GREEN GENERATION -2015 & 2016
PART ONE – GENERAL PRINCIPLES OF ECOLOGY

KAREN L. LANCOUR
National Rules Committee Chairman – Life Science

Green Generation is designed for a two year rotation – the first year will cover aquatic issues, air quality issues and climate change while the second year will cover terrestrial issues and population growth issues.

Part 1: **Review of the General Principles of Ecology**

A. General Principles of Ecology - food webs and trophic pyramids, nutrient cycling, community interactions, population dynamics, species diversity and indicator species **Note: life history strategies (age structure, survival curves, life tables, succession, R and K strategies) for division C only**
B. Overview of Aquatic Environments – freshwater, estuaries, marine **(2015)**
C. Overview of Terrestrial Environments – forests, grasslands, deserts **(2016)**

GENERAL PRINCIPLES OF ECOLOGY

- **Ecology and the abiotic environment**
  - ecology – introduction and terms
    - **ecology** = how organisms interact with one another and with their environment
    - **environment** = biotic (other organisms) and abiotic (physical factors)
  - natural selection – adaptation
  - soils and nutrients
  - climate
- **Four levels of ecological organization:**
  - **Population** - group of individuals of the same species occupying a common geographical area
  - **Community** - two or more populations of different species occupying the same geographical area Populations and communities include only biotic factors
  - **Ecosystem** - a community plus its abiotic factors, e.g. soil, rain, temperatures, etc.
  - **Biosphere** - the portion of the earth that contains living species. It includes the atmosphere, oceans, soils and the physical and biological cycles that affect them
- **Ecology of individual organisms**
  - physiological ecology
  - temperature and water balance
  - light and biological cycles
  - physiological ecology and conservation

Ecology of Populations

- **Population Ecology** = the study of how populations interact with their environment
- **Population** = group of individuals of the same species occupying a common geographical area
- **Habitat** - where a species normally lives

Characteristics of populations - Each population has certain characteristics:

- **Population size** = number of individuals making up its gene pool
- **Population density** = number of individuals per unit of area or volume, e.g.
- persons/square mile
- **Population distribution** = the general pattern in which the population members are dispersed through its habitat, may be: ***Clumped*** (most common), ***Uniformly*** dispersed (rare), or ***Randomly*** dispersed
- **Age structure** defines the relative proportions of individuals of each age: *Pre-reproductive*, ***Reproductive***, and ***Post-reproductive***
- **Population size and growth**

Population size is dependent on births, immigration, deaths, and emigration

- **Zero population growth** designates a near balance of births and deaths
- **Exponential growth:** If birth and death rates of a population remain constant they can be combined into one variable ***r*** = net reproduction per individual per unit time (rate of increase)
- **Population growth may be represented mathematically as: *G = rN*** Where G = population growth per unit time, r = rate of increase and N= the number of individuals. When plotted against time a graph in the shape of a J will be obtained denoting **exponential growth**, i.e. one variable increases much faster than the other
- As long as per capita birth rates remain even slightly above per capita death rates, a population will grow exponentially - with ever-increasing rates and shorted "doubling times"
- It took 2 million years for the world's human population to reach 1 billion, yet it took only 12 years to reach the fifth billion
- If a population lives under ideal conditions it may display its **biotic potential** - the maximum rate of increase under ideal conditions. Few populations live under ideal conditions because a number of factors limit their growth
- **Limiting factor** - any resource that is in short supply, e.g. food, minerals, light, living space, refuge from predators, etc.
- **Carrying capacity** = maximum number of individuals of a species or population a given environment can sustain. Each habitat or area can only support so many individuals
- Because of limiting factors populations rarely exhibit J shaped growth curves
- **Logistic growth**
- Early on populations will exhibit very rapid growth but as they near the carrying capacity they will level off is called **logistic growth** and it produces an **S shaped curve**
- Logistic growth is **density dependent**, i.e. the growth is affected by the density of individuals.
- *For example* - 26 reindeer were introduced onto an island off the coast of Alaska in 1910. Within 30 years the herd increased to 2,000. However, overgrazing reduced the food supply and the population crashed to 8 animals by 1950
- *High density and overcrowding* put individuals at greater risk of being killed, e.g. predators, parasites and pathogens have greater numbers of prey and hosts in a smaller area to interact
- ***Bubonic plague*** swept through Europe in the 14th century, killing at least 25 million. The disease spread rapidly in overcrowded cities where sanitary conditions were poor and rats were abundant
- Population size and growth may also be controlled by **density-independent factors,** e.g. adverse weather, floods, droughts, cold temperatures

