.

Why: Paragraph 2 lists all four measurements; three is the minimum. The cover and the rainwater are the controls.

Also acceptable: Accept 'the soil before and after and the tree before and after' as the measurements.

- Names at least three measured quantities
- Mentions the pierced cover or the rainwater-only rule

2. Using the numbers in paragraph 2, calculate how many pounds the willow gained. Then convert the soil's 2-ounce loss to pounds (16 ounces = 1 pound) and find roughly how many times larger the tree's gain was than the soil's loss. Show your work.

Answer: Gain: $169\text{ lb } 3\text{ oz} - 5\text{ lb} = 164\text{ lb } 3\text{ oz}$, about 164 lb. Soil loss: $2\text{ oz} \div 16\text{ oz per lb} = 0.125\text{ lb}$. Ratio: $164 \div 0.125 = 1,312$, so the tree gained roughly 1,300 times more mass than the soil lost.

Why: Students may drop the 3 ounces; 164 pounds is the accepted figure. The ratio shows how decisive the result was.

Also acceptable: Accept any ratio between about 1,300 and 1,320, or 'more than a thousand times' with the work shown. Accept the metric route: about 74 kg gained $\div$ 0.057 kg $\approx$ 1,300.

3. The passage says van Helmont was 'half right.' Explain which half was right and which half was wrong, using his own evidence.

Answer: Right half: the soil is not where the tree's matter comes from, because the soil lost only about 2 ounces while the tree gained about 164 pounds. Wrong half: he concluded the tree was made from water alone, because he never considered or weighed the air.

Why: The evidence supports ruling out soil; it does not support 'water alone', which required the later gas experiments.

Also acceptable: Accept 'he was right about the soil and wrong about water' with the numbers cited.

- Soil ruled out, with the numbers
- Water-alone conclusion identified as the error, linked to not weighing air

4. Describe Priestley's mint experiment in your own words. What did it show that the willow experiment could not, and why does paragraph 3 say he 'did not know what the plant was adding'?

Answer: A candle or a mouse sealed in a jar used up something in the air; a sprig of mint left in the jar for several days made the air good again, so the candle could burn and a mouse could breathe. It showed that plants change the air, which the willow experiment could not show because van Helmont only weighed solids and water. Priestley did not know the gas was oxygen; oxygen had not yet been identified and named.

Why: The key contrast is air versus soil. Students should notice that 'restored the air' is an observation, while 'oxygen' is a later explanation.

Also acceptable: Accept 'nobody knew about oxygen yet' for the last part.

- Describes the sealed jar with candle or mouse and the mint
- States that it showed plants change the air
- Explains that the gas had not yet been identified as oxygen

5. Ingenhousz 'added two conditions' to Priestley's discovery. State both conditions, quote the evidence from paragraph 4 for each, and explain how they solved the mystery of Priestley's failed trials.

Answer: Condition 1: only green parts. Evidence: 'Roots, flowers and the non-green parts of plants never produced the bubbles.' Condition 2: only in light. Evidence: leaves 'in bright sunlight released a stream of tiny bubbles' while 'the same leaves in the shade or in the dark released almost nothing.' These conditions explained Priestley's failures: 'his jars had sometimes sat in the shade,' so the mint could not restore the air.

Why: Full credit needs both conditions, a quote or close paraphrase for each, and the link to shade explaining the failed trials.

Also acceptable: Accept the glowing-splint observation as evidence that the bubbles were a gas that supports burning, in addition to the light condition.

- Both conditions stated
- Evidence from paragraph 4 for each
- Shade explanation for Priestley's failures

6. Paragraph 5 says Saussure's plants gained more mass than the carbon dioxide they took in. Why did that single comparison tell him that water must be part of the plant's new matter?

Answer: If the plant's only new matter were the carbon dioxide it took in, its gain could not be larger than the mass of that gas. Since the gain was larger, some other substance had to be adding mass, and the only other input was water. So water must be joining the carbon dioxide inside the plant.

