The Water Cycle

Module 4 • i2P • H2O Tour

"All the water that will ever be is, right now."

- National Geographic, October 1993

Where in the World

Pour yourself a glass of fresh water. As you swallow, ponder where the water molecules may have been before they arrived in your body. Individual water molecules do come and go, as they can be broken down into their constituent atoms; oxygen and hydrogen. However of the estimated 75,000,000,000,000,000,000,000,000 water molecules in a glass of water some would likely persist for a long time. Where might they have been?

Maybe some of them were used to bathe Ray Zahab as a newborn baby. Perhaps some once floated in a toxic industrial cesspool, or maybe they flowed over Niagara falls fifty years ago, or were boiled in the first steam engine invented by James Watt in England in 1784. Maybe some had been frozen in the Antarctic Ice Cap for millions of years, or were drunk by a Tyrannosaurus Rex. We shall never know; the possibilities are endless.

Student Exercise

Try and figure out how you would establish the number of water molecules in an 8 ounce glass of water.

For help see: Water Molecules

The Water Cycle

The water cycle, also known as the hydraulic cycle, describes the movement of water on, in, and above the planet Earth. The water cycle is a true cycle in that there is no beginning and no end. On Earth water has been cycling through its three common phases (liquid, gaseous (water vapor) and solid (ice)) for billions of years. Although the amount of water that exists in the cycle stays constant over time, individual water molecules do come and go. For simplicity lets break the water cycle into 3 steps:

- Ocean / lake;
- Atmosphere;
- Ground.

Ocean / Lake

As you can see from table 1, 96.5% of the world's water is in the oceans. Water found in oceans and lakes is heated by the sun to the point where it evaporates and rises into the atmosphere. *Evaporation* from the ocean and lakes accounts for the production of about

TABLE 1: DISTRIBUTION OF WORLD WATER BY LOCATION, VOLUME AND PERCENT

	Volume ($1000\ km^3$)	Percent of Total Water	Percent of Fresh Water
Oceans, Seas, & Bays	1,338,000	96.5	-
Ice caps, Glaciers, & Permanent Snow	24,064	1.74	68.7
Groundwater	23,400	1.7	-
Fresh	(10,530)	(0.76)	30.1
Saline	(12,870)	(0.94)	-
Soil Moisture	16.5	0.001	0.05
Ground Ice & Permafrost	300	0.022	0.86
Lakes	176.4	0.013	-
Fresh	(91.0)	(0.007)	.26
Saline	(85.4)	(0.006)	-
Atmosphere	12.9	0.001	0.04
Swamp Water	11.47	0.0008	0.03
Rivers	2.12	0.0002	0.006
Biological Water	1.12	0.0001	0.003
Total	1,385,984	100.0	100.0

Source: Gleick, P. H., 1996: Water resources. In *Encyclopedia of Climate and Weather,* ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823.

90% of atmospheric moisture. The other two mechanisms that contribute to the creation of water vapor are *sublimation* and *evapotranspiration*.

Water in the form of snow and ice can also contribute to atmospheric moisture through *sublimation*, the process by which snow and ice go from a solid water state directly into water vapor in the atmosphere. It takes the special conditions of low temperatures, strong winds, intense sunlight, and low air pressure for snow or ice to turn directly into water vapor without melting first.

The final way that water can get from the ground to the atmosphere is by *evapotranspiration*, the process by which water is transpired from plants and evaporated from the soil. Like sublimation, environmental factors such as high temperatures, low humidity, high winds and moist soil, can influence the rate of

Student Activity

Sublimation can be easily observed. If you live where it is below zero hang a wet tee-shirt outside. Initially the water will freeze in the shirt as ice. Gradually the ice will sublimate and the shirt will be dry and ice free.

transpiration.

Atmosphere

The air high in the atmosphere is much cooler than the air at the surface of the earth. As water is evaporated it cools causing water vapor arriving from the surface of the Earth to condense into tiny droplets of water that form into tiny clouds. Air currents move these tiny clouds to circulate until they join together to form larger clouds. As more water vapor condenses, clouds become heavier until they can hold no more water, and the water falls from the cloud as precipitation (rain or snow). Water vapor can also be present in the atmosphere in the form of humidity.

Did you know?

The total atmospheric volume of water is about 12,900 km^3, or 0.001% of the Earth's total water volume.

Precipitation can fall from the sky in several different forms depending on the atmospheric temperature. Rain is the most common form of precipitation, but other forms include freezing rain, sleet, snow and hail. Raindrops are not of uniform size or shape. In fact their shape is a function of their size (see figure 1). Precipitation also falls in different amounts and forms in different parts of the world (see: precipitation).

A) Raindrops are not tear-shaped, as most people think.
B) Very small raindrops are almost spherical in shape.
C) Larger raindrops become flattened at the bottom, like that of a hamburger bun, due to air resistance.
D) Large raindrops have a large amount of air resistance, which makes them begin to become unstable.
E) Very large raindrops split into smaller raindrops due to

Figure 1: Shapes of Raindrops (source: the Creative Commons Attribution 3.0 Unported)

Ground

Precipitation either falls back into the oceans or onto land. Most precipitation that falls on land as rain flows over the ground as surface *runoff*.