Life history patterns

- Not all individuals in a population are the same age.
- Different populations may have very different **age structures** and these will determine their growth patterns
- Age structure refers to the proportions of pre-reproductive, reproductive and post- reproductive age individuals in a population. The age structure of a population will determine its future
- Each species has a characteristic life span and the probability of dying increases with age

- Population ecologists, as well as insurance companies track **cohorts** and construct **life tables** for populations
- **Cohort =** a group of individuals born at the same time, e.g. baby boomers are a large group of individuals born just after World War II
- A **life table** is an age-specific death schedule. Such a schedule is often converted to a more palatable **survivorship** schedule. For each age interval there is an predicted life expectancy or survivorship
- Ecologists divide populations into age classes and assign birth rates and mortality risks to each class. Absolute population numbers mean very little unless their age structure is known
- For example, population A might have many more members than population However, all the members of A might be post-reproductive, whereas population B might consist of mostly pre-reproductive and reproductive age individuals. Population A might be in danger of extinction.

Life history strategies

- **r-selected organisms** - put most of their energy into rapid growth and reproduction. This is common of organisms that occupy unpredictable environments, e.g. weeds are usually annuals with rapid growth and early reproduction. They produce large number of seeds containing few stored nutrients
- **K-selected** organisms - put most of their energy into growth. They are common in stable environments near carrying capacity, e.g. long lived trees such as redwoods take many years of growth to reach reproductive age

Ecology of Communities

Community = two or more populations of different species occupying the same geographical area

- **Community Ecology** = the study of how different species interact within communities
- **Habitat** = the physical place where an organism lives, e.g. a pine forest or fresh water lake
- Some organisms, particularly migratory birds require more than one habitat
- **Niche** = the functional role of an organism in a community, its job or position
- Each species has a **potential niche** - what they could do with no competitors or resource limitations but due to competition and/or resource limitations, most organisms occupy a **realized niche**, the part of the fundamental niche that a species actually occupies in nature

Species interactions

- **Neutral** - two species that don't interact at all
- **Commensalism** - beneficial to one species but neutral to another, e.g. birds that nest in trees, epiphytes (plants that grow on other plants) such as tropical orchids
- **Mutualism** - an interaction that is beneficial to both species, e.g. plants and their pollinators, plants and animals that disperse their seeds, certain fungi and plant roots
- **Parasitism** - an interaction that benefits one species and is detrimental to another. Note that the host is generally not killed.
- **Predation** - an interaction beneficial to one species and detrimental to another. In this case the prey is killed. Predators are those that kill and eat other animals. Although many organisms eat plants they usually don't kill them because they are a constant supply of food. Prey are killed and eaten.

Competitive interactions

- Competition has negative effect on both organisms competing for a resource
- Because resources are limited in nature there will always be competition for them
- Competition is the driving force of evolution, those that win leave more offspring

- Types of competition:
  - **Intraspecific** - competition among individuals of the same species, e.g. humans compete against other humans
  - **Interspecific** - competition between different species, e.g. humans compete against a wide variety of species seeking to utilize our food resources
  - The theory of **competitive exclusion** maintains that species who utilize the same resources cannot coexist indefinitely - the "one niche, one species" concept
  - **resource partitioning -** the resources are divided, permitting species with similar requirements to use the same resources in different areas, ways and/or times

Community stability

- Communities are assemblages of many different species occupying the same geographical area
- Communities are not static, they gradually change over time because the environment changes and species themselves tend to also change their habitats

Ecology of Ecosystems

Ecosystem = a community of organisms interacting within a particular physical environment or an ecosystem is a community plus its abiotic factors, e.g. soil, rain, temperatures, etc. Virtually all energy on earth comes from the sun, via **photoautotrophs** (primarily plants), and it is ultimately distributed throughout ecosystems.

