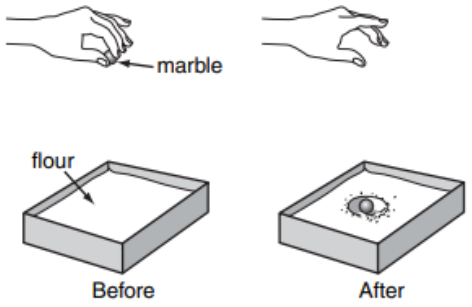
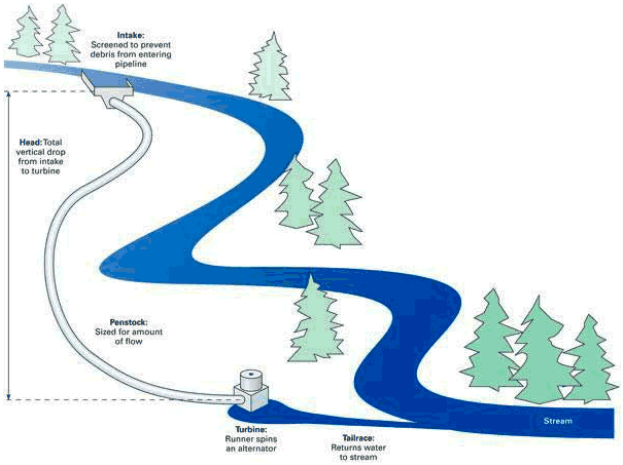
WARM UP

1. A student models an impact crater on the Moon by dropping a marble from a known height onto a pan of smooth flour. Before reaching any conclusions about the results of this simple experiment, the student repeats the activity several times so that
   a. differences produced by standard variability in conditions become clear.
   b. she can produce as large a crater as possible before measuring a diameter.
   c. her ability to simulate a meteor impact becomes more realistic with practice.
   d. she can illustrate a perfectly circular crater for her write-up of the experiment



Some hydroelectric systems generate electricity without building a large dam. Instead, they divert part of the water from a fast-moving river into a tunnel or pipe. These systems are usually built in areas with steep terrain, where water can move downhill over a short distance.



Water enters the diversion system upstream and travels through a tunnel or pipe to a turbine. As the water passes through the turbine, it helps produce electricity. Afterward, the water is returned to the river farther downstream. This creates a section of the river between the intake and return point where conditions may differ from other parts of the stream. (Source)

2. Use the model to make a claim about how the construction of the diversion tunnel would **decrease** the amount of erosion occurring along the banks of the stream.

_____

_____

_____

OBJECTIVE

SWBAT explain how water is transported from the ocean into Earth's interior at subduction zones and describe how this process affects magma formation. (HS-ESS2-1, HS-ESS2-3)
SWBAT analyze how water flux between Earth's interior and surface systems can create feedbacks that influence the water cycle and sea level over geologic time. (HS-ESS2-2)

Criteria For Success (CFS)

Students will receive a minimum score of 80% on the exit ticket

Feedbacks:

Feedback Mechanisms: A process in which a change in one part of a system causes changes in another part, which then affects the original change. Feedbacks can either amplify or reduce the initial change.

(+) Positive Feedback	(-) Negative Feedback
Amplifies or increases the original change.	Reduces or stabilizes the original change.
Weathering and Surface Area: As physical weathering breaks rocks into smaller pieces, the increased surface area allows chemical weathering to occur faster, which further breaks down rocks.	**Cloud Formation and Temperature:** As the surface warms, more water evaporates, forming clouds. Clouds reflect sunlight, which can cool the surface and counteract the warming.

Hint: When analyzing Earth systems, ask yourself: "Does this process make the original change bigger or smaller?"

