



ANGELA'S WAND · BRING SCIENCE ALIVE! 7TH GRADE INTEGRATED

Chapter 10: Energy in Earth's Systems

Chapter 10 of 29 · Earth's Systems

Lesson 10: How does energy from the Sun and from deep inside Earth set rock, water, air and life in motion?

PHENOMENON

A cold draft from a window that is shut

A cold morning. The heater is on the far wall. The window on the opposite wall is closed and locked, yet the students next to it feel a cold draft sliding down the glass and across their ankles. A smoke stick held at the sill shows the smoke drifting down the window, along the floor to the heater, up the warm wall and back across the ceiling. No fan. No open window. The air is circulating in a silent loop.

- Notice: which way does the smoke move at the window, the floor, the heater, the ceiling?
- Wonder: with no fan, what is pushing the air around the room?
- Predict: what happens to the loop if the heater is switched off?





Learning targets

What you will be able to do

- Name Earth's four systems and sort real things into them, including things in two at once.
- Explain how heating changes density and how gravity turns that into a convection cell.
- Tell conduction, convection and radiation apart in real situations.
- Trace where each system gets its energy and follow energy and matter across system borders.
- Explain why matter cycles in the biosphere but energy flows through and leaves as heat.
- Use data from a physical model, like Biosphere 2, to decide what the next version must fix.

One planet, four overlapping systems



Geosphere: all the rock and metal, from the surface to the center.



Hydrosphere: all the water, as liquid, ice and invisible vapor.



Atmosphere: the layer of gases, mostly nitrogen and oxygen, thinning with height.



Biosphere: every living thing plus every place where life can survive.

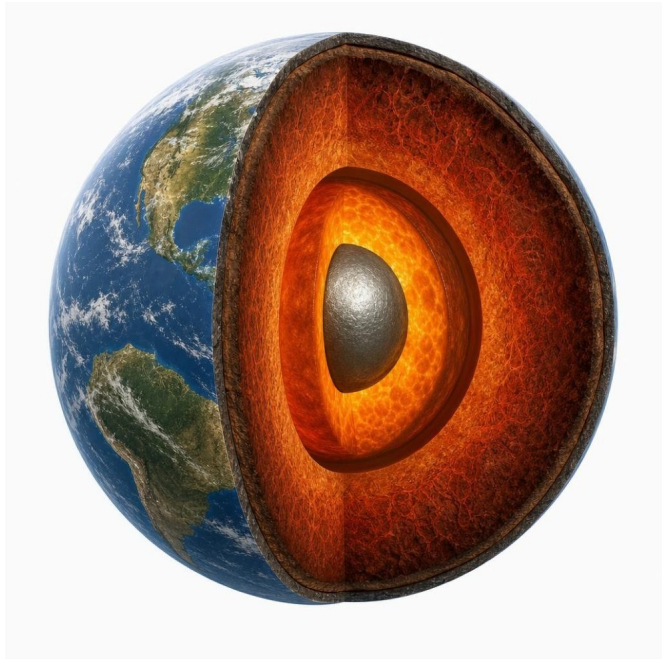


The borders overlap: water vapor is hydrosphere and atmosphere; a fish is biosphere in the hydrosphere.

Inside the geosphere: three layers, three densities

MODEL

Model: From the surface to the center (not to scale)



Top to bottom: Crust: cool, brittle rock; about 35 km under continents, about 7 km under oceans; least dense /

Mantle: about 2,865 km of hot, solid rock that creeps a few centimeters per year /

Outer core: liquid iron and nickel metal /

Inner core: solid iron and nickel metal; the core is the densest and hottest layer

Each layer is denser than the one above it. The core is metal, not rock, and its heat is left over from Earth's formation plus radioactive decay.



