The Water Cycle

WATER is the most abundant compound on the earth's surface. In fact, it covers about 70 percent of the planet. Furthermore, it is continually moving and changing forms. This unit takes a close look at the characteristics of water and the water cycle.

Objective:

Describe the characteristics of water and the water cycle.

Key Terms:

absolute humidity
adhesion
aquifers
atmosphere
biosphere
brackish water
brook
canal
capillarity
cloud
cohesion
condensation
creek
current
dew
dew point
estuary
evaporation
evapotranspiration
fog
fresh water
frost
groundwater
groundwater flow
humidity
hydrosphere
infiltration
lake
lithosphere
marsh
ocean
percolation
polar compound
pond
precipitation
relative humidity
reservoir
river
runoff
saline water
salt water
slough
solute
solution
solvent
specific humidity
stream
streamflow
sublimation
surface water
throughflow
transpiration
water cycle

Water

Water has unique characteristics that make life possible on Earth.

FIGURE 1. Water makes life possible on Earth. (Courtesy, U.S. Geological Survey)

THE PHYSICAL AND CHEMICAL MAKEUP OF WATER

Water, in its purest form, is tasteless, odorless, and colorless. It is a chemical compound made up of two atoms of hydrogen and one atom of oxygen. Its chemical symbol is H_2O. The chemical properties of water are unique.

The Universal Solvent

Water is known as the universal solvent. A **solution** is a mixture of solutes and solvents. A **solute** is a substance that is dissolved in a solution. A **solvent** is a substance that dissolves a solute. In a glass of sweet ice tea, the solutes are the tea and the sugar, and the solvent is the water. Water is the solvent in which all nutrients (solutes) are dissolved and suspended.

Cohesion and Adhesion

Water has both cohesive and adhesive forces.

Cohesion is the bonding of water molecules to each other. This can be evidenced in a puddle of water on a table. Water is a **polar compound**, meaning each molecule has both a

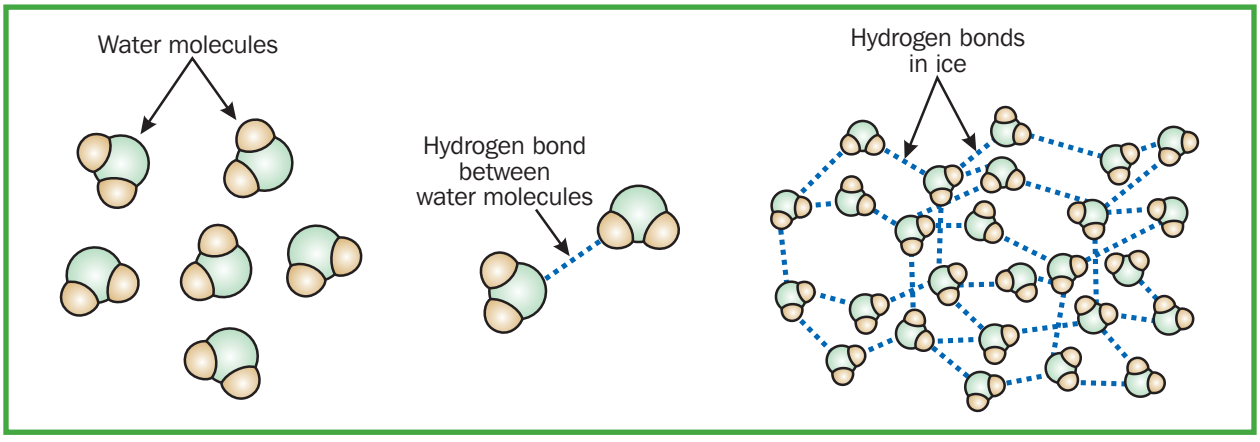

FIGURE 2. Through cohesion water molecules bond to one another.

negatively charged pole and a positively charged pole. Although the net charge of water is zero, the slightly negative and slightly positive poles of its molecules make it possible for them to bond to other water molecules very easily. Water can form hydrogen bonds with up to four adjacent water molecules.

Adhesion is the bonding of water molecules to other substances. Because of polarity, water easily bonds to other substances, especially other polar compounds. A small drop of water will adhere to the side of a car or to a wall.

