



Chapter 18: The Water Cycle

The Water Cycle

Chapter 18 of 29 · Processes that Shape Earth

Lesson 18: What moves Earth's water, what changes its state, and why can it end up anywhere?

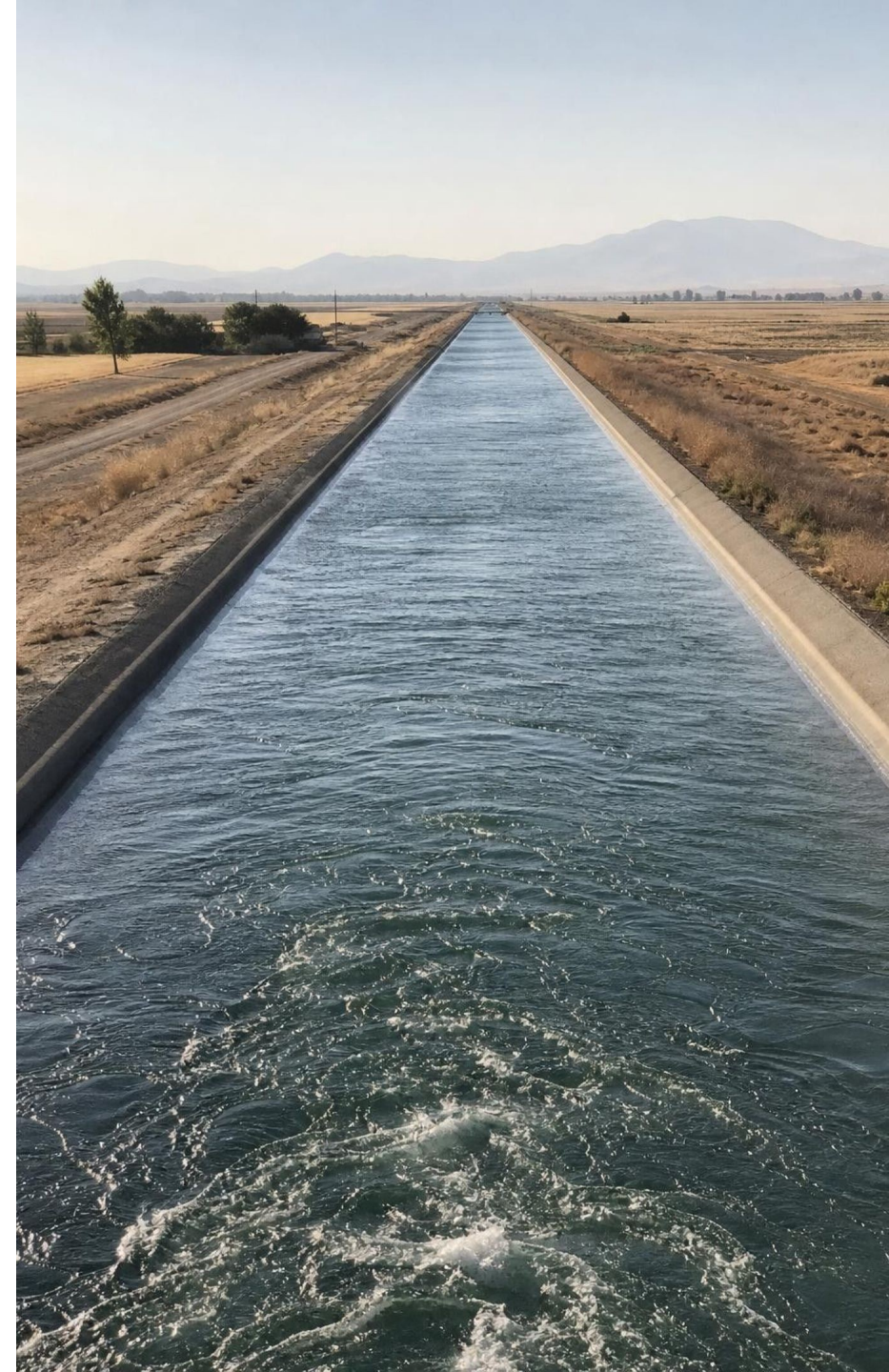
Angela's Wand · Bring Science Alive! 7th Grade Integrated

PHENOMENON

Snow in April, faucets in August

In early April the Sierra Nevada snowpack can be several meters deep. By late August the same slopes are bare rock and dry grass. Yet in August, hundreds of kilometers away, Central Valley canals still flow and town wells still pump water from hundreds of meters underground. The snow did not vanish. What moved it, and how did some of it end up deep in the ground?

- Notice: there is no drain at the bottom of the mountain. Where could several meters of snow go?
- Wonder: how does mountain snow reach a well hundreds of meters below a valley floor?
- Predict: what fraction of the melted snow ever reaches the ocean?