Why: This is a conservation-of-mass argument: output cannot exceed the inputs, so a larger output reveals a hidden input.

Also acceptable: Accept 'matter cannot come from nowhere, so the extra had to be water.'

- States that gain cannot exceed input unless something else is added
- Identifies water as the only other input

7. Using the percentages in paragraph 6, about what fraction of a dried plant's mass came from the soil, and about what fraction can be traced to carbon dioxide? Does this agree with van Helmont's measurement? Explain.

Answer: About 4 percent, roughly one twenty-fifth, came from the soil; about 90 percent (45 percent carbon plus 45 percent oxygen) can be traced to carbon dioxide. Yes, it agrees: van Helmont found the soil lost very little compared with the tree's gain, which matches soil supplying only a few percent.

Why: The modern breakdown confirms van Helmont's measurement while replacing his conclusion. Students should add the two 45 percent figures.

Also acceptable: Accept 'a few percent' and 'nearly all' if the percentages are named.

- About 4 percent from soil
- About 90 percent traced to carbon dioxide
- States agreement with van Helmont's small soil loss

8. Paragraph 7 claims that a scientific explanation is built 'by measurement after measurement.' Using evidence from at least three different paragraphs, explain how each later scientist kept something from the earlier work and corrected something else.

Answer: Example: Priestley (paragraph 3) kept van Helmont's result that soil is not the source but corrected the focus by looking at the air. Ingenhousz (paragraph 4) kept Priestley's finding that plants restore the air but corrected it by adding the conditions of green parts and light, which explained the failed trials. Saussure (paragraph 5) kept the idea that plants take a gas from the air but corrected van Helmont's water-only conclusion by showing both carbon dioxide and water add mass. Each step narrowed where the answer could be.

Why: Full credit requires three paragraphs, each with a kept element and a corrected element. The passage's final paragraph summarizes this but students must supply the specifics.

Also acceptable: A response that includes the modern measurements (paragraph 6) as a final 'kept and corrected' step is strong.

- Evidence from at least three different paragraphs
- For each scientist, something kept and something corrected
- Connects the sequence to building an explanation step by step

Teacher notes

The passage is about 670 words. Historical details are documented: van Helmont's willow (published 1648 in *Ortus Medicinae*) with 200 lb of dried soil, a 5 lb sapling, 169 lb 3 oz after five years and about 2 oz of soil

lost; Priestley's mint and candle (1772); Ingenhousz's Experiments upon Vegetables (1779) with submerged leaves bubbling only in light and only from green parts; Saussure's Recherches chimiques sur la végétation (1804). The modern dry-mass figures (about 45 percent carbon, 45 percent oxygen, 6 percent hydrogen, a few percent minerals) are rounded typical values; the textbook's 'about 70 percent from carbon dioxide' is a different accounting and is not tested here. Note for accuracy: Ingenhousz's bubbles came from leaves under water; plants in open air do not bubble. If students ask what the gas was in the dark, say plants give off carbon dioxide at all times because their cells use sugar for energy day and night; in bright light the oxygen produced outweighs it.

Scaffold offered to students: Evidence ladder

Before writing, draw four rungs on scrap paper labeled 1648, 1772, 1779 and 1804. On each rung write the scientist's name, what he measured or observed in five words or fewer, and what he concluded in five words or fewer. Most questions can be answered by finding the right rung and rereading that paragraph. For q8, draw arrows between rungs and label each arrow 'kept' or 'corrected'.

Extension: Weigh the air

Van Helmont never weighed the air, and it is easy to see why: how do you put air on a balance? Design a modern version of his experiment that keeps track of the gas as well as the soil and water. Describe the container, what you would measure at the start and the end, and how you would tell carbon dioxide taken in from water taken in. Then explain one way your design could still fool you, and how you would guard against it.