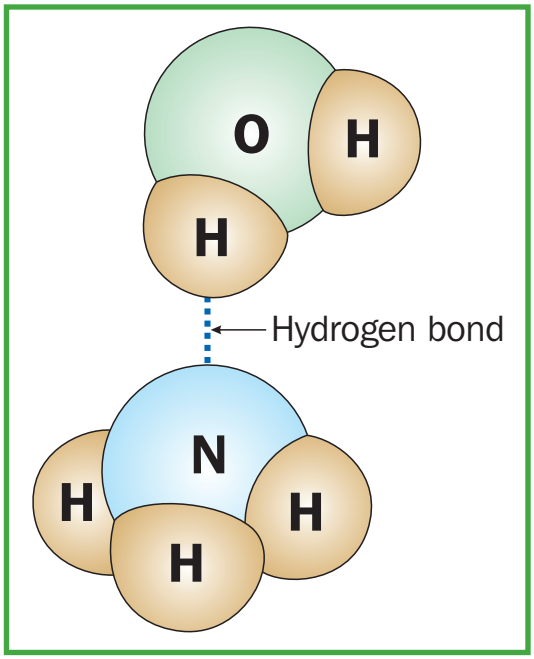

FIGURE 3. Water can form hydrogen bonds with other molecules.

Cohesion and adhesion play an important role in capillarity, or capillary action. **Capillarity** is the ability of a liquid to move upward against the force of gravity by molecular attraction to a surrounding surface. Water can move from the roots of a plant to the leaves because of cohesion and adhesion. Looking at a clear graduated cylinder, one can see how capillarity works in plants. The water bonds to the inside of the graduated cylinder because of adhesion. Water molecules bond to themselves because of cohesion. As the water moves up the sides of the cylinder from adhesion, cohesion pulls more water molecules upward. The narrower the tube, the faster the liquid will move upward against the force of gravity. Cohesion and adhesion are also involved in the movement of water up through pore spaces of soil.

Heat Capacity

Water has a high heat capacity due to its polarity. A great deal of heat or energy is required to break the bonds between water molecules. This is why a pot of water seemingly takes a long time to boil; the heat must work to break the bonds before the water will boil. This characteristic is good for organisms, because we would die if only a small amount of heat were needed (from the sun, for instance) to cause us to "boil."

Water Molecules Split Apart

Water molecules have a slight tendency to split apart, or dissociate. The result is that hydrogen ions (H^+) and hydroxyl ions (OH^-) are found in solution. These same ions readily reunite to form water molecules. There are always some hydrogen ions and some hydroxyl ions in water. In pure water, the concentration of hydrogen ions and hydroxyl ions is equal.

States of Water

Water can be found in three physical states. The solid form of water is called ice. Water freezes at 32°F (0°C). The gaseous form of water is called water vapor or steam. When water boils, it turns into water vapor or steam. Water boils at 212°F (100°C). In between its gaseous and solid forms, water is in its liquid form.

