

A dramatic landscape photograph of a river valley. A river winds through a lush green valley, surrounded by steep, forested mountains. In the distance, a body of water is visible under a sky filled with large, dark, and light-colored clouds. The overall mood is majestic and natural.

Chapter 7: Global Cycles of Matter

Chapter 7 of 29 • Energy and Matter in Ecosystems

Lesson 7: How does the same matter keep moving through Earth's living and nonliving parts?

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

PHENOMENON

The pond that turned green after the rain

A pond sits below a sloping field. In early spring the field is fertilized and the pond is clear. A heavy storm sweeps the field two weeks later. Ten days after that, the pond is covered in green scum, the edges smell of rot, and a few fish float in the shallows. Nobody poured anything into the pond, and the field looks better than ever.

- Notice: what changed in the pond, and what changed in the field?
- Wonder: green scum is made of living matter. Where did that matter come from in ten days?
- Predict: if the storm had missed the field, would the pond have turned green anyway?





LEARNING TARGETS

What you will be able to do

- Explain why Earth is nearly closed for matter but open for energy, and name the exceptions.
- Trace one atom of carbon or nitrogen through living and nonliving reservoirs, naming each process.
- Build a cycle model that shows reservoirs, processes and the system boundary.
- Use a cycle model to predict what fossil-fuel burning or fertilizer runoff changes.
- Evaluate competing plans, such as fertilizer schedules or tree-planting sites, with criteria and constraints.

Spaceship Earth: what comes aboard, what leaves

- Nearly every atom on Earth has been here since the planet formed about 4.6 billion years ago.
- Matter is not created or destroyed by ordinary changes; it only changes form or location.
- Small leaks exist: about 100 tons of space dust arrive daily; some gas escapes the top of the air.
- Next to a planet of six trillion trillion kilograms, those leaks are nothing: Earth is closed for matter.
- Energy is different: sunlight pours in every day and heat radiates back out to space.





VOCABULARY IN CONTEXT

Three words for a planet that reuses everything

- **law of conservation of matter:** Ordinary changes never create or destroy atoms. Seal a system so nothing gets in or out, and its total mass holds steady no matter how its contents change form. *A sealed jar with sprouting seeds keeps the same mass for weeks; atoms only moved from air and water into the seedlings.*
- **closed system:** A system that matter does not enter or leave; energy can still cross the boundary. *A sealed terrarium is closed to matter but needs light coming in to stay alive.*
- **reservoir:** A place where matter is stored for a while inside a cycle. *The atmosphere, the ocean, soil, a tree trunk and a coal seam are all reservoirs for carbon.*

