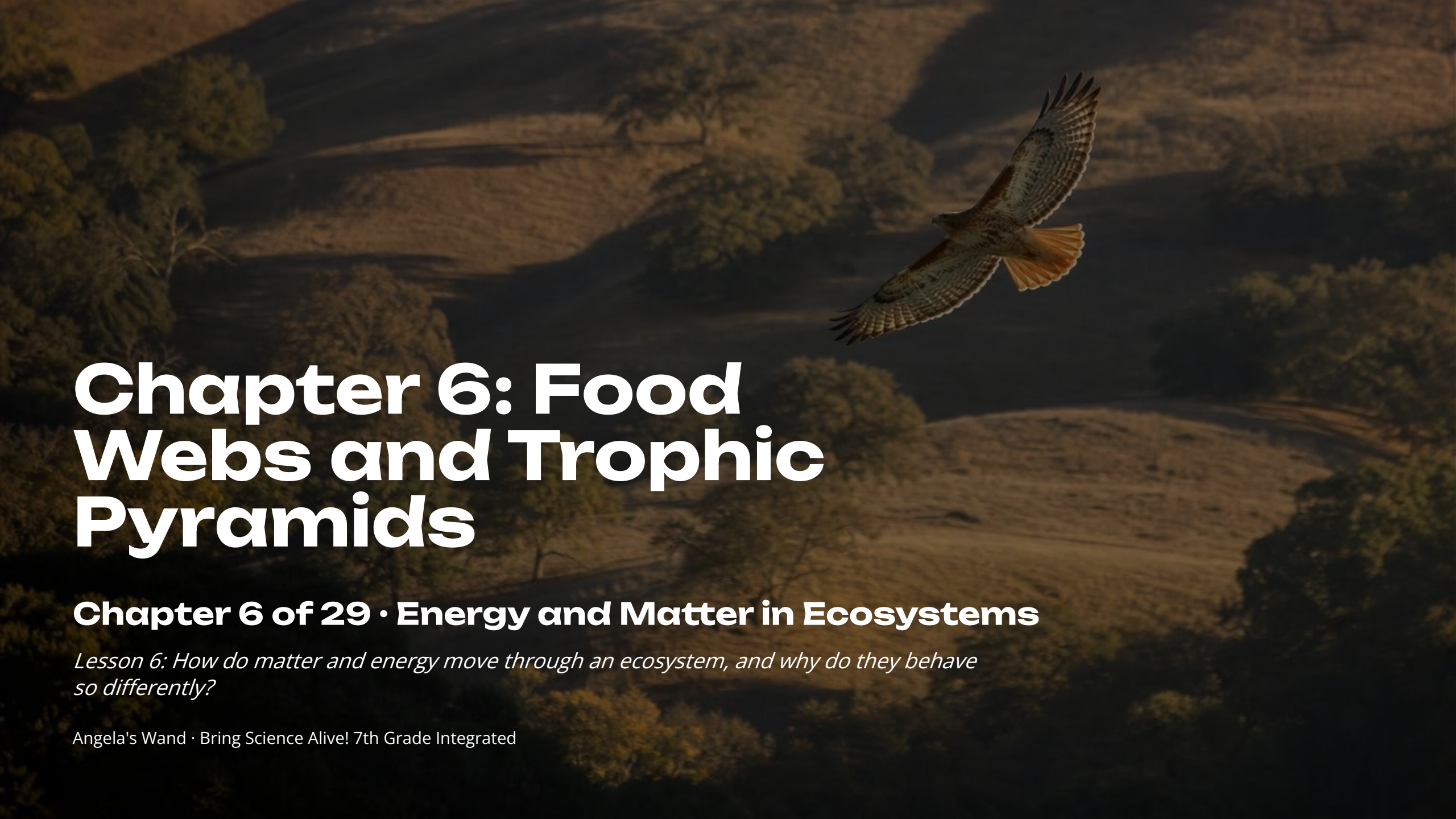


A hawk is shown in flight, its wings spread wide, against a backdrop of a savanna landscape. The landscape features rolling hills, some with sparse trees and others with denser vegetation. The lighting suggests a warm, golden hour, with long shadows and a soft glow. The hawk is positioned in the upper right quadrant of the frame, flying towards the left.

Chapter 6: Food Webs and Trophic Pyramids

Chapter 6 of 29 • Energy and Matter in Ecosystems

Lesson 6: How do matter and energy move through an ecosystem, and why do they behave so differently?

PHENOMENON

Three and a half tonnes of hay, one steer

A 4-H student weighs every bale her steer eats for a year: about 3,600 kg of dry feed. On show day the steer has gained about 360 kg, one tenth of what it ate. The barn is not full of leftover hay and the steer is not ten times heavier. Where did the other 3,200 kg go? (Typical rounded figures.)

- Notice: what numbers do you have, and what number is missing?
- Wonder: what leaves a steer's body every day that you could collect and weigh?
- Predict: if a cougar ate the steer, about how much of it would become cougar?





LEARNING TARGETS

What you will be able to do

- Read a food web: say what each arrow means and find producers, consumers, decomposers and chains.
- Predict direct and indirect effects when one population changes.
- Account for every kilogram an animal eats: tissue, breath, wastes and remains.
- Use a trophic pyramid and the ten-percent rule of thumb to calculate energy at each level.
- Build a model in which matter cycles and energy flows through and leaves as heat.
- Explain how scientists tested and modified a food-web fix for a polluted lake.