VOCABULARY IN CONTEXT

The three layers

- **crust:** The outermost layer: a cool, brittle shell of rock, thin next to the layers below it and the least dense. *A deep mine three kilometers down is still inside the crust, and the rock there is already hot to the touch.*
- **mantle:** The thick layer of hot rock between crust and core; solid, but it creeps over millions of years. *Mantle rock rising under the middle of the Atlantic moves about as fast as your fingernails grow.*
- **core:** Earth's center, mostly iron and nickel metal; liquid outside, solid inside; densest and hottest. *The outer core's flowing metal is what gives Earth its magnetic field, which a compass needle follows.*

Three ways energy gets from here to there



Conduction: particle to particle through things that touch; the material itself stays put.

Convection: moving matter carries the energy along; needs a fluid (or very slowly creeping rock) and gravity.

Radiation: energy travels as light, including infrared; needs no matter, so it crosses space.

Energy always moves from the warmer place to the cooler place in all three.

VOCABULARY IN CONTEXT

Say it like a scientist

- **conduction:** Energy passing between particles that touch, from warmer to cooler, without the material moving. *Rock at the bottom of a mine is warmer than rock at the top because heat conducts slowly up through the crust.*
- **convection:** Energy carried by moving matter when warmer, less dense material is pushed up as cooler, denser material sinks. *A pot of soup heated from below turns over in loops you can see in the floating bits.*
- **radiation:** Energy traveling as light, including invisible infrared light; it needs no matter to carry it. *The Sun's light crosses 150 million kilometers of near-empty space to warm the ocean surface.*



CHECK FOR UNDERSTANDING

Quick check: which transfer is this?

You hold a mug of hot cocoa. Your hands warm up. Steam curls upward from the surface. Across the table, your friend feels the mug's warmth on their face. Match each to conduction, convection or radiation.

- A. Your hands warm up.
- B. Steam and warm air curl upward above the mug.
- C. Your friend feels warmth from across the table.



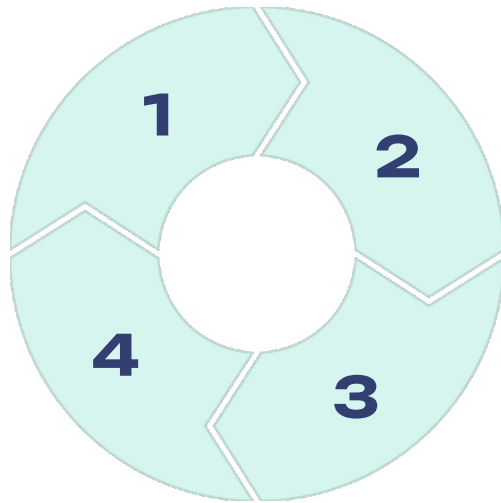
MODEL

Anatomy of a convection cell

Model: One loop, four steps, driven by a warm bottom and a cool top

Material at the bottom is warmed: particles spread out, density drops → (rises)

The now-denser material sinks, replacing what is being warmed below → (returns to the heat source) (back to the start)



Cooler, denser material beside it sinks under gravity and pushes the warm material up → (spreads across the top)

At the top the material loses energy to its surroundings: it cools and its density rises → (sinks)

The loop runs as long as the bottom stays warmer than the top. Energy rides along with the moving matter.





