Section 2.1

The Role of Water in Cycles of Matter

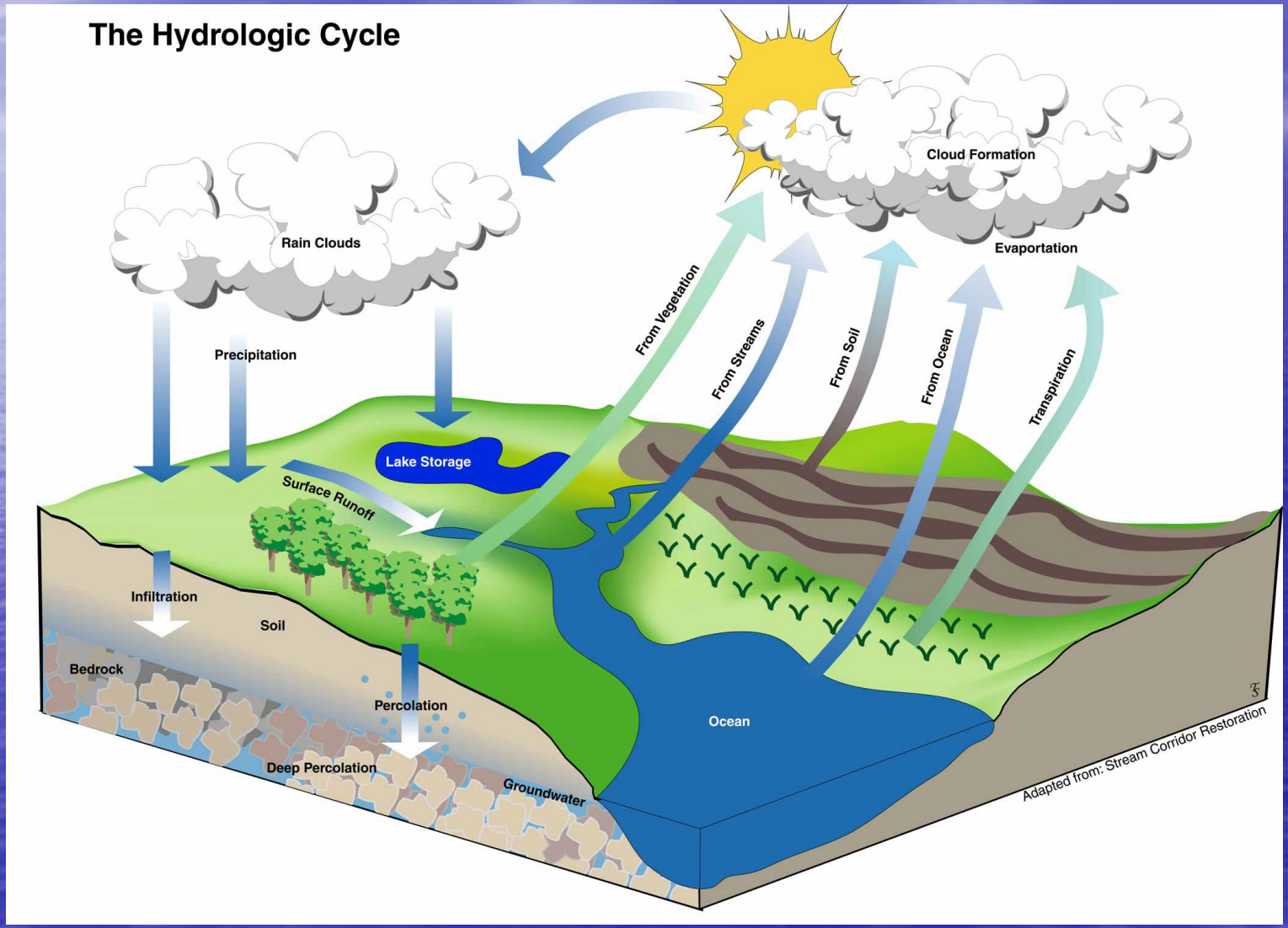
Water in the Biosphere

- Because Earth is a closed system, matter must cycle within it
- The water that we see in surface water sources may have come from snow and ice, from oceans, or it may have been a product of cellular respiration

Water in the Biosphere

- Water in our atmosphere acts as a greenhouse gas, trapping heat and warming the Earth
- The transfer of heat throughout our biosphere is also mostly due to water's ability to absorb large amounts of heat energy

