Chapter 4

Ecosystems and the Physical Environment

**Lecture Outline:**

I. Biogeochemical cycles

A. The carbon cycle

i. 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(CO2), the ocean as carbonate and bicarbonate (CO32-, HCO3-) and sedimentary rock as calcium carbonate (CaCO3)

2. Proteins, carbohydrates, and other molecules essential to life contain carbon

1. Carbon makes up approximately 0.04% of the atmosphere as a gas

ii. Carbon primarily cycles through both biotic and abiotic environments via photosynthesis, cellular respiration and combustion (CO2)

1. Photosynthesis incorporates carbon from the abiotic environment (CO2) into the biological compounds of producers (sugars)

2. Producers, consumers and decomposers use sugars as fuel and return CO2 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)

1. The carbon-silicate cycle (which occurs on a geological timescale involving millions of years) returns CO2 to the atmosphere through volcanic eruptions and both chemical and physical weathering processes

B. The nitrogen cycle

i. The global circulation of nitrogen between organisms and the abiotic environment is know as the nitrogen cycle

1. Atmospheric nitrogen (N2) 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 (N2)

ii. Five steps of the nitrogen cycle

1. Nitrogen fixation

a. Conversion of gaseous nitrogen (N2) to ammonia (NH3)

b. Nitrogen-fixing bacteria (including cyanobacteria) fixes nitrogen in soil and aquatic environments (anaerobic process)

c. Combustion, volcanic action, lightning discharges, and industrial processes also fix nitrogen

2. Nitrification

a. Conversion of ammonia (NH3) or ammonioum (NH4+) to nitrate (NO3-)

b. Soil bacteria perform nitrification in a two-step process (NH3 or NH4+ is converted to nitrite (NO2-) then to NO3-)

c. Nitrifying bacteria is used in this process

3. Assimilation

a. Plant roots absorb NO3-, NO3 or NO4+ and assimilate the nitrogen of these molecules into plant proteins and nucleic acids

b. Animals assimilate nitrogen by consuming plant tissues (conversion of aminio acids to proteins)

c. This step does not involve bacteria

4. Ammonification

a. Conversion of biological nitrogen compounds into NH3 and NH4+

b. NH3 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 NO3- to N2

b. Anaerobic denitrifying bacteria reverse the action of nitrogen-fixing and nitrifying bacteria

C. The phosphorus cycle

i. 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

1. Animals obtain phosphorus from their diets, and decomposers release inorganic phosphate into the environment
2. Once in cells, phosphates are incorporated into biological molecules such as nucleic acids and ATP (adenosine triphosphate)

iii. This cycle has no biologically important gaseous compounds

D. The sulfur cycle

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

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

1. Sea spray, forest fires and dust storms deliver sulfates (SO42-) into the air
2. Volcanoes release both hydrogen sulfide (H2S) and sulfur oxides (Sox)

iii. A tiny fraction of global sulfur is present in living organisms

1. Sulfur is an essential component of proteins

2. Plant roots absorb SO42- and assimilate it by incorporating the sulfur into plant proteins

1. Animals assimilate sulfur when they consume plant proteins and covert them to animal proteins

iv. Bacteria drive the sulfur cycle

E. The hydrologic cycle

i. The hydrologic cycle is 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 cylce results in a balance between water in the ocean, on the land, and in the atmosphere
3. Water moves from the atmosphere to the land and ocean in the form of precipitation
4. Water enters the atmosphere by evaporation and transpiration
5. The volume of water entering the atmosphere each year is about 389,500 km3

II. Solar Radiation

A. The sun powers biogeochemical cycles (i.e., hydrologic, carbon) and is the primary determinant of climate

B. Most of our fuels (i.e., wood, oil, coal, and natural gas) represent solar energy captured by photosynthetic organisms

C. Approximately one billionth of the total energy released by the sun strikes our atmosphere

1. Clouds, snow, ice, and the ocean reflect about 31% of the solar radiation that falls on Earth

ii. Albedo is the proportional reflectance of solar energy from the Earth’s surface

1. Glaciers and ice sheets have a high albedo and reflect 80 to 90% of the sunlight hitting their surfaces

2. Asphalt pavement and buildings have a low albedo (10 to 15%)

3. Forests have a low albedo (about 5%)

iii. 69% 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

D. Temperature changes with latitude

i. 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

ii. 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

E. Temperature changes with season

i. Season’s are determined primarily by Earth’s inclination on its axis

ii. March 21 to September 22 the Northern Hemisphere tilts toward the sun (spring/summer)

iii. September 22 to March 21 the Northern Hemisphere tilts away from the sun (fall/winter)

