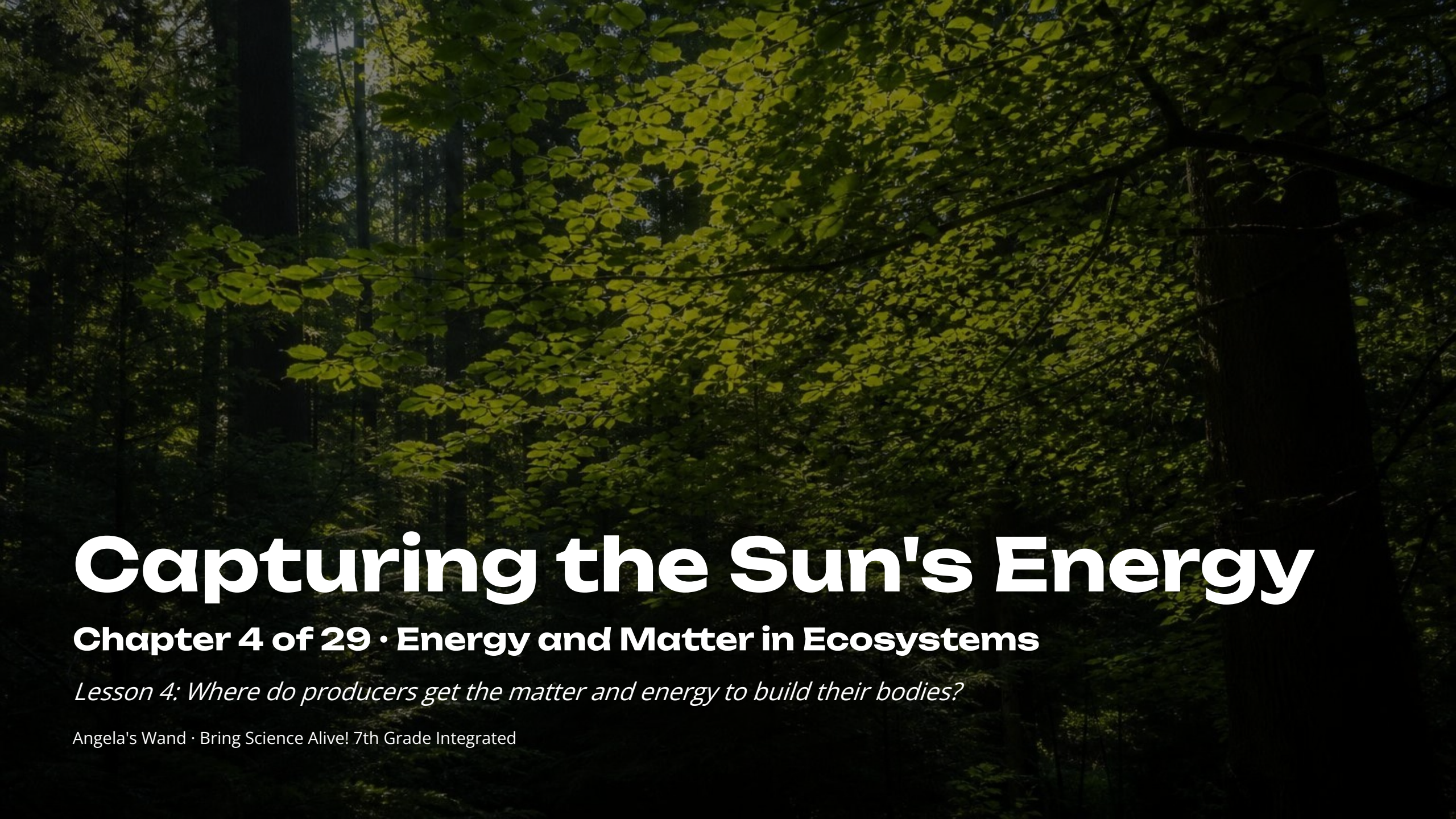




Capturing the Sun's Energy

Chapter 4 of 29 • Energy and Matter in Ecosystems

Lesson 4: Where do producers get the matter and energy to build their bodies?

Angela's Wand • Bring Science Alive! 7th Grade Integrated

PHENOMENON

A tree gains 74 kilograms; the soil loses 60 grams

In the 1640s Jan Baptist van Helmont dried 90 kg of soil, potted it, and planted a 2 kg willow sapling. For five years he added only water and kept dust out. The tree grew to about 76 kg. The dried soil had lost about 60 g. Where did roughly 74 kg of wood, bark and leaves come from?

- Notice: what went into the pot, and what came out?
- Wonder: what touches the tree every day that was never weighed?
- Predict: van Helmont said the mass came from water. Agree or disagree, and why?