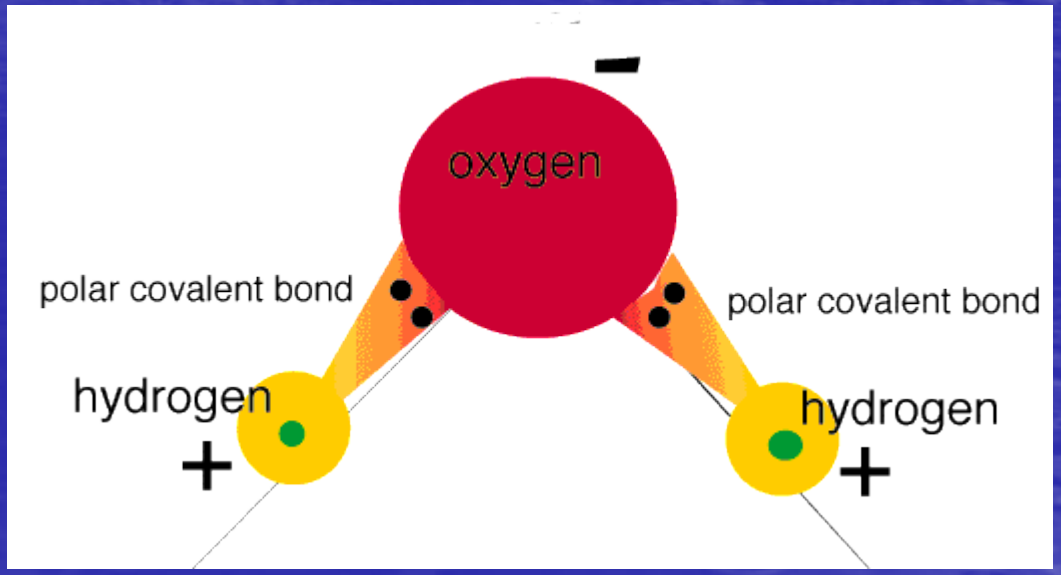
The Hydrologic Cycle



http://www.buffer.forestry.iastate.edu

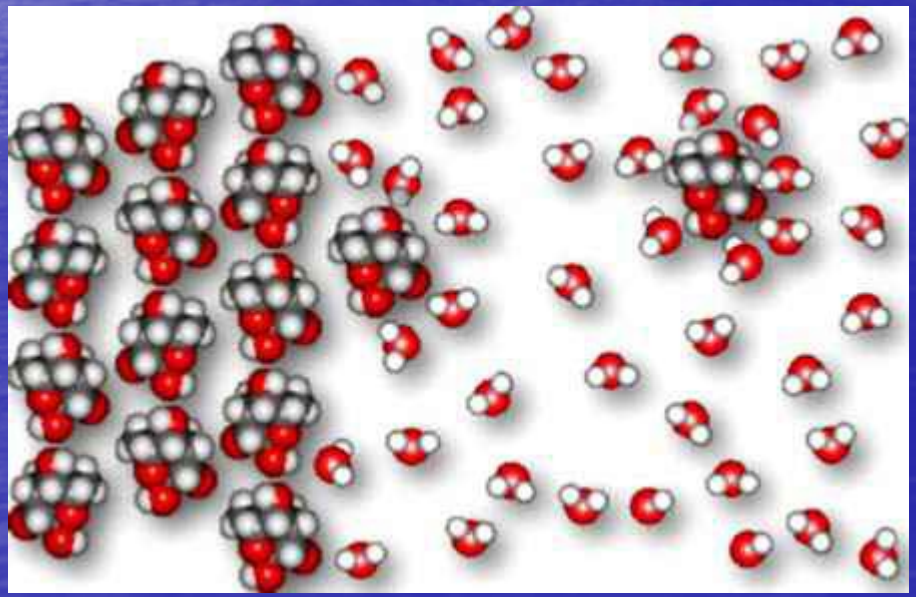
The Universal Solvent

- Water is a polar molecule
- When an ionic compound is placed in water, it pulls apart the ions and makes it dissolve



http://academic.brooklyn.cuny.edu

- As well, there is attraction formed between nearby water molecules as a hydrogen bond forms
- This allows water molecules to surround compounds while dissolving them