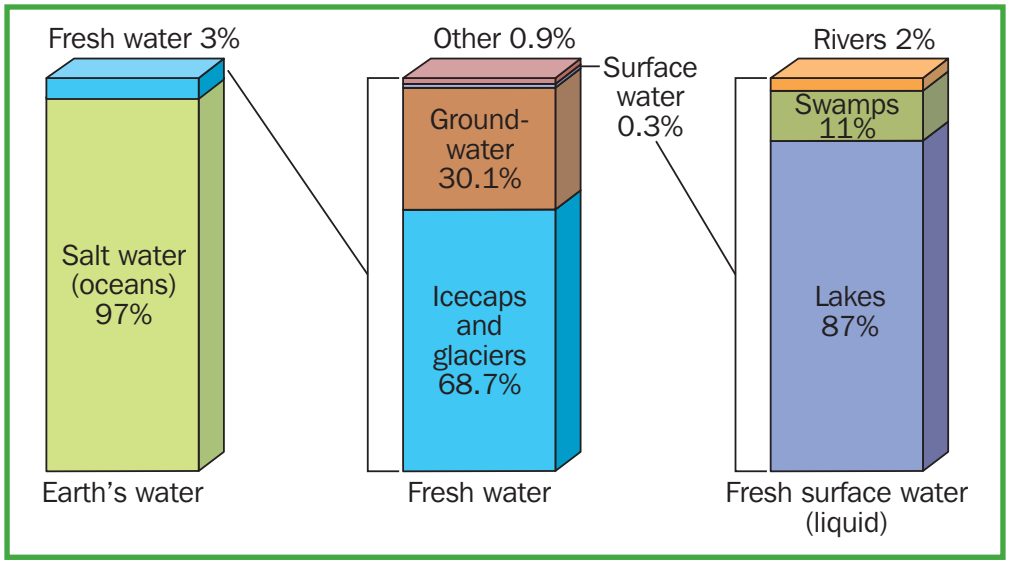

FIGURE 4. Distribution of the earth's water.

Salinity

Water that contains salt is called **saline water**. Sodium chloride, potassium, and magnesium are salts found in water. The amount of salt in water often determines the usefulness of the water. Water with a high salt content cannot be used for drinking or irrigation. Three categories of saline water are fresh water, salt water, and brackish water.

Water with less than 3.0 parts per thousand (ppt) of salt is called **fresh water**. Fresh water is most commonly found in groundwater, streams, and lakes. Only 3 percent of the earth's water is considered fresh water, and of this 3 percent, only 1 percent is available for use.

Water with 16.5 ppt or more of salt is called **salt water**. The salt content of some ocean and sea water is as high as 33 to 37 ppt. Salt water makes up about 97 percent of the earth's water.

A mixture of salt water and fresh water is called **brackish water**. Brackish water is found where fresh water flows into the ocean or another body of salt water.

Table 1 shows the percentage of water found in various locations.

TABLE 1. Percentage of Water Found in Various Locations

Form	Percentage of Total
Oceans	97.3
Icecaps and glaciers	2.19
Groundwater	0.5
Freshwater lakes	0.005
Inland seas and salt lakes	0.001
Atmosphere	0.018
Rivers	0.0001

THE CYCLE OF WATER

The **water cycle**, or hydrologic cycle, is the movement of water throughout the biosphere. The water cycle involves continuous movement of water and many processes. It is a biogeochemical cycle. Water is recycled as it moves between the biotic (living) and the abiotic (nonliving) parts of the environment. Water is not lost in the biosphere, but it can become contaminated and therefore unusable. Water will change states from gas to liquid to solid. The water cycle operates continuously, receiving its energy from the sun.

