Biogeochemical Cycles, the Law of Conservation of Mass, and Mass Balances

PRELAB ASSINGMENT

Read the entire laboratory write up. Write an objective, and answer the following questions in your laboratory notebook before coming to lab. Turn the completed prelab assignment (the carbon copies of the objective and answers to the prelab questions) in as you come to lab. Read the entire laboratory write up before answering the prelab questions.

1. What are the biosphere, geosphere, atmosphere, and hydrosphere? .
2. What is a reservoir in a biogeochemical cycle and how are they illustrated in box models?
3. Examine the first box model you are given for carbon. What is the largest reservoir of carbon and what is the smallest reservoir of carbon? Are these two reservoirs the ones you expected to be largest and smallest?
4. List three transport pathways that move carbon into the atmosphere.
5. List three transport pathways that move carbon out of the atmosphere.
6. Examine the box model for nitrogen. What is the largest reservoir of nitrogen and what is the smallest reservoir of nitrogen?
7. What does it mean when we say the mass of an element in a reservoir is at steady-state?

BACKGROUND INFORMATION

The **law of conservation of matter** states that matter cannot be created nor destroyed. Recall that **matter** is anything that occupies space and has mass. **Mass** is an amount of matter and it's resistance to movement. **Elements** are the simplest form of matter and cannot be created nor destroyed. Because elements cannot be created nor destroyed we can keep track of the mass of elements as they move through the various compartments that make up the earth. We describe the various compartments of the earth as the biosphere, geosphere, hydrosphere, and atmosphere. The **biosphere** contains all of the living components of the earth such as plants and animals. The **geosphere** is made up of the rocks and soil that compose the earth. The **lithosphere** is the uppermost layer of the earth primarily made up of what is more commonly known as the earth's crust and not including the mantel and core. The **hydrosphere** is all of the water on the earth such as lakes, rivers, clouds, ice, and the oceans. The **atmosphere** is the layer of gases surrounding the earth. The movement of elements through these spheres involves biological, geological and chemical processes. Therefore, the sum of processes by which elements move through the various spheres of the earth is called **biogeochemical cycling**. The method of accounting for the mass of an element as it moves through a biogeochemical cycle is called a **mass balance**. Biogeochemical cycles are frequently represented by what are called box models. A **model** is any representation of an actual object or a system. In a box model the boxes (or in some cases pictures or sketches) represent regions where an element can be stored called **reservoirs**. Reservoirs of water include the oceans, rivers, lakes, groundwater, and glaciers. The processes by which elements move from one reservoir to another are represented in box models by arrows. These processes are called **transport pathways**. The change in the mass of an element in a reservoir over time is called its accumulation. In a mass balance the accumulation of an element in a reservoir is equal to the sum of the input processes to that reservoir minus the sum of the output processes from that reservoir. In other words the change in an element's mass within a reservoir is the sum of the mass coming into the reservoir by all possible processes minus the sum of the mass of the element leaving the reservoir by all possible processes, or accumulation = inputs – outputs. When the inputs to a reservoir equal the outputs from the reservoir the accumulation is zero and the reservoir is said to be at **steady-state**.

Human alterations to biogeochemical cycles can cause adverse environmental impacts. Alterations to the carbon cycle may cause global warming also referred to as climate change. Alterations to the nitrogen and sulfur cycles may cause air pollution and acid rain. Alterations to the nitrogen and phosphorus cycles may cause **eutrophication**. Eutrophication is excess plant growth in water bodies resulting from excess plant nutrient concentrations. Nitrogen and phosphorus are the two nutrients that most frequently limit plant growth. Have you ever seen fertilizers labeled 10-10-10 or 30-30-30? The first two numbers in a fertilizer label identify the amounts of nitrogen and phosphorus in the fertilizer. Excess plant growth in a water body is unsightly and can make the water unusable for activities such as swimming or boating. When the plants die they use up dissolved oxygen in the bottom waters of a lake, river, or region of the ocean. Dissolved oxygen is vital for fish and other aquatic organisms. Therefore excess plant growth can make lakes, rivers or parts of the ocean unsuitable for fish and other aquatic animals.

PROCEEDURE

This lab contains several box models for the carbon, nitrogen, sulfur, phosphorus and water cycles. The water cycle is called the **hydrologic cycle**.

1. Follow the steps listed below to calculate the accumulation of carbon in the atmosphere for each of the two box diagrams for the carbon cycle included in this lab.