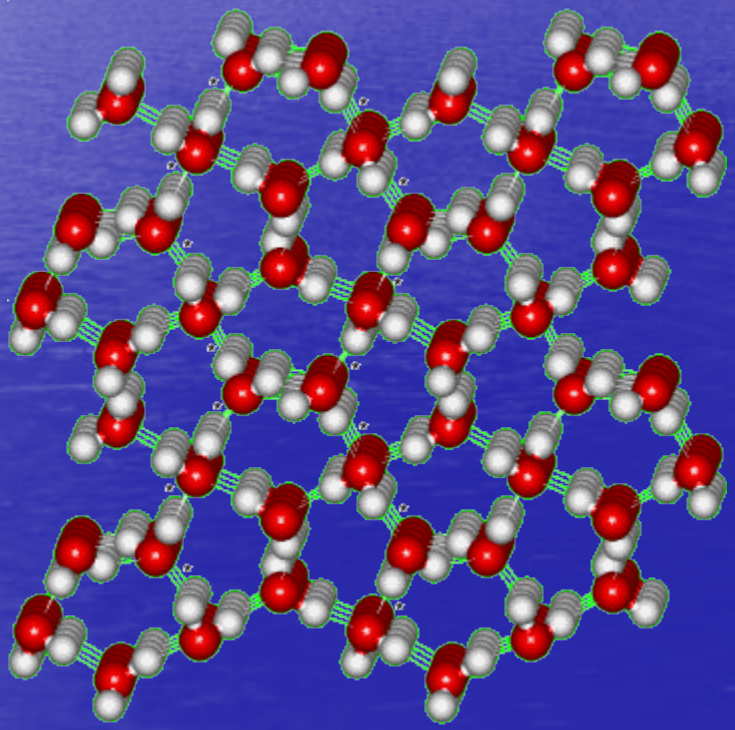


http://antoine.frostburg.edu

Hydrogen Bonding and Water's Phases

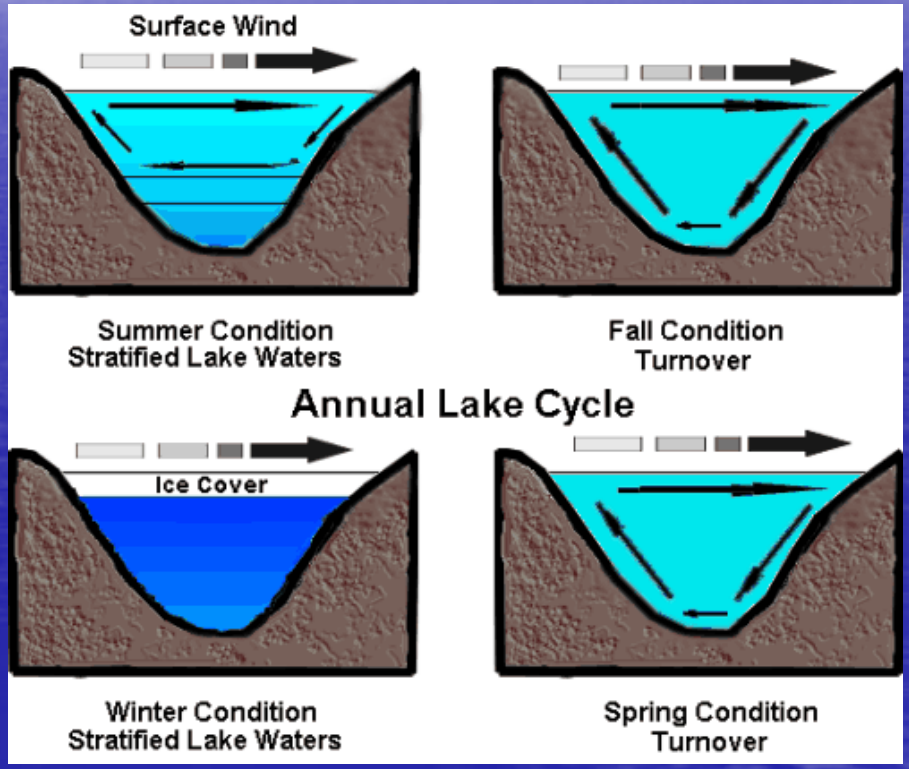
- Because water molecules have relatively strong hydrogen bonds between them, it requires a large amount of energy to break these bonds so that the molecules can move freely
- This means that water will have very high heats of fusion and vaporization
- It also means that water has high melting and boiling points when compared to similar hydrogen compounds

- These hydrogen bonds and the forces of repulsion between the oxygen atoms contributes to the open spacing seen in the crystal structure of ice



http://www.lsbu.ac.uk

- Because ice is less dense than water, lakes always freeze from the top down
- This prevents most lakes and ponds from freezing solid
- As well, it contributes to the cycling of oxygen and nutrients during the spring and fall in bodies of water



http://www.islandnet.com

- The hydrogen bonds in water produce cohesion between molecules, which gives water its surface tension
- Adhesion also occurs between water molecules and molecules of other substances (such as glass)
- The force of adhesion is responsible for the capillary action that occurs in the xylem of plants

Water and Heat

- The hydrogen bonds between water molecules means that water has a high specific heat capacity
- As a result, water stores huge amounts of heat energy
- Large bodies of water will moderate temperatures because of this
- At the level of the individual organism, the high specific heat capacity of water prevents body temperatures from changing too quickly