LEARNING TARGETS

What you will be able to do

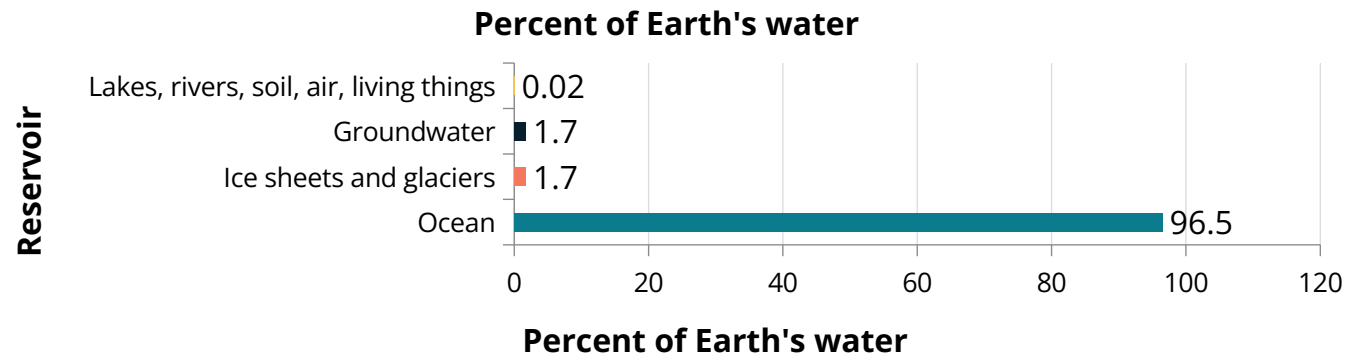
- 1 Describe the main water cycle processes and the change of state each one involves.
- 2 Explain which processes the Sun powers, which gravity powers, and what cooling does.
- 3 Use a particle model to explain evaporation below boiling and condensation on cooling.
- 4 Trace several different routes water can take and explain why there is no fixed order.
- 5 Use test data from a water-collecting design to decide what to change and improve it.

MODEL

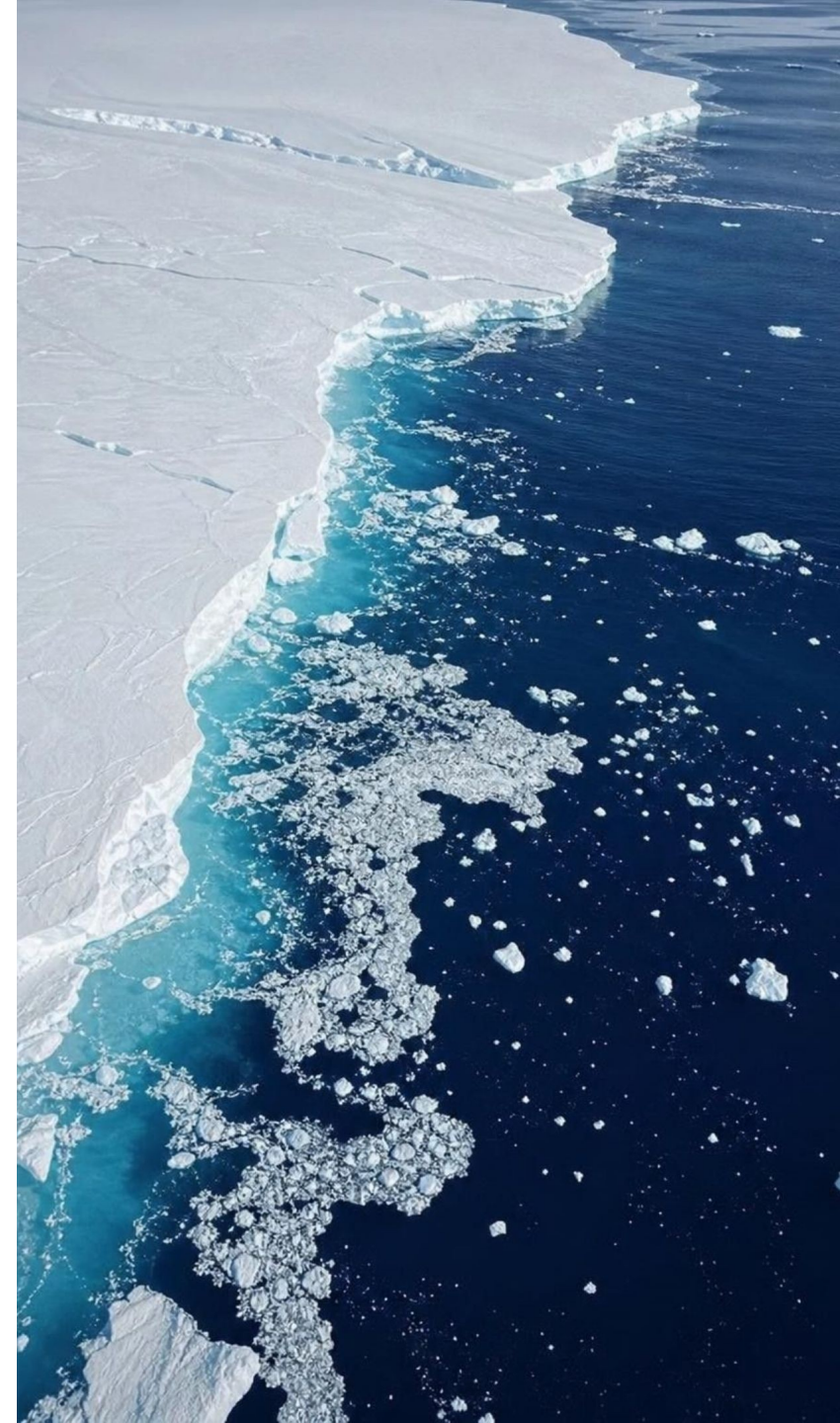
Where Earth's water is right now

- About 97 percent of Earth's water is salty ocean water.
- Most of the fresh water is locked in ice sheets and glaciers or stored underground.
- Rivers, lakes and the atmosphere together hold a tiny fraction, yet they are where most of the action is.