Who eats whom: reading the arrows

- A food web is a model of feeding links among the populations in an ecosystem.
- Each arrow runs from the food to the eater: grass → grasshopper means grass becomes grasshopper.
- The arrow tracks matter and energy. They move toward the arrowhead.
- No arrow points at a producer: producers build food from air, water and light, not from other organisms.
- A food chain is one path through the web, from a producer to an animal nothing in the model eats.





MODEL

One chain through a California oak woodland

Model: A food chain: five trophic levels



Each arrow carries matter and energy toward the eater. Grass is level 1; the hawk here is level 5.



VOCABULARY IN CONTEXT

Three words for reading a web

- **food web:** A model of the feeding connections among the populations in an ecosystem; arrows run from food to eater. *In the woodland web, five arrows leave the needlegrass because so many animals feed on it.*
- **food chain:** One single path through a food web, from a producer to an organism nothing in the model eats. *Grass → grasshopper → lizard → snake → hawk is one chain; grass → squirrel → hawk is another.*
- **top predator:** An animal no other animal in the model eats. It is 'top' only relative to the organisms the model includes. *The hawk is a top predator in a five-card chain; add a great horned owl, which takes young hawks, and it is not.*

Ripples: direct and indirect effects

- Direct effect: a change in a population that eats, or is eaten by, the one that changed.
- More coyotes → fewer jackrabbits. Coyotes eat jackrabbits, so this is direct.
- Indirect effect: a change passed through a third population in the middle.
- Fewer jackrabbits → more grass survives the summer. Coyotes never touch grass, so this is indirect.
- To predict a ripple, follow the arrows one link at a time and write the sign (+ or -) at each step.





CHECK FOR UNDERSTANDING

Quick check: direct or indirect?

1. More gopher snakes → fewer deer mice.
2. More gopher snakes → more beetles.
3. Fewer deer mice → more grass seeds sprout next spring.
4. More gopher snakes → more hawks (hawks eat gopher snakes).
5. More gopher snakes → fewer seeds eaten, so more grass → more grasshoppers.

In the woodland web, gopher snakes eat deer mice, and deer mice eat grass seeds and beetles. Label each effect D (direct) or I (indirect).

The arrows most diagrams leave out: decomposers

- Every organism eventually dies or sheds wastes, leaves, hair, skin, dung.
- Decomposers, mainly bacteria and fungi, feed on those wastes and remains.
- They are consumers: they get matter and energy from food, by cellular respiration, like you.
- An arrow should run from every organism in a web to the decomposers.
- Their wastes are carbon dioxide, water and mineral nutrients: exactly what producers take in.





MODEL

Matter comes back around

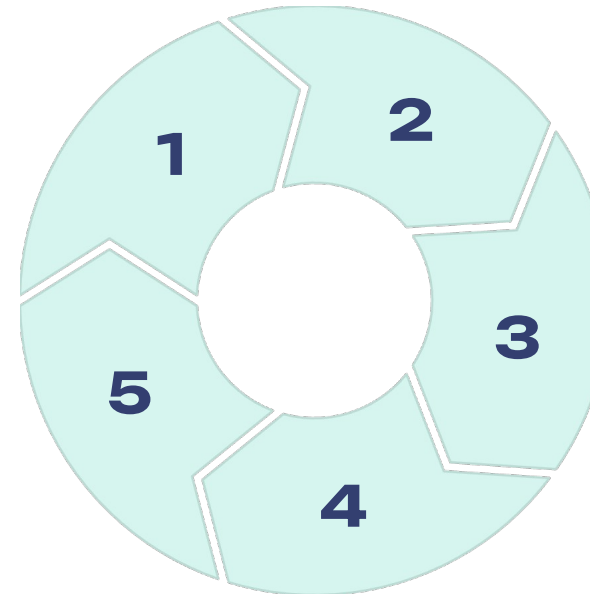
Model: The matter loop of an ecosystem

Air, water and soil

(carbon dioxide, water, nutrients) → (taken in by)

Decomposers

break remains down and respire → (released back to) (back to the start)



Producers

build sugar and tissue → (eaten by)

Consumers

eat and build their own tissue → (shed by)