Water and Organisms

- Organisms gain water from their environment through eating, drinking, absorption, and cellular respiration
- Organisms lose water through breathing, sweating, and in their waste

Water as a Resource

- When ecosystems lack water, the producers that use it during photosynthesis quickly disappear
- Therefore, droughts in areas can be devastating to ecosystems
- If global temperatures rise, then droughts will become more common in areas such as Alberta, which will greatly affect our economy

Water Quality

- Not all freshwater is suitable for use
- In many areas, the water is contaminated with toxic chemicals or pathogens
- Even if the pathogens can be killed by chemical treatment or boiling, some toxins are extremely difficult to remove from polluted water

Water and Ecosystems

- Changes in the amount of water available in an ecosystem will affect the growth of producers
- Research carried out in the rainforest shows that trees exposed to drought conditions will extend their roots deeper than normal in search of water

- As well, the rate of growth of the trees decreased, and some of the largest trees died
- This could contribute further to climate change as less CO_2 would be absorbed from the atmosphere
- The lack of growth in trees and other producers due to drought will also affect other chemical cycles in our biosphere

Section 2.2

Biogeochemical Cycles

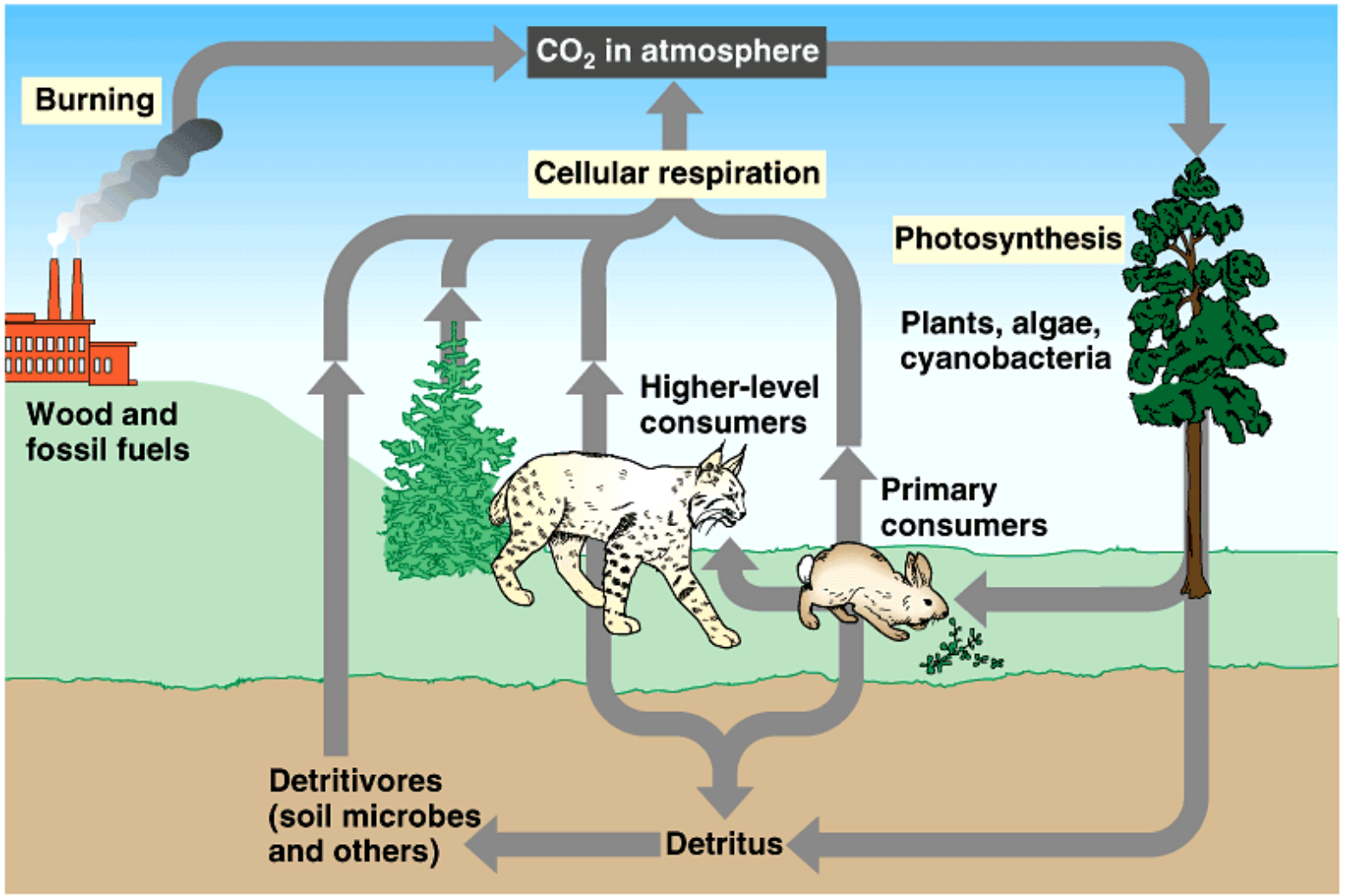
The Necessity of Cycles

- Again, because there is a limited amount of matter in our ecosystem, chemicals must be recycled constantly
- The main biogeochemical cycles are the oxygen, carbon, nitrogen, sulfur, and phosphorus

The Carbon and Oxygen Cycle

- Carbon and oxygen are closely related in our ecosystem
- As a result, they can often be illustrated in the same cycle

Carbon-Oxygen Cycle



http://kentsimmons.uwinnipeg.ca

Slow vs. Rapid Cycling of Carbon

- Organisms are involved in the rapid cycling of carbon through photosynthesis and cellular respiration
- However, some larger producers (like large trees) also store carbon for long periods of time in their tissues, and the carbon is not recycled until the tree dies and is broken down by decomposers

