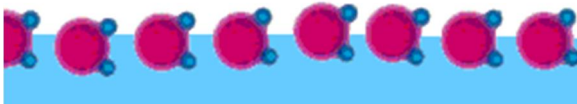


PART 1 – FRESHWATER ECOLOGY

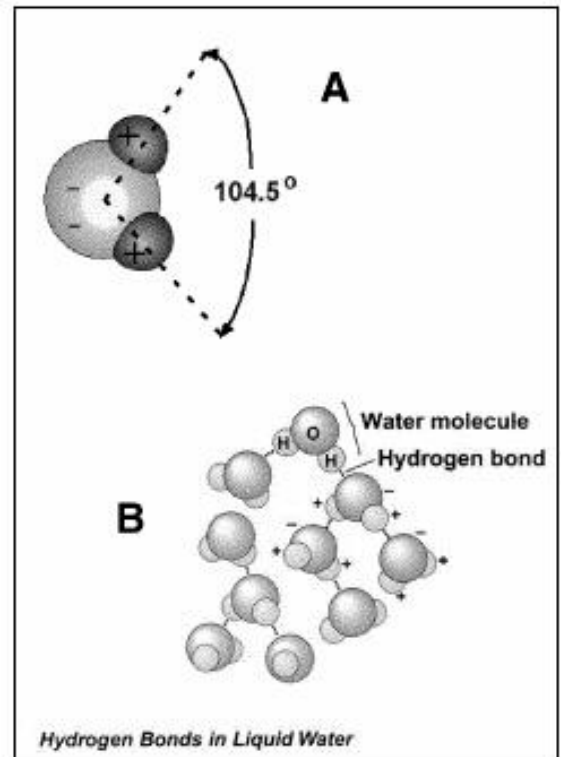
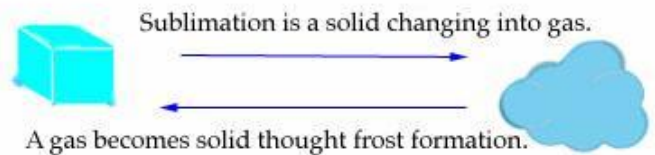
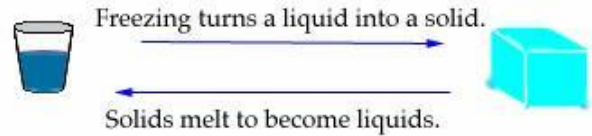
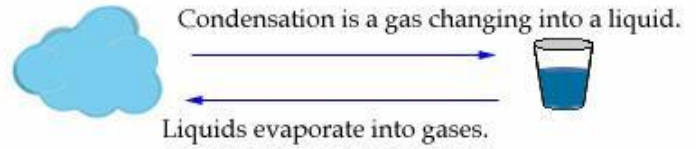
Physical and chemical properties of water

- Water is 775 times as dense as air at 0 °C
- Exists in liquid form at normal atmospheric temperature and pressure
- Water is found on earth in three forms 6 liquid, solid and gas
- Density 6 maximum density is at 4°C not at freeing point of 0°C and expands as it freezes so ice floats
- The boiling point of water is 100 °C
- The H₂O molecule is polar and hydrogen bonding is present
- Water molecules are attracted to other water molecules termed cohesion
- Cohesion of water molecules at the surface of a body of water (surface tension) is very high