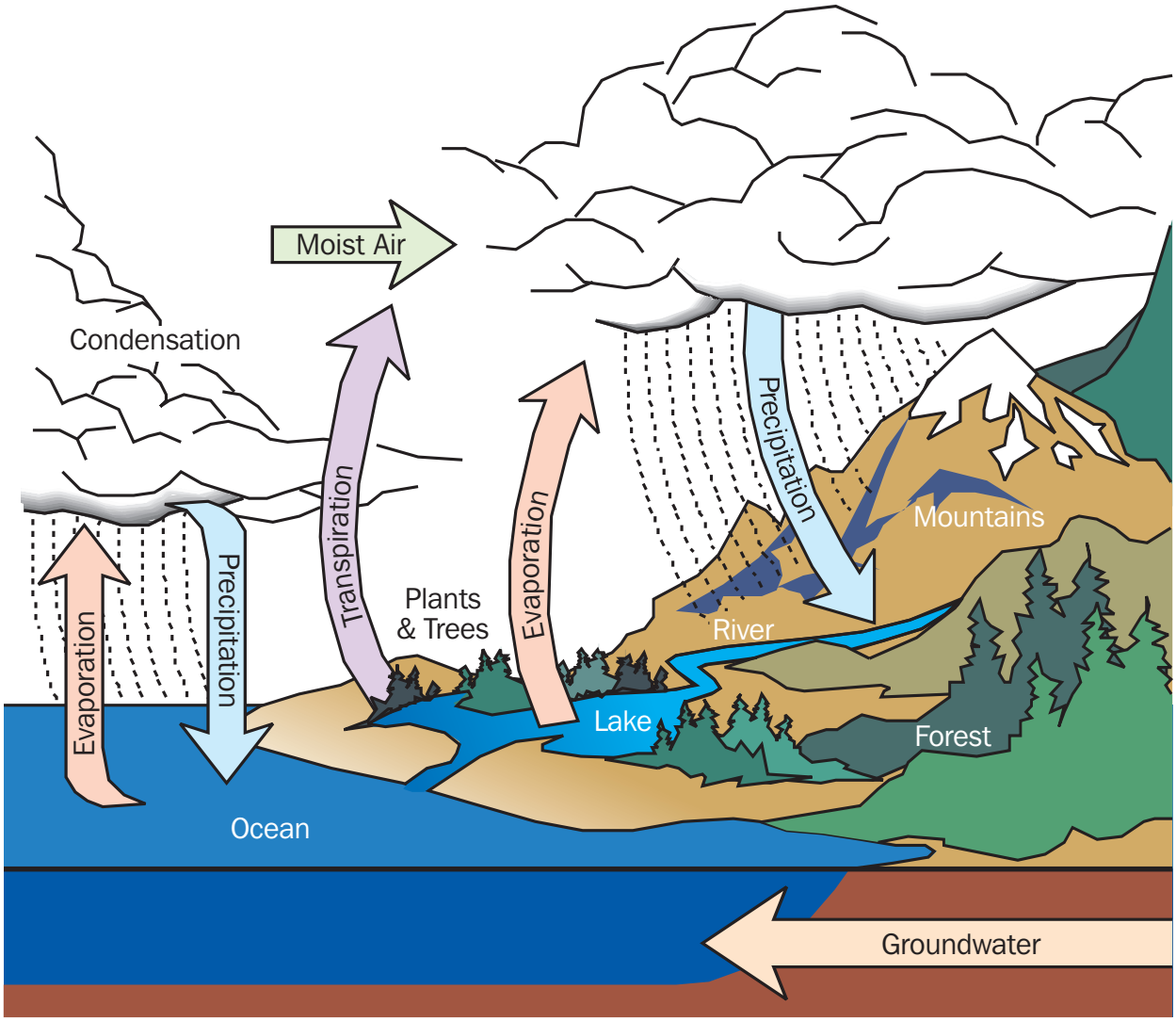

FIGURE 5. The water cycle (hydrologic cycle).

Overlapping Spheres

The water cycle is made up of four overlapping spheres: hydrosphere, atmosphere, biosphere, and lithosphere. The **hydrosphere** is all the water on Earth, whether liquid, solid, salty, or fresh. Oceans, seas, lakes, ponds, and streams are sources of liquid water, while gla-

ciers and icecaps hold solid water. The **atmosphere** is the gaseous layer that encompasses the earth. Air holds moisture as water vapor. All the communities of living things on earth compose the **biosphere**. Water makes up about 70 to 80 percent of plants and about 75 percent or more of muscles and internal organs in animals. The **lithosphere** is the soil and rock that make up the earth's crust. Water is found in the pore spaces, cracks, and other openings in the crust.

Processes of the Water Cycle

The water cycle can be broken into a number of processes, including evaporation, condensation, and precipitation.

Evaporation

Evaporation is the process by which water leaves the surface of the earth and becomes water vapor. This occurs when some of the molecules on the surface of a liquid turn into a gaseous form as a result of heat. The water vapor rises into the atmosphere, where it changes form, absorbs or releases heat, condenses, and then returns to the earth as precipitation.

Humidity is the amount of water vapor in the air as compared with the amount of water vapor the air can hold at a certain temperature. Three terms used to refer to humidity are *absolute humidity*, *relative humidity*, and *specific humidity*. **Absolute humidity** is the amount of water in a volume of air. **Relative humidity** is the ratio of the partial pressure of water vapor in a mixture of air and water vapor to the saturated vapor pressure of water at a given temperature. Relative humidity is expressed as a percentage. For example, air might be measured as having

BROADENING AWARENESS...

AMAZING ASPECTS: Interesting Facts About Water

- There is the same amount of water on earth as there was when the earth was formed. The water that came from your faucet could contain molecules that dinosaurs drank.
- The overall amount of water on our planet has remained the same for 2 billion years.
- Groundwater can take a human lifetime just to traverse a mile.
- Water regulates the earth's temperature.
- Water is the only substance that is found naturally on earth in three forms: gas, liquid, and solid.
- Frozen water is 9 percent lighter than water, which is why ice floats on water.
- Approximately 66 percent of the human body consists of water.
- Human brains are 75 percent water.
- A tomato is 95 percent water.
- An acre of corn will give off 15,000 liters (4,000 gallons) of water per day in transpiration.