How to perform a mass balance:

(1) Identify the reservoir for which the mass balance will be performed. In other words identify which box you will be examining.
(2) List the mass of the element for all of the pathways entering the reservoir (all of the arrows pointing into or toward the box),
(3) Add all of the numbers in your list. This value is the total inputs.
(4) List the mass of the element for all of the pathways leaving the reservoir (all of the arrows pointing out of or away from the box),
(5) Add all of the numbers in your list. This value is the total outputs.
(6) Recall that accumulation = inputs – outputs. So, subtract your total outputs from your inputs to calculate the accumulation in the reservoir of interest.
(7) If your accumulation value is positive the element's mass in this reservoir is increasing.
(8) If your accumulation value is negative the element's mass in this reservoir is decreasing.
(9) If your accumulation value is zero the element is at **steady-state** and its mass is not changing. When a reservoir is at steady-state the inputs = the outputs.

2. Repeat the steps above to (a) calculate the accumulation of sulfur in the atmosphere over the continents, (b) the accumulation of nitrogen in the ocean, and (c) the accumulation of water in the US.

QUESTIONS
Answer all questions.

1. Briefly describe what a biogeochemical cycle is?

2. According to these box models is the mass of carbon in the atmosphere increasing or decreasing?

3. Did you get the same value for the accumulation of carbon in the atmosphere for both models?

4. Do you think the actual value for the accumulation of carbon in the atmosphere can be determined exactly and why or why not?

5. What environmental problem(s) can result from an increasing mass of carbon in the atmosphere?

6. According to this box model is the mass of sulfur in the atmosphere increasing or decreasing and by how much?

7. What environmental problem(s) can result from an increasing mass of sulfur in the atmosphere?

8. According to this box model is the mass of nitrogen in the ocean increasing or decreasing and by how much?

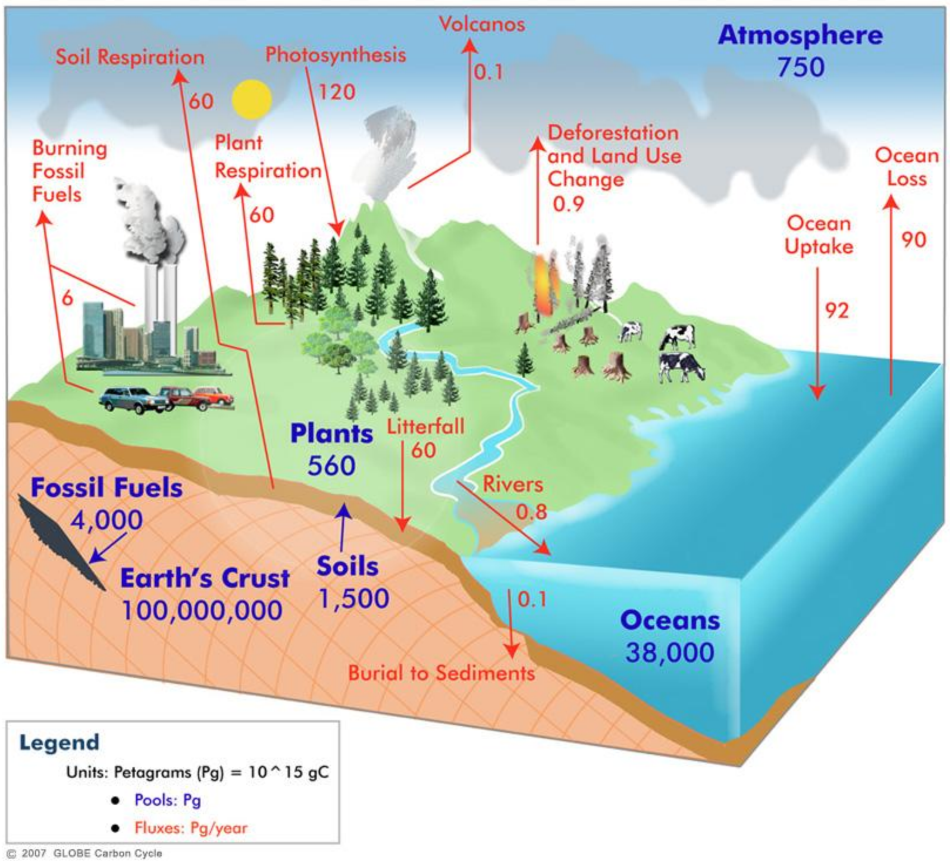
9. What environmental problem(s) can result from an increasing mass of nitrogen in the ocean?