Model: Share of all Earth's water, by reservoir (approximate percent)



Approximate shares from U.S. Geological Survey estimates. Lakes, rivers, soil, the atmosphere and living things combined hold only about two hundredths of a percent; frozen ground holds about as much again.



The loop you have seen before, and what it hides

Model: The simplest water cycle model

Ocean and lakes → (evaporation (Sun))

Water vapor in the air → (condensation (cooling))

Clouds → (precipitation (gravity))

Rain and snow on land → (runoff and infiltration (gravity))

Rivers and groundwater → (flow back to the sea (gravity)) (back to the start)

A useful starting model. Real water skips steps, repeats steps and runs the loop in many directions at once.



Three words for the upward half

water vapor: Water as an invisible gas. Clouds and fog are not vapor; they are droplets or ice crystals you can see. *Humid summer air in Sacramento holds far more water vapor than a clear winter day in the desert, and both look the same.*

evaporation: Liquid water becoming vapor at the surface of the liquid, at any temperature, because the fastest surface molecules escape. *A wet swimsuit dries on a cool, breezy day without ever getting hot.*

transpiration: Water moving from roots to leaves, evaporating inside the leaf and leaving through tiny pores (stomata) as vapor. *A bag tied over a leafy branch in sunlight collects droplets within hours.*



MODEL

How a puddle dries without boiling

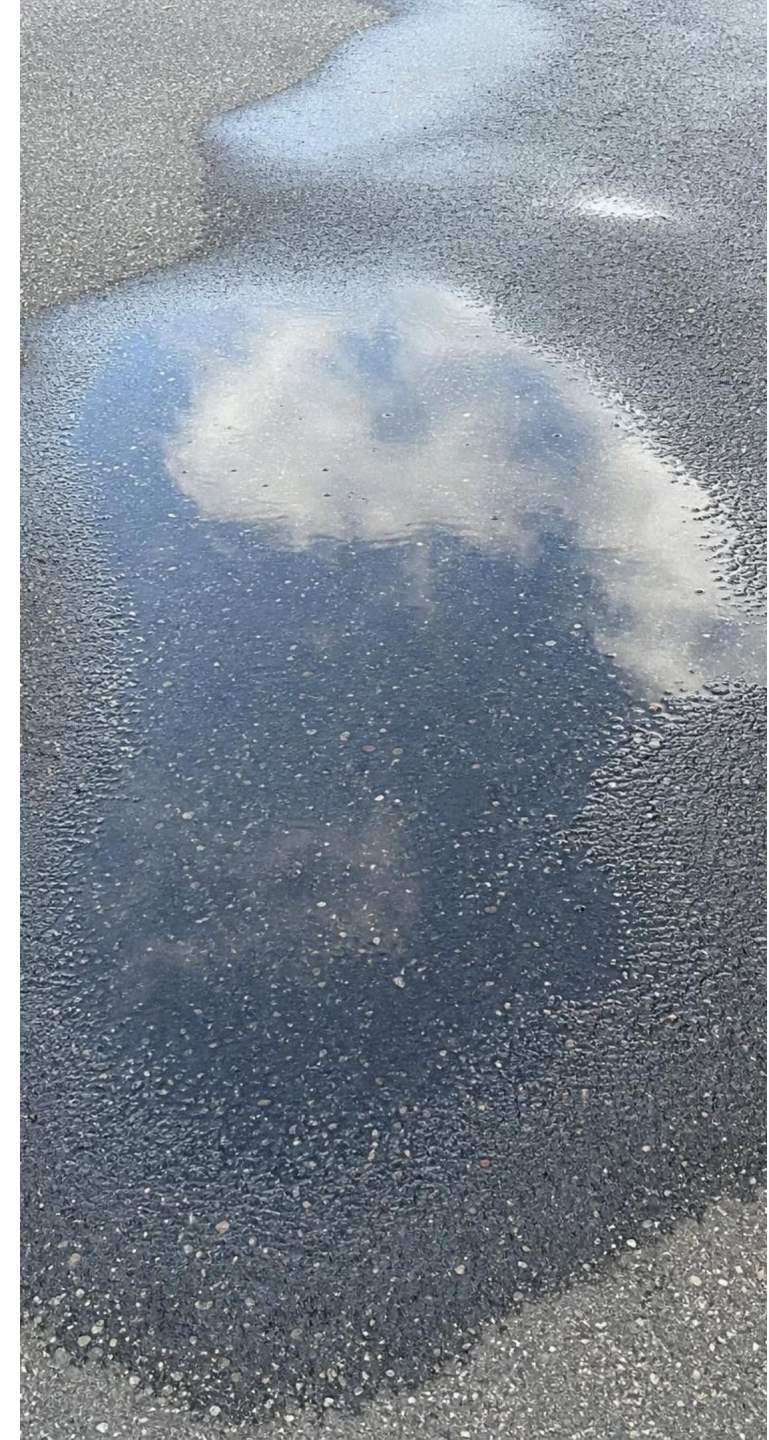
- Molecules in liquid water are close together and moving at many different speeds.
- Sunlight adds energy, so more molecules move fast enough to break free from the surface.
- Escaped molecules spread out as vapor; the liquid left behind is a little cooler.
- Warmer, windier or drier air speeds evaporation; boiling is not required.

Model: Water molecules at a puddle surface

Liquid water (surface): particles tightly spaced; Close together; the fastest ones at the top can escape.

Water vapor above: particles loosely spaced; Far apart, moving freely, invisible.