Surface Tension

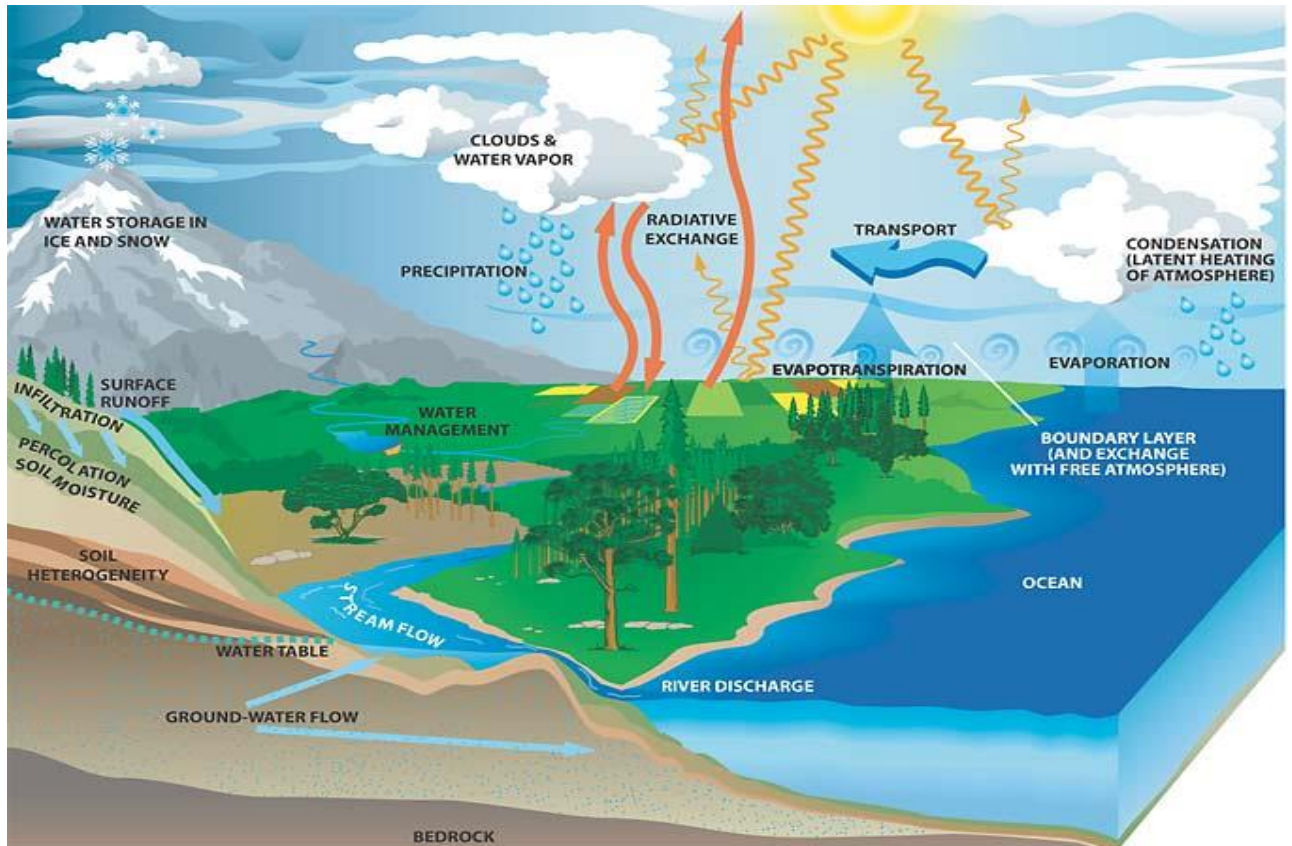


- Water is attracted to other types of molecules termed adhesion
- Water is an excellent solvent for ions and polar molecules
- Capillary action due to stickiness (cohesion) of water molecules allows water to go up a small tube



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



The six major process in the water cycle are

- **Precipitation** ó water from the clouds fall to earth rain, snow, hail or sleet
- **Surface Runoff** ó water on the surface of the land that flows downhill into bodies of water such as streams, rivers, ponds, and lakes
- **Infiltration** ó rain water soaks into the ground through soil and rock layers under the soil with some remaining underground as groundwater
- **Evaporation** ó liquid water changes to a gaseous state as water vapor
- **Transpiration** ó water that has been absorbed by plants will evaporate through the leaves as water vapor
- **Condensation** ó water vapor is changed into a liquid Water vapors join dust particles to form clouds

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.



