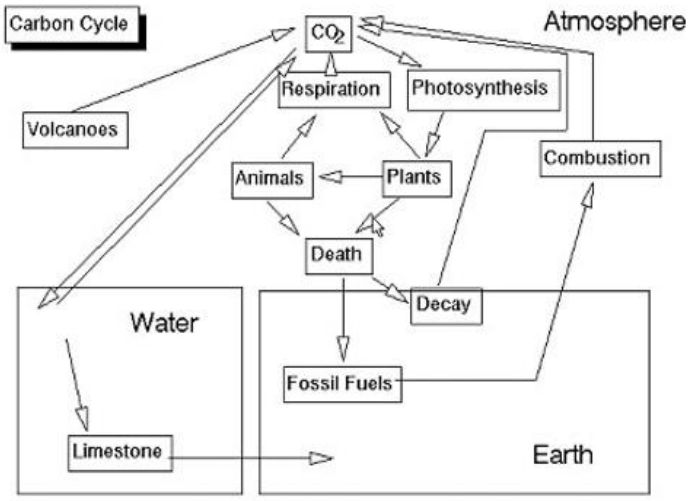
# THE CYCLING OF MATERIALS WITHIN ECOSYSTEMS

## The Carbon Cycle

The global movement of carbon between organisms and the abiotic environment is known as the carbon cycle

1. Carbon is present in the atmosphere as carbon dioxide($CO_2$), the ocean as carbonate and bicarbonate ($CO_3^{2-}$, $HCO_3^-$) and sedimentary rock as calcium carbonate ($CaCO_3$)
2. Proteins, carbohydrates, and other molecules essential to life contain carbon
3. Carbon makes up approximately 0.04% of the atmosphere as a gas

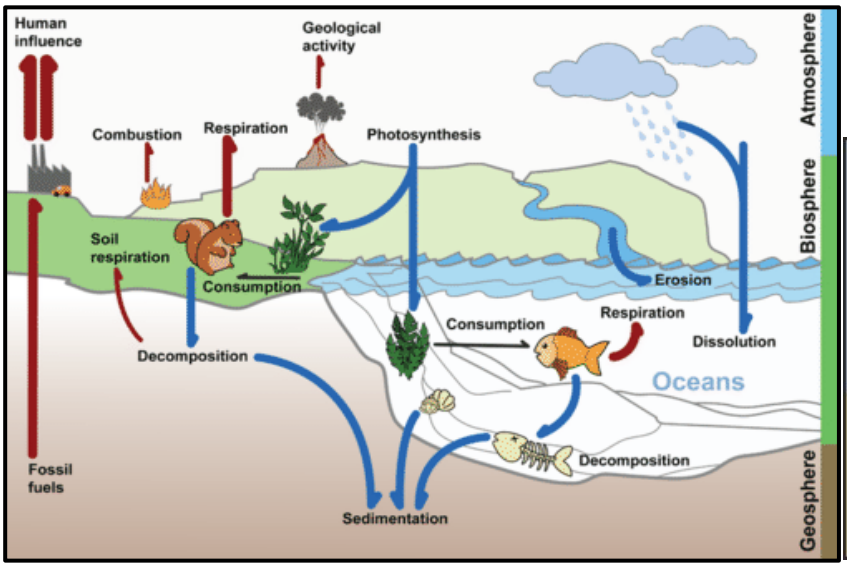


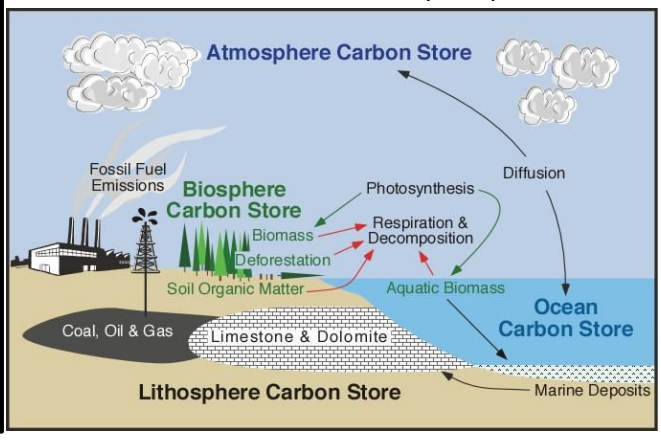

**Carbon** primarily cycles through both biotic and abiotic environments via photosynthesis, cellular respiration and combustion ($CO_2$)