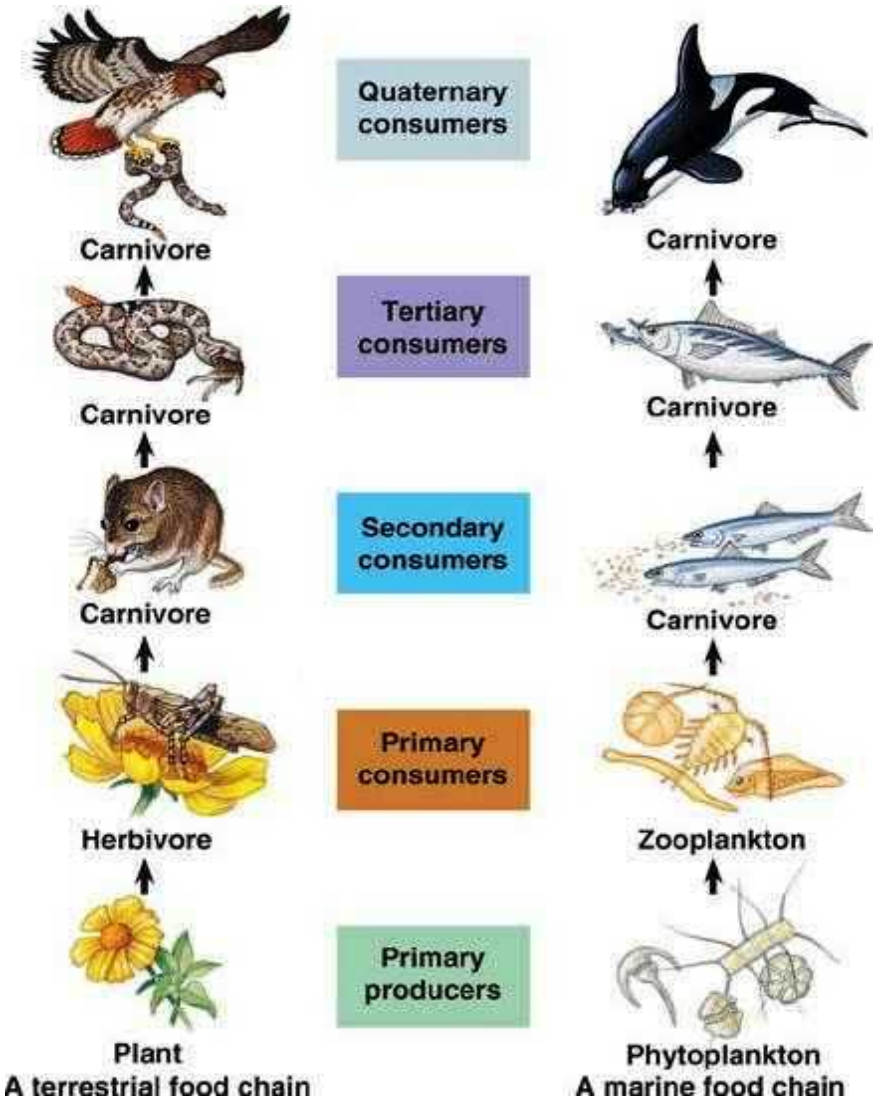
- **Primary producers** are the autotrophs
- All other organisms are **consumers** Consumers which eat plants are called **herbivores**
- Consumers which eat animals are called **carnivores** Organisms such as humans, which eat both plants and animals, are called **omnivores**
- **Decomposers,** which includes fungi and bacteria, obtain their energy by breaking down the remains or products of organisms
- **Detritivores** are decomposers which eat **detritus** - organic wastes and dead organisms

Structure of ecosystems

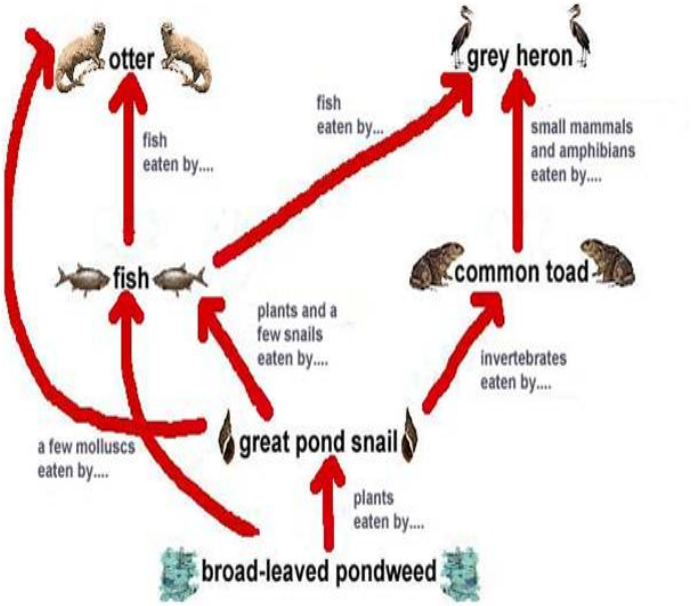
- Energy flows through ecosystems via **food webs**, intricate pathways of energy flow and material cycling
- Ecosystems are arranged by **trophic** (feeding) levels between various producers, the autotrophs, and consumers, the heterotrophs:
- **First trophic level** - contains the autotrophs which build energy containing molecules
- They also absorb nitrogen, phosphorous, sulfur and other molecules necessary for life
- They provide both an **energy-fixation** base as well as the **nutrient-concentration** base for ecosystems
- Two types of autotrophs: Photoautotrophs - plants and some Protista
- Chemoautotrophs - bacteria
- **Second trophic level -** contains the primary consumers which eat the primary producers including herbivores, decomposers and detritivores, e.g. insects, grasshoppers, deer and wildebeest
- **Third trophic level** - contains the secondary consumers, primary carnivores which eat the herbivores, e.g. mice, spiders and many birds
- **Fourth trophic level** - contains the tertiary consumers, secondary carnivores who eat the primary carnivores, e.g. weasel, owl, sharks and wolves.
- Linear **food chains** as described above are probably rare in nature because the same food source may be part of several interwoven food chains and many organisms have several food sources
- Decomposers play a key role in ecosystems but are often not represented on food chains