- 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 ó industrial, residential, commercial, and environmental
- Some types of pollution may include
 - organic pollution ó decomposition of living organisms and their byproducts
 - inorganic pollution ó dissolved and suspended solids as silt, salts, and minerals
 - toxic pollution ó heavy metals and other chemical compounds that are lethal to organisms
 - thermal pollution ó waste heat from industrial and power generation processes

Safe Drinking Water Act - Protecting America's Public Health



MULTIPLE RISKS REQUIRE MULTIPLE BARRIERS

Safe drinking water is essential to the health of American citizens and the economic health of our communities. However, drinking water is vulnerable to contamination from many potential threats. There are programs and activities that when operated effectively form a protective web of multiple barriers to ensure the safety of our drinking water. The success of these barriers relies on the involvement and vigilance of local, state and federal officials, the private sector, public interest groups and individual citizens.

This poster identifies examples of

1. Surface and groundwater sources of drinking water (in blue),
2. Potential threats to those drinking water sources (in red), and
3. The multiple barriers that together protect our nation's public health (in green).

Risk Prevention Barrier
Risk Management Barrier
Risk Monitoring and Compliance Barrier
Individual Action Barrier

Safe Drinking Water Hotline – (800) 426-4791 Safewater Web Site – www.epa.gov/safewater

Types of Aquatic Ecosystems in the Watershed

Lentic ecosystems ó 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 ó flowing water

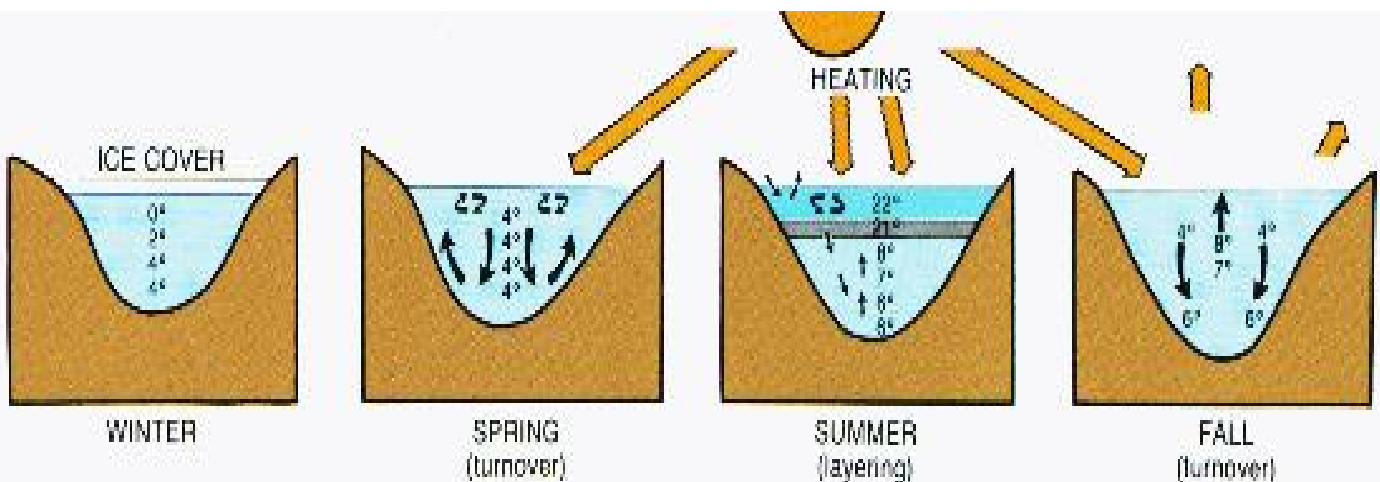
Streams - bodies of moving water, contained within a bank (sides) and bed (bottom).

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

Lentic Ecosystems

Ponds and Lakes

- Standing bodies of water vary greatly in size with **ponds** being smaller than **lakes**
- Exhibit a significant **vertical stratification** in water light penetration and temperature