Evaporation happens only at the surface and at any temperature. Boiling is different: vapor bubbles form inside the liquid.



CHECK FOR UNDERSTANDING

Quick check: the shrinking puddle

A puddle on the blacktop is gone by lunchtime on a 22 °C day. Which statement best explains where the water went?

- A. It soaked into the asphalt and is still there.
- B. The fastest surface molecules escaped as invisible vapor, a few at a time, until none were left.
- C. The puddle heated to 100 °C and boiled away.
- D. The water turned into air.





Plants are part of the pump

- 1 Roots take in liquid water, which rises up the stem and into the leaves.
- 2 Inside the leaf, water evaporates from cell surfaces and leaves through stomata as vapor.
- 3 Stomata open and close, so a plant can slow its water loss on a hot, dry afternoon.
- 4 Evaporation cools the leaf, the same way sweat cools skin.
- 5 Roughly **nine tenths** of the air's water vapor comes from open water; most of the rest comes from plants.

Cooling: vapor turns back into liquid

- 1 **Rising air expands and cools;** cold surfaces cool the air that touches them.
- 2 **Cooler vapor molecules slow down, collide and stick together,** usually on a speck of dust, salt or smoke.
- 3 **Air can hold only so much vapor at a given temperature;** at that limit it is saturated and condensing begins.
- 4 **Condensation releases energy to the surroundings;** evaporation took that energy in.
- 5 **Clouds, dew and the wet outside of a cold can** are all condensation.



MODEL

A cold can on a warm day

Model: Where the droplets come from

Warm room air: Holds invisible water vapor, more on humid days.

Thin layer of air touching the can: Cooled by the metal to below the point where it can hold its vapor.

Droplets on the outside: Vapor molecules from the room slowed, stuck together and became liquid.

Inside the can: Sealed. Nothing passes through the metal; the inside liquid is not the source.

Test: An empty sealed cold can sweats too; a warm full can does not.

Condensation needs a surface cooler than the surrounding air's dew point, not a leak.





VOCABULARY IN CONTEXT

Three words for cooling and for ice

condensation: Water vapor becoming liquid water when air cools or becomes saturated. Energy is released. *Fog over the bay at dawn is condensation; it clears as the Sun warms the air and the droplets evaporate again.*

crystallization: Water becoming solid ice. Freezing is liquid to solid; deposition is vapor straight to ice, as in frost and many snowflakes. *Frost on a car roof on a clear night formed by deposition; the puddle beside it froze from liquid.*

sublimation: Ice becoming vapor directly, without melting. It takes in energy, usually from sunlight, and is fastest in dry, windy air. *A snowbank shrinks on a sunny, windy week even though the air never rises above 0 °C.*

CHECK FOR UNDERSTANDING

Quick check: the sweating water bottle

A sealed, cold bottle of water gets wet on the outside in a warm classroom. Where did that water come from?

- A. It leaked through tiny holes in the plastic.
- B. It came out of the air in the room, which held invisible water vapor that condensed on the cold surface.
- C. The bottle made new water from the cold.
- D. It came from the student's hands.





THINK, PAIR, SHARE

Discuss: what is a cloud made of?

A cloud is clearly made of water. Is it water vapor, liquid water, ice, or some mix? What evidence from your own experience supports your answer?

Gravity's half: rain, snow and the downhill journey

- Cloud droplets are tiny; rising air holds them up even though gravity pulls on them.
- Droplets collide and merge, or ice crystals grow, until they are heavy enough to fall.
- Falling drops meet air resistance; larger drops flatten underneath and very large ones break apart.
- On the ground, gravity keeps working: downhill as runoff, downward as infiltration.
- Melting snow joins the same two paths; some snow sublimates instead.



MODEL

Underground is not a cave: water in pores

Model: A cut through the ground beneath a valley

Top to bottom:

Soil: roots, air and some water in the spaces

Unsaturated zone: pores hold both air and water; water trickles down

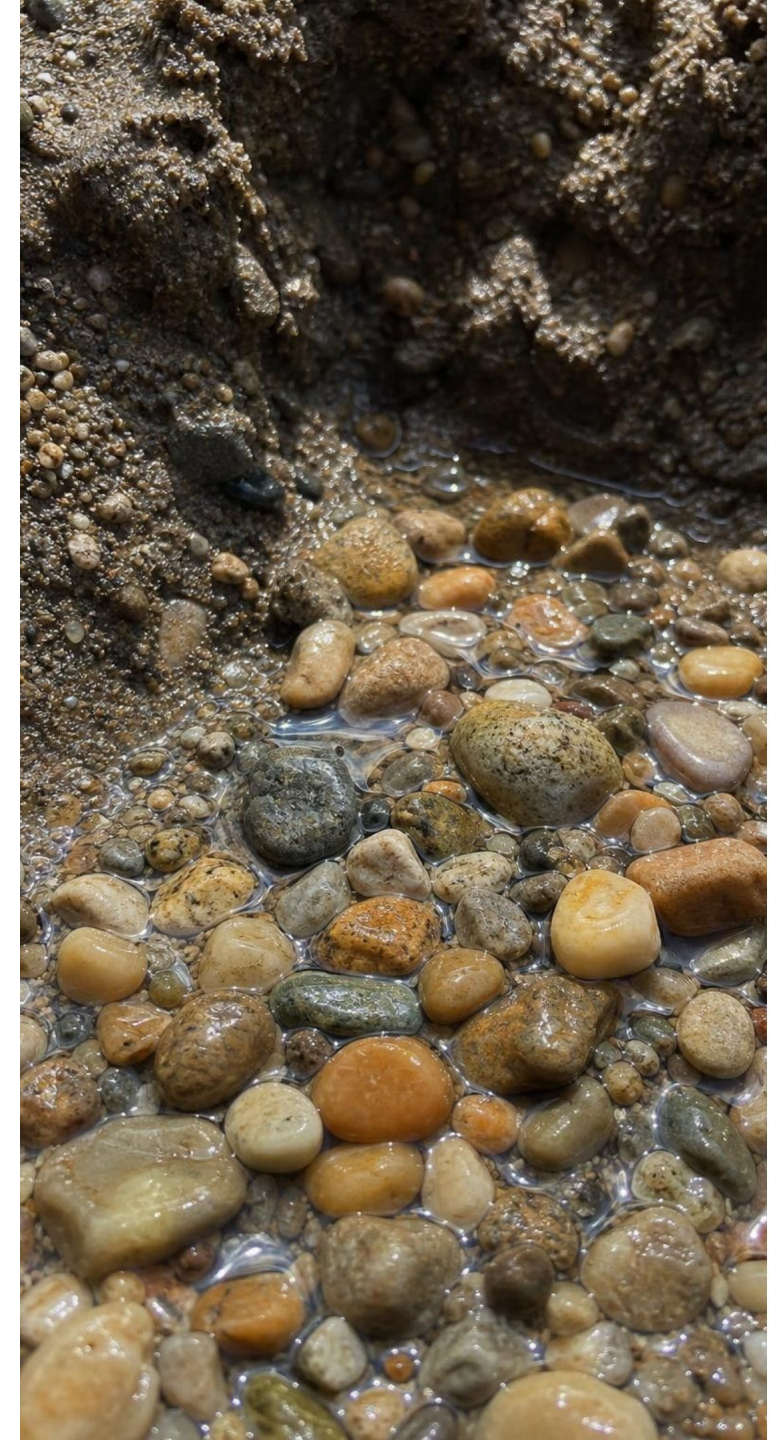
Water table: the top of the fully saturated zone

Aquifer: sand and gravel with every pore full of water; wells draw from here

Clay layer: tiny pores, water barely moves through it

Bedrock: few connected pores; little water flows

Groundwater fills the spaces between grains, like water in a sponge, and moves slowly sideways and downward under gravity.





REAL-WORLD CONNECTION

California's water: the whole cycle in one state

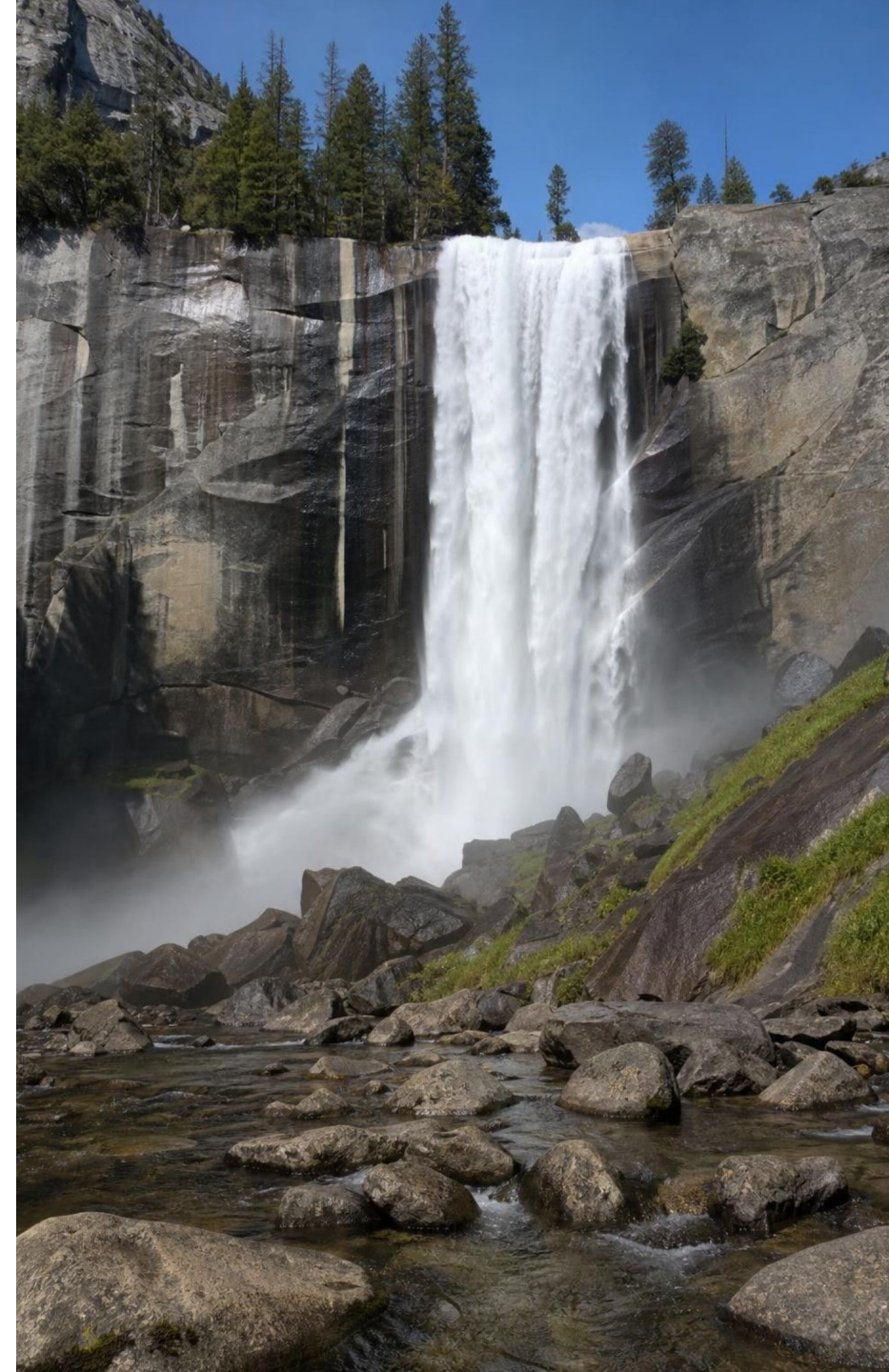
- Winter storms off the Pacific drop rain on the coast and snow on the Sierra Nevada.
- The snowpack is a natural reservoir; its spring melt feeds rivers, dams and canals all summer.
- Some melt infiltrates and joins the Central Valley aquifer system that farms and towns pump.
- Evaporation from the ocean, the Delta and irrigated fields sends water back up to start again.
- Pumping faster than infiltration refills the aquifer has sunk parts of the San Joaquin Valley by meters.