1. Photosynthesis incorporates carbon from the abiotic environment ($CO_2$) into the biological compounds of producers (sugars)
2. Producers, consumers and decomposers use sugars as fuel and return $CO_2$ to the atmosphere in a process called cellular respiration
3. Carbon present in wood and fossil fuels (coal, oil, natural gas) is returned to the atmosphere by the process of combustion (burning)
4. The carbon-silicate cycle (which occurs on a geological timescale involving millions of years) returns $CO_2$ to the atmosphere through volcanic eruptions and both chemical and physical weathering processes
5. Human activities are increasingly disturbing the balance of biogeochemical cycles, including the carbon cycle.

Global climate change
Extinction of organisms

Agriculture disruption
Flooding
Drought
Increased wildfires
Rise in sea levels
Altertered precipitation



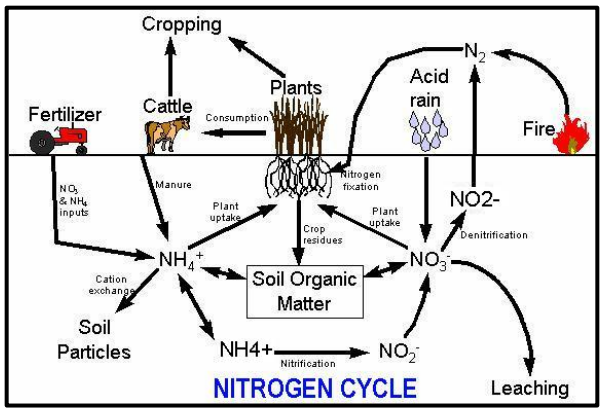
# THE NITROGEN CYCLE

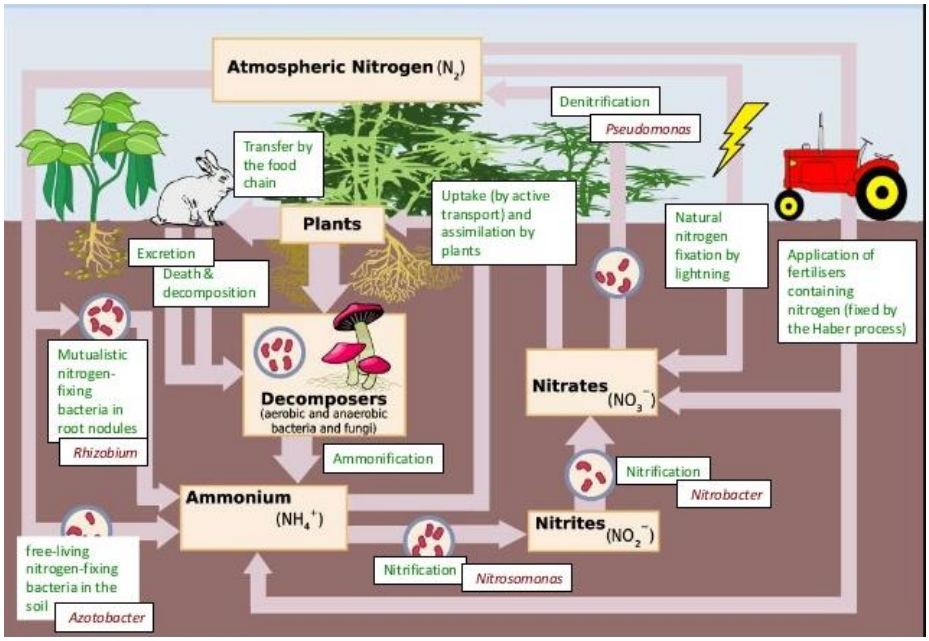
Global circulation of nitrogen between organisms & the abiotic environment is know as the nitrogen cycle