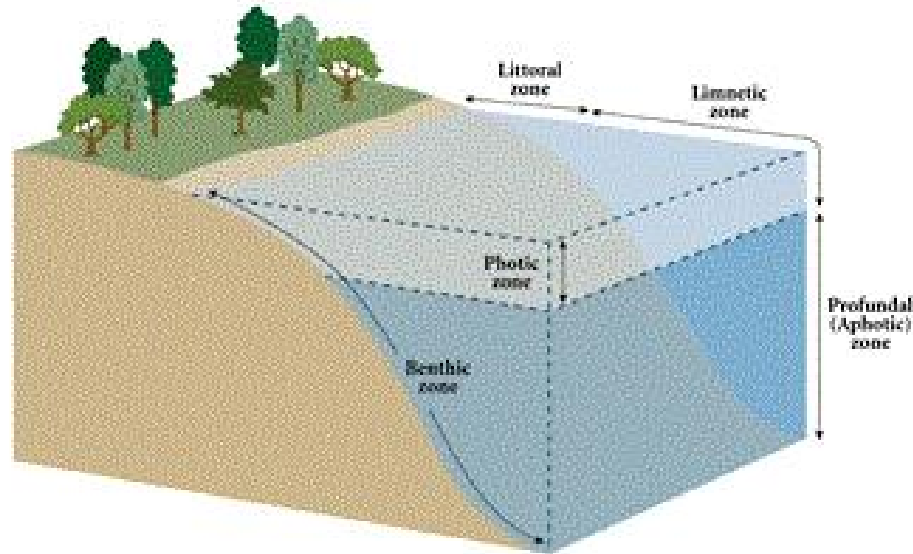
É **Light penetration stratification** - Ponds or lakes are divided into two layers due to a decrease in light intensity with increasing depth - as light is absorbed by the water and suspended microorganisms.

- upper **photic zone** is the layer where light is sufficient for photosynthesis
- lower **aphotic zone** receives little light and no photosynthesis occurs

É **Temperature stratification** also occurs in deeper ponds and lakes during summer in temperate zones.

- Heat energy from sunlight warms the upper layers of water as far as it penetrates; the deeper waters remain cold.
- As depth increases, the separation point of the warmer upper water from the lower colder water is the **thermocline** (a narrow vertical zone between the warmer and colder waters where a rapid temperature change occurs)

- Distribution of plants and animals in a lake or pond shows stratification based on water depth and distance from the shore



The **benthic zone** is the zone at the lowest level or bottom of the lake including sediment surface and some subsurface layers ó most of the organisms are scavengers and decomposers

The **littoral zone** is shallow, well-lighted, warm water close to shore.

- Has rooted and floating vegetation, and a diverse attached algal community (especially diatoms)
- Has a diverse animal fauna including suspension feeders (clams); herbivorous grazers (snails); and herbivorous and carnivorous insects, crustaceans, fishes, and amphibians
- Also has some reptiles, water fowl, and mammals

The **limnetic zone** is the open, well-lighted waters away from shore ó

Eutrophic zone .

- Has photosynthetic phytoplankton (algae and cyanobacteria), zooplankton (rotifers and small crustaceans) that graze on phytoplankton, and small fish which feed on the zooplankton.
- Animals visiting this zone may include large fish, turtles, snakes, and birds

Profundal zone is the deep, aphotic zone lying beneath the limnetic zone.

- This is an area of decomposition where *detritus* (dead organic matter that drifts in from above) is broken down.
- Water temperature is usually cold and oxygen is low due to cellular respiration of decomposers.
- Mineral nutrients are usually plentiful due to decomposition of detritus.
- Waters of the profundal zone usually do not mix with surface waters due to density differences related to temperature.
- Mixing of these layers usually occurs twice each year in temperate lakes and ponds so oxygen enters the profundal zone and nutrients are cycled into the limnetic zone.

Lakes are often classified as *oligotrophic*, *mesotrophic*, or *eutrophic*, depending on the amount of organic matter produced.