Wastes and remains

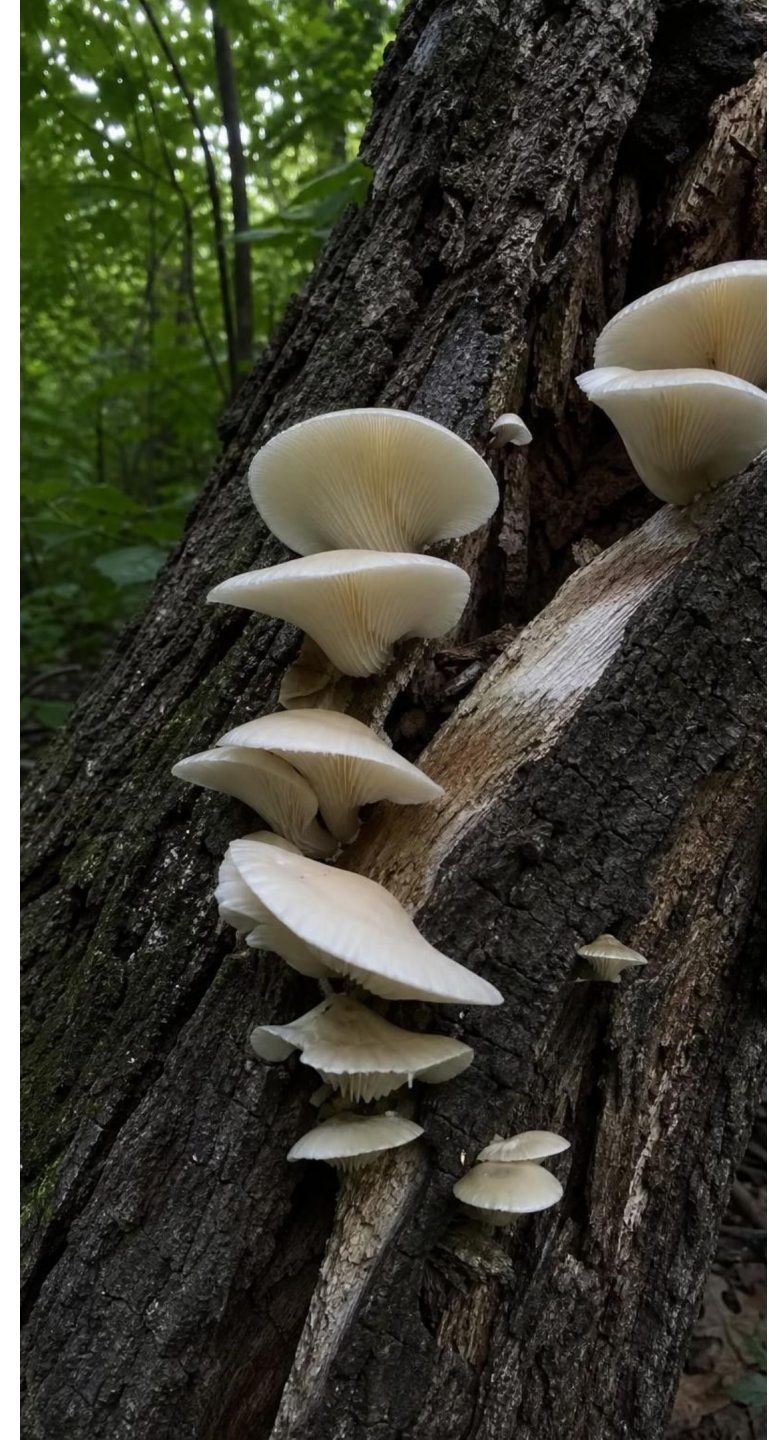
from every level → (fed on by)

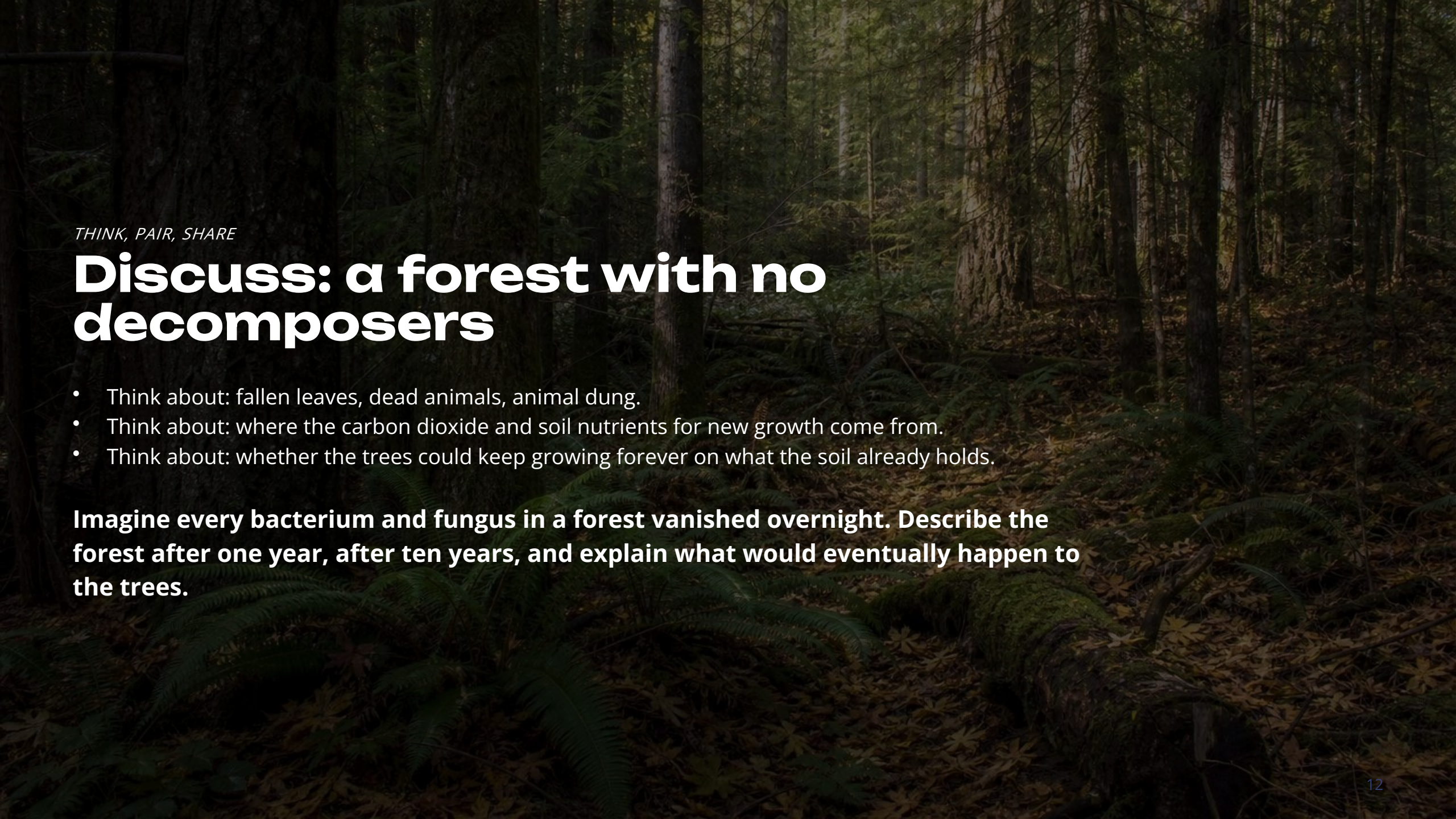
Atoms travel this loop again and again. Nothing is created or destroyed along the way.