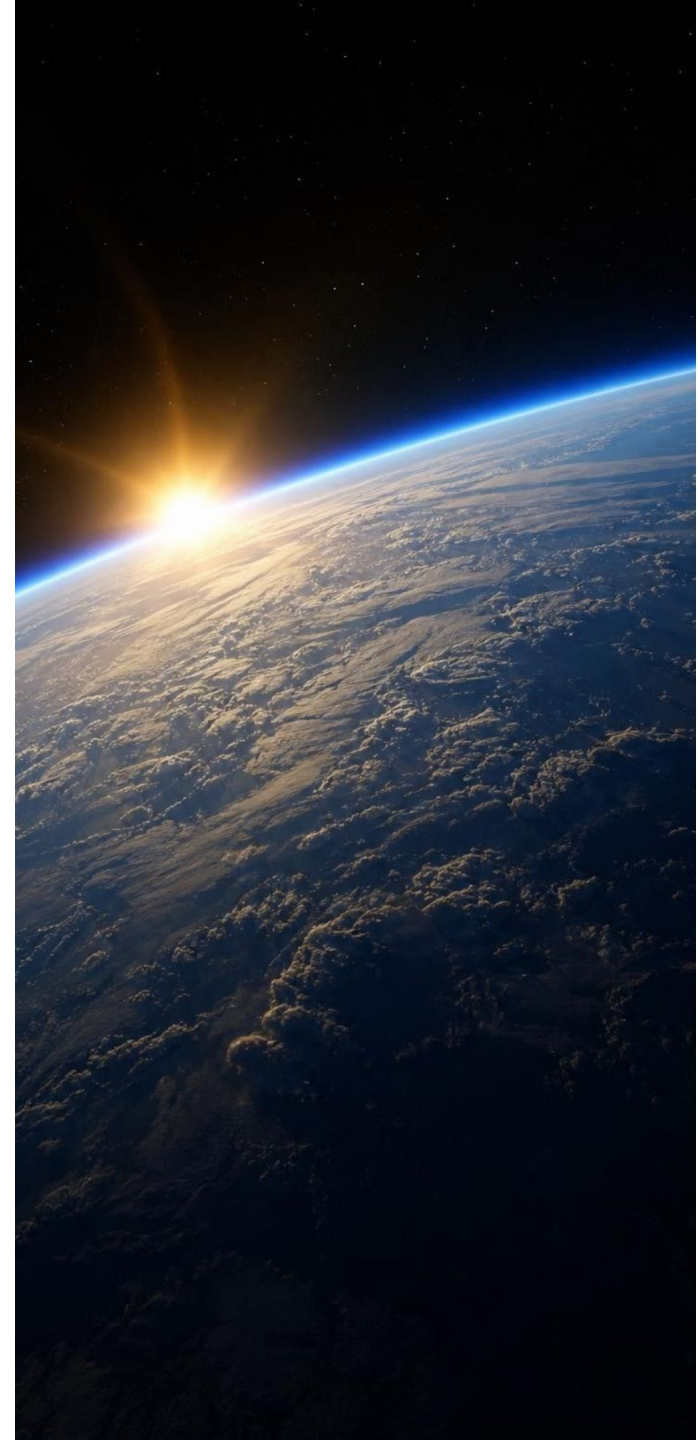
MODEL

At the edge of the planet: matter stays, energy flows

Model: What crosses Earth's boundary with space

Matter: stays aboard	Energy: passes through
The same atoms since Earth formed	Sunlight arrives every day
Water, carbon and nitrogen move only between reservoirs on Earth	Drives evaporation, photosynthesis, wind and weather
Tiny exceptions: space dust in, a little gas and a few spacecraft out	Heat radiates from Earth back out to space
Result: the cycles must reuse what is here	Result: the cycles never run out of power

Define the system first. For the whole planet, the boundary is the top of the atmosphere.





CHECK FOR UNDERSTANDING

Quick check: which one is closed for matter?

Which of these systems is closed for matter during the time described?

A. An open aquarium over a month, with fish fed daily

B. A sealed glass terrarium on a windowsill for a year

C. A campfire burning for an hour

D. A pond with a stream running in and out

Same atoms, new molecules

Matter changes form two ways inside the cycles. It can change state: liquid water becomes vapor, and the molecules stay whole. Or its atoms can be rearranged into different molecules: carbon dioxide and water become sugar and oxygen in a leaf. In both cases every atom is still there. What is not guaranteed to survive is the molecule. Plants split water molecules apart, and your cells build brand-new ones.





The water cycle as a reservoir map

Model

Model: One route a water molecule can take

Water vapor in the air →
(condensation)

Cloud droplets and ice →
(precipitation)

Rain and snow on land →
(soaking in, runoff)

Soil water, rivers, lakes,
ocean →
(root uptake)

Inside plants and animals
→
(transpiration)

(back to the start)

Sun and gravity drive this cycle: sunlight lifts water as vapor, gravity brings it down as rain and runoff. Animals drink water and return it to the air by exhaling; evaporation from soil, lakes and the ocean sends water back without passing through living things. Ice can go straight to vapor by sublimation.

CHECK FOR UNDERSTANDING

Quick check: name the arrow

A snowbank shrinks during a week of dry, sunny, below-freezing weather and no meltwater appears. Which process moved the water out of the snow?

A. Evaporation

B. Sublimation

C. Condensation

D. Transpiration





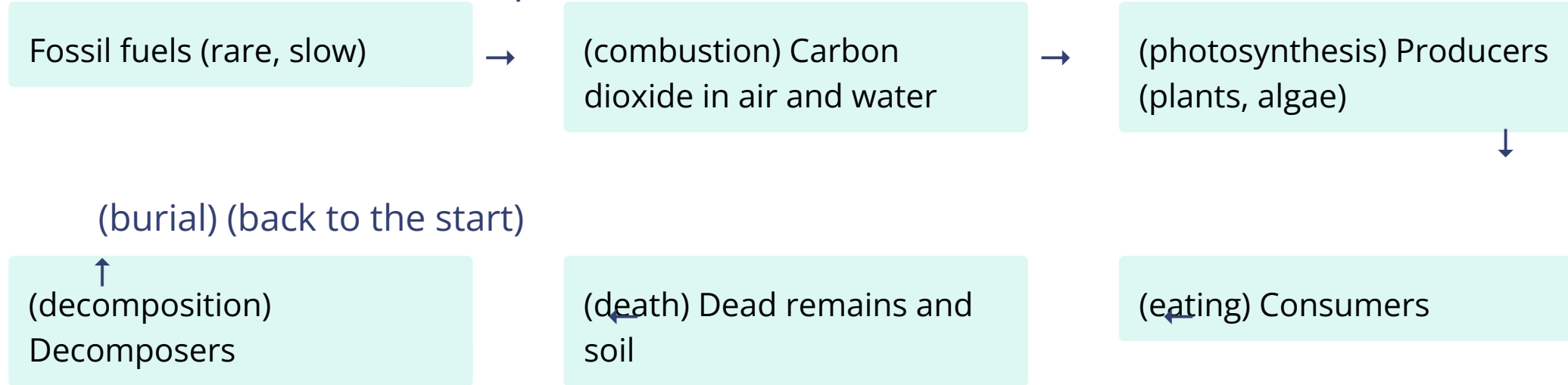
Carbon's main doorway in, and its main doorway out