10. What environmental problem(s) can result from an increasing mass of phosphorus in the ocean?

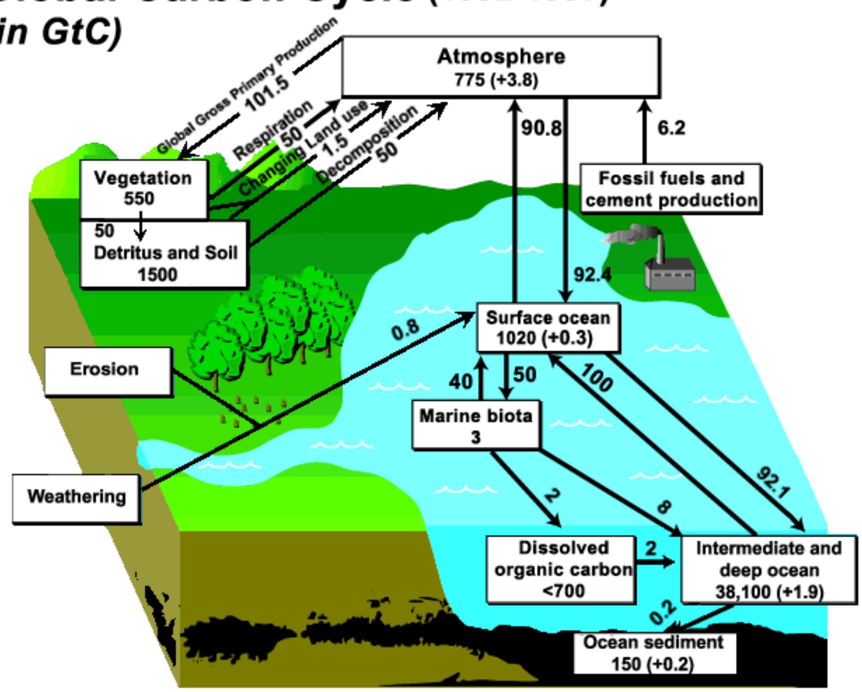
11. According to this model is the volume of water in the US increasing or decreasing and by how much?