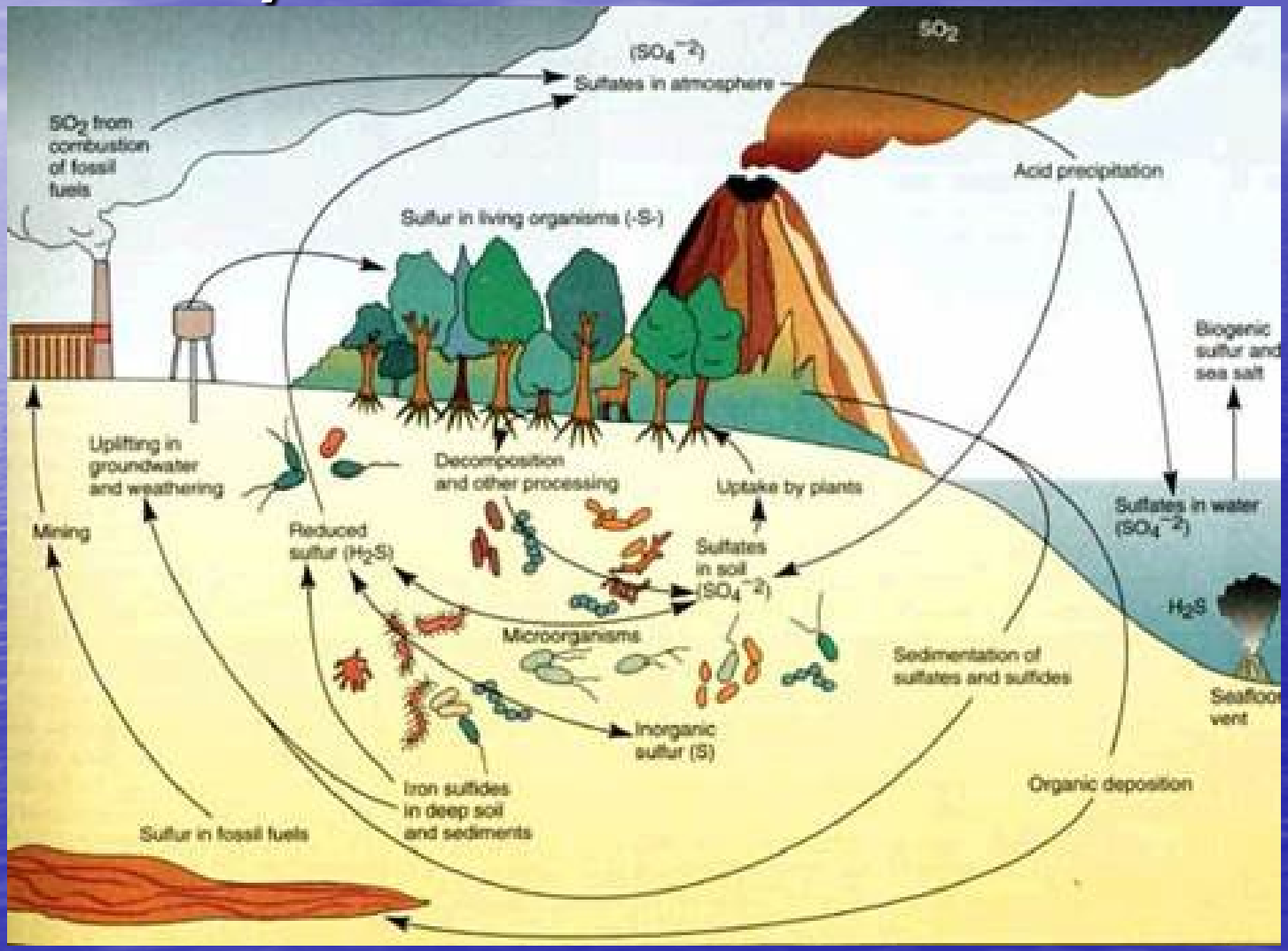
Carbon Sinks

- A carbon sink is a storehouse of carbon in the biosphere
- The largest stores of carbon in the biosphere are Earth's oceans
- The water in the ocean contains billions of tonnes of dissolved carbon dioxide
- Other carbon sinks include forests, limestone rock (calcium carbonate) and petroleum deposits

The Sulfur Cycle

- Sulfur is an important component of proteins
- Many bacteria use sulfur compounds in photosynthesis or certain types of cellular respiration