- In: photosynthesis. Producers take carbon dioxide from air or water and build it into sugars.
- Along: eating. Consumers take in producers' carbon and rebuild it into their own fats, proteins and DNA.
- Out: cellular respiration. Every living cell, plant or animal or microbe, releases carbon dioxide.
- Decomposers eat dead remains and wastes; their respiration returns most of that carbon to the air.
- Slow side road: remains buried under sediment can become fossil fuels over millions of years.

The carbon cycle as a reservoir map

MODEL

Model: Where a carbon atom can be, and how it moves



Start at carbon dioxide (upper right) and follow the arrows clockwise. Consumers also pass carbon to the remains reservoir as wastes. Burial under sediment for millions of years turns a small share of remains that decomposers never finish into fossil fuels; combustion returns that carbon to the air. Not shown: every living node also has its own arrow straight back to the air, labeled cellular respiration, and carbon dioxide moves both ways between air and water.





VOCABULARY IN CONTEXT

Three processes that move carbon

- **cellular respiration:** The process in every living cell that breaks down sugar with oxygen to release usable energy, giving off carbon dioxide and water. *A sprouting seed in a sealed jar respires, so the carbon in its stored food moves into the jar's air as carbon dioxide.*
- **combustion:** Burning: a fast reaction between a fuel and oxygen that releases energy and sends the fuel's carbon into the air as carbon dioxide. *A campfire turns most of a log into gases; the ash is the small part that was never carbon-based fuel.*
- **fossil fuel:** Coal, oil or natural gas, formed over millions of years from buried remains of living things under sediment, heat and pressure. *The carbon in coal was pulled from the air by photosynthesis in swamp forests roughly 300 million years ago, before the first dinosaurs.*

THINK, PAIR, SHARE

Discuss: where were your breakfast's carbon atoms a year ago?

- Backward: food, then the plant or animal it came from, then photosynthesis, then the air.
- Forward: your cells, then cellular respiration, then the air, then maybe a leaf.
- Name the process on every step, not just the places.

Pick one thing you ate this morning. Work backward: where were its carbon atoms one year ago, and what processes moved them to your plate? Then go forward: where will they be next week?





CHECK FOR UNDERSTANDING

Quick check: the fallen leaf

An oak leaf falls in October. By the next summer it has vanished from the forest floor. Where did most of its carbon atoms go?

A. Into the soil, where they stay as part of the dirt

B. Into the air as carbon dioxide, released by decomposers' cellular respiration

C. They were destroyed as the leaf rotted away

D. Into the roots of the oak tree, which pulled them back up

Nitrogen: an ocean of it in the air, and almost none usable

- About 78 percent of the air is nitrogen gas, two atoms locked together by a very strong bond.
- Every protein and every strand of DNA needs nitrogen, but almost no living thing can use the gas.
- Fixation breaks the lock. Bacteria in soil and in the roots of beans and peanuts do most of it.
- Lightning fixes a little, making nitrogen oxides that reach the ground in rain as nitrate.
- Fertilizer factories fix nitrogen too, on a huge scale, using natural gas for energy.



The nitrogen cycle as a reservoir map

Model: Where a nitrogen atom can be, and who moves it

Ammonium in soil and water → (nitrifiers)
Nitrate in soil and water → (root uptake)
Producers (proteins, DNA) → (eating)
Consumers (proteins, DNA) → (death)
Dead remains and wastes → (soil bacteria)
Nitrogen gas in the air → (fixation)
(back to the start)

Start at nitrogen gas (upper left) and follow the arrows clockwise. Bacteria run four of these arrows: nitrogen-fixing bacteria make ammonium from the gas, nitrifying bacteria turn ammonium into nitrate, decomposers release ammonium from remains and wastes, and denitrifying bacteria turn nitrate back into nitrogen gas, closing the loop. Roots absorb ammonium as well as nitrate; consumers also shed nitrogen in wastes. Lightning and factories also fix nitrogen; fertilizer adds it straight to the soil.