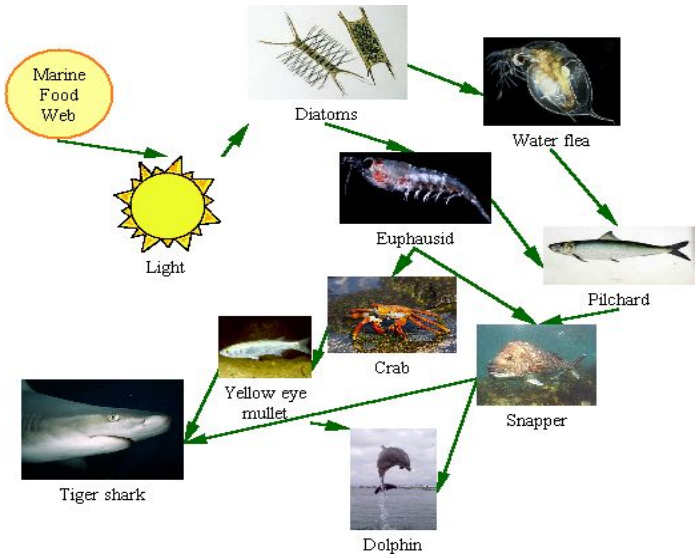
Food Chains

- **Producer**
- **1st order Consumer or Herbivore**
- **2nd order Consumer or 1st order Carnivore**
- **3rd order Consumer or 2nd order Carnivore**
- **4th order Consumer or 3rd order Carnivore**
- **Decomposers – consume dead and decaying matter as bacteria**



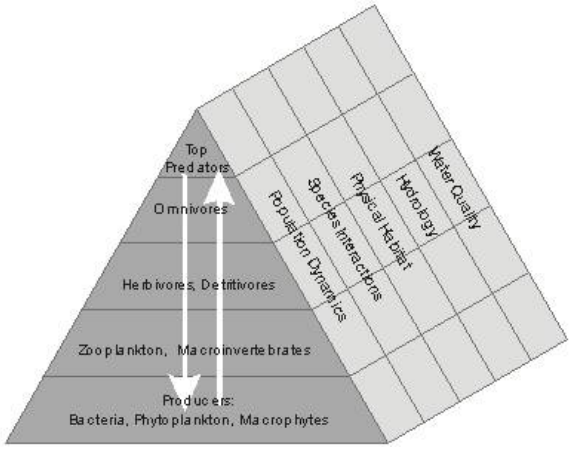
Food Web – many food chains in relation to each other





Energy flows through ecosystems via **food webs**, intricate pathways of energy flow and material cycling

- Ecosystems are arranged by **trophic** (feeding) levels between various producers, the autotrophs, and consumers, the heterotrophs:
- **First trophic level** - contains the autotrophs which build energy containing molecules
- They also absorb nitrogen, phosphorous, sulfur and other molecules necessary for life
- They provide both an **energy-fixation** base as well as the **nutrient-concentration** base for ecosystems
- Two types of autotrophs: Photoautotrophs - plants and some Protista
- Chemoautotrophs - bacteria
- **Second trophic level -** contains the primary consumers which eat the primary producers including herbivores, decomposers and detritivores, e.g. insects, grasshoppers, deer and wildebeest
- **Third trophic level** - contains the secondary consumers, primary carnivores which eat the herbivores, e.g. mice, spiders and many birds
- **Fourth trophic level** - contains the tertiary consumers, secondary carnivores who eat the primary carnivores, e.g. weasel, owl, sharks and wolves.
- Linear **food chains** as described above are probably rare in nature because the same food source may be part of several interwoven food chains and many organisms have several food sources