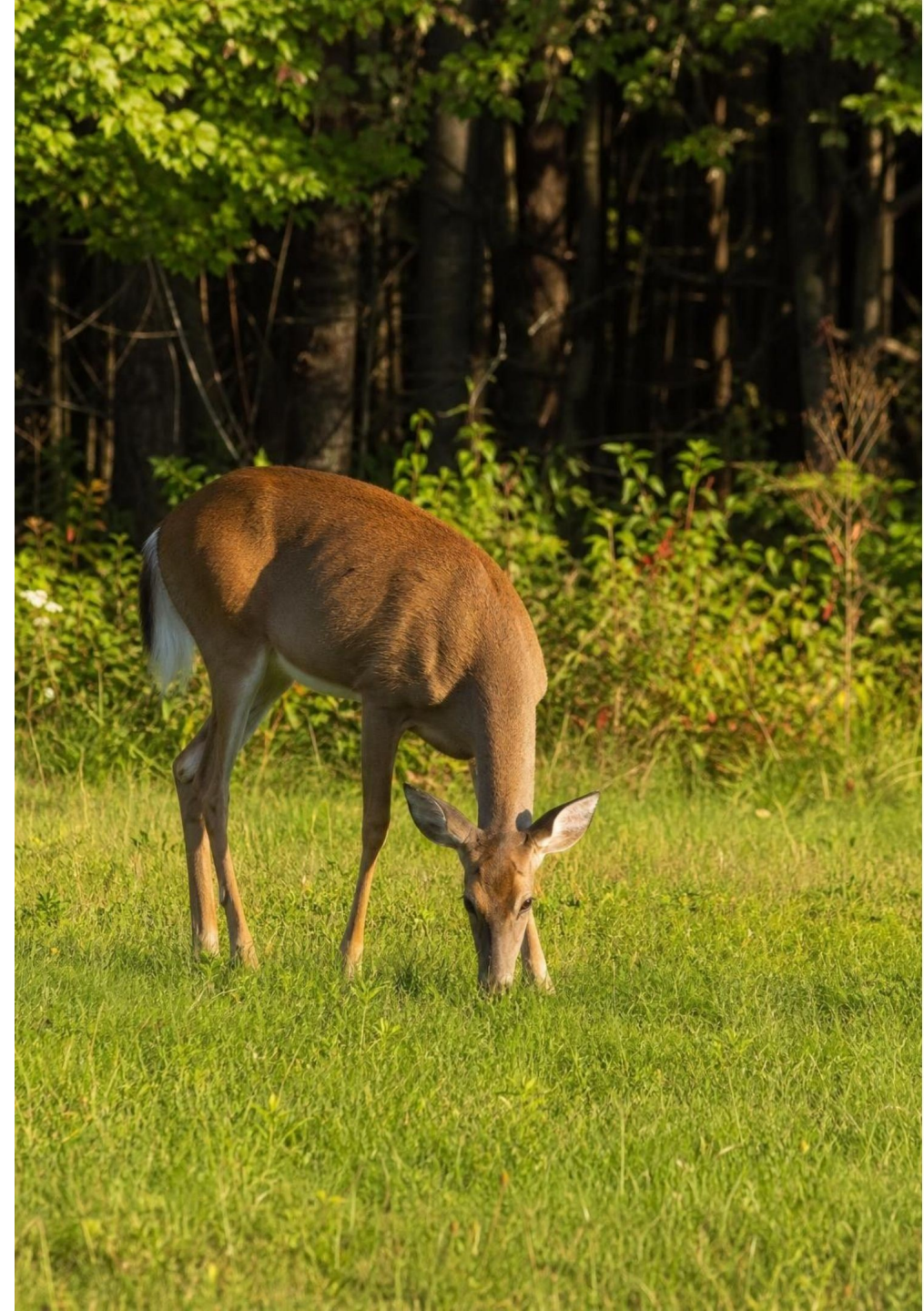
LEARNING TARGETS

What you will be able to do

- Identify producers on land and in water and explain how they make food instead of eating it.
- Describe the leaf parts that capture light and explain why most producers look green.
- Count atoms across the photosynthesis equation and separate matter from energy.
- Use experimental evidence to explain where a plant's mass comes from.
- Trace sugar into energy use, storage and building, and link it to biomass.
- Judge sources of biomass for jet fuel against criteria and constraints.

Every living thing needs matter and energy

- Matter is anything with mass that takes up space. Bodies, cells and air are all matter.
- Growing means adding matter: new cells, new wood, new leaves.
- Moving, growing and repairing all take energy.
- Animals get both by eating. Producers do not eat; they build food from simple substances.
- Nearly every other organism on Earth lives on what producers make.