12. What problems could result from a decreasing volume of water in the US?

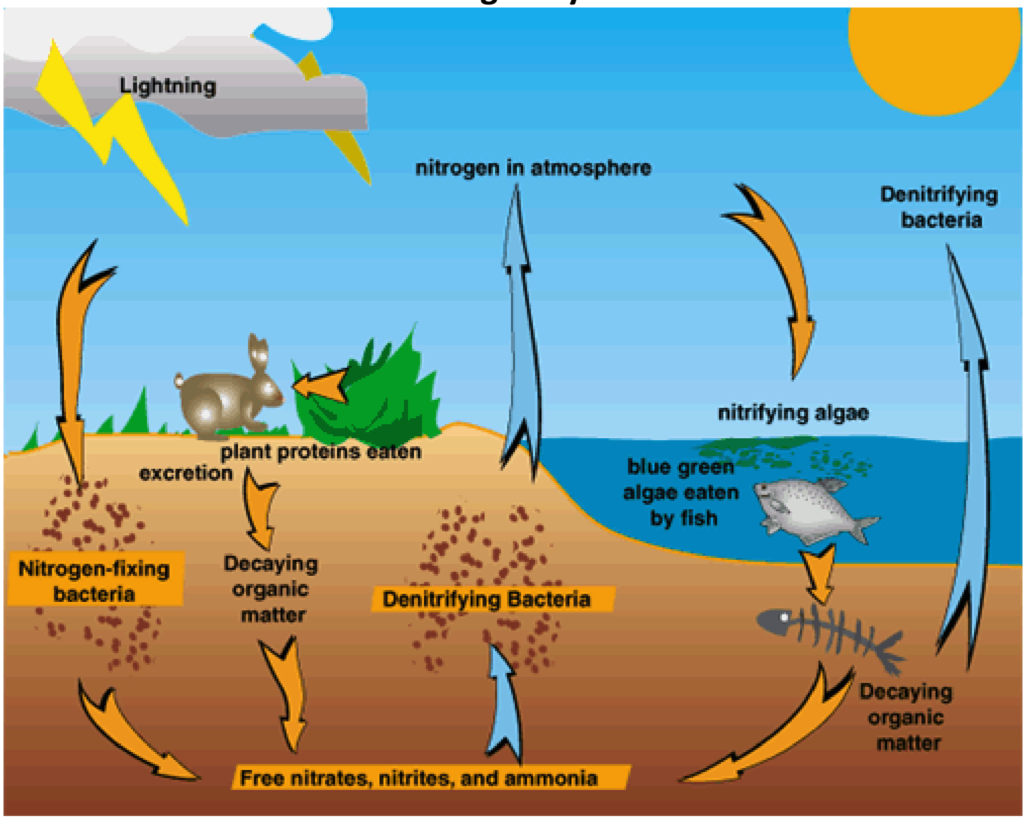
Global Carbon Cycle

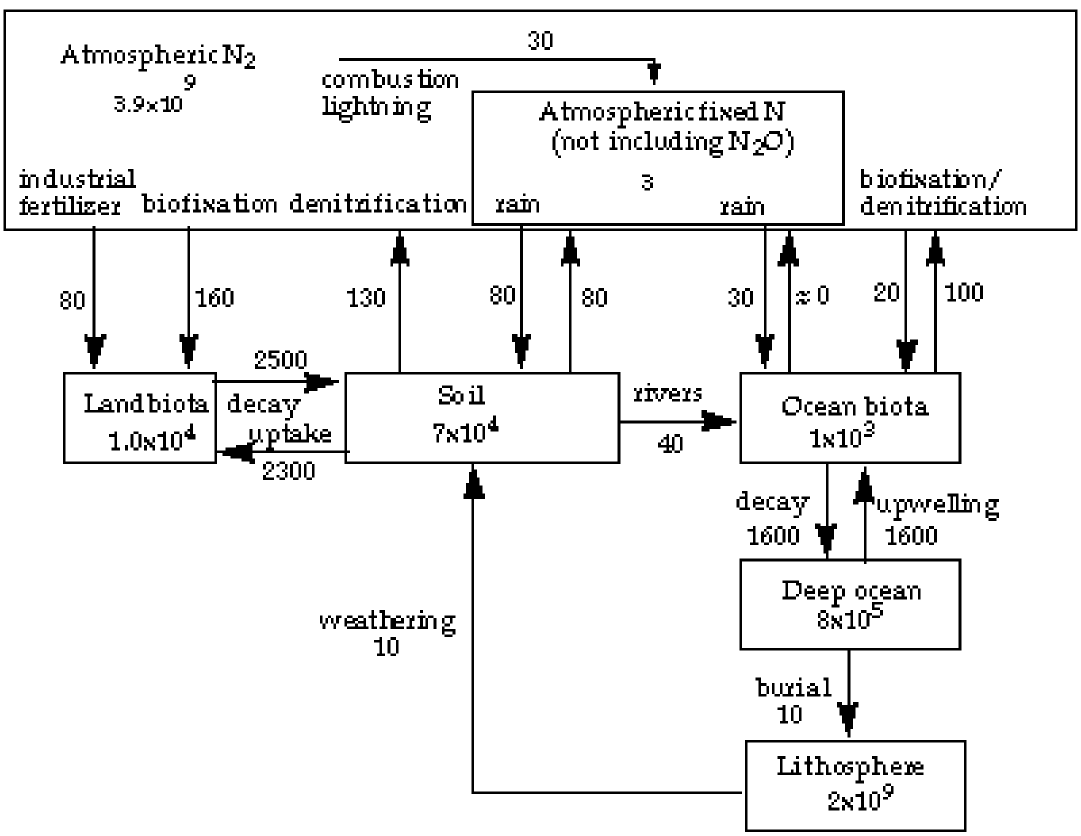


Global Carbon Cycle (1992-1997)
(in GtC)