OLIGOTROPHIC

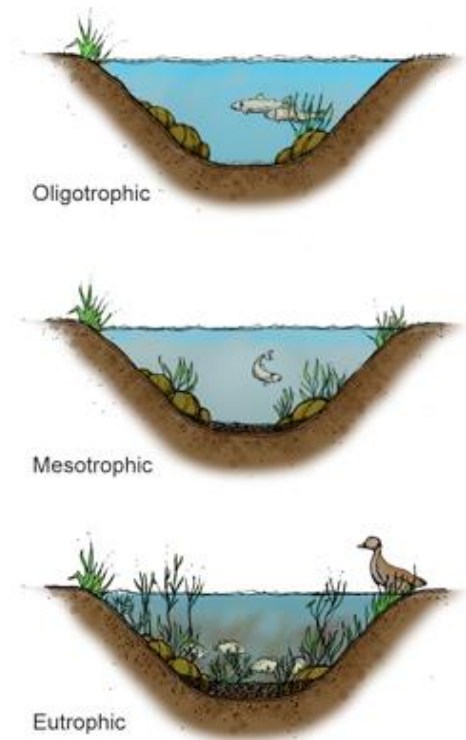
- É Clear water, low productivity
- É Very desirable fishery of large game fish

MESOTROPHIC

- É Increased production
- É Accumulated organic matter
- É Occasional algal bloom
- É Good fishery

EUTROPHIC

- É Very productive
- É May experience oxygen depletion
- É Rough fish common



Oligotrophic lakes are deep, nutrient-poor lakes in which the phytoplankton is not very productive. The water is usually clear and the profundal zone has a high oxygen concentration since little detritus is produced in the limnetic zone to be decomposed.

- They may develop into eutrophic lakes over time
- Runoff from surrounding terrestrial habitats brings in mineral nutrients and sediments.
- Human activities increase the nutrient content of runoff due to lawn and agricultural fertilizers
- Municipal wastes dumped into lakes dramatically enriches the nitrogen and phosphorus concentrations which increases phytoplankton and plant growth.
- Algal blooms and increased plant growth results in more detritus and can lead to oxygen depletion due to increased decomposition.

Eutrophic lakes are usually shallow, nutrient-rich lakes with very productive phytoplankton.

- The waters are usually murky due to large phytoplankton populations
- The large amounts of detritus being decomposed may result in oxygen depletion in the profundal zone during the summer.

Wetlands

A *-wetland* is an area covered by water that supports aquatic vegetation.

- Wetlands are among the richest and valuable of biomes.
- A diverse invertebrate community is present which supports a wide variety of birds.
- A variety of herbivorous species consume the algae, detritus, and plants.
- They provide water storage basins that reduce the intensity of flooding.
- They improve water quality by filtering pollutants.

Form in one of three topographic situations

- **Basin wetlands** develop in shallow basins ranging from upland depressions to lakes and ponds that have filled in.
- **Riverine wetlands** develop along shallow and periodically flooded banks of streams and rivers.

- **Fringe wetlands** are found along coasts of large lakes and seas where rising lake levels or tides cause water to flow back and forth.

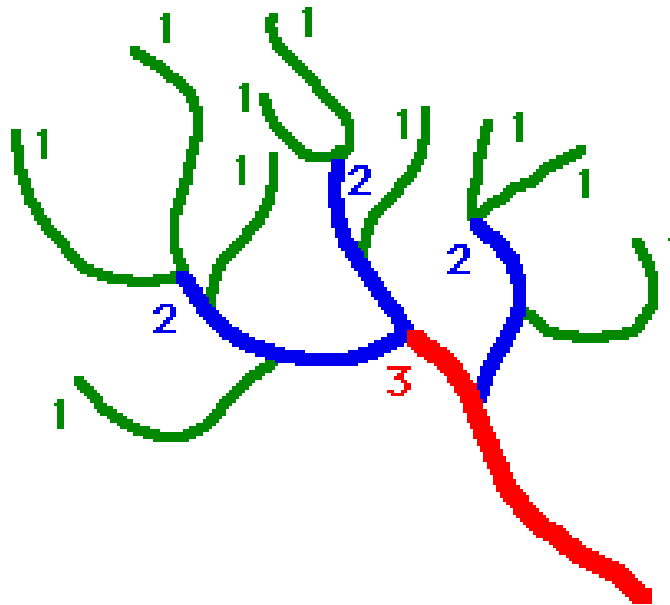
Lotic Systems – flowing water

Streams and Rivers are bodies of water that move continuously in one direction.

They are physically ordered relative to size. To qualify as a stream the flowing water must be either recurring (having water in the channel for part of the year) or perennial (all year).