Producers live almost everywhere

Model: Six producers, two of them not plants

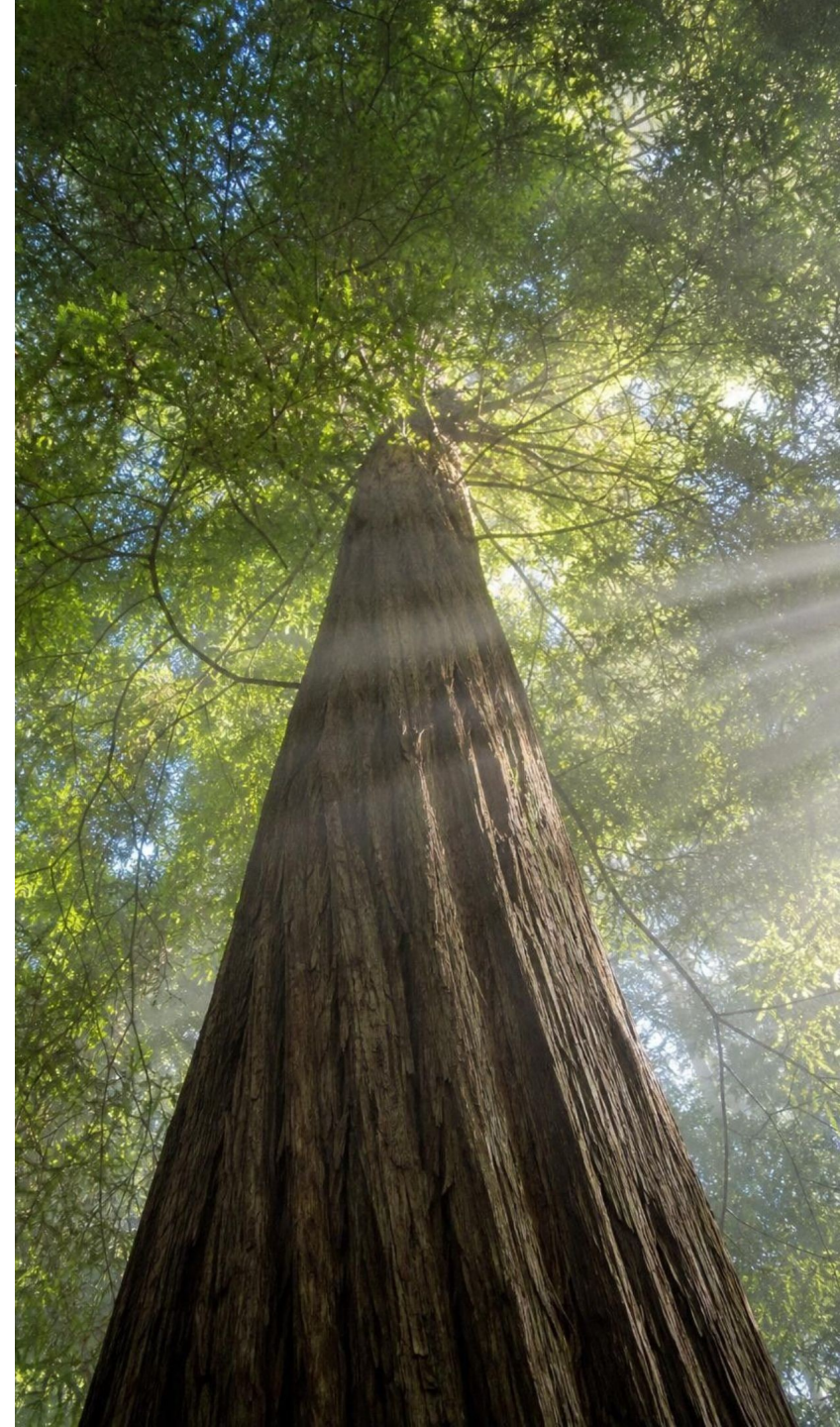
- **Pine, maple, sequoia:** Land plants. Leaves or needles catch light; roots pull up water.
- **Grasses, mosses, ferns:** Land plants that dominate prairies, forest floors and damp rocks.
- **Eelgrass:** A true plant that grows under water in bays and lakes.
- **Diatoms:** Single-celled algae drifting in the sunlit top of the ocean; the main producers of open water.
- **Volvox:** Green algae living as spinning spheres of thousands of cells in ponds.
- **Cyanobacteria:** Single-celled bacteria that photosynthesize; found in ponds, soil crusts, very hot springs and frozen lakes.

Plants are the familiar producers on land, but algae and cyanobacteria do most of the photosynthesis in water.



Three words to anchor the lesson

- **matter:** Anything that has mass and takes up space; it is made of atoms. *The carbon dioxide a leaf takes in is matter you cannot see.*
- **producer:** An organism that builds its own food from simple substances, usually using light energy. *A diatom in the Pacific is a producer; so is a redwood.*
- **photosynthesis:** The reaction in which a producer uses light energy to turn carbon dioxide and water into sugar and oxygen. *Photosynthesis slows in the shade, so the shaded leaves make less sugar.*



CHECK FOR UNDERSTANDING

Quick check: which one is a producer?

Which organism makes its own food from carbon dioxide, water and light?

A. A mushroom growing on a log

B. A diatom drifting in the ocean

C. A caterpillar eating a leaf

D. A sponge filtering seawater



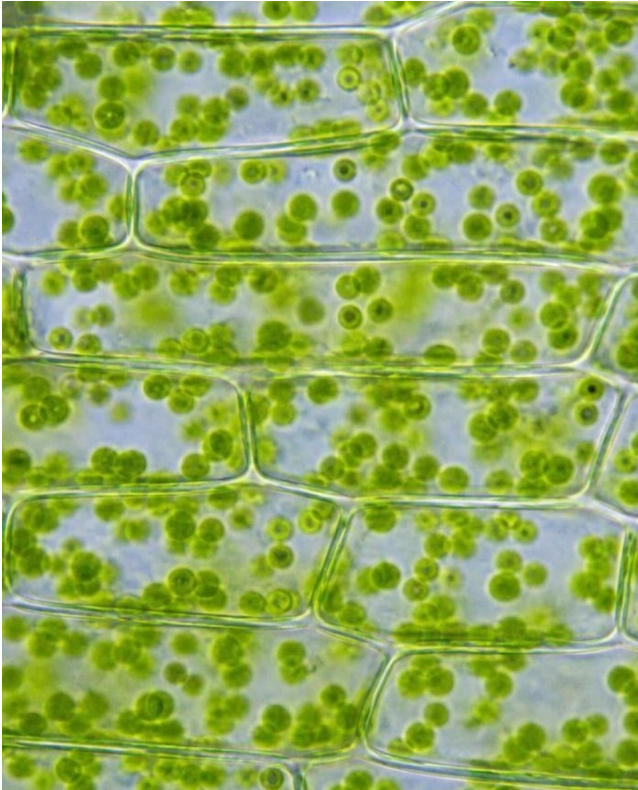


Zoom in: where a leaf catches light

- A leaf is made of cells. Many of them are packed with chloroplasts.
- Chloroplasts are the structures where photosynthesis happens.
- Inside each chloroplast is chlorophyll, a green pigment that absorbs light energy.
- Chlorophyll absorbs red and blue light strongly and green light less strongly.
- More green light leaves the leaf than any other color, so the leaf looks green to you.