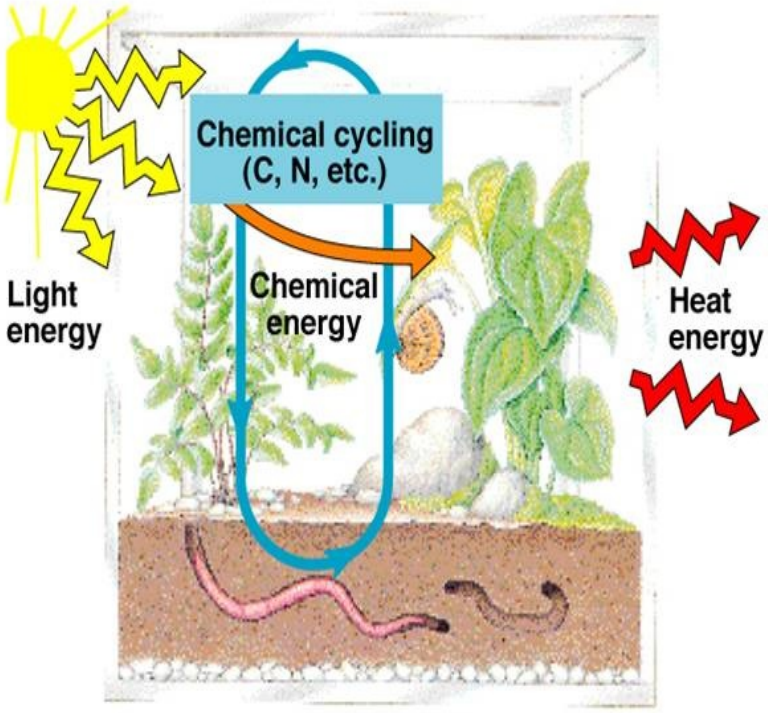


Energy flow though ecosystems

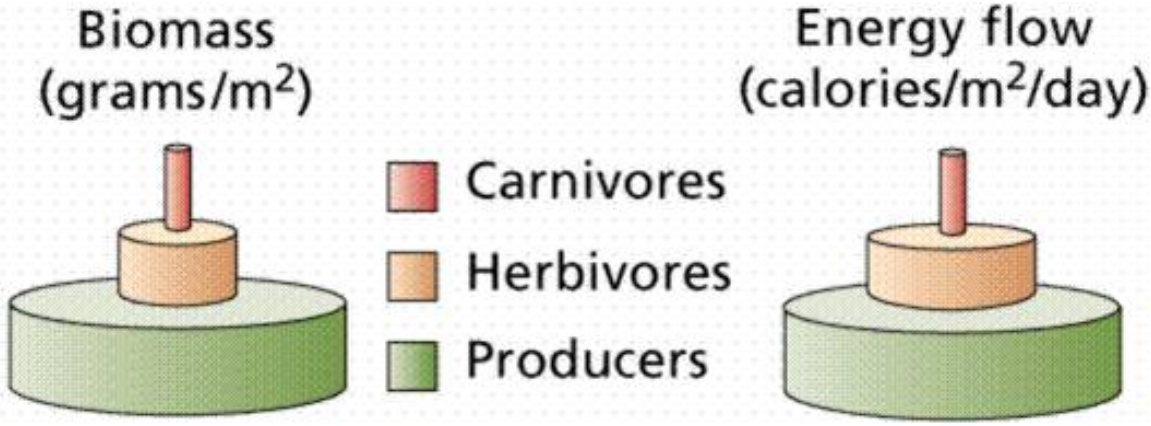
- **Gross primary productivity** = the rate at which the primary producers capture and store energy per unit time since the primary producers expend energy during respiration the **net primary productivity** is considerably lower than the gross productivity
- Productivity is usually measured as biomass (dry weight of organic matter) per unit area per a specified time interval, e.g. ***kg/m^2/yr***
- The trophic structure of an ecosystem is often represented by an **ecological pyramid**, with the primary producers at the base and the other levels above
- Most of the food eaten by organisms is converted to biomass, or used to maintain metabolic functions, or lost as heat, only about **10% of the energy** makes it to the next level
- This massive energy loss between trophic levels explains why food chains can't contain more than a few levels It takes billions of primary producers (plants) to support millions of primary consumers, which support a few secondary consumers. This is why there are so few large carnivores on earth
- An **energy pyramid** is a more useful way to depict an ecosystem's trophic structure
- Each block of the pyramid is proportional to the amount of energy it contains
- Pyramids may also represent biomass or numbers of individuals
- The energy pyramid concept helps explain the phenomenon of **biological magnification** - the tendency for toxic substances to increase in concentration at progressively higher levels of the food chain

Energy vs. Nutrients

- Nutrients are **cyclic** – biogeochemical cycles
- Energy flow is **one way**



Biomass and Energy Pyramids



Ecological succession = a directional, cumulative change in the species that occupy a given area, through time

- **Primary succession -** starts from barren ground, e.g. new islands or de-glaciated areas
- **Secondary succession** - starts from disturbed areas, e.g. abandoned farm land or storm ravaged land
- Succession starts with a **pioneer community**, the first organisms to occupy an area
- Several **transitional communities** may come and go
- A **climax community**, a stable, self-perpetuating array of species in equilibrium with one another and their habitat, will form.