The smallest tributaries are referred to as **first-order streams** while the largest river is a **twelfth-order** waterway (Strahler stream classification system).

First-order through third-order streams are called **headwater**. 80% of the Earth's waterways are headwater streams.

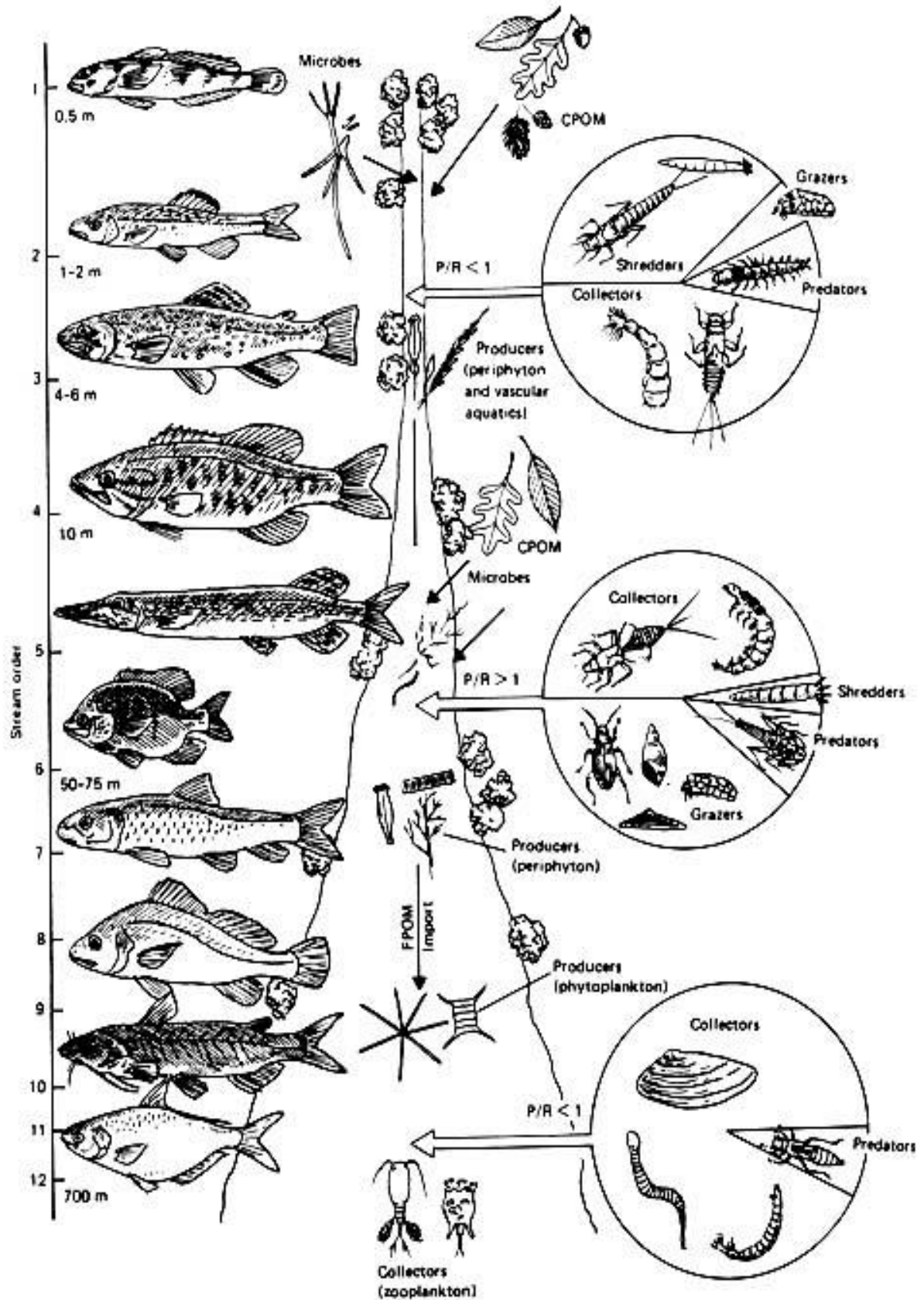


In the most commonly used scheme, the uppermost headwater streams that have no tributaries are **first-order** streams. When two first order streams join, they form a **second-order** stream. Likewise, when two second-order streams join, they form a **third-order** stream, and so forth.... When a lower order stream joins a higher order stream (for example, a first-order stream joins a second-order stream), the order of the receiving stream does not change. When a stream is assigned an order, the number refers to the lowermost section of the stream.