III. The Atmosphere

1. The atmosphere is an invisible layer of gases that envelops Earth and protects it’s surface from lethal amounts of high energy radiation (i.e., UV rays, X rays and cosmic rays)

i. 99% of dry air is composed of oxygen (21%) and nitrogen (78%)

ii. Argon, carbon dioxide, neon, and helium make up the remaining 1%

B. The interaction between atmosphere and solar energy is responsible for weather and climate

C. Layers of the atmosphere vary in altitude and temperature with latitude and season

i. Troposphere

1. Closest layer to Earth’s surface

2. Temperature decreases with increasing altitude

3. Extends to a height of approximately 10 km

4. Weather, including turbulent wind, storms, and most clouds occurs in the troposphere

ii. Stratosphere

1. Temperature is more or less uniform, but does increase with increasing altitude

2. Extends from 10 to 45 km above Earth's surface

3. Steady wind, but no turbulence (commercial jets fly here)

4. Contains ozone layer

iii. Mesosphere

1. Temperatures drop steadily (to lowest temperature in atmosphere)

2. Extends from 45 to 80 km above Earth's surface

iv. Thermosphere

1. Very hot (nearly 1000˚C or more)

2. Extends from 80 to 500 km

3. Aurora borealis occurs in this level of the atmosphere

v. Exosphere

1. The outermost layer of the atmosphere

2. Begins about 500 km above Earth's surface

3. The exosphere continues to thin until it converges with interplanetary space

D. Differences in temperature caused by variations in the amount of solar energy reaching different locations on Earth drive the circulation of the atmosphere

1. Air is heated by warm surfaces near the equator cause it to rise and expand

ii. Due to subsequent chilling, air tends to sink to the surface at about 30 degrees north and south latitudes

iii. Similar upward movements of warm air and its subsequent flow toward the poles occur at higher latitudes, farther from the equator

iv. This continuous turnover moderates temperatures over Earth's surface

E. Surface winds

i. Horizontal movements resulting from differences in atmospheric pressure and from the Earth's rotation are called winds

ii. Winds tend to blow from areas of high atmospheric pressure to areas of low pressure (greater difference = stronger winds)

1. The influence of Earth's rotation, which tends to turn fluids (air and water) toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere is called the Coriolis effect

iv. The atmosphere has three prevailing winds

1. Polar easterlies blow from the northeast near the North Pole or from the southeast near the South Pole

2. Westerlies generally blow in the midlatitudes from the southwest in the Northern Hemisphere or the northwest in the Southern Hemisphere

1. Trade winds (tropical winds) generally blow from the northeast in the Northern Hemisphere or the southeast in the Southern Hemisphere

IV. The Global Ocean

A. The global ocean is a single, continuous body of salt water that covers nearly ¾ of the Earth's surface

B. Geographers divide it into four sections separated by continents (Pacific, Atlantic, Indian, and Arctic oceans)

C. Prevailing winds blowing over the ocean's surface and the position of land masses influence patterns of circulation

i. Currents are mass movements of surface-ocean water

ii. Gyres are large, circular ocean current systems that often encompass an entire ocean basin

iii. The Coriolis effect also influences the paths of surface-ocean currents

B. The varying density of seawater affects deep-ocean currents and creates a vertical mixing of ocean water

1. The ocean conveyor belt moves cold, salty deep-sea water from higher to lower latitudes

ii. The ocean conveyor belt affects regional and possibly global climate and shifts from one equilibrium state to another in a relatively short period (years to decades)

C. Ocean interactions with the atmosphere are partly responsible for climate variability

i. El Niño-Southern Oscillation (ENSO) is a periodic, large scale warming of surface waters of the tropical eastern Pacific Ocean that temporarily alters both ocean and atmospheric circulation patterns

1. Most ENSOs last 1 to 2 years

2. ENSO has a devastating effect on fisheries off South America and alters global air currents (causing severe and unusual weather worldwide)

ii. La Niña occurs when the surface water temperature in the eastern Pacific Ocean becomes unusually cool, and westbound trade winds become unusually strong

1. La Nina often occurs after an ENSO

2. La Nina also affects weather patterns around the world, but its effects are more difficult to predict

V. Weather and Climate

A. Weather

i. Weather refers to the conditions in the atmosphere at a given place and time

ii. Weather includes temperature, atmospheric pressure, precipitation, cloudiness, humidity, and wind

iii. Weather is continuously changing (hour to hour, day to day)

B. Climate

1. The average weather conditions that occur in a place over a period of years is termed climate
2. Climate is determined by temperature and precipitation

iii. Other climate factors include wind, humidity, fog, cloud cover, and occasionally lightning

1. Precipitation
2. Precipitation refers to any form of water that falls from the atmosphere
3. Examples of precipitation include rain, snow sleet and hail
4. Precipitation has a profound effect on the distribution and kinds of organisms present
5. Rain shadows, tornadoes and tropical cyclones (hurricanes/typhoons) are extreme forms of weather that can have a significant impact on regional climate

VI. Internal Planetary Processes

1. Plate tectonics
   1. Plate tectonics is the study of the dynamics of Earth’s lithosphere (outermost rigid rock layer)

1. The lithosphere is composed of seven large plates, plus a few smaller ones

2. The plates float on the asthenosphere (the region of the mantle where rocks become hot and soft)

* 1. Plate boundaries are typically sites of intense geologic activity – earthquakes and volcanoes are common in such a region

1. Earthquakes

i. Forces inside Earth sometimes push and stretch rocks in the lithosphere

1. The energy is released as seismic waves causing earthquakes

2. Most earthquakes occur along fault zones

3. More than 1 million earthquakes are recorded each year

ii. Landslides and tsunamis are some of the side effects of earthquakes

1. Volcanoes
   1. When one plate slides under or away from an adjacent plate, magma may rise to the surface, forming a volcano
   2. Volcanoes occur at subduction zones, spreading centers, and above hot spots