- Bacteria also release sulfur that is in forms that cannot be used by other organisms

Sulfur Cycle



http://web.missouri.edu

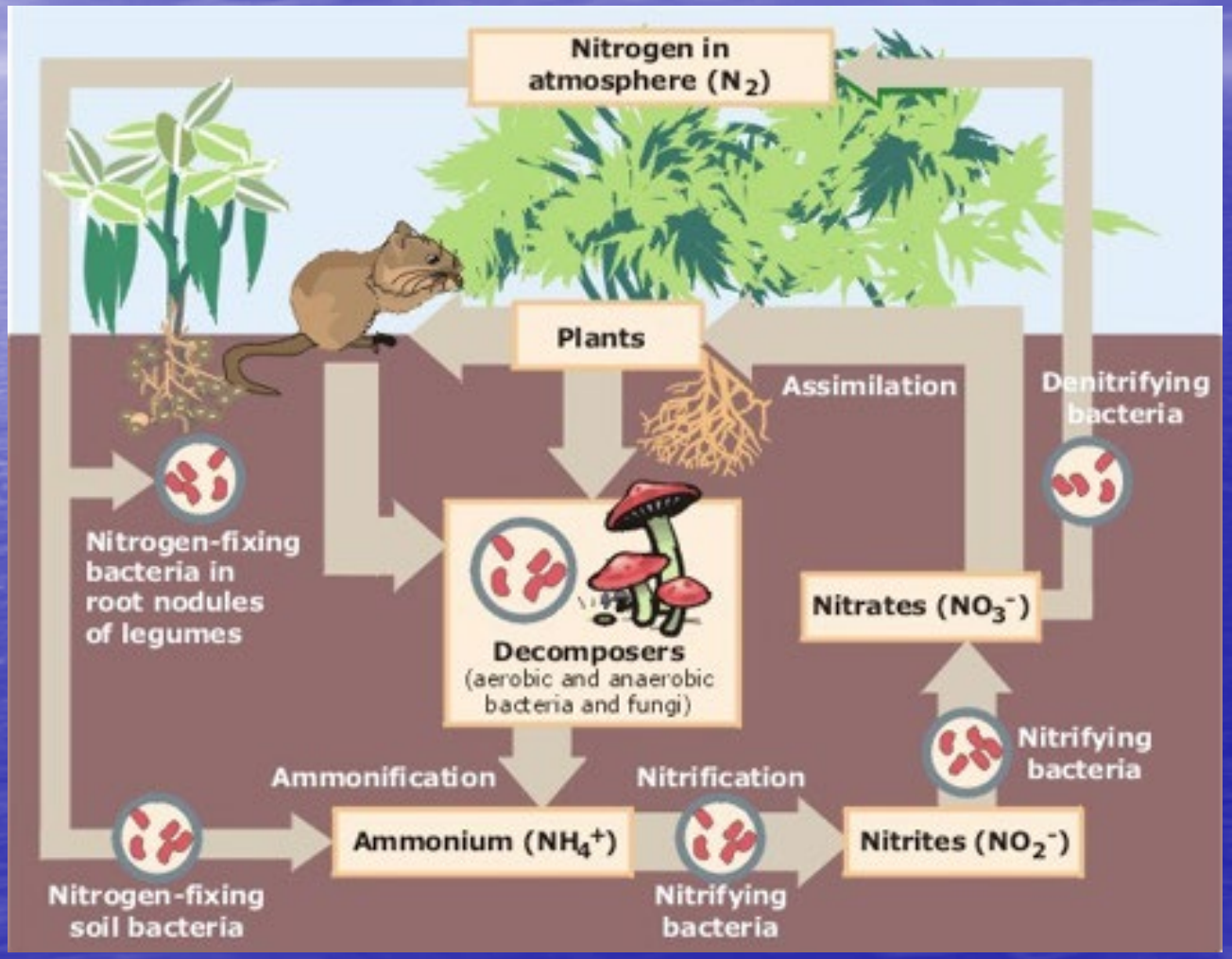
Acid Deposition

- The combustion of fossil fuels that contains sulfur releases sulfur oxides into the atmosphere
- Sulfur dioxide reacts with oxygen and water vapour in the atmosphere to form sulfuric acid and sulfurous acid
- When this acid condenses, it falls as acid precipitation
- The acid can change soil and water pH, making it impossible for organisms to survive