Biodiversity - Biodiversity, the number of different species within an area, is greatest in tropical areas near the equator and it decreases towards the poles

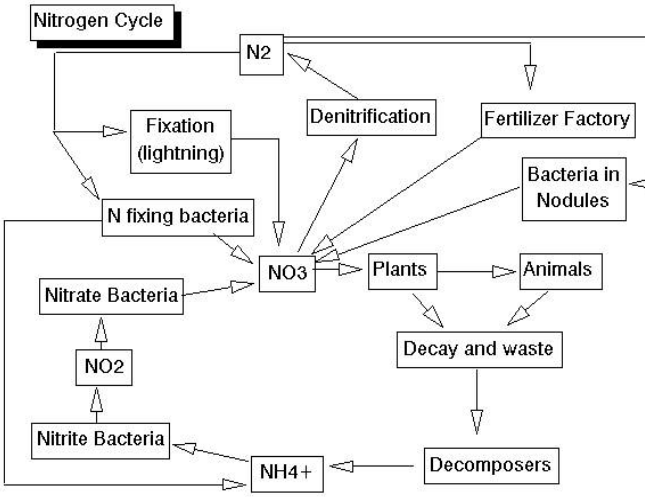
- Tropical areas have more sunlight and of greater intensity, more rainfall and longer growing seasons for plants
- This environment is quite stable and contains many vertical "layers" which provide more microhabitats
- These areas can support more species, e.g. the number of bird species is directly correlated with latitude

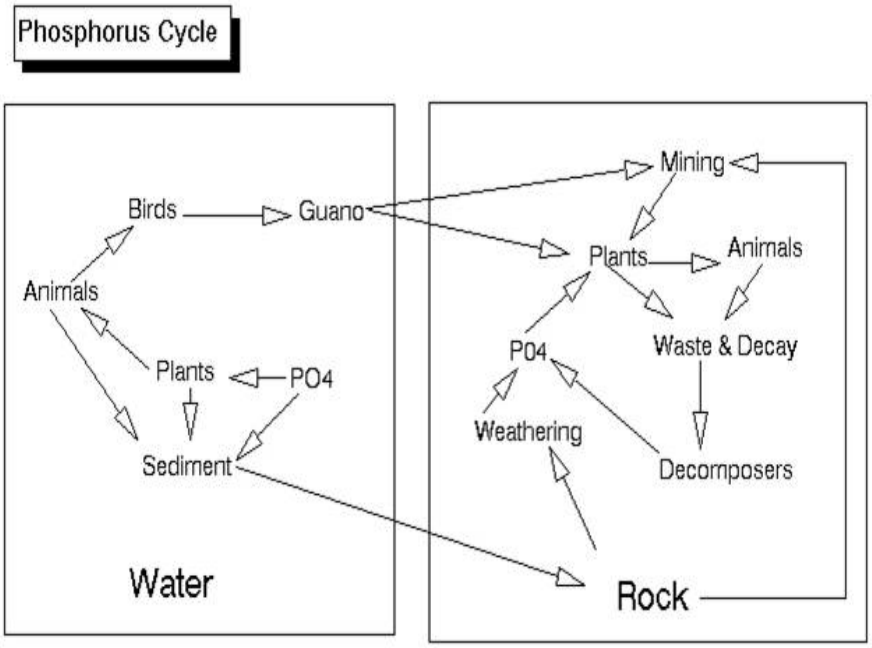
Weather and climate

- **Biome** = a large region of land characterized by the climax vegetation of the ecosystems within its boundaries
- The distribution and key features of biomes are the outcome of temperatures, soils and moisture levels (which vary with latitude and altitude), and evolutionary history
- **Weather** = the condition of the atmosphere at any given time
- **Climate** = the accumulation of weather events over a long period of time (temperatures, humidity, wind, cloud cover, rainfall)
- Climate is dependent upon several factors:
  - Solar radiation
  - The earth's daily rotation
  - The earth's rotation around the sun
  - The distributions of continents and oceans