Density, gravity and a solid that flows

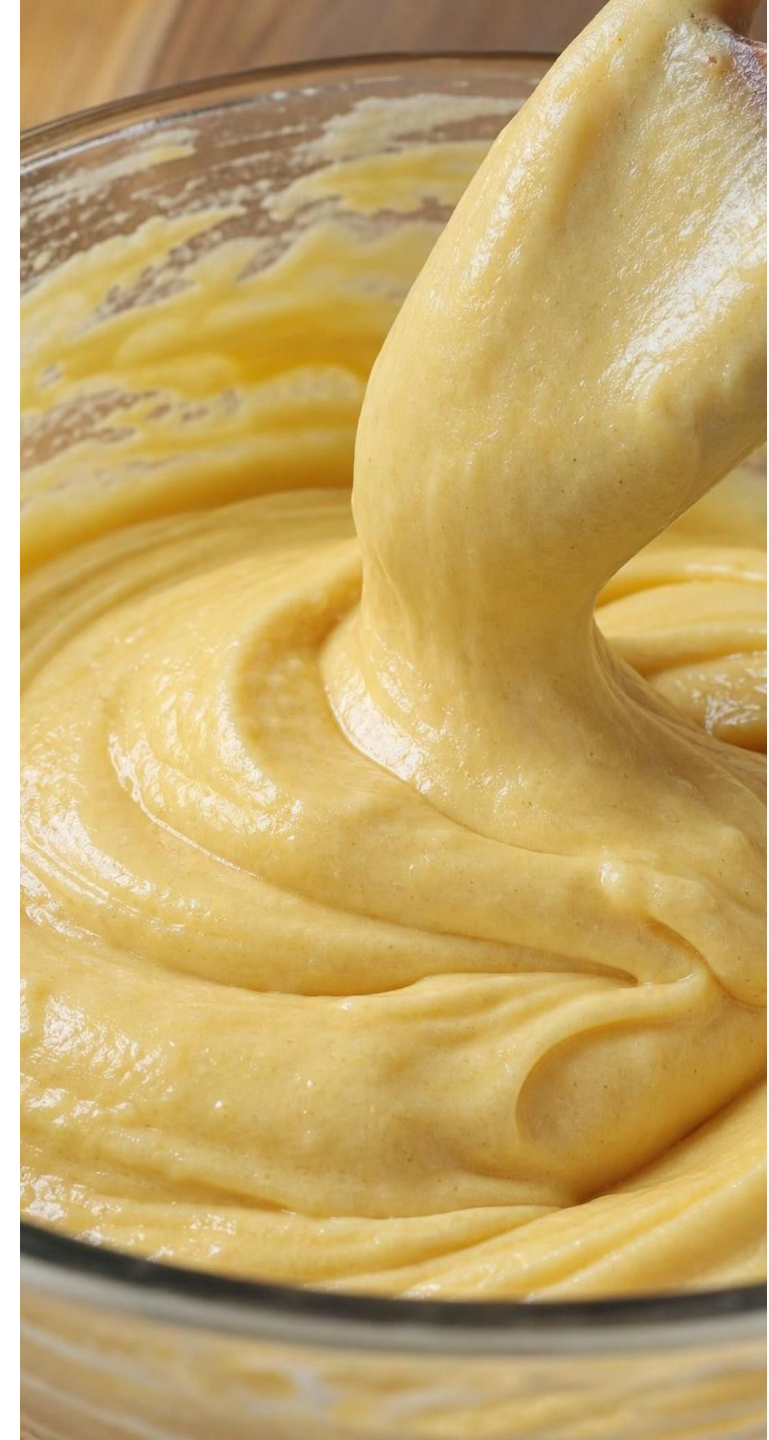
- Warming spreads particles out: same mass, more volume, lower density.
- Gravity pulls harder on the denser material, so it sinks and shoves the less dense material up.
- Mantle rock is solid, yet over millions of years it creeps a few centimeters a year, like very stiff putty.
- Heat from the core keeps the bottom of the mantle warmer than the top, so the slow loop never stops.
- Where the rising rock nears the surface, some of it partly melts into magma and can erupt.

THINK, PAIR, SHARE

Discuss: is the mantle like cake batter?

The textbook says the mantle flows like cake batter. In what ways is that comparison useful, and in what ways could it mislead you?

- Useful: both move slowly and in loops when heated from below.
- Useful: both are thick, so the motion is smooth rather than splashy.
- Misleading: batter is a liquid; the mantle is solid rock.
- Misleading: batter turns over in minutes; the mantle takes a hundred million years.



CHECK FOR UNDERSTANDING

Quick check: what starts the loop?

A tank of room-temperature water sits still. Which single change will start a convection loop?