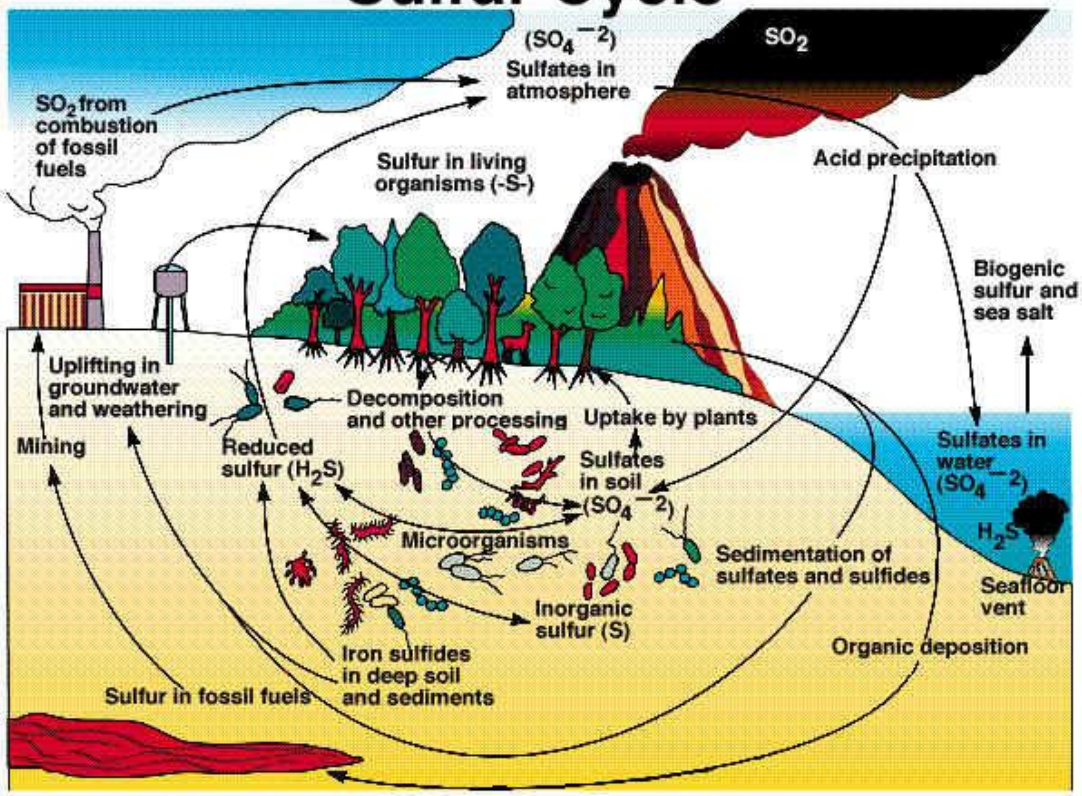


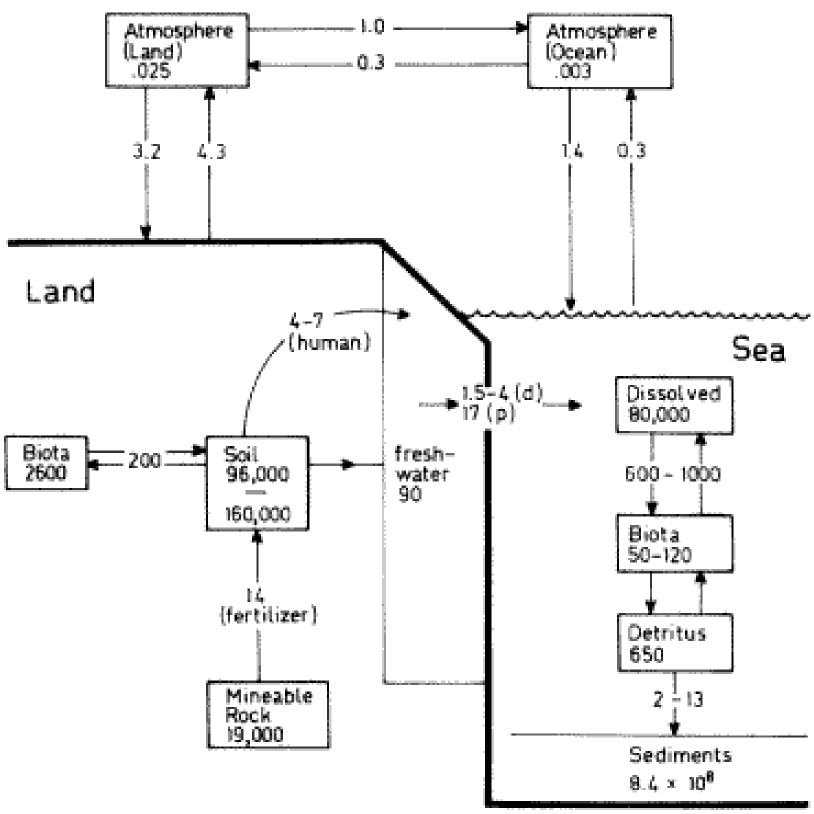
Nitrogen Cycle



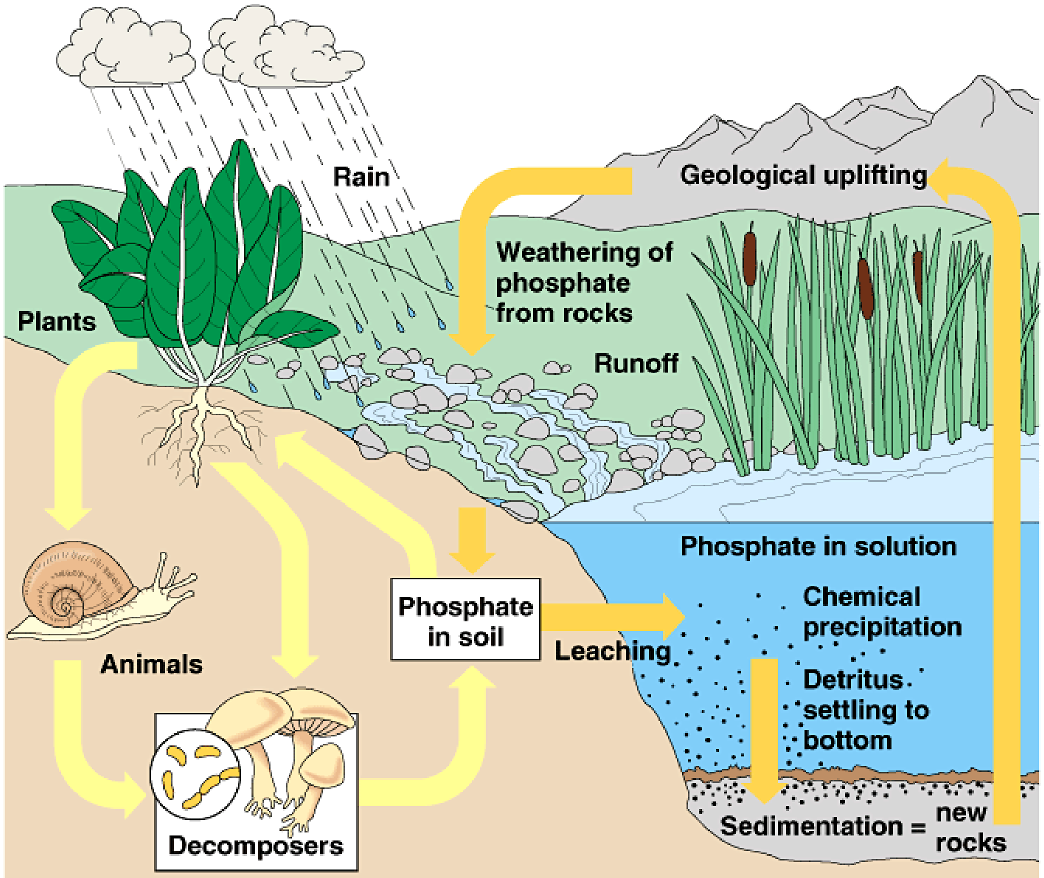