VOCABULARY IN CONTEXT

Words for the loop and the levels

- **decomposer:** A consumer, such as a bacterium or a fungus, that feeds on wastes and dead remains and releases simple substances that producers can reuse. *A mushroom on a fallen oak is the visible part of a fungus that is turning the log into carbon dioxide and soil nutrients.*
- **trophic level:** A feeding step in a food chain: producers are level 1, their eaters level 2, and so on. *A lizard eating a grasshopper that ate grass is feeding at level 3.*
- **biomass:** The total mass of living matter in a group of organisms, usually measured dry. *All the grass in a hectare of meadow has far more biomass than all the hawks that hunt over it.*





THINK, PAIR, SHARE

Discuss: a forest with no decomposers

- Think about: fallen leaves, dead animals, animal dung.
- Think about: where the carbon dioxide and soil nutrients for new growth come from.
- Think about: whether the trees could keep growing forever on what the soil already holds.

Imagine every bacterium and fungus in a forest vanished overnight. Describe the forest after one year, after ten years, and explain what would eventually happen to the trees.



Back to the steer: where 3,600 kg of feed went



About **360 kg** became new steer: muscle, bone, fat, hide. That is the only part the next eater can use.



Most of the rest left as carbon dioxide and water vapor in every breath, released by cellular respiration.



A large share left as dung and urine, and went to decomposers in the soil.



Energy left too, as body heat. Heat is not matter, but a large share of the feed's energy left that way.



Every kilogram is somewhere. None was destroyed and none 'turned into energy'.

The trophic pyramid: energy shrinks at every step

Model

Model: Energy available at each level (ten-percent rule of thumb)

Top to bottom:

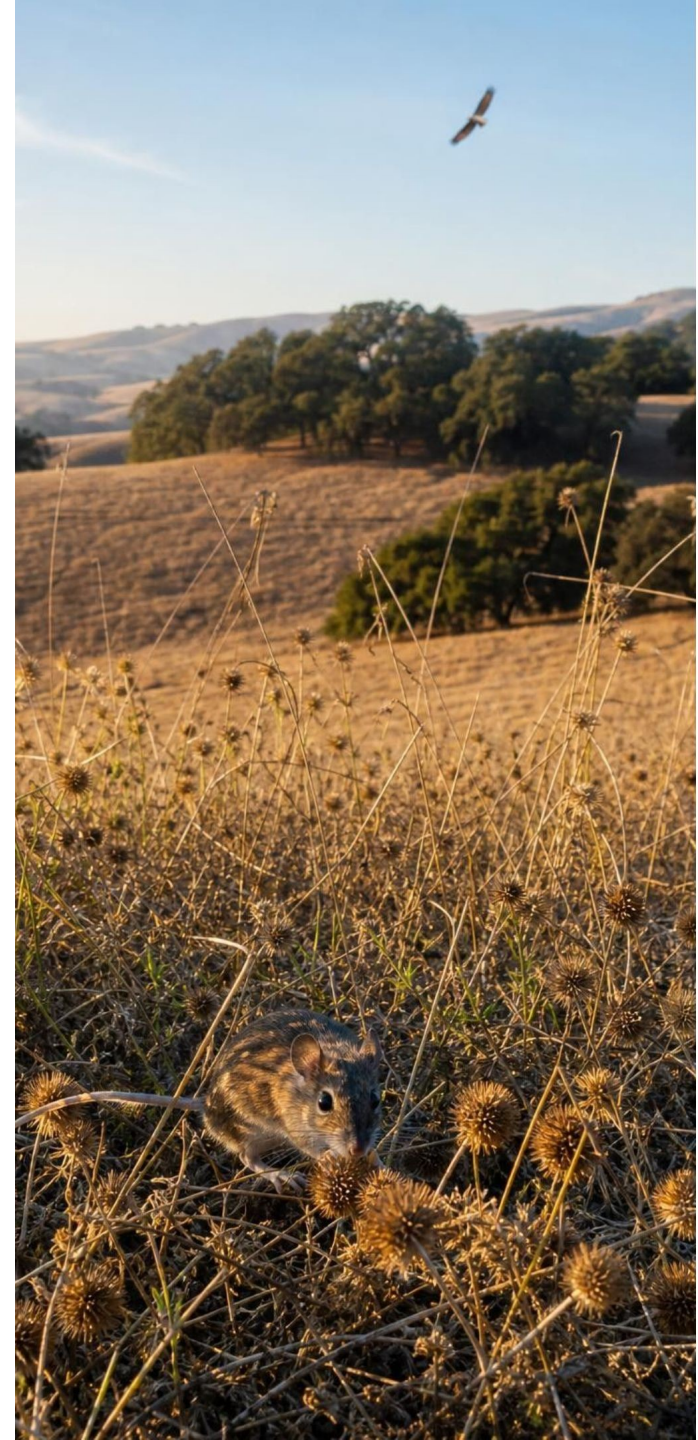
Level 4, hawks: about **10** units /

Level 3, snakes and lizards: about **100** units /

Level 2, grasshoppers and mice: about **1,000** units /

Level 1, grass and oaks: **10,000** units captured from sunlight

Each layer receives roughly a tenth of the energy stored by the layer below. The other nine tenths left as heat or went to decomposers.