From a whole leaf to a single pigment

Model: Zooming into a leaf



1

Leaf: flat and thin so light reaches every cell →

2

(look inside the leaf)
Leaf cell: one of millions in the leaf →

3

(look inside one cell)
Chloroplast: dozens in each cell; the site of photosynthesis →

4

(look inside one chloroplast)
Chlorophyll: the pigment that absorbs light energy

Each step is a closer look at the same leaf. Photosynthesis happens at the third level, inside the chloroplast.

The parts that capture light

- **chloroplast:** A small green structure inside plant and algae cells where photosynthesis takes place. *A single spinach leaf cell can hold dozens of chloroplasts.*
- **chlorophyll:** The green pigment inside chloroplasts that absorbs light energy. *When chlorophyll breaks down in autumn, yellow and orange pigments show through.*
- **pigment:** A substance that absorbs some colors of light and lets others pass or bounce back. *Kelp looks brown because its extra pigments absorb different colors than chlorophyll alone.*



What goes in, what comes out

- One energy input: light, absorbed by chlorophyll.
- Two matter inputs: carbon dioxide from the air (or dissolved in water) and water.
- Two matter outputs: sugar (glucose) and oxygen gas.
- In words: carbon dioxide + water + light energy → sugar + oxygen
- In symbols: $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$



MODEL

Count the atoms: nothing is created or destroyed

Model: Reactants versus products in photosynthesis

Reactants (go in)	Products (come out)
6 CO ₂ molecules: 6 carbon, 12 oxygen	1 C ₆ H ₁₂ O ₆ molecule: 6 carbon, 12 hydrogen, 6 oxygen
6 H ₂ O molecules: 12 hydrogen, 6 oxygen	6 O ₂ molecules: 12 oxygen
Light energy (not matter, no atoms)	Stored chemical energy in the sugar
Total atoms: 6 C, 12 H, 18 O	Total atoms: 6 C, 12 H, 18 O

Every atom in the sugar came from carbon dioxide or water. The light contributed energy, not atoms.





CHECK FOR UNDERSTANDING

Quick check: oxygen atoms

How many oxygen atoms are on each side of $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$, and where do the twelve oxygen atoms in the oxygen gas come from?

A. 12 on each side; all from carbon dioxide

B. 18 on each side; from carbon dioxide and water together

C. 24 on each side; from the air

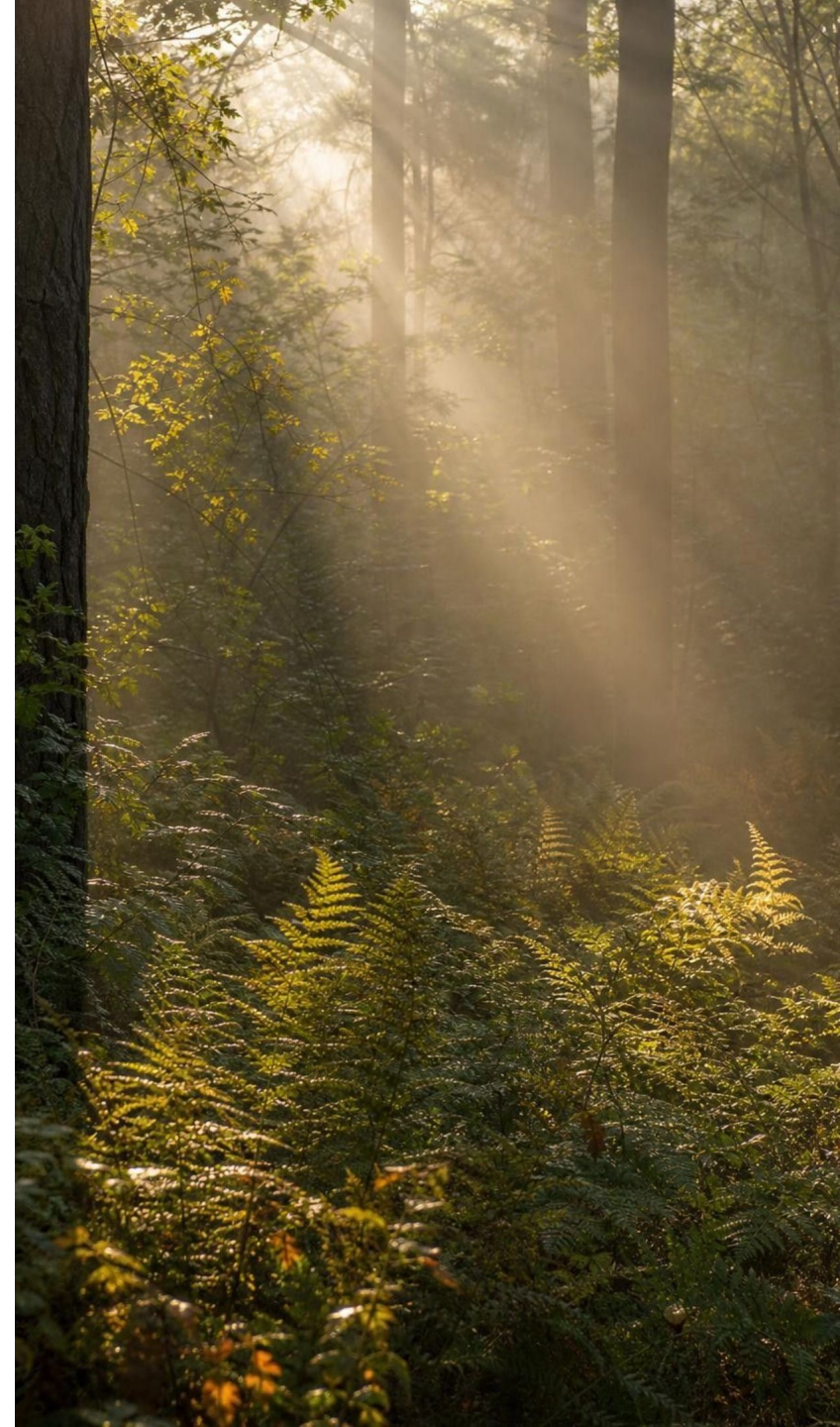
D. 18 on the left, 12 on the right; six are lost

THINK, PAIR, SHARE

Discuss: where did the light go?