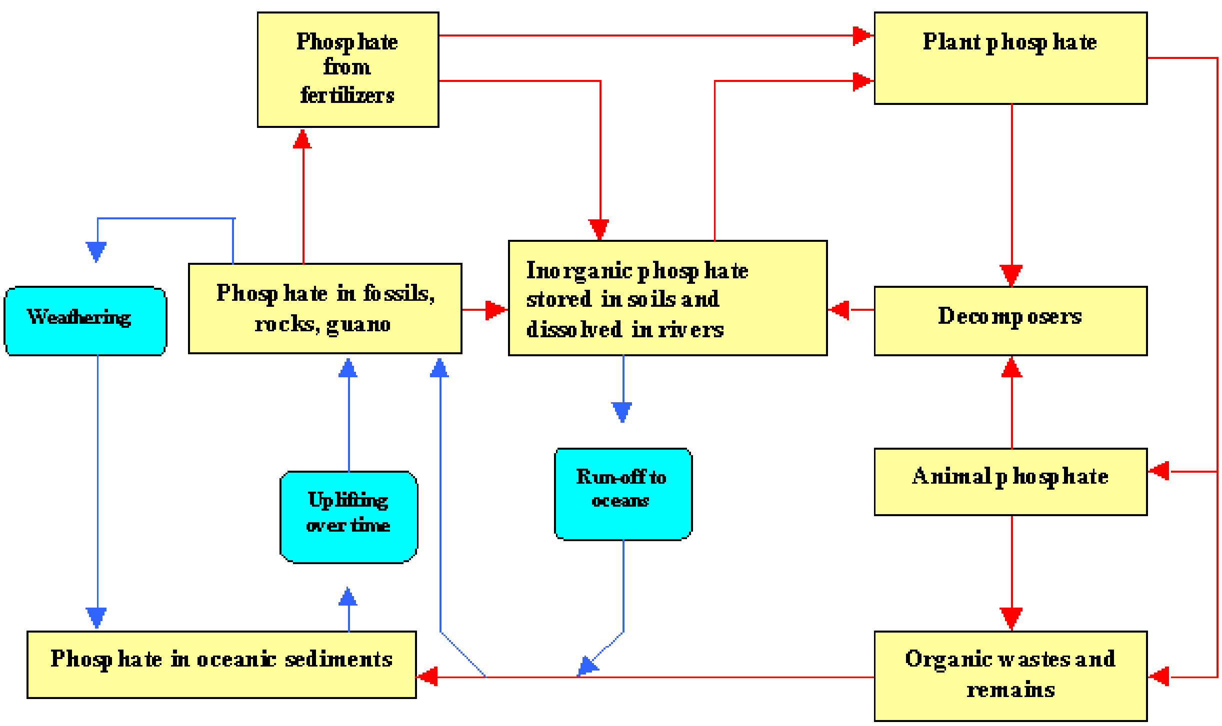
Sulfur Cycle

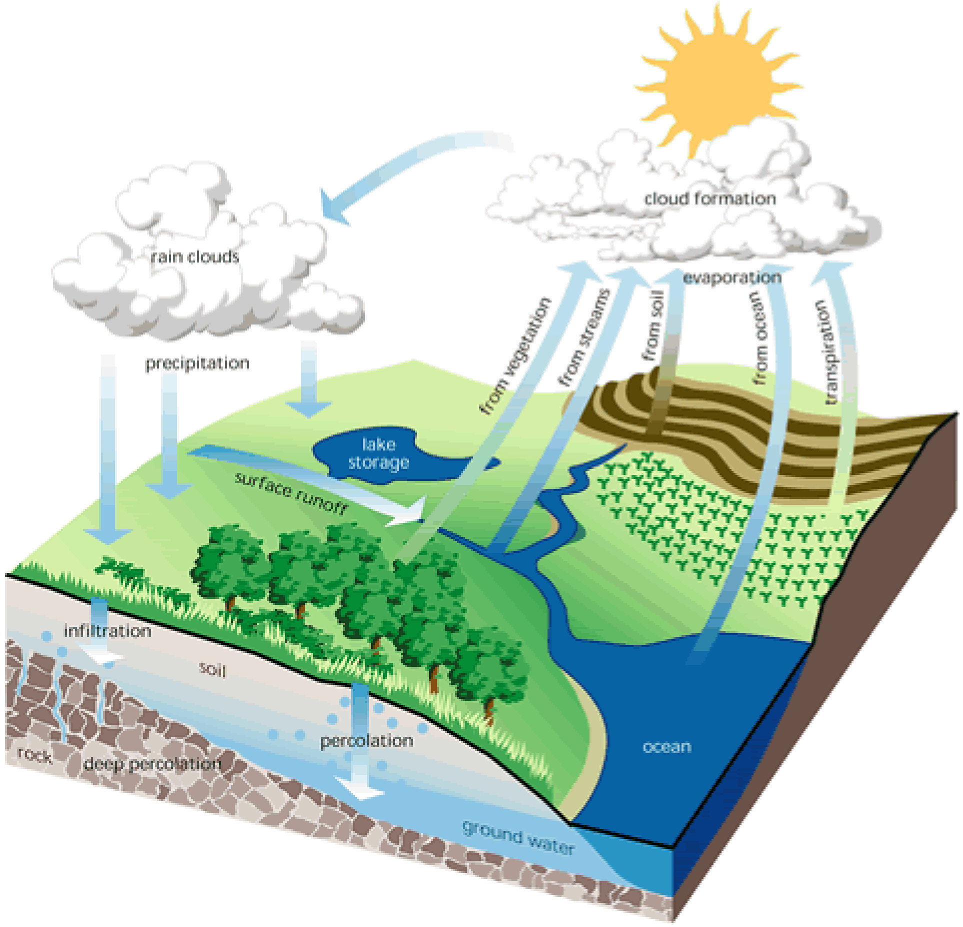