The Nitrogen Cycle

- Nitrogen is required by organisms to form the amino acids that form proteins and to make up the structure of DNA
- However, the nitrogen gas in our atmosphere cannot be used for this purpose
- The nitrogen gas must therefore be converted into other forms

Nitrogen Cycle



http://www.epa.gov

Processes in the Nitrogen Cycle

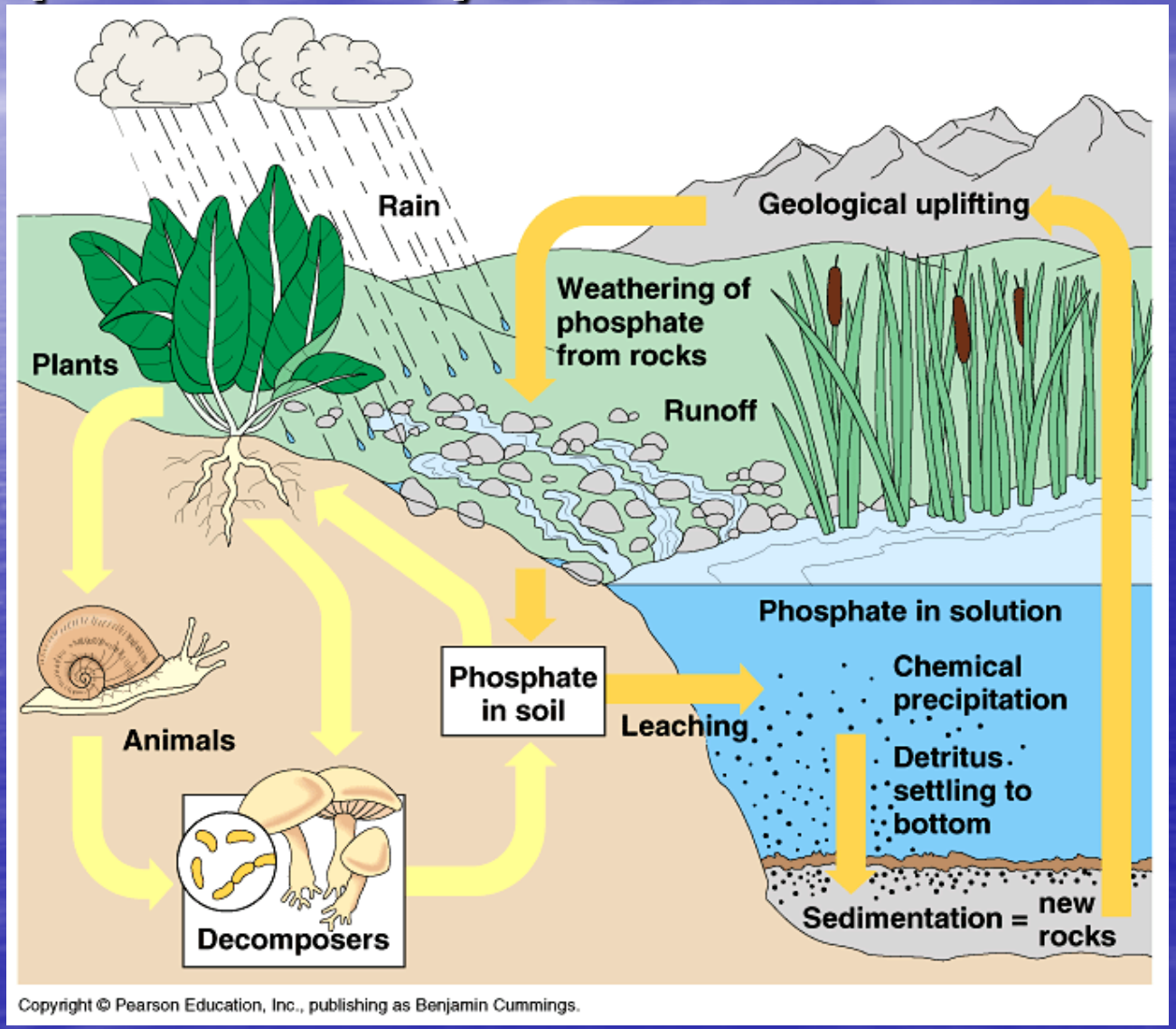
- Nitrogen fixation is the conversion of atmospheric nitrogen into ammonium (NH_4^+)
- This is carried out by nitrogen-fixing bacteria found in nodules attached to the roots of legumes
- Ammonification also produces ammonium as bacteria break down organic matter