- Light is energy, not matter. It cannot become atoms.
- The reaction needs an energy input; without light it does not run.
- The light's energy ends up stored as chemical energy in the sugar.
- That stored energy is released later when the sugar reacts with oxygen.

A classmate says, 'The sunlight turned into the sugar.' Another says, 'The sunlight is gone; it just made the reaction happen.' Who is closer to right, and what actually happened to the light's energy?



How scientists found the answer

- 1640s: van Helmont's willow gained about 74 kg; the soil lost about 60 g. Not soil.
- 1770s: Joseph Priestley found a sprig of mint could 'restore' air that a candle had spoiled.
- 1779: Jan Ingenhousz put leaves under water in sunshine: bubbles of oxygen only in light.
- 1804: Nicolas-Théodore de Saussure sealed plants in jars and tracked the carbon dioxide they took in.
- Result: most of a plant's dry mass traces back to carbon dioxide from the air.



A timeline of experiments on plant matter

MODEL

Model: Ruling out the wrong answers, one experiment at a time

- **1640s: van Helmont's willow:** Soil barely lost mass while the tree gained about 74 kg. Soil is not the source.
- **1771: Priestley's mint:** A living sprig restored air that a burning candle had spoiled. Plants change the air.
- **1779: Ingenhousz's bubbles:** Submerged green leaves gave off oxygen bubbles only in light. Light and green parts are needed.
- **1804: de Saussure's sealed jars:** Measured carbon dioxide taken in; it and water account for the mass gain.
- **Today: tracking atoms:** Scientists follow labeled carbon atoms from the air into sugar, starch and wood.

Each experiment kept the useful finding of the last one and fixed what it got wrong.



CHECK FOR UNDERSTANDING

Quick check: predict the bubbles

A water plant sits in a sealed jar of water under a bright lamp and bubbles steadily. After an hour the bubbles stop, though the lamp is still on. What most likely ran out?

A. Light

B. Water

C. Carbon dioxide dissolved in the water

D. Chlorophyll





Day and night: two things happen at once

Plant cells break sugar down with oxygen to release energy all the time, day and night, the same way animal cells do. In bright light, photosynthesis runs much faster than that, so the plant takes in more carbon dioxide than it gives off and releases oxygen overall. In the dark, photosynthesis stops, the breakdown continues, and the plant gives off carbon dioxide. Nothing switches modes; one process stops.

Three jobs for every sugar molecule

Model: What a producer does with the sugar it makes

Use it now: React it with oxygen to release energy for growth, repair and moving materials. Carbon dioxide and water leave.

Store it: Link sugar units into starch and pack it into roots, seeds and fruits for nights, winters and sprouting.

Center: Sugar made in the leaf

Build with it: Link sugar units into cellulose, the tough chains that form cell walls and most of wood.

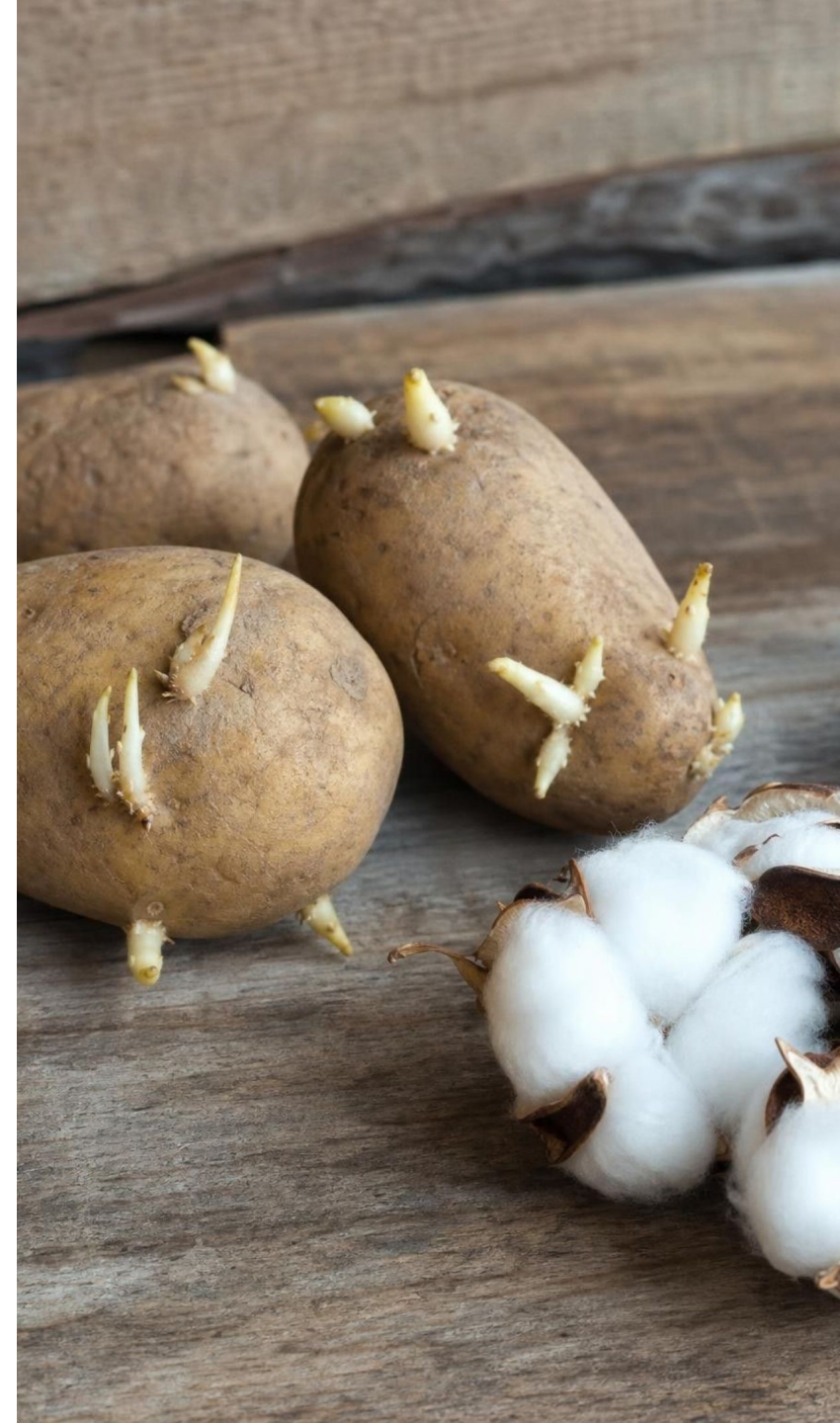
Pass it on: When an animal eats the plant, the sugar, starch and cellulose become that animal's matter and energy supply.