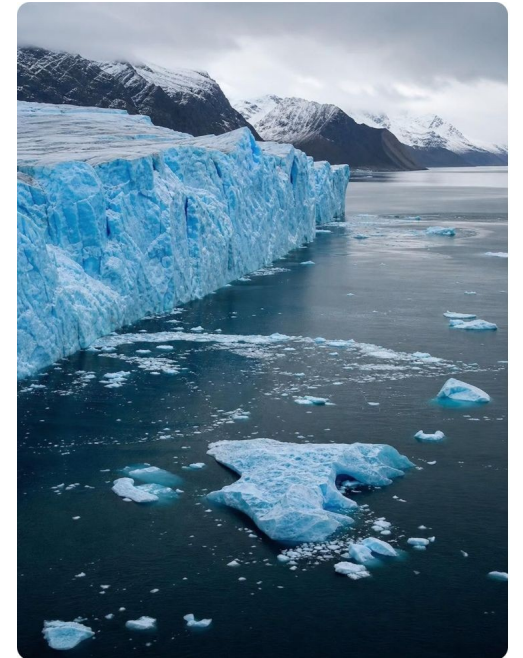
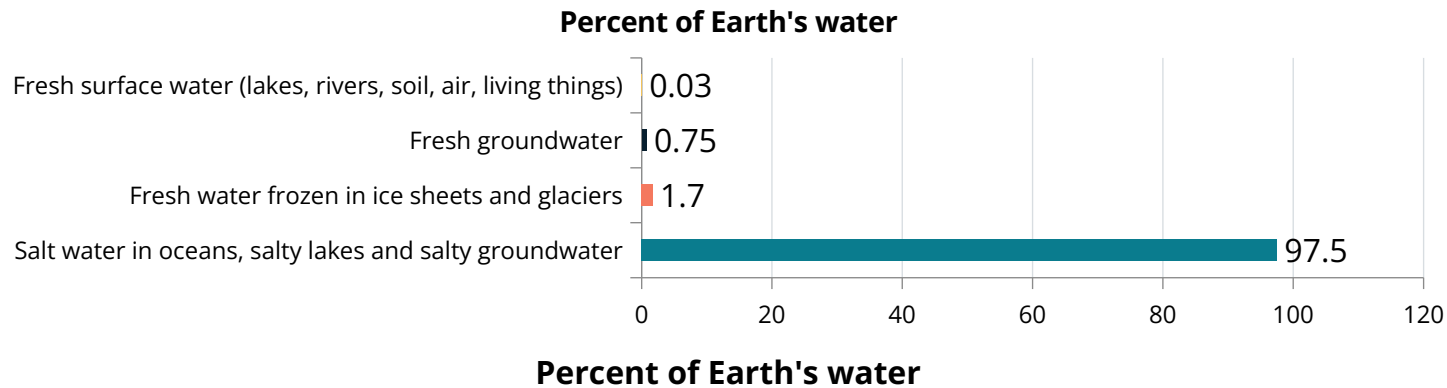
- A. Adding food coloring to the bottom
- B. Warming the water at the bottom while the top stays cool
- C. Warming the whole tank evenly to 40 °C
- D. Warming the water at the top while the bottom stays cool



MODEL

The hydrosphere: where Earth's water is

Model: Share of all water on Earth (rounded, USGS)



About 97.5% of Earth's water is salty. Of the small fresh share, most is ice, next most is underground, and only a sliver is in lakes and rivers.

The ocean's slow loop

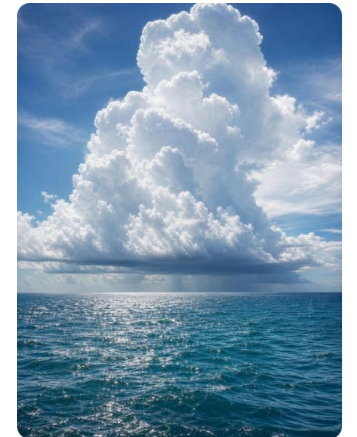
- Sunlight is strongest near the equator, so the ocean surface is warmest there and stays on top.
- Near the poles the surface loses energy to cold air, and sea ice forming leaves salt behind.
- Cold and salty means dense: that water sinks and creeps along the sea floor toward the equator.
- Winds drag the surface water along and help pull deep water back up.
- One trip around the whole loop takes roughly a thousand years.