1. Atmospheric nitrogen ($N_2$) is so stable that it must first be broken apart in a series of steps before it can combine with other elements to form biological molecules
2. Nitrogen is an essential part of proteins and nucleic acids (DNA)
3. The atmosphere is 78% nitrogen gas ($N_2$)

## Five steps of the nitrogen cycle

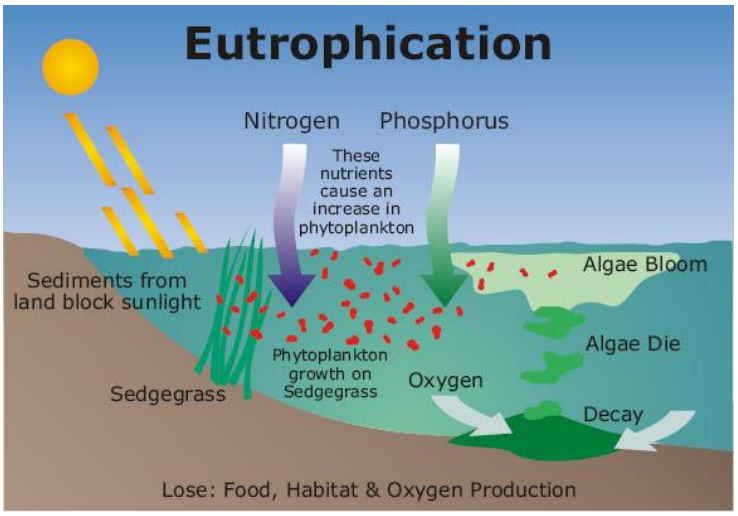
1. **Nitrogen fixation**
   a. Conversion of gaseous nitrogen ($N_2$) to ammonia ($NH_3$)
      - Nitrogen-fixing bacteria (including cyanobacteria) fix nitrogen in soil and aquatic environments (anaerobic process)
      - Combustion, volcanic action, lightning discharges,
      - Industrial processes also fix nitrogen
2. **Nitrification**
   a. Conversion of ammonia ($NH_3$) or ammonium ($NH_4^+$) to nitrate ($NO_3^-$)
   b. Soil bacteria perform nitrification in a 2-step process ($NH_3$ or $NH_4^+$ is converted to nitrite ($NO_2^-$) then to $NO_3^-$)
   c. Nitrifying bacteria is used in this process
3. **Assimilation**
   a. Plant roots absorb $NO_3^-$, $NO_3$ or $NO_4^+$ and assimilate the nitrogen of these molecules into plant proteins and nucleic acids
   b. Animals assimilate nitrogen by consuming plant tissues (conversion of amino acids to proteins)
   c. This step does not involve bacteria
4. **Ammonification**
   a. Conversion of biological nitrogen compounds into $NH_3$ and $NH_4^+$
   b. $NH_3$ is released into the abiotic environment through the decomposition of nitrogen-containing waste products such as urea and uric acid (birds), as well as the nitrogen compounds that occur in dead organisms
   c. Ammonifying bacteria is used in this process
5. **Denitrification**
   a. Reduction of $NO_3^-$ to $N_2$
   b. Anaerobic denitrifying bacteria reverse the action of nitrogen-fixing and nitrifying bacteria



Scientists **have** determined that **humans** are disrupting the **nitrogen cycle** by **altering** the amount of **nitrogen** that is stored in the biosphere.

- Increased fossil fuel combustion, which releases nitric oxides into the air that combine with other elements to form smog and acid rain and increase atmospheric pollutants
- Addition of fertilizers to soil- runoff and leaching of N into groundwater… too much nitrogen in water – leads to eutrophication
- Nitrates in drinking water. A sort of "**blue baby syndrome**" can also be caused by methemoglobinemia. It is widely believed to be caused by nitrate contamination in groundwater resulting in decreased oxygen carrying capacity of hemoglobin in **babies** leading to death.