A carrot's sweetness, a seed's head start and a sequoia's trunk are all sugar sent to different jobs.



Words for stored matter and energy

- **starch:** A storage molecule made of many linked sugar units, packed into roots, seeds and fruits. *A potato is a starch store that fed the plant's next spring shoots before they had leaves.*
- **cellulose:** Long chains of linked sugar units that form plant cell walls; the largest single ingredient of wood. *A cotton T-shirt is nearly pure cellulose, which is why you cannot digest it.*
- **biomass:** The total mass of living things; it holds both matter and stored chemical energy. *Most of a forest's biomass is tree trunks, not animals.*

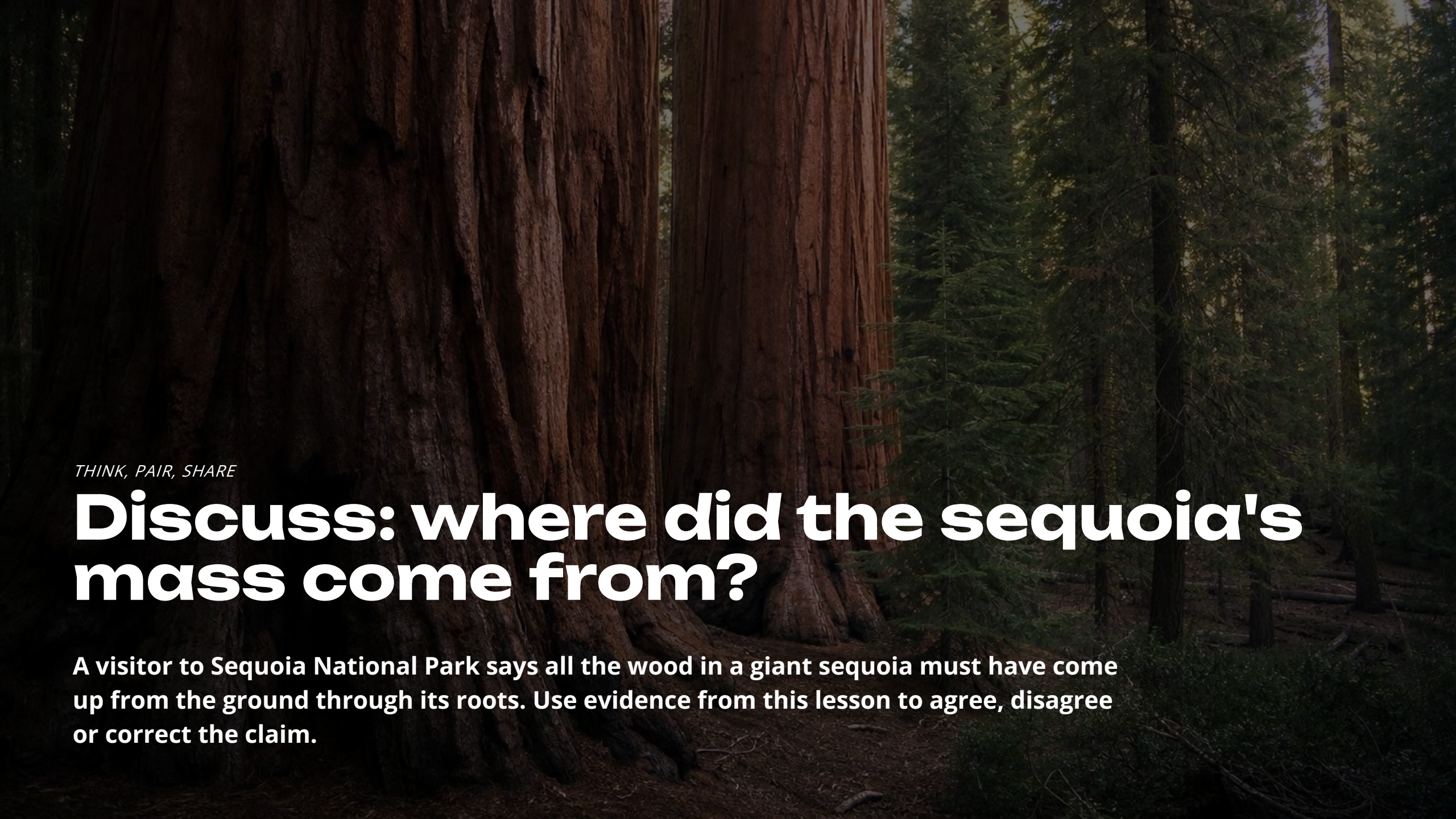


REAL-WORLD CONNECTION

California connection: a forest that is not made of plants

Off Monterey and along much of the California coast, giant kelp forms underwater forests 30 meters tall. Kelp is a brown alga, not a plant, yet the whole kelp forest depends on it. In good conditions it can grow up to about 60 centimeters a day on carbon dioxide from seawater and light from the surface. Urchins, snails and fish eat it; sea otters eat the urchins. All that biomass starts with the kelp.