90 percent relative humidity. **Specific humidity** is the ratio of 'water vapor' to 'dry air plus water vapor' in a particular volume.

Water absorbed by plants is lost to the atmosphere through transpiration. **Transpiration** is the process through which plants release water. Much of the water loss is through stomata and from plant surfaces. The rate of transpiration is affected by humidity, temperature, wind, and soil moisture. The rate increases when humidity is low, temperature high, wind speed high, and soil moisture adequate. Leaf shape, leaf surface area, and number of stomata are other factors that determine the rate of transpiration. Broad, thin leaves with an abundance of stomata transpire more than narrow, thick leaves with few stomata.

Evapotranspiration is the return to the atmosphere of the water that transpires from plants and evaporates from soil.

Sublimation is a form of evaporation in which water vaporizes from ice without becoming water first. This occurs when the temperature of the air is colder than the temperature of the snow or ice. The phenomenon can be observed in winter as snow slowly disappears under cold conditions.

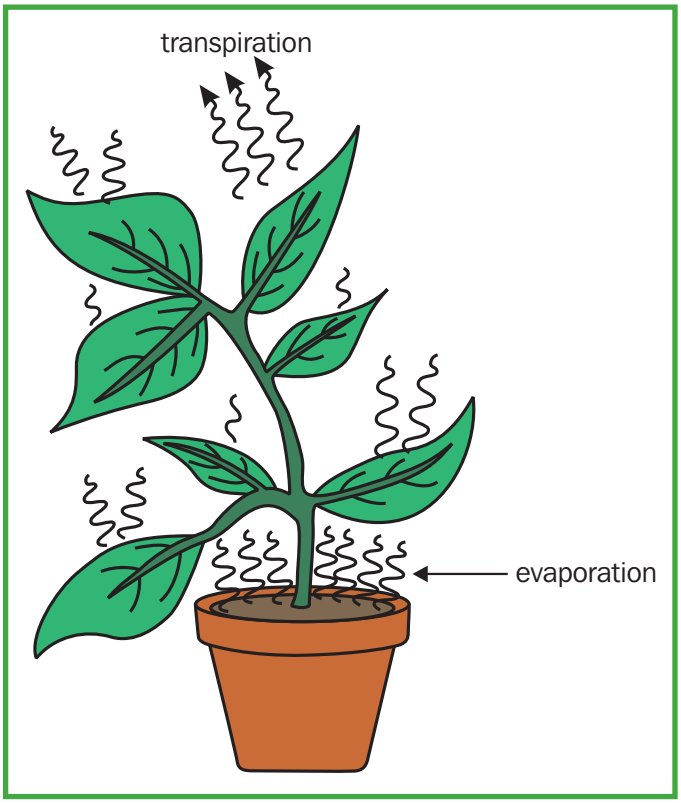

FIGURE 6. Evapotranspiration.

Condensation

Condensation is a change in the state of matter to a denser phase. Water vapor in the atmosphere may condense to liquid as air cools. A **cloud** is the condensation of water vapor in the atmosphere into tiny droplets or frozen crystals. **Fog** is condensation similar to a cloud but in contact with the ground. Another form of condensation is dew. **Dew** is water in the form of droplets that appears on objects such as grass in the morning or evening. As grass blades cool, water vapor condenses on them. The temperature at which dew forms is called the **dew point**. When air temperatures are low enough, dew freezes and is called **frost**.

Precipitation

Precipitation is moisture from the atmosphere that is returned to the earth. Rain, snow, sleet, and hail are common forms of precipitation. Precipitation is a product of condensation. Precipitation falls to the oceans and other bodies of water and to land.

Most water from precipitation that falls on land runs along the surface of the ground and is called **runoff**. Runoff enters streams, lakes, and oceans. The water on the surface of the earth

is called **surface water**. Water that does not run off may evaporate quickly, be absorbed by plants, or infiltrate the ground.

The process of water entering the soil is known as **infiltration**. The downward movement of water through the soil is called **percolation**. Water that infiltrates the ground percolates down to the water table. It eventually returns to the surface through hillside seeps, springs, or wells. Some of this water flows horizontally and is known as **throughflow**. Water found within the earth in the pores, cracks, and openings of soil and rock is **groundwater**. Groundwater can be a long-term source of natural water. Groundwater slowly returns to the oceans. The horizontal movement of groundwater is called **groundwater flow**.