There is a change in structure of these bodies of water from their headwaters (point of origin) to their mouths (where they empty into a larger body of water). As water moves from the headwater streams to the mouth of the large rivers, the depth, width, and velocity gradually change as does the amount of water that is discharged.

The **River Continuum Concept** is a model used to determine the biotic community expected as the size of the stream increases.

River Continuum Concept



At the **headwaters**:

- the water is cold and clear, carries little sediment, and has few mineral nutrients
- channel is narrow with a rocky substrate and the water flows swiftly

Near **the mouth**,

- water moves slowly and is more turbid due to sediment entering from other streams and erosion; the nutrient content is also higher
- channel is usually wider with a silty substrate that has resulted from deposition of silt.

Many factors influence the nutrient and oxygen content, turbidity, and rate of flow in rivers and streams

- Rough, shallow bottoms produce rapid turbulent flow known as *riffles*;
- smooth, deep bottoms result in a slower, smooth flow in areas called *pools*.
- Nutrient content of the water is higher in streams and rivers flowing through densely vegetated regions and where erosion takes place.
- Leaves and other vegetation entering the water add organic matter.
- Erosion of rocks in the streambed increases inorganic nutrient content.
- Oxygen content of the water is affected by the flow rate.
- Turbulent flow constantly oxygenates the water while slow, murky waters contain relatively little oxygen.
- Turbidity reflects the amount of material suspended in the water.
- Streams and rivers flowing through areas of high erosion will have more suspended materials than those surrounded by hard substrates.
- Large amounts of suspended organic matter also increases turbidity.

The biological communities found in rivers and streams differ from headwaters to mouth as well as from those found in ponds and lakes.

- Due to the current, large plankton communities are not found in rivers and streams.
- Photosynthesis which supports the food chains is carried out by attached algae and rooted plants.
- Organic material washed into the system also provides an important food source, especially where dense vegetation along the shore blocks out sunlight or high turbidity in slow waters prevents light penetration.
- In upstream areas where water is cool, clear, and has a high oxygen content, there are many aquatic insects and fish such as trout.
- Near the mouth where water is murky and warmer with a lower oxygen content, fish such as carp and catfish are prominent; a different group of insects is also found in this area.

Various adaptations are found in organisms which permit them to inhabit their specific areas of rivers and streams.

- Small animals typically have flattened bodies and can attach temporarily to rocks.
- Many insects and other invertebrates live on the underside or downstream sides of rocks to escape the current.
- Some insects produce silken nets used to filter food from the water.

Channelization (increases flow rate) and damming (slows flow rate) alter the natural characteristics of flowing waters