A large, textured brown tree trunk of a sequoia tree dominates the left side of the frame. The bark is deeply furrowed and has a warm, reddish-brown hue. To the right, a dense forest of green coniferous trees is visible, their needles creating a soft, out-of-focus background. The lighting is natural, suggesting a forest interior with sunlight filtering through the canopy.

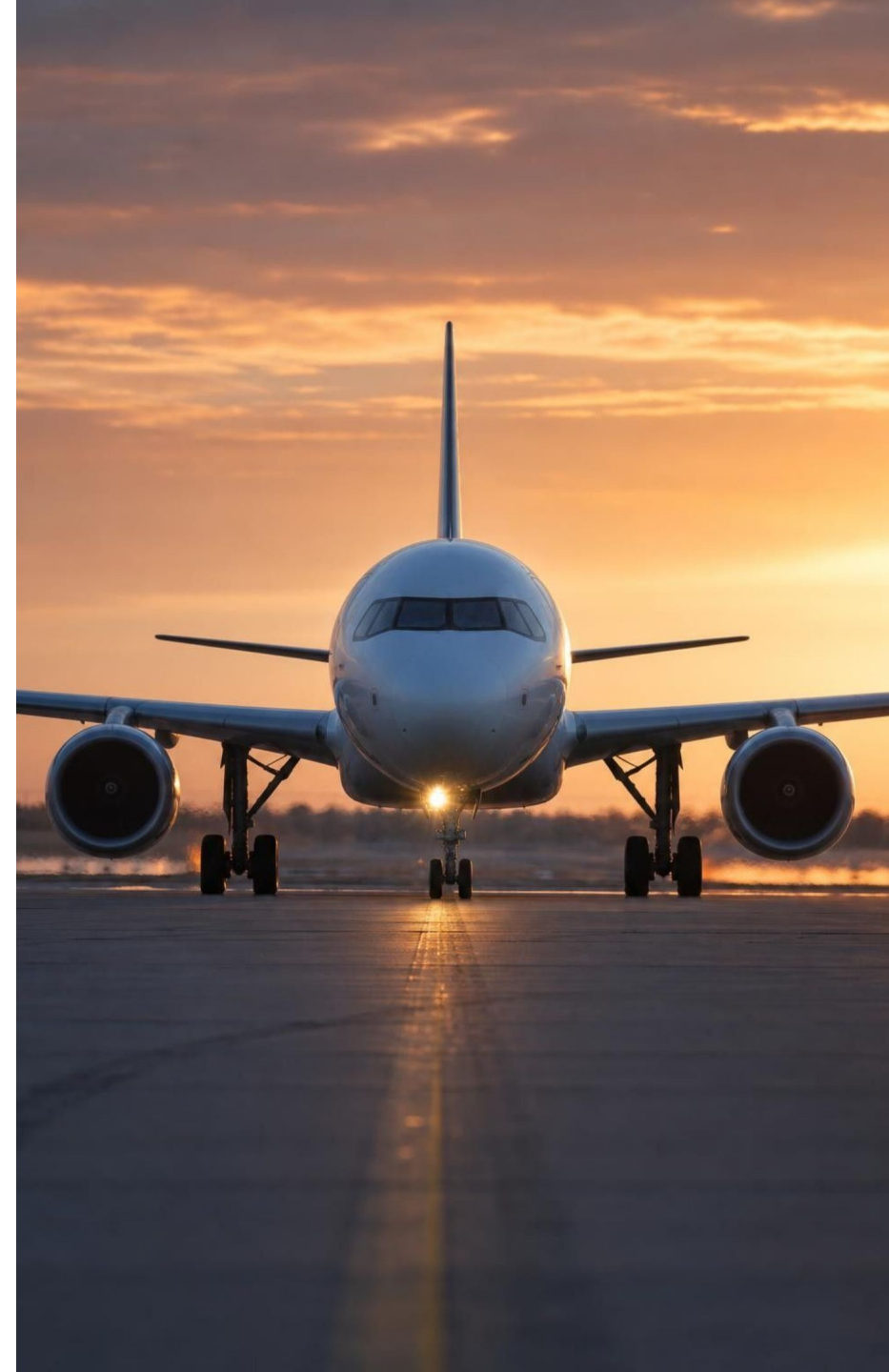
THINK, PAIR, SHARE

Discuss: where did the sequoia's mass come from?

A visitor to Sequoia National Park says all the wood in a giant sequoia must have come up from the ground through its roots. Use evidence from this lesson to agree, disagree or correct the claim.

Engineering: can biomass fuel a jet?

- Jets burn fuel to release stored chemical energy. Every extra kilogram of fuel is more to lift.
- Criterion: pack as much energy as possible into each kilogram of fuel.
- For decades fossil fuels met that criterion, but they are not renewable.
- In the 2000s airlines added a constraint: the fuel source should be renewable.
- Biofuel: a fuel made from biomass. Its carbon was pulled from the air by producers recently.
- More constraints: affordable, regrown fast enough, and not pushing out food crops.