- During denitrification, bacteria complete the cycle by breaking down nitrogen compounds and releasing nitrogen gas back into the atmosphere
- Denitrification typically occurs in anaerobic environments

The Phosphorus Cycle

- Phosphorus is required for cellular materials such as DNA, phospholipids, and ATP
- Phosphorus does not cycle in the atmosphere, but is found in soil and water
- Large amounts of phosphorus are stored in rocks and released during erosion

Phosphorus Cycle



Overabundance of Phosphorus

- Because most of the world's phosphorus is locked in rocks and sediments, the growth of plants is limited
- However, adding excess phosphorus can cause uncontrolled growth of algae and plant life, which reduces available oxygen in aquatic ecosystems

Energy and Matter Transfer

- Remember that energy is involved in each step of these cycles
- As well, water is also a necessary component of these cycles, so the biogeochemical cycles are all linked together through energy and water

2.3 – The Balance of Matter and Energy Exchange

- The amount of sunlight an area receives often determines its productivity
- Productivity rates are often expressed as energy or biomass
- As well, moisture plays a significant role in the productivity of an ecosystem

Balance in the Biosphere

- Inside our own bodies, we maintain homeostasis
- To do this, we must use energy
- In 1979, James Lovelock proposed the Gaia Hypothesis, which is homeostasis on a global level
- In essence, this hypothesis suggests that the Earth is self-regulating

The Gaia Hypothesis and Living Things

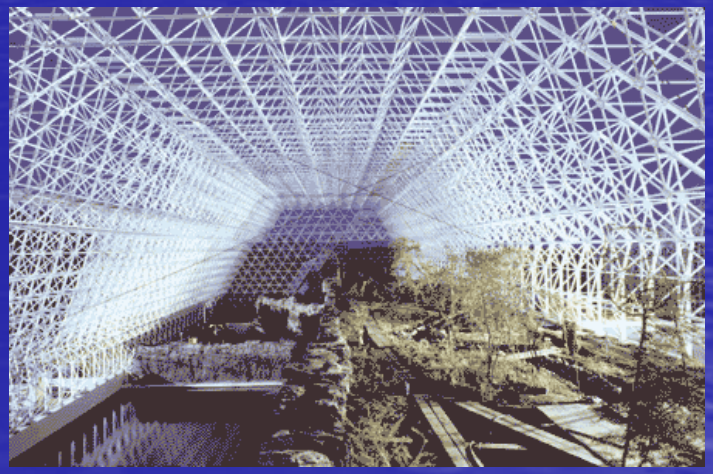
- Life itself plays a large role in the balance we see in our biosphere
- The composition of our atmosphere, for instance, would be very different if living things had not modified it through cellular respiration and photosynthesis
- As well, some of the sediments that make up our geological features come from biological sources

- Stromatolites are formations of sedimentary rocks that are composed partly of the cellular debris of organisms
- Early stromatolite layers show that there was large amounts of oxygen trapped in iron oxides
- Later layers indicate that this oxygen was no longer being trapped – it had moved out of the oceans and into the atmosphere

Replicating Earth's Biosphere

- Scientists have tried to replicate the biosphere on a small scale
- However, these experiments were not very successful because our biosphere is extremely complex

http://www.mistershape.com



http://www.theoctobergallery.com

Future Projects

- NASA programs such as ALS (Advanced Life Support) are being studied to see how plants may be grown in a space colony for food and oxygen
- Such programs also look for ways to recover usable resources from waste

The Haughton-Mars Project

- In the Canadian Arctic, NASA sponsors a research station that is intended to simulate the conditions of Mars' surface
- The purpose of such research is to study what factors need to be in place for sustainable manned missions to other planets

http://www.space.gc.ca

Human Interference

- Humans have significant ability to change our surroundings
- However, sometimes these changes cause a disruption in the flow of matter and energy, which interrupts the delicate natural balance of ecosystems
- Therefore, much work is being done into looking for ways to reduce our environmental impact

Preserving Natural Balance

- The development of alternative energy sources is one possible method of reducing the impact we have on our planet
- As well, we may need to reconsider how we use land and resources to prevent damage to the ecosystems around us