Bigger → Positive feedback Smaller → Negative feedback

Feedback Type	Earth Science Example	Sphere(s) Involved
	Melting glaciers expose darker land or water surfaces, absorbing more heat, which increases melting.	☐ cryosphere ☐ atmosphere ☐ geosphere ☐ biosphere ☐ hydrosphere
	Rising temperatures from atmospheric CO_2 can lead to better growing conditions for plants. Increased photosynthesis absorbs more atmospheric CO_2.	☐ cryosphere ☐ atmosphere ☐ geosphere ☐ biosphere ☐ hydrosphere
	Weathering in warm climates removes CO_2 from the air. The climate cools, which reduces the rate of chemical weathering in that area.	☐ cryosphere ☐ atmosphere ☐ geosphere ☐ biosphere ☐ hydrosphere
	An earthquake triggers landslides, which destabilize slopes further, leading to more landslides during aftershocks.	☐ cryosphere ☐ atmosphere ☐ geosphere ☐ biosphere ☐ hydrosphere
	Increased solar output warms Earth, which increases evaporation and forms more clouds. Clouds reflect sunlight and reduce warming.	☐ cryosphere ☐ atmosphere ☐ geosphere ☐ biosphere ☐ hydrosphere

The Water Cycle

Clouds form from **water vapor** in the air. Water vapor comes mostly from **evaporation**, when water changes from a liquid to a gas. The Sun's energy (**insolation**) drives evaporation, which happens faster on warm, dry, or windy days. Most water vapor comes from the **oceans**, which cover about 70% of Earth's surface. Water also enters the air through **transpiration**, when plants release moisture from their leaves.

The warm, moist air rises and cools. When it reaches the **dew point**, water droplets form on dust particles. This process is called **condensation**, which creates clouds. If the droplets or ice crystals become heavy, they fall as **precipitation**, such as rain, snow, sleet, freezing rain, or hail. Once precipitation reaches Earth, it can soak into the ground (**infiltration**), **run off** along the surface, collect as ice in **glaciers**, or **evaporate** back into the air.

Reading Comprehension Questions:

1. What is the source of energy for the water cycle? _____
2. Describe the weather conditions that would result in a lot of evaporation: _____

   _____
3. Where does most of the water vapor in the atmosphere come from? _____

   Support your answer. _____

   _____
4. Other than evaporation, what other process **adds** water vapor to the atmosphere?

   _____ Describe this process. _____

   _____
5. Describe how clouds form. _____

   _____

   _____
6. When does precipitation begin to occur? _____

   _____

7. Name the five types of precipitation listed in the reading:

   _____, _____, _____,

   _____, and _____

8. What four things can happen to precipitation once it hits the ground?

   a. _____

   b. _____

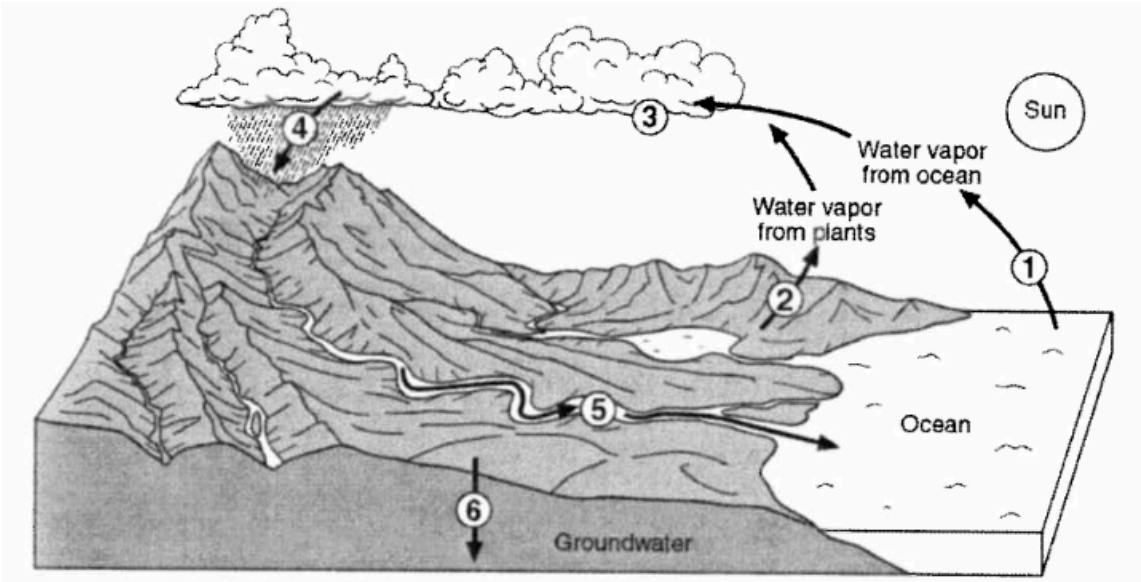
   c. _____

   d. _____

Matching:

____ 1.	Condensation	A. water soaking into the ground
____ 2.	Evaporation	B. change in phase from liquid water to water vapor (gas)
____ 3.	Infiltration	C. movement of water along Earth's surface
____ 4.	Precipitation	D. change in phase from water vapor (gas) to liquid water
____ 5.	Runoff	E. rain, sleet, and hail are examples
____ 6.	Transpiration	F. water vapor enters the atmosphere from the leaves of plants

Picture This: The diagram below shows a model of the water cycle. The arrows show the movement of water molecules through the water cycle. The circled numbers represent the processes that occur as the water molecules reach the different stages of the water cycle. Complete the table below by identifying the name of the water cycle process occurring at each number. Describe or give examples of each process. Step 1 has been completed for you as an example.



No.	Water Cycle Process	Description or Example
1	Evaporation	Liquid water from the ocean turns to water vapor in the air
2		
3		
4		
5		
6		

Infiltration and Runoff

For water to soak into the soil, the soil must have **porosity**, which is the amount of empty space (pores) between soil particles. **Permeability** describes how easily water can move through those spaces. The **permeability rate** depends on size, sorting, and how tightly packed the soil is.

When soil is full of water, it is **saturated**, meaning all the pores are filled. Soil that is frozen or made of solid rock is **impermeable**, and water flows off the surface as runoff. Steeper slopes and heavy rain also increase runoff, while plants help slow it down.

The **zone of aeration** is the upper soil layer where air and water fill the spaces between particles. The **zone of saturation** is below it, where all spaces are filled with water. The top of this layer is the **water table**, which rises after rain and falls during dry periods.

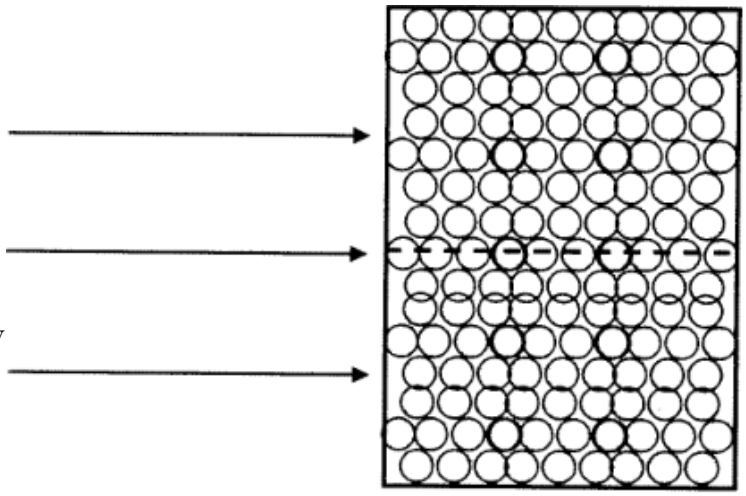
Capillarity is the upward movement of water from the water table through small soil pores, allowing plants to access water.

Matching:

_____ 1.	Permeability rate	A. the amount of air space within the soil
_____ 2.	Porosity	B. located at the top of the zone of saturation
_____ 3.	Capillarity	C. how fast water infiltrates into the soil
_____ 4.	Water table	D. the area within the soil that is not filled with water
_____ 5.	Zone of Aeration	E. when water is drawn upward through the soil
_____ 6.	Zone of Saturation	F. the area within the soil that is filled with water