VOCABULARY IN CONTEXT

Three jobs that bacteria do for everyone

- **nitrogen fixation:** Turning nitrogen gas into usable nitrogen compounds such as ammonia. Bacteria do most natural fixing; lightning and factories also fix nitrogen. *Bacteria in the root nodules of a bean plant fix enough nitrogen to leave the soil richer after harvest.*
- **nitrification:** Bacteria in soil and water changing ammonium into nitrate, a form that dissolves easily and that roots absorb readily. *After a farmer spreads ammonium fertilizer, nitrifying bacteria convert much of it to nitrate within weeks.*
- **denitrification:** Bacteria in low-oxygen soil or mud changing nitrate back into nitrogen gas, which returns to the air. *In a soggy wetland, denitrifying bacteria remove nitrate from the water before it reaches the river.*





CHECK FOR UNDERSTANDING

Quick check: the nitrogen in your muscles

You eat a handful of peanuts. Which statement correctly describes how your body gets nitrogen from them to build your own proteins?

A. Your cells absorb nitrates stored in the peanuts and turn them into protein

B. Your lungs take nitrogen from the air you breathe while you chew

C. You digest the peanut proteins into amino acids and rebuild them into your own proteins

D. Bacteria in your stomach fix nitrogen gas from swallowed air

MODEL

The pond explained: a nutrient flood, then an oxygen famine

Model: From fertilizer bag to dead fish

Fertilizer on the field (fixed nitrogen, phosphorus) → (rain) Storm runoff carries nitrate downhill → (nutrients in) Pond algae take up nutrients and bloom → (fast growth) Bloom dies; decomposers feed on it → (die-off) Decomposers' respiration uses up dissolved oxygen → (oxygen out) Fish suffocate, worst before dawn

Nothing was created: the atoms in the scum came from the fertilizer, the air and the water. Runoff carries phosphate as well as nitrate. The harm comes from one flow running far faster than usual.





REAL-WORLD CONNECTION

California connection: nitrate under the Central Valley

In the Tulare Lake Basin and the Salinas Valley, decades of fertilizer and dairy manure have let nitrate seep down into groundwater. A 2012 UC Davis study for the State Water Board found that roughly a quarter of a million people there rely on wells at risk of nitrate above the drinking-water limit, with farms the main source. The nitrogen cycle does not stop at the pond; it reaches the kitchen tap.

People and the carbon cycle: a fast arrow added to a slow one

- Burial of remains that become fossil fuels takes millions of years; burning them takes seconds.
- Since the 1800s people have moved fossil carbon into the air far faster than nature buries it.
- Carbon dioxide in the air traps heat, so the extra carbon is warming the climate.
- One partial fix: reforestation. Growing trees pull carbon from the air into wood through photosynthesis.
- Engineers choose sites by criteria (most carbon, kept longest) within constraints (cost, land, roads, people).



Task: choose the reforestation site



Site	Carbon captured (tons per hectare per year)	Cost per hectare	People living on the land	Road access	Wildfire risk
A: warm, wet river valley	6	\$900	a village farms part of it	good	low
B: cool mountain slope	2	\$400 plus \$300 to build a road	none	none yet	low
C: edge of dry grassland	3	\$500	none	good	high
D: abandoned farmland, mild and rainy	5	\$600	none	good	moderate

Simulated data for practice.

A fund will plant trees on one site. Criteria: capture the most carbon over 30 years and keep it stored. Constraints: at most \$600 per hectare, nobody displaced, reachable by road. Score the sites and choose.



THINK, PAIR, SHARE

Discuss: is planting trees enough?

- For: growing trees really do move carbon from the air into wood.
- Against: the fossil carbon was stored for millions of years; a forest stores it only while it stands.
- Against: a forest stops absorbing much once it is mature; the burning does not stop.
- What would change your answer?

A company says it will keep burning fossil fuels and plant a forest to balance it. Using the carbon-cycle map, argue for and against. What would the forest have to do, and for how long, to truly balance the burning?

MISCONCEPTION CHECK

True or false? Fire destroys matter

"When a log burns in a campfire, most of its matter is destroyed and turned into heat and light, which is why only a small pile of ash is left."

True or false? Explain your reasoning.





PUTTING IT TOGETHER

Putting it together

- Earth is nearly closed for matter and open for energy, so the same atoms cycle on solar power.
- Every cycle is a map of reservoirs joined by processes; atoms persist while molecules get rebuilt.
- Carbon enters life by photosynthesis and leaves by cellular respiration or combustion.
- Nitrogen is locked in the air until bacteria, lightning or factories fix it; bacteria run the rest.
- People change the cycles by speeding one arrow: fossil-fuel burning, or fertilizer washed into a pond.
- Good solutions are judged against criteria and constraints, with storage and side effects included.

EXIT TICKET

Exit ticket

- Finish the sentence: Earth is closed to ___ but open to ___, and the exception for the first is ___.
- Trace a carbon atom from the air into your body and back out, naming the two processes.
- Why can a cow not get nitrogen from the air it breathes? Who fixes the nitrogen it finally eats?
- The pond turned green after the rain. Where did the nutrients come from, and what process killed the fish?