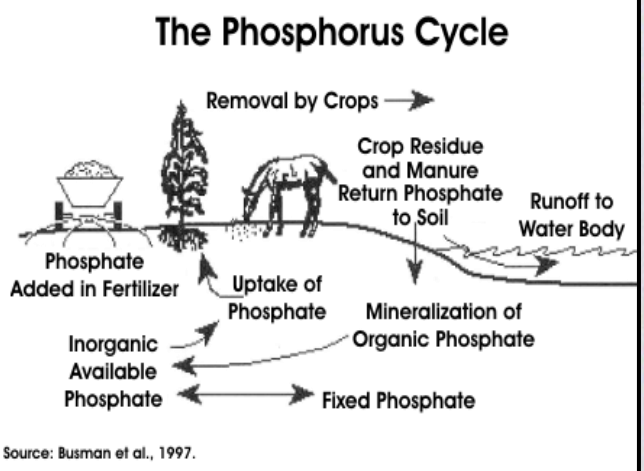

## THE PHOSPHORUS CYCLE

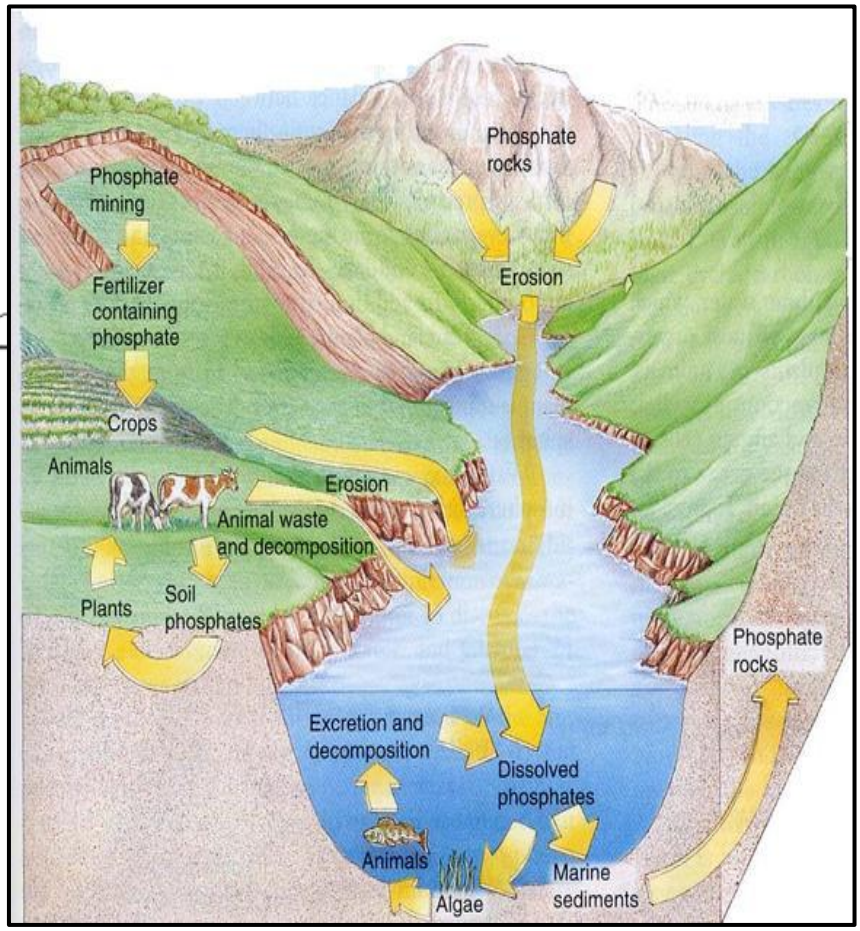
Phosphorus cycles from land to sediments in the ocean and back to land