CHECK FOR UNDERSTANDING

Quick check: who is driving?

Which list contains only processes that gravity drives?

- A. Evaporation, transpiration, melting
- B. Precipitation, runoff, infiltration, groundwater flow
- C. Condensation, crystallization
- D. Runoff, evaporation, condensation



Energy accounting: where water gains it and where it gives it off

Model: Changes of state in the water cycle

Water takes energy in (from the Sun)

Water gives energy off (as it cools)

Evaporation: liquid to vapor

Condensation: vapor to liquid

Transpiration: liquid to vapor inside leaves

Freezing: liquid to ice

Melting: ice to liquid

Deposition: vapor straight to ice (frost)

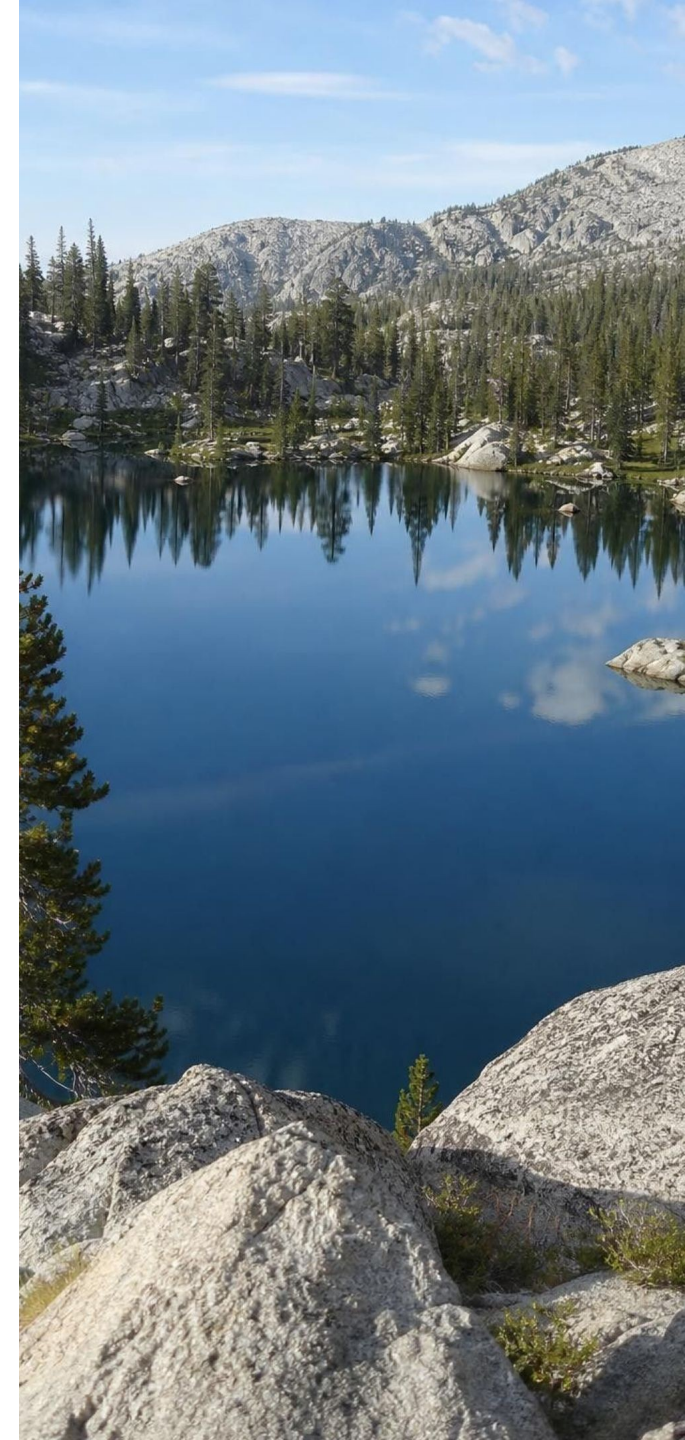
Every change of state is an energy transfer. The amount of water never changes; only its state and location do.