Same loop, three systems

Mantle, ocean, air: the same four-step loop runs in all three, with different energy sources, speeds and materials.

System	What warms the bottom	What cools the top	What moves	Typical speed
Mantle	Heat from the core (interior)	Cool crust and surface	Solid rock, creeping	Centimeters per year
Ocean	Sunlight on the tropical surface	Cold polar air, sea ice forming	Seawater	Centimeters per second in deep flow
Air	Sun-warmed ground and sea	Radiation to space from high, cold air	Air with water vapor	Meters per second



REAL-WORLD CONNECTION

California connection: steam from the ground at The Geysers

In the hills of Sonoma and Lake Counties, about 120 km north of San Francisco, hot rock a few kilometers down turns groundwater into steam. The Geysers geothermal field pipes that steam to turbines and generates roughly 700 megawatts, the largest geothermal complex in the world. Because the steam was running low, Santa Rosa now pumps treated wastewater back into the rock to keep the cycle going.

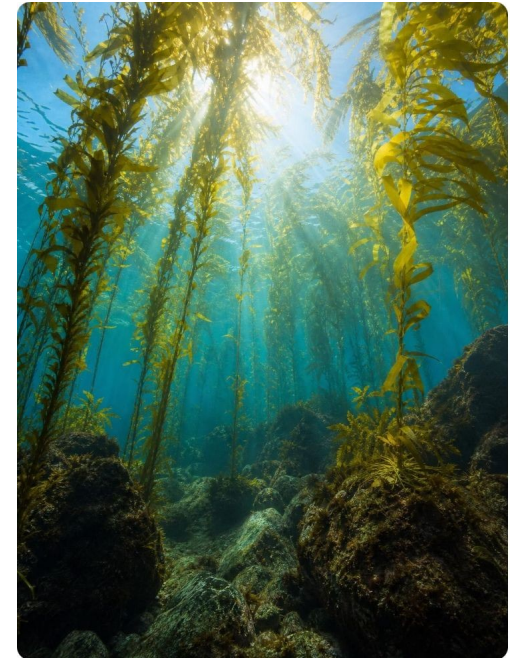


CHECK FOR UNDERSTANDING

Quick check: Sun or interior?

For each process, name the main energy source: the Sun or Earth's hot interior.

- A. Mantle rock slowly rising under the middle of the Atlantic Ocean
- B. A thunderstorm building on a hot afternoon
- C. Cold, salty water sinking near Antarctica
- D. Steam rising from the ground at The Geysers
- E. A kelp forest growing off Monterey



THINK, PAIR, SHARE

Discuss: a candle on the space station

Astronauts on the International Space Station are in constant free fall, so nothing there sinks or floats. Predict what a candle flame looks like on the station, and what that tells you about convection on Earth.



MODEL

The biosphere: energy flows through, matter goes around

Model: Following the Sun's energy through living things

1

Sunlight (radiation) →
(captured)

2

Producers capture it and
store it in food → (eaten)

3

Consumers eat and use
it → (broken down)

4

Decomposers break
down remains → (lost as
heat)

5

Heat leaves at every step
and radiates to space

Matter (carbon, nitrogen, water) loops from decomposers back to producers. Energy does not loop; it enters as sunlight and leaves as heat.



Crossing the borders between systems

Model

Model: Energy and matter moving between Earth's four systems

Center: Earth's systems: two energy inputs, one energy exit, matter looping

Sun to hydrosphere and geosphere: Radiation warms the ocean surface and the ground; the surface then warms the air.

Interior to geosphere: Heat from the core drives slow mantle convection; rising rock partly melts and erupts as lava and ash.

Hydrosphere to atmosphere: Water evaporates into warm rising air; vapor condenses into clouds; rain and snow fall under gravity.

Atmosphere to biosphere: Producers take in carbon dioxide; every organism breathes gases back out.