1. Phosphorus erodes from rock as inorganic phosphates and plants absorb it from the soil
2. Animals obtain phosphorus from their diets, and decomposers release inorganic phosphate into the environment

Once in cells, phosphates are incorporated into biological molecules such as nucleic acids and ATP (adenosine triphosphate)

Not found in gas form




## THE SULFUR CYCLE

Most sulfur is underground in sedimentary rocks and minerals or dissolved in the ocean

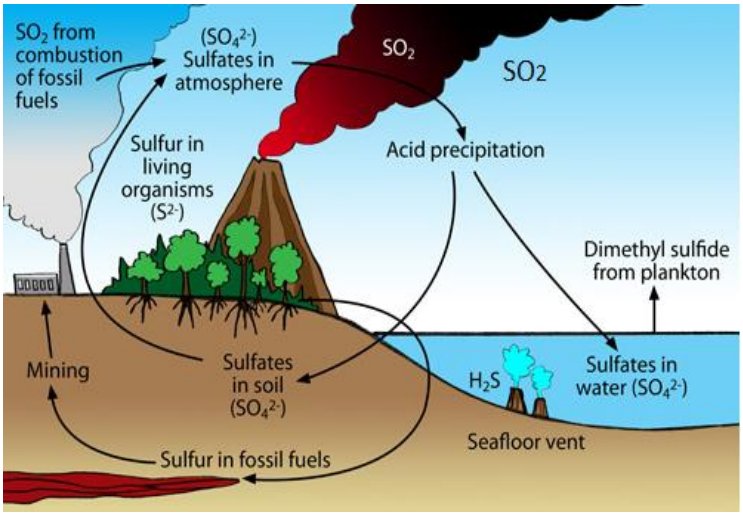
Sulfur gases enter the atmosphere from natural sources in both ocean and land

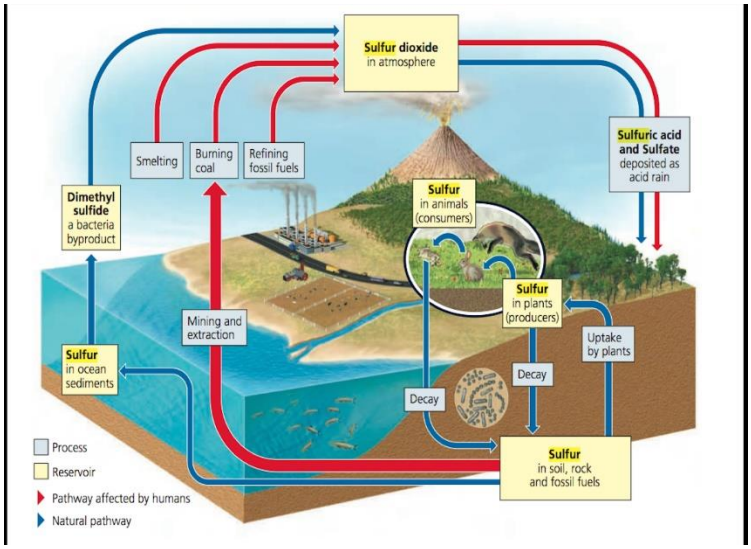
1. Sea spray, forest fires and dust storms deliver sulfates ($SO_4^{2-}$) into the air
2. Volcanoes release both hydrogen sulfide ($H_2S$) and sulfur oxides ($So_x$)

A tiny fraction of global sulfur is present in living organisms

1. Sulfur is an essential component of proteins
2. Plant roots absorb $SO_4^{2-}$ and assimilate it by incorporating the sulfur into plant proteins
3. Animals assimilate sulfur when they consume plant proteins and covert them to animal proteins

Bacteria drive the sulfur cycle




## THE HYDROLOGIC CYCLE

The global circulation of water for the environment to living organisms and back to the environment