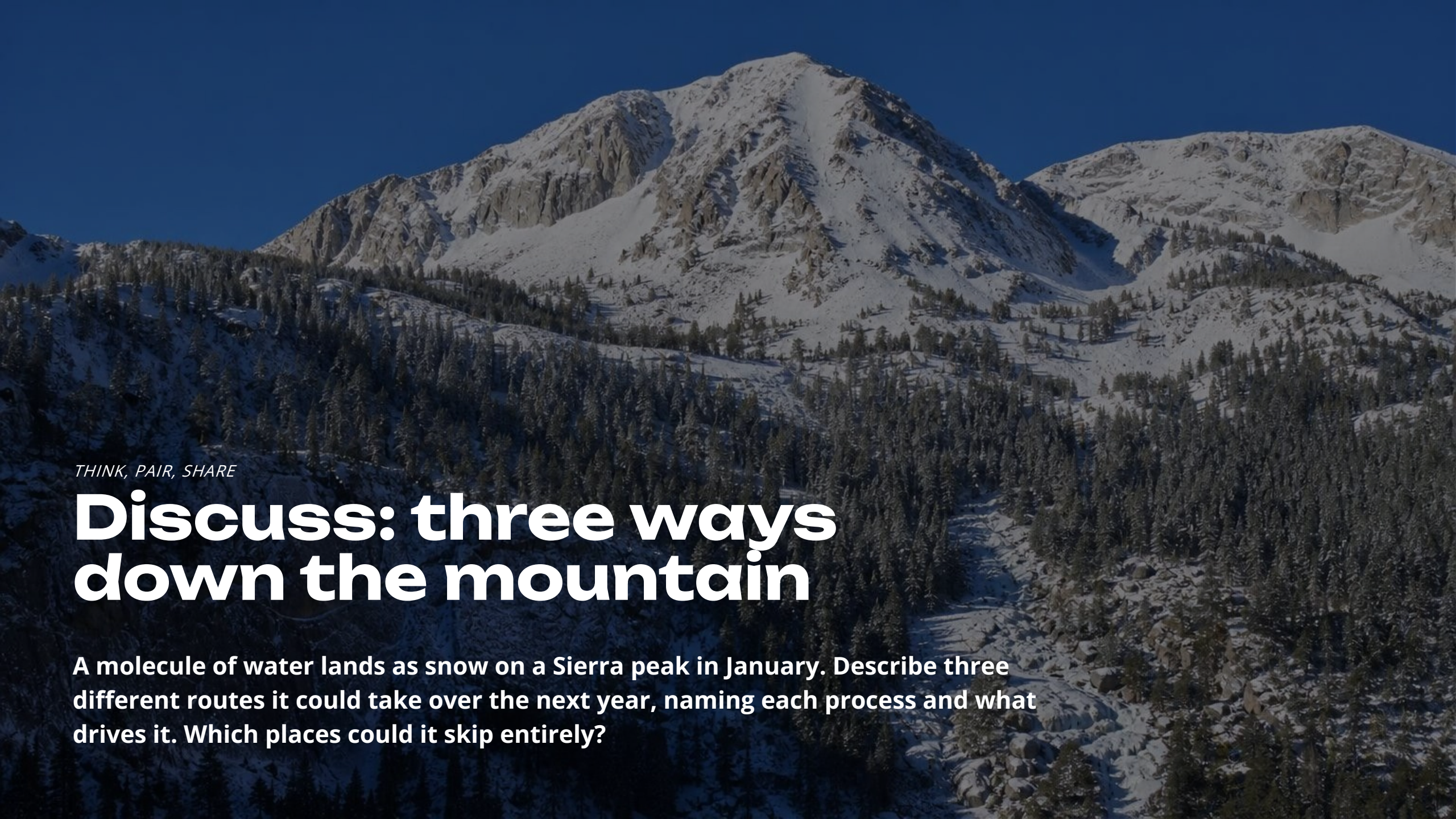


How long does water stay? It depends where it is

Some water races through the cycle; some barely moves. A molecule in the air usually falls back within about a week or two. A molecule in a river reaches the sea within months. In a deep aquifer or the deep ocean it can sit for centuries or longer.

Reservoir	Typical stay (approximate)	What moves it on
Atmosphere	about 9 days	condensation then precipitation
Rivers	weeks to months	flow to the sea; evaporation
Seasonal snowpack	months	melting; some sublimation
Lakes	years to centuries	outflow; evaporation; seepage
Groundwater	years to thousands of years	slow flow to springs, rivers, sea
Ocean	thousands of years	evaporation from the surface
Ice sheets	thousands of years or more	melting at the edges; sublimation





THINK, PAIR, SHARE

Discuss: three ways down the mountain

A molecule of water lands as snow on a Sierra peak in January. Describe three different routes it could take over the next year, naming each process and what drives it. Which places could it skip entirely?

Task: which solar still features are worth combining?

Simulated data for practice.

Five groups tested one change each to a basic solar still. Which features raised output, which lowered it, and what combined design would you build next?

Design	Change from the basic still	Fresh water collected in 24 h (mL)
A (basic)	Clear bowl, flat plastic-wrap cover, cup in the middle	6
B	Black paper liner under the salt water	11
C	Pebble on the cover so it sags to a point above the cup	14
D	Two layers of plastic wrap instead of one	4
E	Cover left loose with small gaps at the rim	2
F	Started with warm (40 °C) salt water	9



Fog catchers: a design that the water cycle makes possible

- Where moist air chilled over a cold ocean blows onto a dry coast, fog forms: a cloud touching the ground.
- Fog droplets are too small to fall as rain, but they stick to a fine mesh and merge.
- Once drops are heavy enough, gravity drains them down the net into a tank.
- Decades of tests on mesh size and material improved the nets; each test informed the next.