Biosphere to geosphere: Shells and dead organisms settle into sediment; roots break rock into soil.

Earth to space: The only exit: infrared radiation from the surface and the air, balancing the sunlight that comes in.

Matter stays on Earth and loops; energy comes in from the Sun and the interior and leaves as infrared light.



Task: what the oxygen data told the Biosphere 2 team

Apply it

Simulated data for practice.

Biosphere 2 was sealed with eight people inside in September 1991. Use the oxygen readings below to decide when the model started to fail, propose a cause, and plan the next test.

Months since sealing	Oxygen in the air (%)	Crew notes
0	20.9	Sealed; plants and animals in place
4	19.5	Winter: short days, less sunlight
8	18.2	Soil kept moist for crops
12	16.9	Crew tired on stairs
16	14.5	Crew short of breath; medical review
17	19.0	Oxygen pumped in from outside





Biosphere 2: a model you can live inside

- A conceptual model is a diagram or equation; a physical model is a built, testable copy at smaller scale.
- Biosphere 2 in Oracle, Arizona, was a glass-sealed physical model: rainforest, ocean, desert, farm.
- Closed to matter, open to energy: sunlight came in through the glass and heat went out.
- Its data exposed a problem the designers had not predicted, and the next version changed.
- Today the University of Arizona runs it as a research site for climate and ecosystem experiments.

MISCONCEPTION CHECK

True or false? Volcanoes prove the mantle is liquid

"Lava is liquid rock that comes from the mantle, so the mantle must be a sea of liquid magma with the crust floating on top."

True or false? Explain your reasoning.

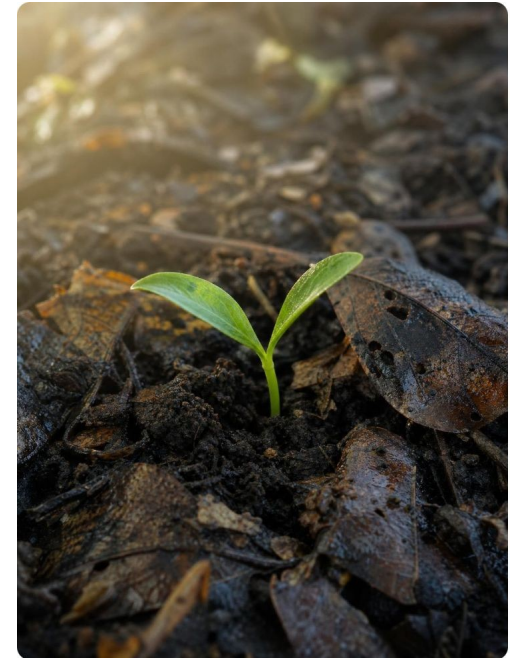


CHECK FOR UNDERSTANDING

Quick check: fix the arrow

A diagram shows an arrow from decomposers back to producers labeled 'energy and matter.' What should the label say, and why?

- A. Energy only; decomposers give plants the energy they need
- B. Matter only; energy leaves organisms as heat and plants get new energy from the Sun
- C. Energy and matter; both are recycled in a food chain
- D. Nothing; decomposers do not connect to producers



Putting it together

Putting it together

- Earth has four overlapping systems: rock and metal, water, gases, and life plus where it lives.
- Two energy inputs, the Sun and the hot interior; one exit, infrared radiation to space.
- Heating lowers density; gravity sinks the denser material; the result is a convection cell.
- The same loop turns the solid mantle, the ocean and the air at wildly different speeds.
- Matter cycles; energy flows through and leaves as heat.
- A physical model earns trust by being tested, and its data decide what to change next.





Exit ticket

Exit ticket

- Explain the window draft in two sentences that use the words density and gravity.
- Name the main energy source for mantle convection and for ocean convection.
- A spoon handle gets hot in soup; sunlight warms a roof; soup turns over in the pot. Name each transfer.
- Why can energy not loop from decomposers back to plants the way carbon does?
- What did the Biosphere 2 oxygen data tell the designers to change?