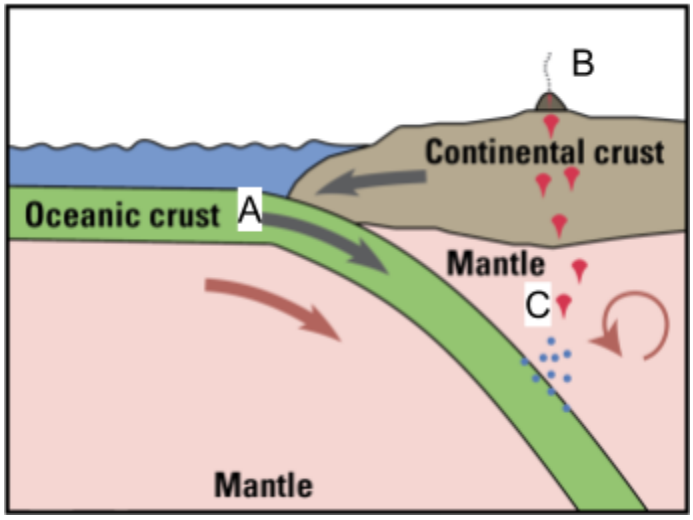
Picture This: The diagram below shows a cross-section of soil. The small circles represent soil particles. The dotted line illustrates how high the water level is within the soil.

- ☐ Label the lower half of the diagram the zone of saturation. Color it **blue**.
- ☐ Label the upper half of the diagram the zone of aeration. Do **not** color it.
- ☐ Label the water table (dashed line).
- ☐ Using red, draw one downward arrow through both zones to illustrate infiltration. Label the arrow infiltration.
- ☐ Using red, draw one upward arrow through both zones to illustrate capillary action. Label the arrow capillary action.



Water Flux: How Water Melts Rock Deep Underground

We usually think of melting rock by simply heating it up, like putting butter in a hot pan. However, deep underground in **subduction zones** (where one tectonic plate sinks beneath another), rocks melt for a different reason: chemistry.



When an oceanic tectonic plate sinks, it carries water with it. This water isn't just in pools on the surface; it is trapped inside the minerals of the rock itself (like water in a sponge). As the plate sinks deeper into the Earth, the immense heat and pressure squeeze this water out.

This super-heated water rises up into the **Mantle Wedge**—the section of the hot mantle trapped just above the sinking plate. Even though this mantle rock is already very hot, it is solid. However, when water mixes with this hot rock, it changes the rock's chemistry.

This process is called **Flux Melting**. Just as throwing salt on an icy sidewalk lowers the melting point of the ice (causing it to melt even when it is freezing outside), adding water to hot mantle rock lowers its melting temperature. The rock, which was solid before, suddenly finds itself hot enough to melt because its melting point has dropped. This creates magma, which rises to the surface to form volcanoes.