1. It provides a renewable supply of purified water for terrestrial organisms
2. the hydrologic cycle results in a balance between water in the ocean, on the land, & in the atmosphere
   - Water moves from the atmosphere to the land and ocean in the form of precipitation
   - Water enters the atmosphere by evaporation and transpiration
   - The volume of water entering the atmosphere each year is about 389,500 $km^3$

**Vocab:**

evaporation – conversion of water into water vapor

transpiration – evaporation from leaves of water extracted from soil by roots and transported throughout the plant

condensation – conversion of water vapor into droplets of liquid water

precipitation – rain, sleet, hail, and snow

infiltration – movement of water into soil

percolation – downward flow of water through soil and permeable rock formations to ground water storage areas, aquifers

run off – down slope surface movement back to the sea to resume the cycle

aquifer -rock that holds water; underground water storage

water table - the level closest to the surface of the aquifer

- The water cycle is powered by energy from the sun and by gravity
- Water cycle & topography are responsible for weather (short-term)
- Water Cycle & air temperature are responsible for climate (long-term)

The amount of water vapor air can hold depends on air temperature

- *Warm air is capable of holding* more water vapor than cold air
- Absolute humidity – the amount of water vapor found in a certain mass of air and is usually expressed as grams of water per kilogram of air
- Relative humidity – expressed as a percentage of maximum amount it could hold at that temperature

For precipitation to occur, air must contain condensation nuclei

- Condensation nuclei are tiny particles such as volcanic ash, soil, dust, smoke, sea salts, and particulate matter from industry and vehicles
- Water droplets collect on the condensation nuclei and falls to earth
- Dew point is the temperature at which condensation occurs.
- About 77% of precipitation falls back into the sea
- The rest falls on terrestrial ecosystems and becomes surface runoff that flows into streams and lakes
- Surface run-off causes soil erosion

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Evaporation from oceans, lakes, rivers
↓
Condensation forms clouds (condensation nuclei = ash, dust, sea salt)
↓
Precipitation: rain, snow, hail, (dew, fog-- moisture due to humidity/water vapor at low levels)
↓ ↓
Run-off percolation into soils
↓ ↓
Rivers, lakes, ocean groundwater
↓
rivers, lakes, ocean