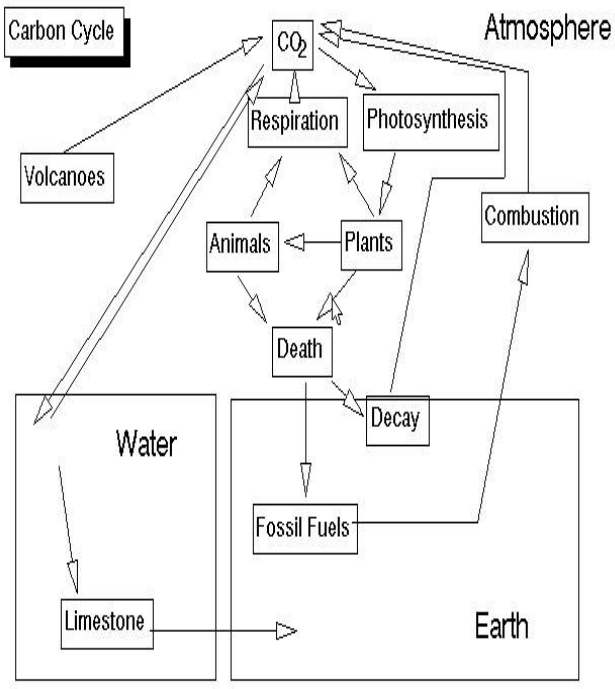
<u>Elevation or Depth of Light Penetration</u> Heat energy from the **sun** drives the earth's weather systems, which ultimately determine the composition of ecosystems
In aquatic environments it is often the depth of light penetration that is the key factor.

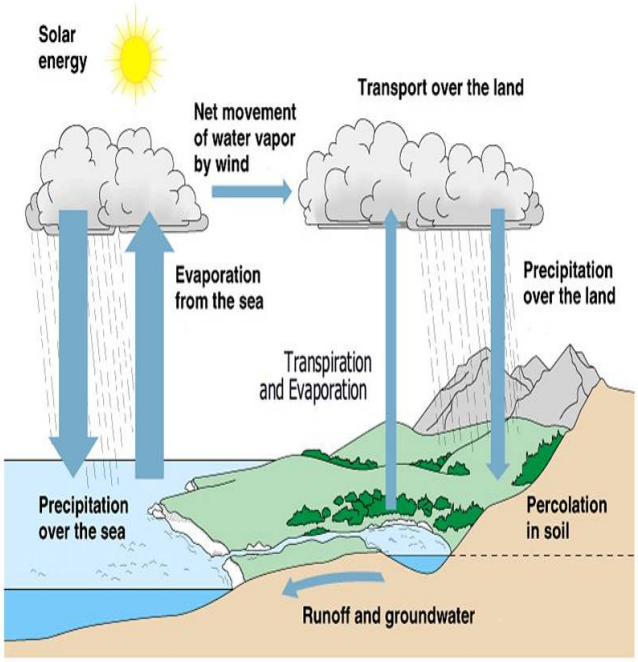
Nutrient Recycling – Biogeochemical Cycles





Hydrologic (Water) Cycle





Watershed

A **watershed or drainage basin** is an area of land where water from rain and melting snow or ice drains downhill into a body of water, such as a river, lake, reservoir, wetland. All of the major terrestrial and aquatic ecosystems are impacted by what happens in a watershed.



The rivers will eventually flow into large rivers which become estuaries and flow into the oceans.

- Watershed surface water management plans are implemented to reduce flooding, improve water quality, and enhance stream and wetland habitat.
- Land usage and water treatment methods are important in maintaining water quality in the watershed
- Sources of water pollution may include **point source pollution** from a clearly identifiable location or **nonpoint source pollution** that comes from many different places.
- Sources of pollution usually fall into four main categories – industrial, residential, commercial, and environmental
- Some types of pollution may include
  - **organic pollution** – decomposition of living organisms and their bi-products
  - **inorganic pollution** – dissolved and suspended solids as silt, salts, and minerals
  - **toxic pollution** – heavy medals and other chemical compounds that are lethal to organisms
  - **thermal pollution** – waste heat from industrial and power generation processes

OVERVIEW OF AQUATIC ECOSYSTEMS (2015)

Aquatic Ecosystems

Freshwater
- Lotic ecosystems – flowing water
  - Streams
  - Rivers
- Lentic ecosystems – still water
  - Ponds
  - Lakes
  - Wetlands

Estuary ecosystems
Marine ecosystems

Types of Freshwater Ecosystems in the Watershed

Lentic ecosystems – still water

Ponds - small body of freshwater, with no stream draining it - often fed by an underground spring

Lakes - larger body of freshwater, usually drained by a stream. May be naturally occurring or man made.

Wetlands - region of land that holds a great deal of water for significant periods of time, and that contains specialized plants able to grow in these wet conditions

Lotic ecosystems – flowing water

Streams - bodies of moving water, contained within a bank (sides) and bed (bottom).