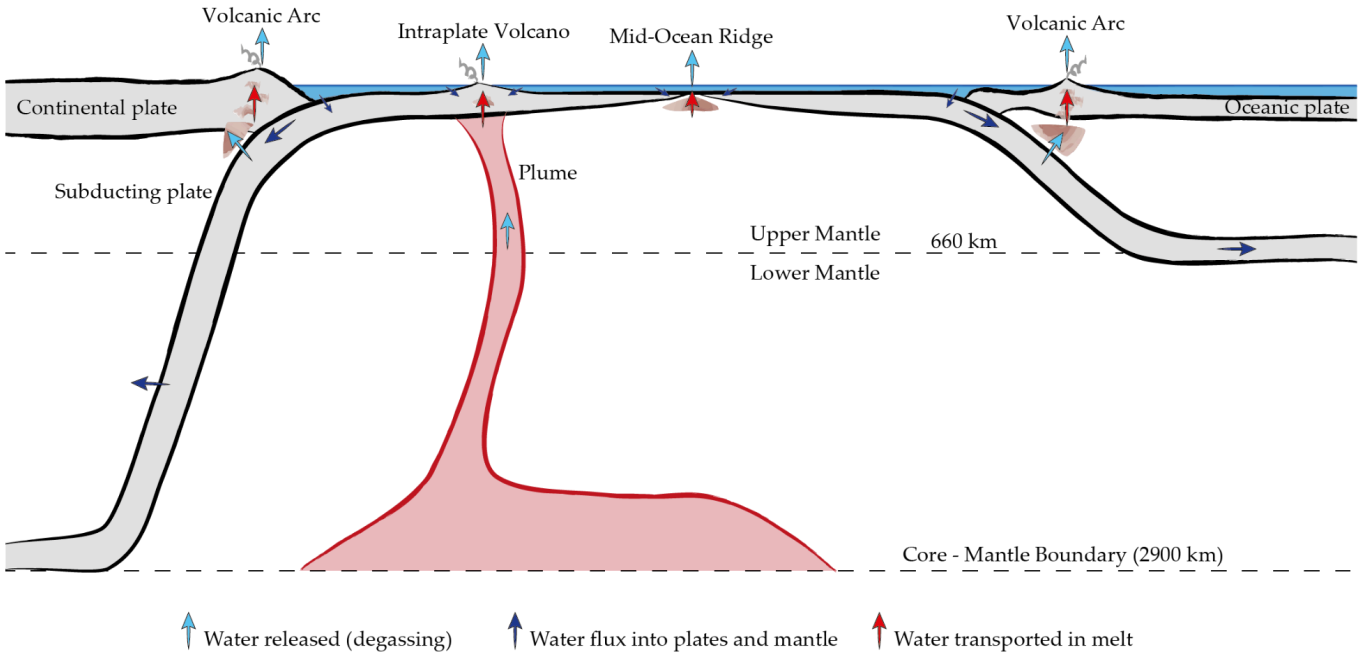
Part A1: Visualizing the Process

Look at the diagram. Use the reading to match the labels **(A, B, C)** to the correct description.

Descriptions:

1. ____ The Mantle Wedge: The hot, solid rock region located above the sinking plate.
2. ____ The Subducting Slab: The sinking oceanic plate that releases water as it heats up.
3. ____ The Volcanic Arc: The chain of volcanoes formed on the surface from the rising magma.

Scenario: Subduction zones act like a giant conveyor belt, taking water from the ocean (trapped in rocks) and moving it deep into the Earth's mantle. While some of this water returns to the surface through volcanoes, scientists believe a large amount stays trapped deep underground. The model below shows arrows representing **water flux**, or the movement of water in and out of Earth's interior.



Part A2: Review Questions

1. What is the primary cause of melting in a subduction zone?
   a. The friction of the plates rubbing together creates intense heat and pressure, starting a fire.
   b. The sinking plate touches the Earth's superheated molten core and melts.
   c. Water released from the sinking plate lowers the melting temperature of the mantle.
   d. The pressure decreases, allowing the rock to expand and melt.

2. Analogy Check: The reading compares water affecting hot rock to salt affecting ice.

   In this analogy, the salt represents the: _____

   In this analogy, the ice represents the: _____

3. Critical Thinking: If the sinking plate were completely dry (containing zero water), would volcanoes still form in the same way? Why or why not?

   _____

   _____

Exit Ticket Grade

_____/_____

Name: _____

Date: _____

Class: _____

OBJECTIVE

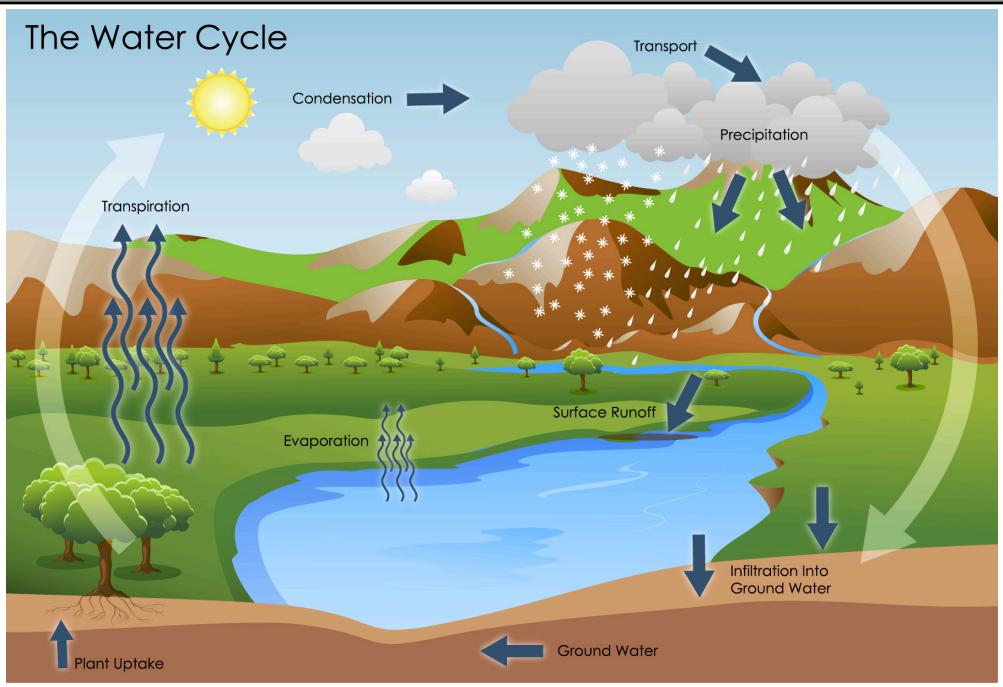
SWBAT explain how water is transported from the ocean into Earth's interior at subduction zones and describe how this process affects magma formation.