Model: Iterative testing

Define the problem and criteria → Build a version → Test and measure output → Analyze what the data say → Change one feature

The loop repeats until the design meets its criteria within its constraints.

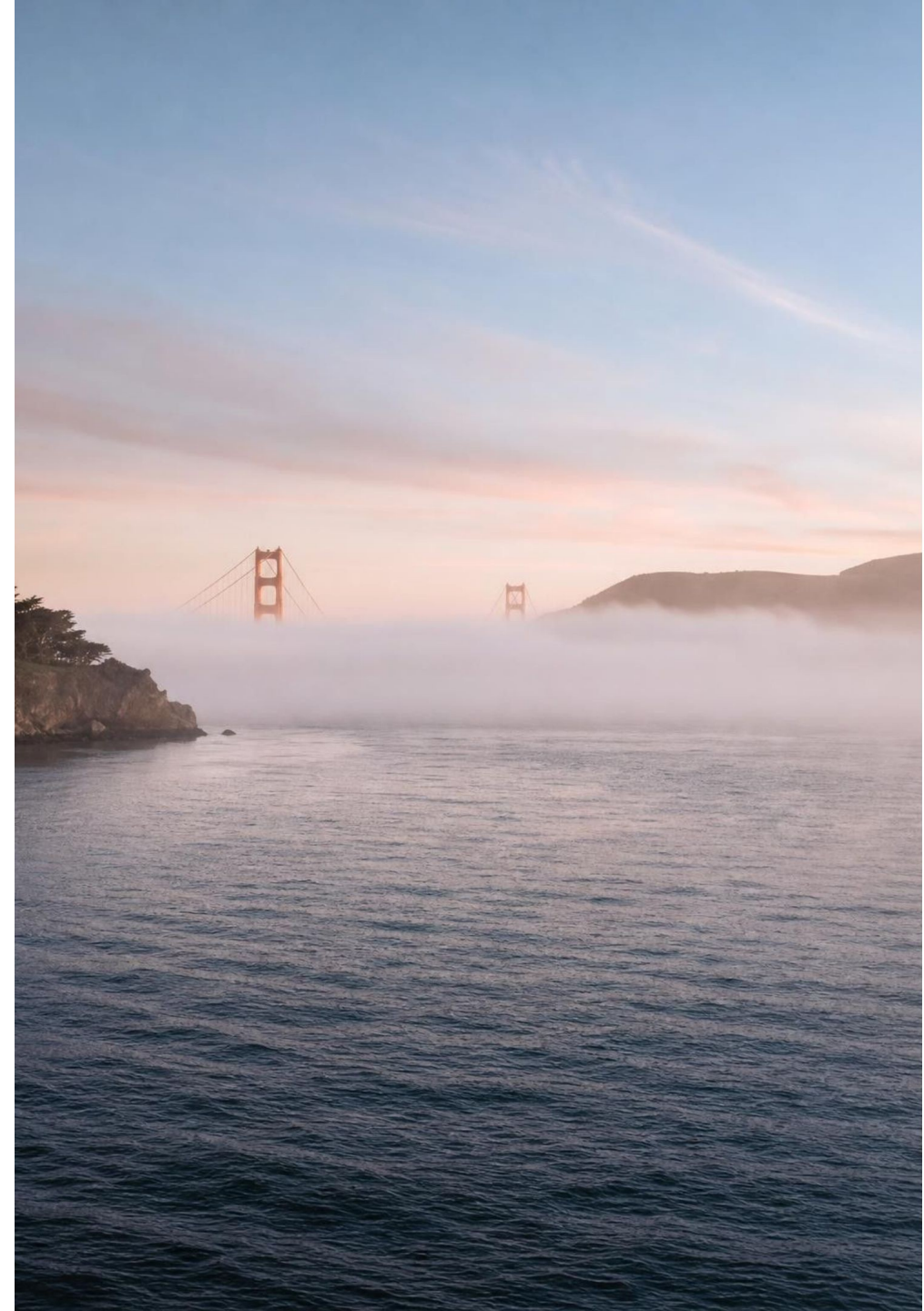


MISCONCEPTION CHECK

True or false? Evaporation needs boiling

"Water only turns into a gas when it boils, so a lake loses almost no water to the air unless the weather is very hot."

True or false? Explain your reasoning.





PUTTING IT TOGETHER

Putting it together

- Water cycles among ocean, air, land, ground and living things; its amount stays the same.
- The Sun supplies the energy for evaporation, transpiration, melting and sublimation.
- Cooling lets vapor condense into droplets or deposit as ice, releasing energy.
- Gravity brings water down as precipitation and moves it downhill and underground.
- There is no fixed order; water skips and repeats places and stays days to millennia.
- Engineers use the cycle on purpose: fog nets and solar stills, improved by iterative testing.

EXIT TICKET

Exit ticket

- Name one process the Sun powers, one gravity powers, and one that happens because water cools.
- A cold can sweats in a warm room. In one sentence, where did the water come from?
- Write a route for a water molecule from the ocean to a well that never passes through a river.
- Your solar still made 8 mL; after one change it made 13 mL. What should you do next, and why?