Groundwater can be extracted through wells. Some wells tap into large underground reserves of water called **aquifers**. Aquifers contain vast amounts of water that have collected over thousands of years.

SURFACE WATER

One of the most important parts of the water cycle is surface water. Surface water is sometimes classified as flowing and nonflowing. Surface water provides the basis for a wide variety of ecosystems. The variety is due to water salinity, depth, temperature, turbidity, current, and other factors.

Flowing Surface Water

A **stream** is a flowing body of water. Most streams are fresh water, and they can flow through natural or human-made channels. There are four types of streams. The stream type is determined by the volume of the water and by the velocity of the water, or **streamflow**. The rate of flow in a stream is called a **current**. The four types of streams are rivers, creeks, brooks, and canals.

FIGURE 7. A stream is a flowing body of water.

A **river** is the largest stream. Rivers have high streamflows.

A **creek** is a stream that is smaller than a river. Creeks often flow into rivers, lakes, and oceans.

A **brook** is a small stream. Brooks often flow into creeks, rivers, lakes, and oceans.

A **canal** is an artificial waterway built for transportation, to relieve flooding, or to divert the flow of water.

Nonflowing Surface Water

Many bodies of water do not flow. These bodies may be natural or artificial. Nonflowing bodies of water influence the weather and climate of an area. Commerce, food supply, and recreational activities can also be influenced by the nonflowing bodies of water in an area. Bodies of water that do not flow still have water movement. The internal movement is caused by temperature changes and salinity. The seven types of nonflowing bodies of water are oceans, lakes, ponds, reservoirs, sloughs, marshes, and estuaries.

An **ocean** is a large body of salt water. Oceans cover almost 75 percent of the surface of the earth.

A **lake** is a body of fresh water surrounded by land. Lakes vary in size. Some are natural, and others are human-made.

A **pond** is a nonflowing body of water that is smaller than a lake. Ponds are commonly human-made and used for recreation or by livestock.

A **reservoir** is a large body of stored water. Reservoirs are commonly used to generate electric power.

A **slough** is a thick, muddy area of shallow water.

A **marsh** is an area of land covered with shallow water and plants such as cattails. Marshes do not contain trees and are similar in nature to sloughs.

An **estuary** is an area where a freshwater stream flows into the ocean or a saltwater lake.

FIGURE 8. A lake is a body of fresh water surrounded by land.

FIGURE 9. A South Carolina estuary. (Courtesy, NOAA)

Summary:

Water, in its purest form, is tasteless, odorless, and colorless. It is known as the universal solvent and has a high heat capacity. It has both cohesive and adhesive forces. Water molecules have a slight tendency to split apart, or dissociate. Water can be found in three physical states: gas, liquid, and solid. Water that contains salt is called saline water.

The water cycle, or hydrologic cycle, is the movement of water throughout the biosphere. It is made up of four overlapping spheres: hydrosphere, atmosphere, biosphere, and lithosphere. The water cycle can be broken into a number of processes, including evaporation, condensation, and precipitation.

Surface water is sometimes classified as flowing and nonflowing. A stream is a flowing body of water. The four types of streams are rivers, creeks, brooks, and canals. The seven types of nonflowing bodies of water are oceans, lakes, ponds, reservoirs, sloughs, marshes, and estuaries.

Checking Your Knowledge:

1. What is the physical and chemical makeup of water?
2. How do the three categories of saline water compare?
3. What are the major processes in the water cycle?
4. What is groundwater?
5. What are the types of surface water?

Expanding Your Knowledge:

Investigate the source of water in your community. Does it come from groundwater or surface water? How is the supply replenished?

Web Links:

US EPA Thirstin's Water Cycle
http://www.epa.gov/ogwdw/kids/flash/flash_watercycle.html

The Hydrologic Cycle
http://www.nwrfc.noaa.gov/info/water_cycle/hydrology.cgi

Water Cycle Diagram
http://earthguide.ucsd.edu/earthguide/diagrams/watercycle/

Agricultural Career Profiles
http://www.mycaert.com/career-profiles