

Slow Fire: How Scientists Learned That Living Things Burn Their Food

Learning target: I can explain, with evidence from a passage, how cellular respiration resembles burning, where in the cell most of it happens, and why plants carry it out too.

Reading with evidence

About 35 min

Individual

MS-LS1-7 · supports

reading

writing

Standards connections

MS-LS1-7 (supports): The passage gives the historical and conceptual background for the idea that food is broken apart and recombined with oxygen to release energy. It builds understanding behind the model students develop in W4 and W9 rather than producing that model itself.

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

Answers with reasoning

Slow Fire

[1] Hold your hand a safe distance from a candle flame and you feel warmth. Watch for an hour and the candle is shorter. The wax has not vanished. It has reacted with oxygen from the air and left as two invisible gases, carbon dioxide and water vapor. A burning candle is a chemical reaction: a fuel and oxygen go in, new molecules come out, and energy leaves as heat and light. People long suspected that a living body's warmth came from a fire inside it, but nobody could test the idea until chemists learned to measure gases and heat.

[2] The test came in the winter of 1782 to 1783, in Paris. The chemist Antoine Lavoisier and the mathematician Pierre-Simon Laplace built an ice calorimeter: a chamber surrounded by a jacket packed with ice. Anything warm inside melted some ice, and the water that dripped out could be weighed to measure the heat. They kept a guinea pig in the chamber for about ten hours and collected the melted ice and the carbon dioxide it breathed out. Then they burned charcoal until it had produced the same amount of carbon dioxide, and measured the heat from that. The two amounts of heat were close. Lavoisier concluded that breathing animals carry out a slow form of combustion, a burning without flame.

[3] Why no flame? In a candle, the reaction runs fast and hot in one place. In a living thing, the same overall change, food plus oxygen becoming carbon dioxide and water, happens in many small steps at body temperature, inside cells. Energy is released a little at a time. The cell captures part of it to power its work, such as building new molecules or moving, and the rest spreads out as heat, which is why a guinea pig, a person and even a pile of sprouting seeds feel warm. One detail matters for later classes: the reaction releases energy because the molecules it forms, carbon dioxide and water, hold less chemical energy than the sugar and oxygen that went in. Energy is not created in the cell; it is converted from one form to another.

[4] Where inside the cell does this happen? In 1890 the German scientist Richard Altmann described tiny grains in stained cells and guessed they were important to the cell's life. In 1898 another German scientist, Carl Benda, named them mitochondria, from Greek words meaning thread and grain. During the twentieth century, researchers showed that most of the steps of cellular respiration take place inside these structures. Mitochondria are found in plant cells, animal cells and many single-celled organisms such as amoebas. Not every cell has them: your mature red blood cells do not. A heart muscle cell, which contracts every second of your life, is packed with them.

[5] Here is the part that surprises many students: the slow fire burns in plants too. A seed sprouting in dark soil, a root growing underground, and a leaf at midnight are all releasing energy from sugar in their mitochondria, using oxygen and giving off carbon dioxide. A bag of sprouting seeds in a closed, insulated container warms up by several degrees. Plants have no lungs or gills. In an animal, breathing moves air or water across a surface where oxygen enters the blood and carbon dioxide leaves; that is a transport job, not the reaction itself. Plant cells get oxygen from the air through tiny openings in their leaves and from air pockets in the soil. When a field stays flooded for days, those air pockets fill with water and the roots can die for lack of oxygen.

[6] Lavoisier's guinea pig and the candle on your table run the same overall reaction at different speeds. In both, the atoms are conserved. The carbon in the gas the guinea pig breathed out had arrived in its body as carbon in its food; the carbon in the gas above the candle had been part of the wax. More than two hundred years later, the central idea has not changed: living things get the energy they need by combining the molecules in their food with oxygen, a controlled burn that happens, in tiny steps, inside almost every cell.

Questions: cite the passage

1. According to paragraph 1, what goes into a candle's reaction and what comes out? Name the two gases, and say what happens to the energy.