(NOVICE) 1 2 3 4 5 (MASTERY)

SWBAT analyze how water flux between Earth's interior and surface systems can create feedbacks that influence the water cycle and sea level over geologic time.

(NOVICE) 1 2 3 4 5 (MASTERY)

Exit Ticket



1.) Which process in the water cycle allows groundwater levels to be replenished after rainfall?

a.) Runoff
b.) Infiltration
c.) Evaporation
d.) Transpiration

2.) Soil in a delta becomes compacted due to over-farming and heavy machinery. Identify one water cycle process that would be impacted and describe the impact.

Water Cycle Process: _____

Impact: _____

_____

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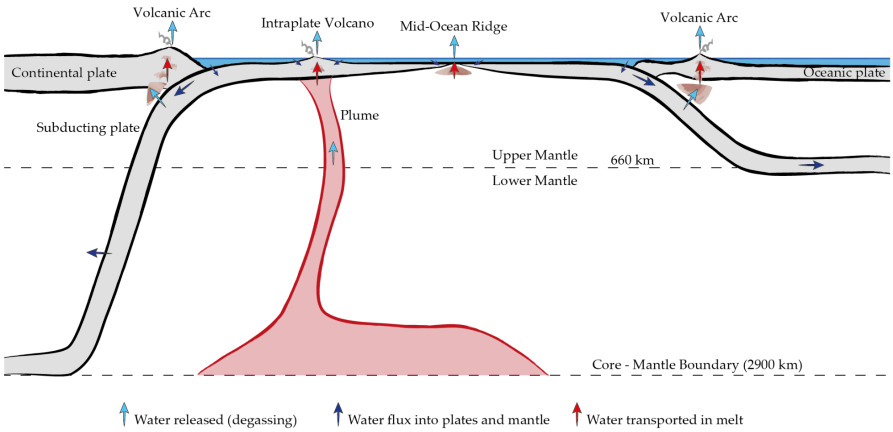

3.) Imagine that tectonic activity increased and Earth suddenly developed **twice as many subduction zones** as it has today. Over millions of years, how would this affect the hydrosphere (specifically, water flux) and how would it affect global Sea Levels?

Impact on the hydrosphere: Water flux will _____

Impact on global sea levels: Sea levels will _____

4.) For each statement below, indicate whether it represents a positive feedback or a negative feedback.

Statement	Feedback Type
As water is subducted into the mantle, sea level drops, exposing more land. Increased weathering and runoff return water to the oceans.	
Water subducted into the mantle leads to increased volcanic activity, which releases water vapor into the atmosphere, leading to more precipitation that returns water to the surface.	
Some water carried deep into the mantle remains trapped, reducing the amount of surface water available for evaporation and precipitation.	

5.) Which outcome best demonstrates the interdependence of Earth systems involving the water cycle?

a.) Volcanic eruptions release water vapor, increasing atmospheric moisture and precipitation, which returns water to the hydrosphere.

b.) Volcanic eruptions only affect the geosphere and have little influence on the water cycle.

c.) Water released from volcanoes permanently leaves Earth's system and does not reenter the water cycle.

d.) Volcanic activity decreases evaporation by blocking sunlight worldwide.