The ten-percent rule of thumb, and where the ninety goes

- On average, only about one tenth of the energy at one level becomes stored energy at the next.
- Much is used for living (moving, staying warm, growing) and leaves as heat.
- Some is never eaten: roots, bark, bones and bodies go to decomposers.
- Some is eaten but not digested, and leaves as waste.
- Ten percent is an average. Measured values run from a few percent to over twenty.
- To estimate the next level: multiply by 0.1. To estimate two levels up: multiply by 0.01.

CHECK FOR UNDERSTANDING

Quick check: energy up the pyramid

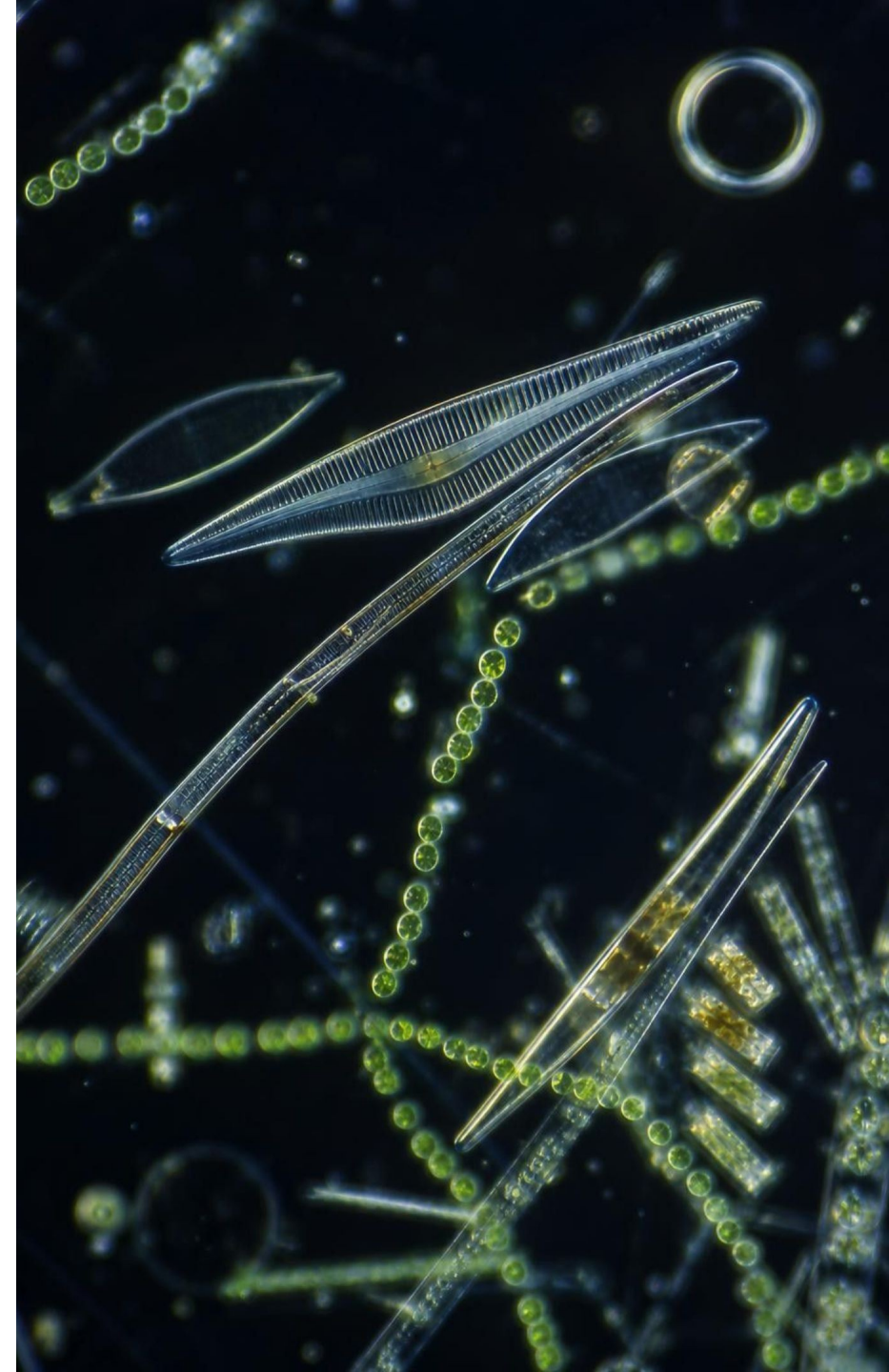
The phytoplankton in a bay store 40,000 units of energy in a year. Using the ten-percent rule of thumb, about how much is available to small fish at level 3?