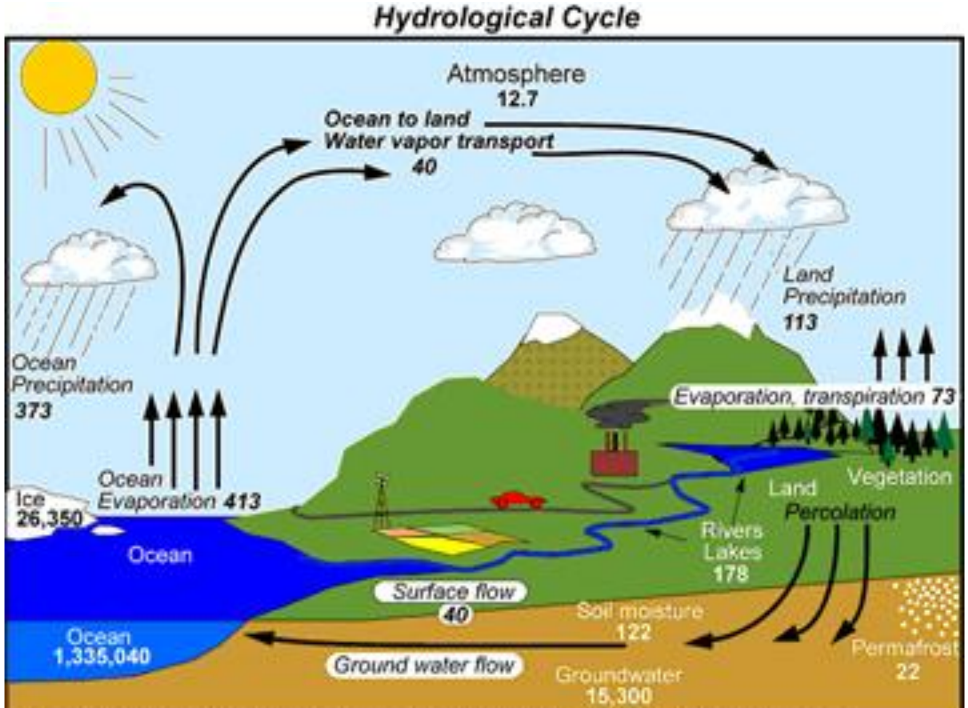
Phosphorus Cycle





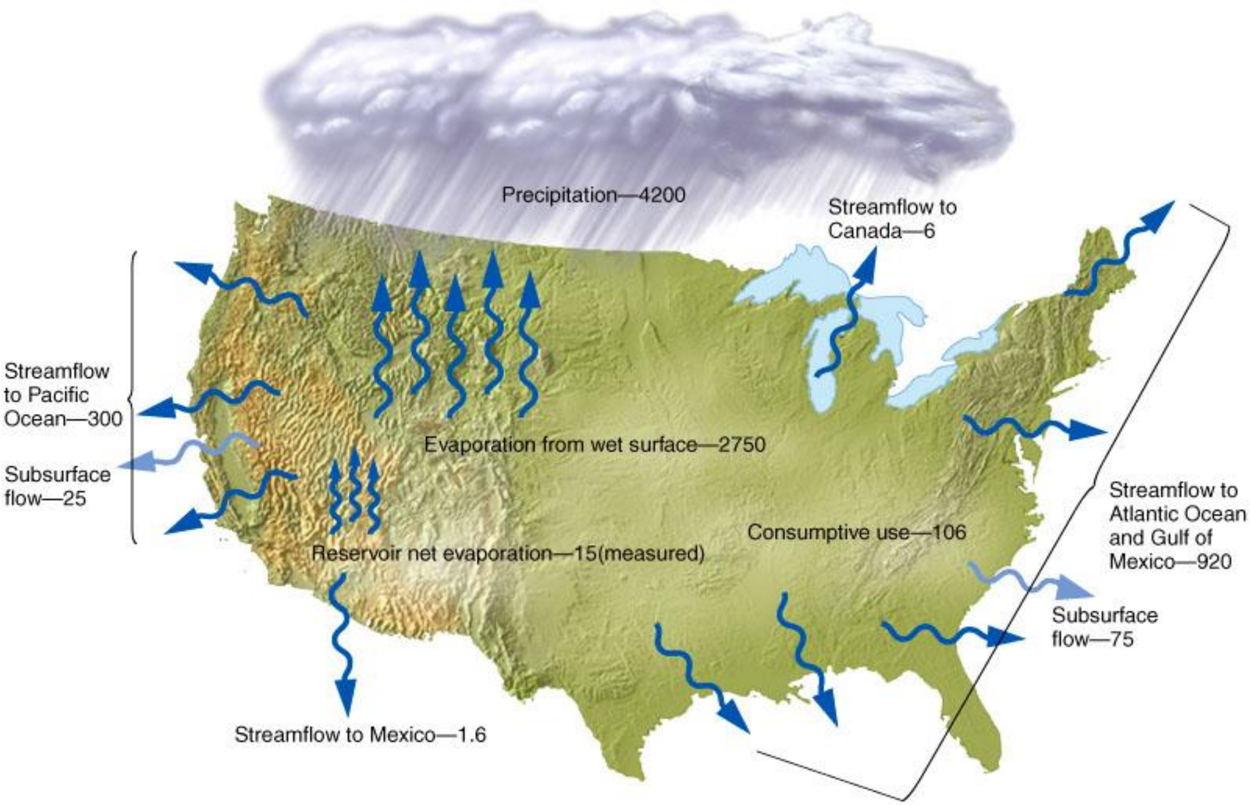


Hydrological Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

Box Model for Water in the US



Note that precipitation is the only input in this system.