Task: which biomass should become jet fuel?

Screen the four sources with three constraints (regrows within 5 years, under \$0.40 per kg, no competition with food), then compare energy per kg. Which do you recommend, and what is its weakness?

Biomass source	Energy per kg of feedstock (MJ)	Years to regrow	Cost (\$ per kg)	Competes with food?
City yard and food waste	12	0.1	0.05	No
Corn grain	16	1	0.25	Yes
Fast-growing grass crop	17	1	0.15	Only if planted on farmland
Forest timber	19	40	0.1	No

Simulated data for practice.





MISCONCEPTION CHECK

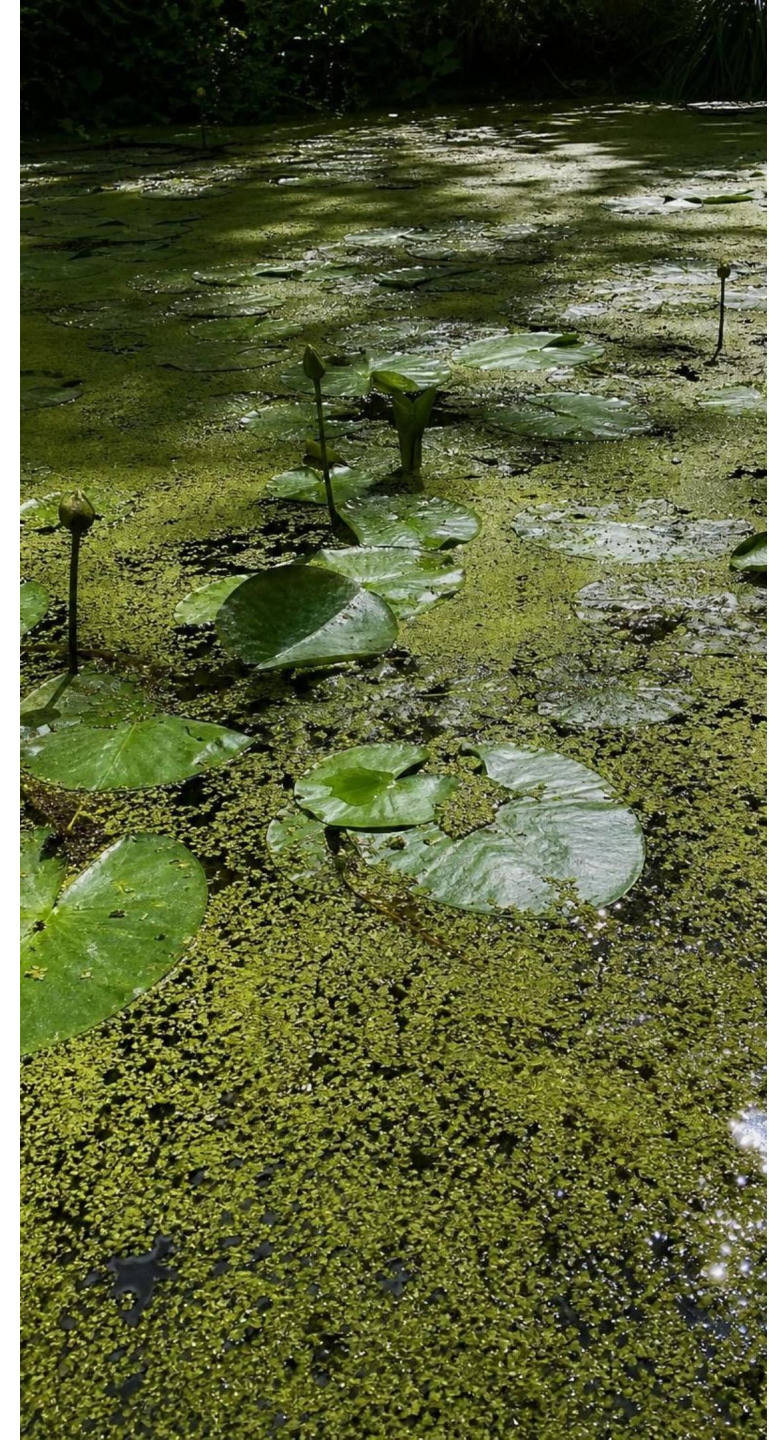
True or false? Plants eat soil

"A plant gets its food from the soil through its roots, the way an animal gets food through its mouth. That is why we feed plants with fertilizer."

True or false? Explain your reasoning.

Putting it together

- Producers (plants, algae, cyanobacteria) build food from carbon dioxide, water and light energy.
- Chlorophyll in chloroplasts absorbs the light; the reaction rearranges atoms into sugar and oxygen.
- Atoms are conserved: 6 C, 12 H, 18 O on each side. Light adds energy, never atoms.
- Experiments from van Helmont to de Saussure traced a plant's mass to the air, not the soil.
- Sugar is used now, stored as starch, or built into cellulose; all of it is biomass others live on.
- Biomass can be a fuel, judged by energy per kilogram and by renewable, cost and food constraints.





EXIT TICKET

Exit ticket

- Name the one energy input and the two matter inputs of photosynthesis.
- A sapling gains 5 kg in a year. In one sentence, say where most of that mass came from and how it got in.
- What happened to the light's energy? Finish: 'It ended up ____.'
- Name one criterion and one constraint for a jet biofuel, and label which is which.
- Leaf disks in a dark cup never rose. What does that show photosynthesis needs?