A. 4,000 units

B. 400 units

C. 40 units

D. 4 units



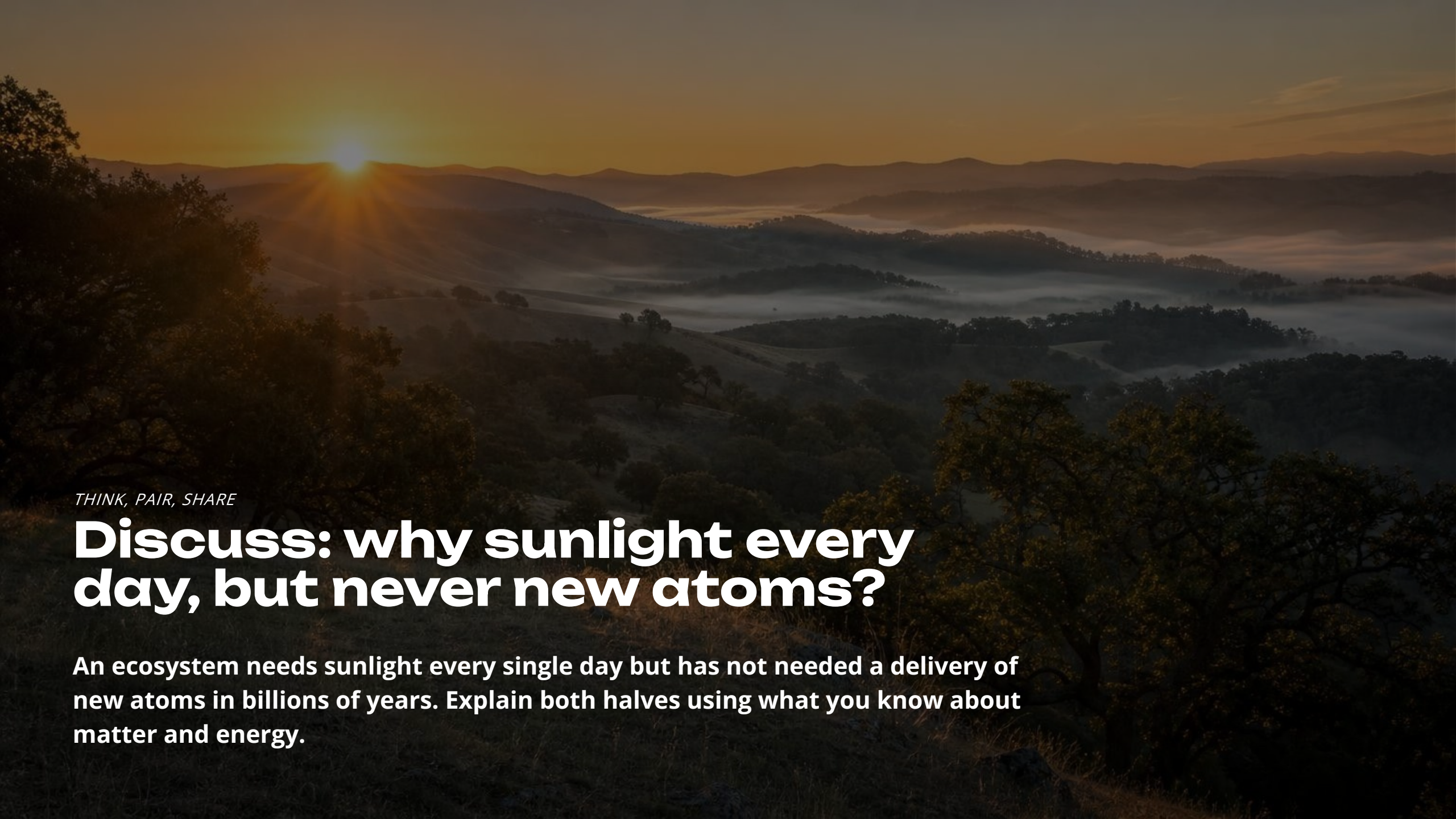


MODEL

Matter cycles. Energy flows. Here is the difference.

Model: Two things that travel through a food web · *The textbook says energy 'cycles' and is 'recycled'. It is not: energy flows one way and leaves as heat.*

Matter (atoms)	Energy
Enters living things from air, water and soil	Enters living things as sunlight captured by producers
Is passed from food to eater	Is passed from food to eater, about a tenth at a time
Leaves living things as carbon dioxide, water, wastes and remains	Leaves living things as heat at every level
Is returned to air, water and soil by decomposers	Cannot be gathered back by producers once it is heat
Goes around again and again; never used up	Flows through once; the ecosystem needs a new supply every day

A scenic landscape at sunrise or sunset. The sun is low on the horizon, casting a warm, golden glow over rolling hills. The hills are covered in dense vegetation, and the sky is a mix of orange and blue. The overall mood is peaceful and contemplative.

THINK, PAIR, SHARE

Discuss: why sunlight every day, but never new atoms?

An ecosystem needs sunlight every single day but has not needed a delivery of new atoms in billions of years. Explain both halves using what you know about matter and energy.



Pyramids that flip, and the one that never does

- A pyramid of numbers counts organisms. One oak can feed thousands of caterpillars, so it flips.
- A pyramid of biomass weighs each level. On land it usually narrows upward.
- In open water a biomass snapshot can flip: phytoplankton are eaten almost as fast as they grow.
- A pyramid of energy tracks energy passed up over a year. It can never flip.