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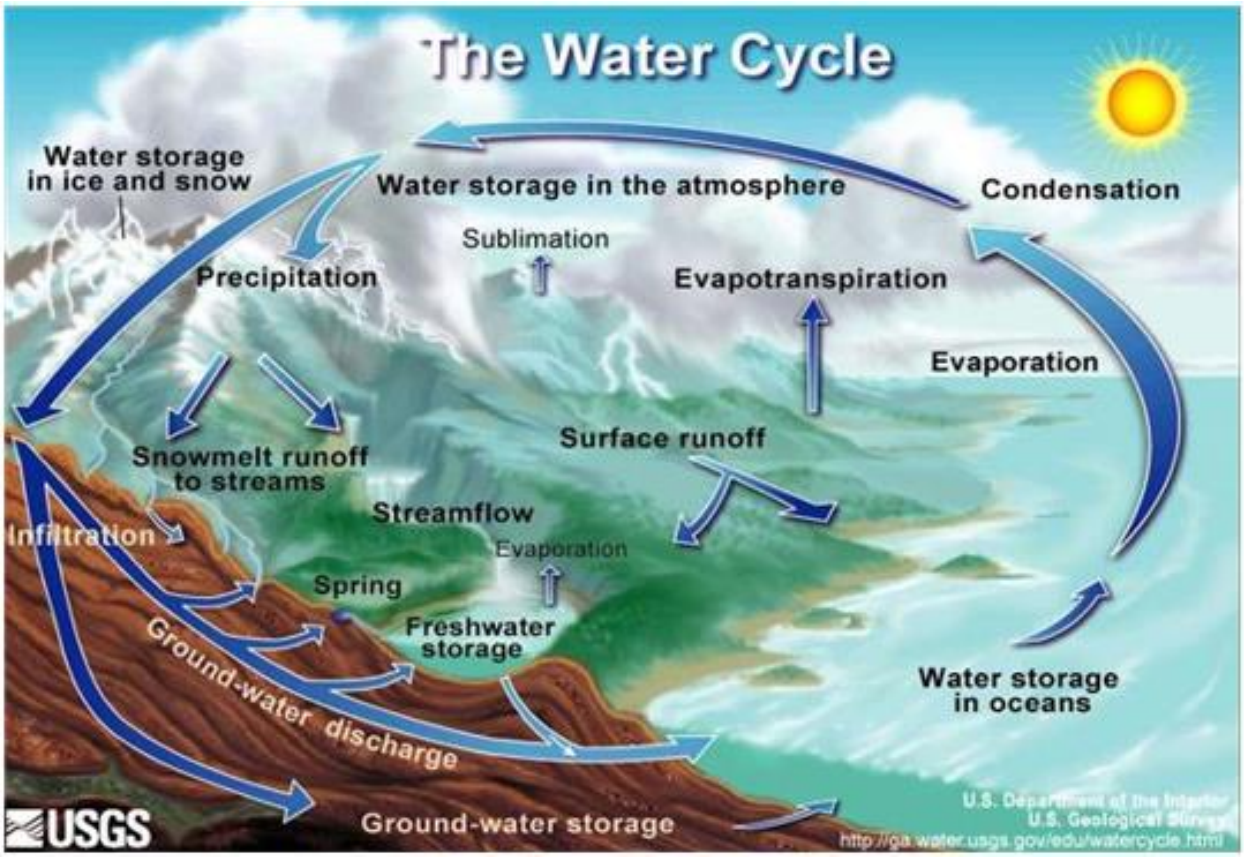
-Water is polar molecule → cohesion & adhesion → capillary action, high surface tension, high storage of heat

How are humans influencing the water cycle?

- Withdraw large quantities of fresh was from streams, lakes, and underground sources.
  This causes groundwater depletion or salt water intrusion
- The clearing of vegetation from land for agriculture, mining, road and building construction and other activities.
  This increases runoff and reduces infiltration that recharges groundwater supplies
  Also increases flooding risks and accelerates soil erosion
- We modify water quality by adding nutrients, such as phosphates, and other pollutants and by changing ecological processes that naturally purify water




**Solar Radiation**

- The sun powers biogeochemical cycles (i.e., hydrologic, carbon) and is the primary determinant of climate
- Most of our fuels (i.e., wood, oil, coal, and natural gas) represent solar energy captured by photosynthetic organisms
- Approximately one billionth of the total energy released by the sun strikes our atmosphere
  - Clouds, snow, ice, and the ocean reflect about 31% of the solar radiation that falls on Earth
  - Albedo is the proportional reflectance of solar energy from the Earth's surface
  - Glaciers and ice sheets have a high albedo and reflect 80 to 90% of the sunlight hitting their surfaces
    *Asphalt pavement and buildings have a low albedo (10 to 15%)*
    *Forests have a low albedo (about 5%)*
- 70% of the solar radiation that falls on the Earth is absorbed and runs the hydrologic cycle, drives winds and ocean currents, powers photosynthesis, and warms the planet

**Temperature changes with latitude**

- Near the equator, the sun's rays hit vertically
  1. *Energy is more concentrated*
  2. *Produces higher temperatures*
  3. *Rays of light pass through a shallower envelope of air*
- Near the poles, the sun's rays hit more obliquely
  1. *Energy is spread over a larger surface area (less concentrated)*
  2. *Produces lower temperatures*
  3. *Rays of light pass through a deeper envelope of air, causing the sun's energy to scatter and reflect back to space*

**Temperature changes with season**

- Season's are determined primarily by Earth's inclination on its axis
- March 21 to September 22 the Northern Hemisphere tilts toward the sun (spring/summer)
- September 22 to March 21 the Northern Hemisphere tilts away from the sun (fall/winter)