There are several ways that runoff can contribute to water sources. One third of runoff enters streams which carry the water towards the ocean. Runoff can also accumulate and become stored as water in lakes, or can soak into the ground to

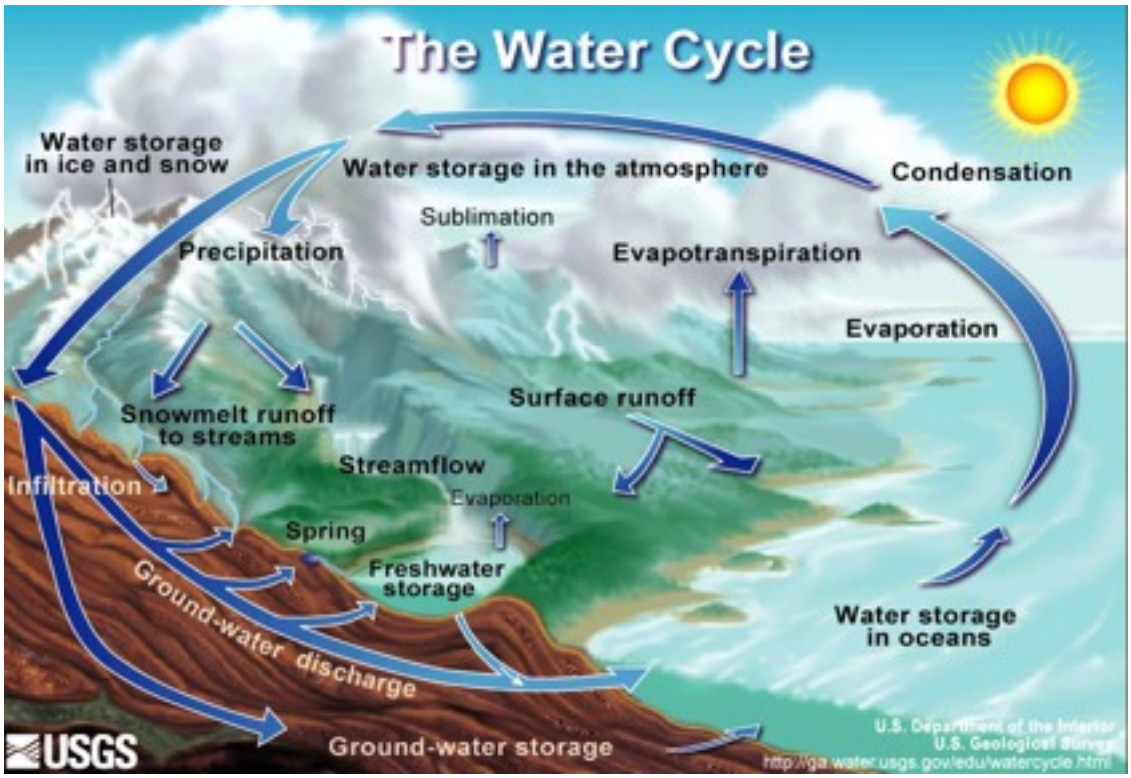

Figure 2: The Water Cycle (Source: United States Geological Survey - Wikimedia Commons)

replenish groundwater in a process known as *infiltration*. Some infiltrated water stays close to the surface of the land, allowing it to seep as springs into bodies of water such as lakes and oceans. Other water travels deep into groundwater reserves where it can remain as fresh water for tens of thousands of years. Without precipitation runoff, and discharge from aquifers, over time oceans would gradually empty due to evaporation.

Precipitation that falls as snow can accumulate in ice caps and glaciers, or melt and join surface runoff. Water frozen in ice caps can remain in place for thousands of years (see: Frozen Water module 8). When snow melts, the resulting water will join other surface runoff.

Back to the Beginning

Ultimately the majority of water that falls to the ground as precipitation makes its way to the ocean. Whether in the ocean or elsewhere on the surface of the earth, the water can then be evaporated, sublimated or transpired in order to start the water cycle all over again.

Student Exercise

Based on the reservoir times found in table 2, estimate the time it would take for a water molecule to go through the water cycle as snow

TABLE 2: DURATION IN YEARS OF WATER RESERVOIRS BY LOCATION

Average reservoir residence times	
Reservoir	**Average residence time**
Oceans	3,200 years
Glaciers	20 to 100 years
Seasonal snow cover	2 to 6 months
Soil moisture	1 to 2 months
Groundwater: shallow	100 to 200 years
Groundwater: deep	10,000 years
Lakes (see lake retention time)	50 to 100 years
Rivers	2 to 6 months
Atmosphere	9 days

Source: PhysicalGeography.net. CHAPTER 8: Introduction to the Hydrosphere. Retrieved on 2009-12-28

The amount of time water spends in the various phases of the water cycle is variable. Water locked in ice can remain in place for thousands of years, until the slow flow of the glacier finally deposits it in the ocean, or it makes its way to the surface of the glacier and is sublimated. Water that seeps into deep pools of groundwater can remain in place for many thousands of years. In the atmosphere water vapor has a short life span, being dumped back down to earth in just a few short days.

Student Activity

Measure snow/rainfall using the US Geological Survey calculator:

http://ga.water.usgs.gov/edu/sc2.html

The water cycle is of central importance to life on Earth (see: Water Cycle). Without the evaporation, sublimation or transpiration of water from the surface of the Earth there would be no clouds to create precipitation, and without precipitation there would be no new freshwater. Without a means of renewing fresh water the world would soon run out of this precious resource and all life would cease. It is thanks to the water cycle that new clean fresh water is constantly generated, allowing us to safely drink water that was once in a cesspool, or a Tyrannosaurus Rex, or was used to bathe Ray Zahab.

Now that you have studied the Water Cycle take the water cycle Quiz: Water Cycle Quiz