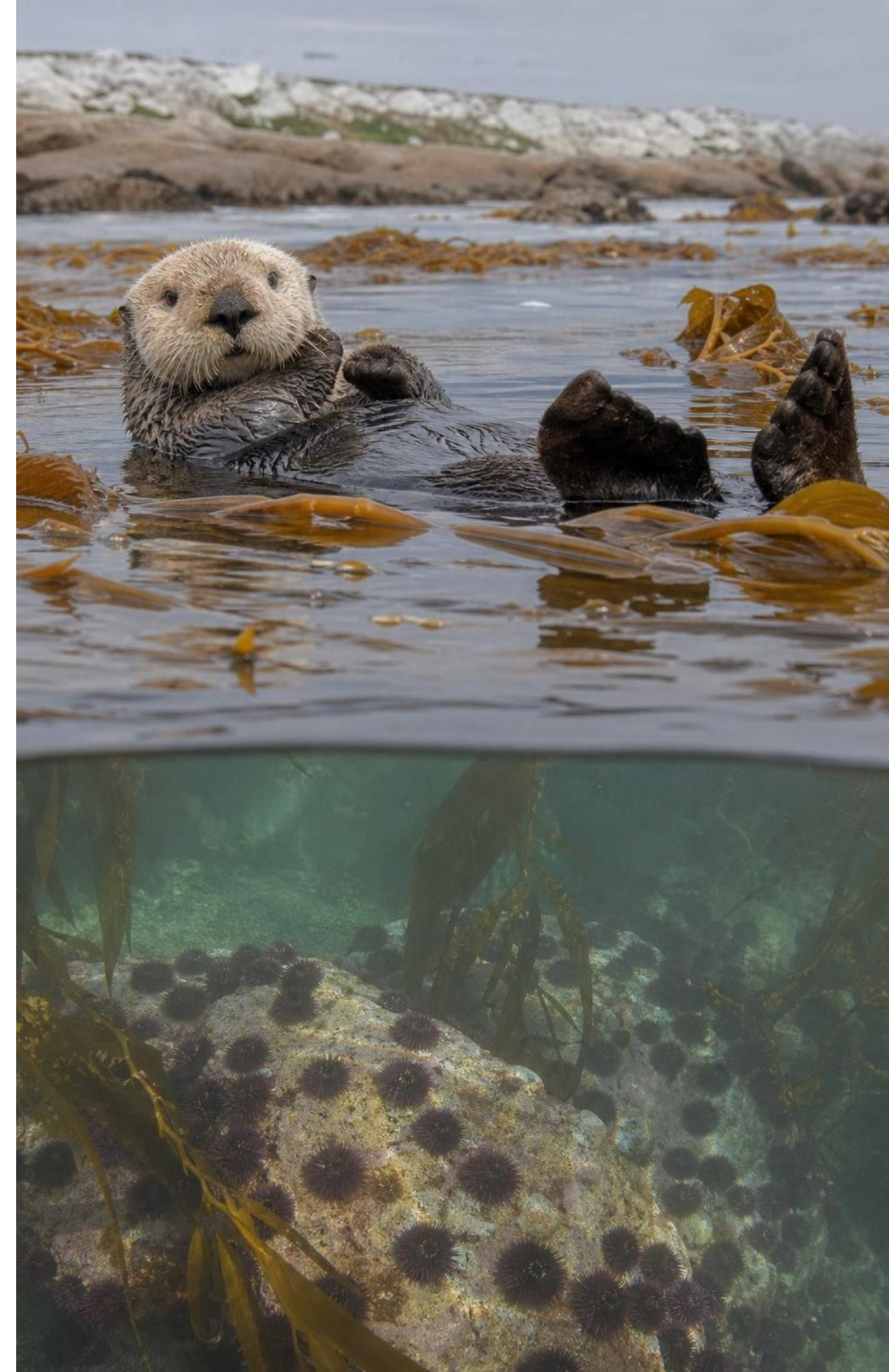
Reason: no level can receive more energy than the level below captured and stored.

REAL-WORLD CONNECTION

California connection: sea otters, urchins and kelp

Along the central California coast, sea otters eat purple sea urchins, and urchins graze kelp. Where otters are numerous, urchins stay in cracks and kelp forests stand tall. North of San Francisco otters are absent; after a disease killed sea stars in 2013 and a marine heat wave began in 2014, urchins boomed and most of the bull kelp forest was grazed down to bare rock.

- Otter → urchin: a direct effect.
- Otter → kelp: an indirect effect, through the urchins.
- Kelp is the producer that feeds fish, abalone and the whole forest web.





APPLY IT · SIMULATED DATA FOR PRACTICE.

Task: did the lake fix work? Read the monitoring data

A murky lake was treated in two steps. Use the table to decide whether step 1 worked, why the team modified it, and what evidence shows step 2 worked.

Year	Action taken	Roach per net-night	Zooplankton per liter	Algae cells per drop	Clarity depth (m)
1	Monitoring only	42	12	900	0.7
2	Half the roach netted out	20	30	600	1.1
3	Netting continued	24	28	550	1.2
4	Predatory fish stocked, netting continued	15	45	300	1.9
5	Predators growing	8	60	150	2.8
6	Monitoring only	9	58	160	2.7

Engineering with a food web: test, measure, modify

Lake Vesijärvi, Finland: years of sewage fed the algae; the water turned murky and stayed that way.