Rivers - natural streams of water of fairly large size flowing in a definite course or channel or series of diverging and converging channels

Estuaries

- An *estuary* is the areas of water and shoreline where a freshwater stream or river merges with the ocean
- Estuaries can be partially enclosed body of water (such as bays, lagoons, sounds or sloughs) where two different bodies of water meet and mix
- They often bordered by salt marshes or intertidal mudflats
- Salinity varies within the estuary from nearly fresh water to ocean water
- It also varies daily in these areas due to rise and fall of tides
- They are very productive due to nutrients brought in by rivers
- A unique combination of salt and fresh water



creates a variety of habitats in which the plants and animals survive in various brackish water combinations

- Estuaries have a diverse flora and fauna and tremendous productivity
    - Salt marsh grasses, algae, and phytoplankton are the major producers
    - Many species of annelids, oysters, crabs, and fish are present
    - Many marine invertebrates and fish breed in estuaries or migrate through them to freshwater habitats upstream
    - A large number of water fowl and other semi-aquatic vertebrates use estuaries as feeding areas
- Human activities are having a large impact on estuaries
    - Estuaries receive the pollutants dumped into the streams and rivers that feed them
    - Residential and commercial development not only adds to pollution but eliminates some estuaries due to land filling
- Freshwater from rivers sometimes mixes with large freshwater bodies as the Great Lakes creating a "freshwater estuary" that functions like typical brackish estuaries

Marine ecosystems deal with the interdependence of all organisms living in the ocean, in shallow coastal waters, and on the seashore. The environment consists of the **abiotic - a non-living component**, e.g. physical factors such as soil, rainfall, sunlight, temperatures and the **biotic -** a living component – interactions of the organisms

***The Water Cycle* - 97 %** of the water on earth is **salt water in the ocean**. Of the **3%** of water that is **fresh water**, **2%** is **frozen in ice caps** and only **1%** is usable by **organisms** as liquid water or water vapor found in lakes, rivers, streams, ponds, in the ground water, and as vapor in the atmosphere

OVERVIEW OF TERRESTRIAL ECOSYSTEMS (2016)

Characteristics of Forests:

- **Trees dominate biome** – major producer
- **One-third of earths land area** – as forests
- **Global climate-buffering capacity in forests**
- **Most diverse biotic communities in the world**
- **Over two-thirds of the leaf area of land plants –** photosynthesis
- **About 70% of carbon present in living things –** carbon cycle
- **Canopy** - affects other producers, consumers, decomposers and their niches
- **Insects, birds, and mammals** – key components of food web
- **Potential medicines and many thousands of unseen and undiscovered species**
- **Human civilizations** – bringing deforestation, pollution, and industrial usage problems
- **Forest types** – depend upon climate (latitude) and seasonal rainfall
    - Tropical
    - Temperate or Deciduous
    - Boreal (taiga) or coniferous

***Characteristics of Deserts*:**

- **Cover 1/5 of earth's land surface**
- **Most occur at low latitudes but some are cold deserts**

- **Scarcity of water –** less than 25 cm (10 inches) of precipitation per year
- **Intense solar radiation** – strong tendency to lose water by evaporation
- **Water loss** – tendency for water loss may exceed annual rainfall
- **Temperature variation** – daytime over 120 degrees and drop as sunsets
- **Winters** – may be cold
- **Relatively poor soil quality** – high mineral content but little organic matter
- **Flooding problems during rains**
- **Special adaptations of desert organisms** – to withstand or avoid water stress
- **Desert expansion** – growth of deserts in parts of the world
- **Types of deserts**
  - Hot and dry
  - Semiarid
  - Costal
  - Cold
- **Regions of low, sparse vegetation with minimal precipitation and humidity high temperatures during some of the year and great daily temperature fluctuations**

***Characteristics of Grasslands or Prairies*: Breadbaskets of the world**

- Precipitation is too low to support trees but too great for deserts to form.
- Grasses are major producer with several genera and species common but usually with one or two dominate.
- Most grasses possess rhizomes and are wind pollinated.
- Moderate temperature with notable extremes: -20° F to 110° F common, and even colder temperatures in the north.
- Variable precipitation: 6-40 in (15-100 cm).
- Scattered rain and lightening common in summer months ("convection storms") with more general rains and snows in winter months.
- Soils generally fertile, deep and rich; variable
- Growing season of 120-200 days.
- Generally flat to rolling topography cut by stream drainages where there is a river-bank habitat.
- Fire a major factor in maintaining biome.
- Dominated by grazing animals (deer, antelope, buffalo - once common but now rarely native to the range), burrowing small animals, and song birds.