Answer: In: the fuel (wax) and oxygen from the air. Out: carbon dioxide and water vapor. The energy leaves as heat and light.

Why: Paragraph 1 states the inputs, the two gases and the energy forms directly.

Also acceptable: Accept 'the candle' for the fuel.

- Names wax (fuel) and oxygen as inputs
- Names carbon dioxide and water (vapor) as outputs
- Says the energy leaves as heat and light

2. Explain how the ice calorimeter in paragraph 2 measured heat. Why was melted ice a useful thing to weigh?

Answer: The chamber was surrounded by a jacket of ice. Heat from whatever was inside melted some ice, and the water that dripped out was weighed. Melted ice was useful because the amount of water is a measure of the amount of heat: more heat, more ice melted, more water to weigh.

Why: The key inference is that mass of meltwater stands in for heat, which could not be measured directly in 1783.

Also acceptable: Accept 'they could weigh water but could not weigh heat.'

- Describes the ice jacket and the dripping water
- Explains that more heat means more melted ice, so the water's mass measures heat

3. Lavoisier and Laplace compared the guinea pig with burning charcoal. In your own words, explain what they matched between the two, what they measured, and what result let Lavoisier conclude that breathing is 'a slow form of combustion.'

Answer: They matched the amount of carbon dioxide: the guinea pig breathed out a certain amount in about ten hours, and they burned charcoal until it had produced the same amount. They measured the heat from each (by the melted ice). The two amounts of heat were close, so producing a given amount of carbon dioxide released about the same heat whether a guinea pig or a fire did it. That is why Lavoisier concluded that the animal was carrying out a slow combustion.

Why: Full credit requires all three parts: what was matched (carbon dioxide), what was measured (heat), and the result (close agreement).

Also acceptable: Accept 'fixed air' only if the student has read elsewhere that this was the old name for carbon dioxide; the passage does not use it.

- Says the carbon dioxide amounts were matched
- Says heat was measured for both
- States that the heats were close and connects that to the conclusion

4. Paragraph 3 gives two differences between burning in a candle and the reaction in a cell. State both. Then quote the sentence that says what happens to the energy that the cell does **not** capture.

Answer: Differences: (1) a candle runs fast and hot in one place, while the cell's reaction happens in many small steps at body temperature; (2) energy in the cell is released a little at a time and partly captured for the cell's work. Quote: 'the rest spreads out as heat, which is why a guinea pig, a person and even a pile of sprouting seeds feel warm.'

Why: Students must quote or closely paraphrase the 'spreads out as heat' sentence.

Also acceptable: Accept 'inside cells' versus 'in one place' as one of the differences.

- Two differences stated
- Quotes the sentence about the rest spreading out as heat

5. Paragraph 3 says energy 'is not created in the cell.' According to the passage, why does the reaction release energy at all?

Answer: Because the molecules formed by the reaction (carbon dioxide and water) hold less chemical energy than the sugar and oxygen that went in. The difference is released. Energy is converted from chemical energy into forms the cell can use plus heat; it is not made from nothing.

Why: This is the accurate version of the textbook's 'energy stored in bonds is released when sugar breaks down.' The passage avoids saying that breaking bonds releases energy; students need only the before-and-after comparison.

Also acceptable: Accept 'the products have less chemical energy, so the extra comes out.'

- Compares the chemical energy of products with that of reactants
- States that energy is converted, not created

6. Using paragraph 4, write a short timeline: what happened in 1890, what happened in 1898, and what was shown later. Then give one example from the paragraph of a cell with many mitochondria and one with none.

Answer: 1890: Richard Altmann described tiny grains inside cells and guessed they mattered for the cell's life. 1898: Carl Benda named them mitochondria (thread and grain). Later, in the twentieth century, researchers showed that most of cellular respiration takes place inside them. Many mitochondria: a heart muscle cell. None: a mature red blood cell.

Why: Both the timeline and the two examples come directly from paragraph 4.

Also acceptable: None.