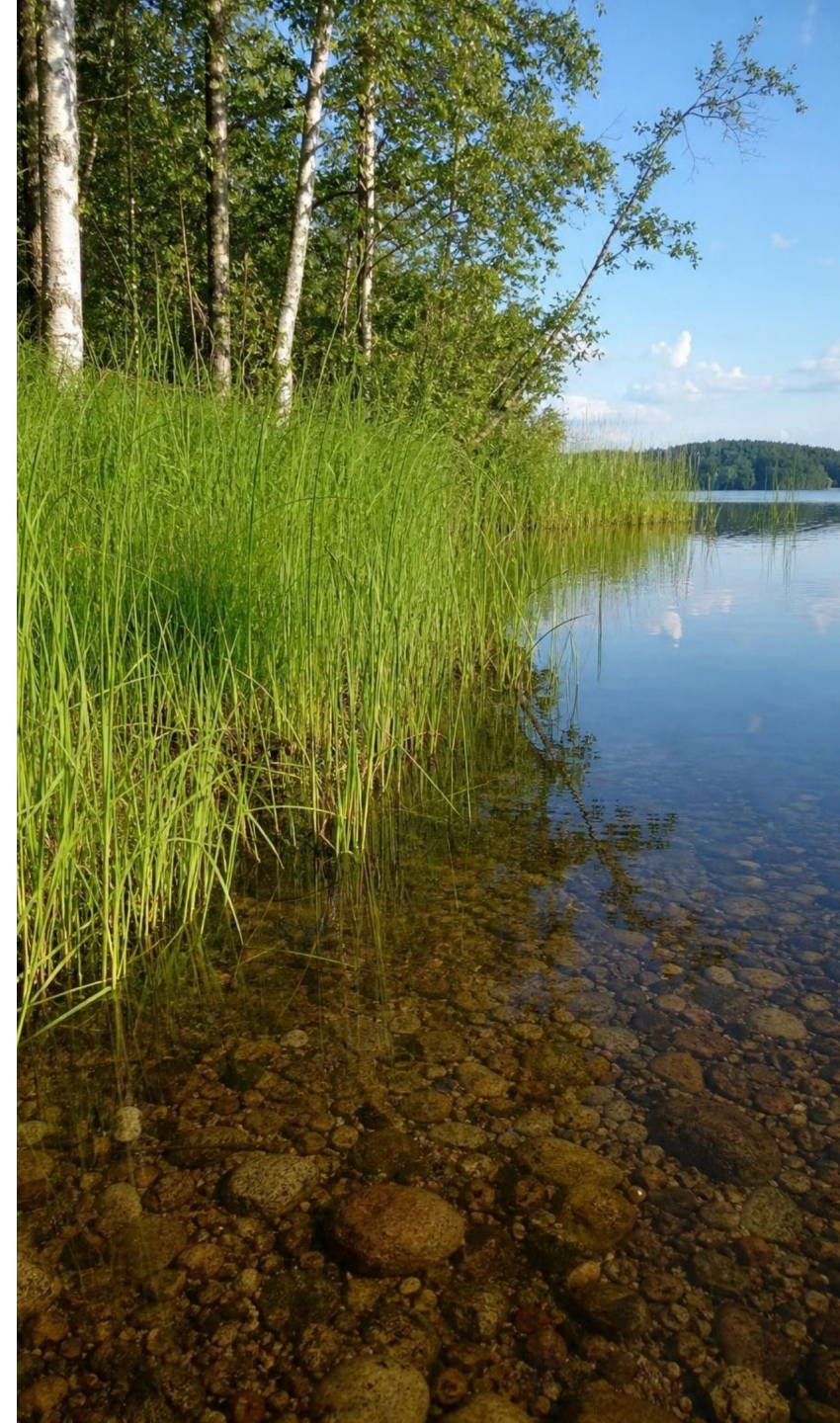
Test 1: net out huge numbers of roach. Measured result: better, but not clear enough.

Measuring: count algae cells in a drop of lake water under a microscope, then scale up to the whole lake.

The model's bet: plankton-eating fish were keeping zooplankton low, so algae grew unchecked.

Modify: stock predatory fish that eat roach. Measured result: zooplankton up, algae down, water clear.

The real history was messier: cutting off the sewage did much of the work, and the fish steps overlapped.





CHECK FOR UNDERSTANDING

Quick check: what counts as good evidence?

A team claims that adding predatory fish cleared a lake. Which single piece of evidence supports that claim most strongly?

A. The lake looked clearer to visitors the summer after stocking.

B. Algae counts fell in the two years after stocking, and roach and zooplankton changed in the predicted directions.

C. Predatory fish are known to eat roach in other lakes.

D. The team expected the plan to work because the food-web model said it would.



MISCONCEPTION CHECK

True or false? Energy goes around the loop too

"Decomposers recycle matter back to the producers, and in the same way they recycle energy back to the producers, so an ecosystem could keep running without the sun once it got started."

True or false? Explain your reasoning.

PUTTING IT TOGETHER

Putting it together

- A food web's arrows point from food to eater and carry matter and energy together.
- Change one population and the effects ripple: direct through one link, indirect through two or more.
- Decomposers return every atom to the air, water and soil, so matter cycles.
- Only about a tenth of each level's energy is passed up; the rest leaves as heat or goes to decomposers.
- Energy enters as sunlight and leaves as heat, so it flows through, and the pyramid can never flip.
- A food-web model can guide an ecosystem repair, but the plan must be tested, measured and modified.





EXIT TICKET

Exit ticket

- Draw a three-link food chain from your neighborhood, arrows pointing the right way, and number the levels.
- Coyotes are removed from a valley. Write the sign chain for jackrabbits, then grass, then grasshoppers.
- Producers store 20,000 energy units. Using the ten-percent rule of thumb, how much reaches level 3?
- Finish the sentence: 'Matter cycles but energy flows because ____.'