- Three dated events in order
- Heart muscle cell as the many example
- Mature red blood cell as the none example

7. A classmate says, 'Plants don't do cellular respiration; they don't even breathe.' Using at least two pieces of evidence from paragraph 5, explain which part of the statement is true and which part is false.

Answer: True part: plants do not breathe; they have no lungs or gills (paragraph 5). False part: plants do carry out cellular respiration. Evidence: a sprouting seed, a root underground and a leaf at midnight all release energy from sugar in their mitochondria, using oxygen and giving off carbon dioxide; a container of sprouting seeds warms up by several degrees; flooded roots die for lack of oxygen, which only makes sense if roots need oxygen. Breathing is a transport job that animals do; cellular respiration is the reaction inside cells, and plants do that too.

Why: The answer must separate breathing (transport of gases) from cellular respiration (the reaction) and use at least two pieces of evidence from paragraph 5.

Also acceptable: A student who says plants 'exchange gases' through leaf openings and so do a kind of breathing is making a fair point; accept it if the student still distinguishes gas exchange from the reaction itself.

- Identifies 'don't breathe' as true in the sense of lungs and gills
- Identifies 'don't do cellular respiration' as false
- Two pieces of evidence from paragraph 5
- Distinguishes breathing from the cell reaction

8. The passage calls cellular respiration a 'controlled burn.' Using evidence from at least two different paragraphs, explain what the candle and the guinea pig have in common and why the word 'controlled' is needed.

Answer: In common: both combine a fuel with oxygen, produce carbon dioxide and water, release energy as heat, and conserve atoms (paragraphs 1, 2 and 6; Lavoisier's experiment showed the heat per amount of carbon dioxide was nearly the same for the animal and for charcoal). 'Controlled' is needed because in the cell the reaction happens in many small steps at body temperature, releasing energy a little at a time so that part of it can be captured for the cell's work (paragraph 3). A candle releases its energy all at once as heat and light and captures none of it.

Why: Full credit needs evidence from at least two paragraphs and an explanation of 'controlled' that mentions small steps, body temperature or capturing energy for work.

Also acceptable: A student who also notes that both the wax carbon and the food carbon end up in carbon dioxide (paragraph 6) is giving a strong answer.

- Names shared inputs and outputs (fuel and oxygen in; carbon dioxide and water out)
- Cites Lavoisier's heat comparison or atom conservation
- Explains 'controlled' as stepwise, at body temperature, with energy captured for work
- Evidence from at least two paragraphs

Teacher notes

The passage is about 700 words. Historical facts are established: Lavoisier and Laplace ran the ice-calorimeter guinea pig experiment in the winter of 1782-83 and reported it to the Paris Academy in 1783; Altmann described the structures in 1890 and Benda named them mitochondria in 1898. The passage corrects three textbook simplifications on purpose: most (not all) of cellular respiration occurs in mitochondria and the first steps occur outside them; not every cell has mitochondria (mature mammalian red blood cells do not); and plants respire in every living cell, day and night, including roots and seeds that take oxygen from their surroundings. It also uses the accurate energy statement (products hold less chemical energy than reactants) instead of 'energy stored in bonds is released when bonds break.' If students ask about the steps inside the mitochondria, say that they will meet them in high school; the assessment boundary for MS-LS1-7 excludes those details.

Scaffold offered to students: Mark the margins

After your first reading, write one of these labels in the margin beside each paragraph: FIRE, EXPERIMENT, WHY NO FLAME, WHERE IN THE CELL, PLANTS TOO, SAME ATOMS. Every question names or hints at a paragraph; find the matching label, reread only that paragraph, and underline the sentence you will quote before you start writing.

Extension: Redo the experiment with a plant

Lavoisier used a guinea pig. Design a version of the ice calorimeter experiment that would test whether a bag of sprouting seeds also produces heat and carbon dioxide in the dark. Describe what you would put in the chamber, what you would measure, what comparison you would need (think about Flask B in Worksheet 1), and what result would support the claim in paragraph 5. Then explain one reason the seeds would melt less ice per hour than the guinea pig did.