Pollutants may be taken up by or destroy the natural flora and fauna

Review of General Ecology of Freshwater Ecosystems

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**

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

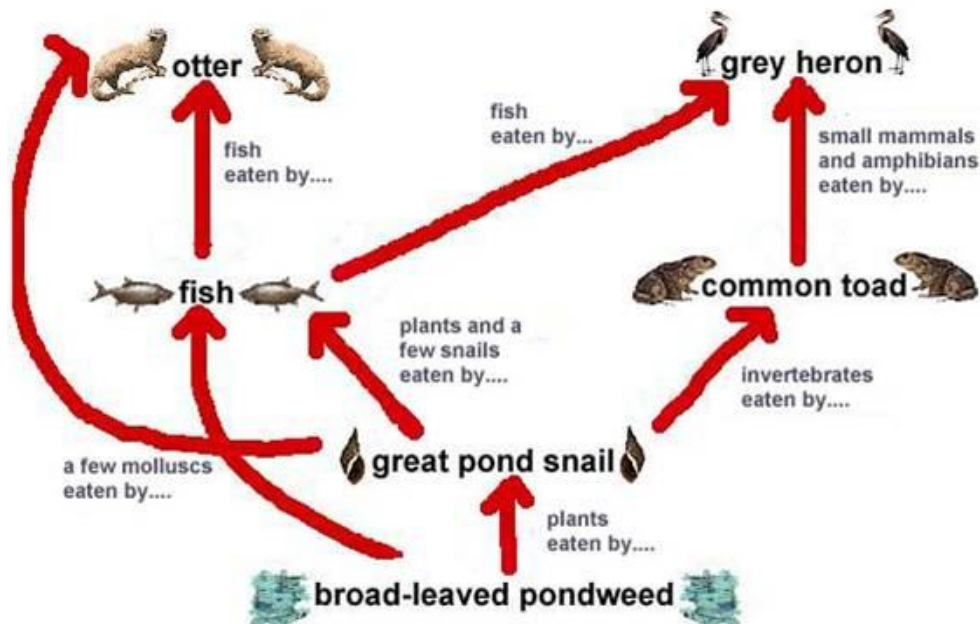
Ecology of Ecosystems :

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.

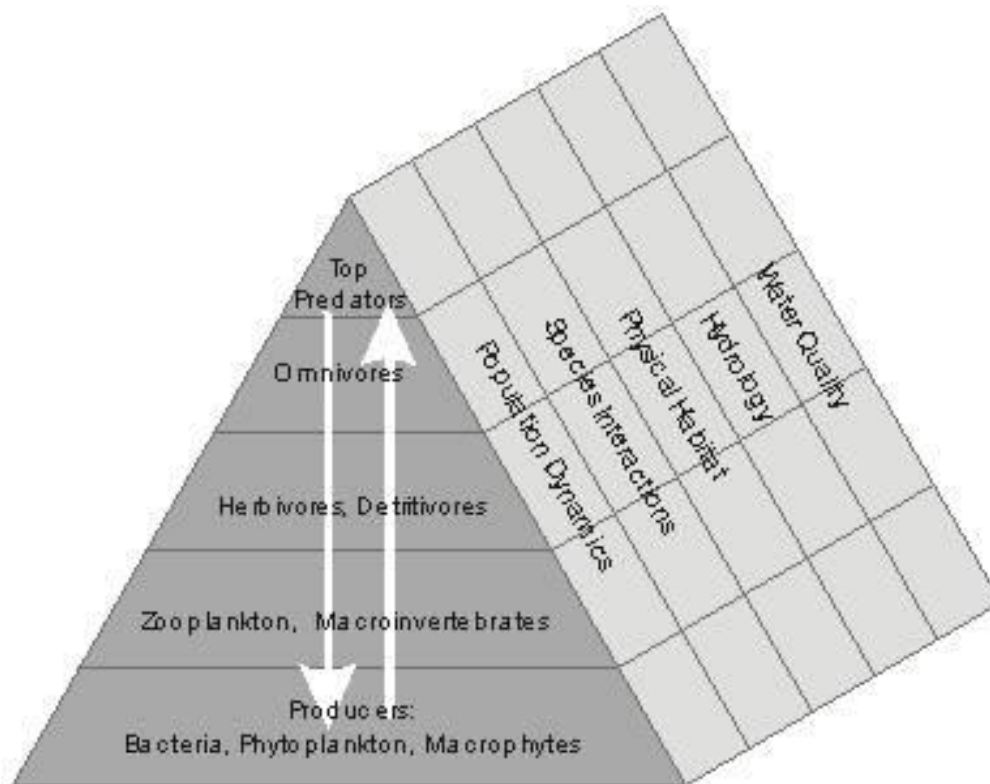
- **Primary producers** are the autotrophs
- All other organisms are **consumers** Consumers which eat plants are called **herbivores**
- Consumers which eat animals are called **carnivores** Organisms such as humans, which eat both plants and animals, are called **omnivores**
- **Decomposers**, which 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

- **Food Chains**
algae → mayflies → stoneflies → trout → humans
- **Food Web** ó 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

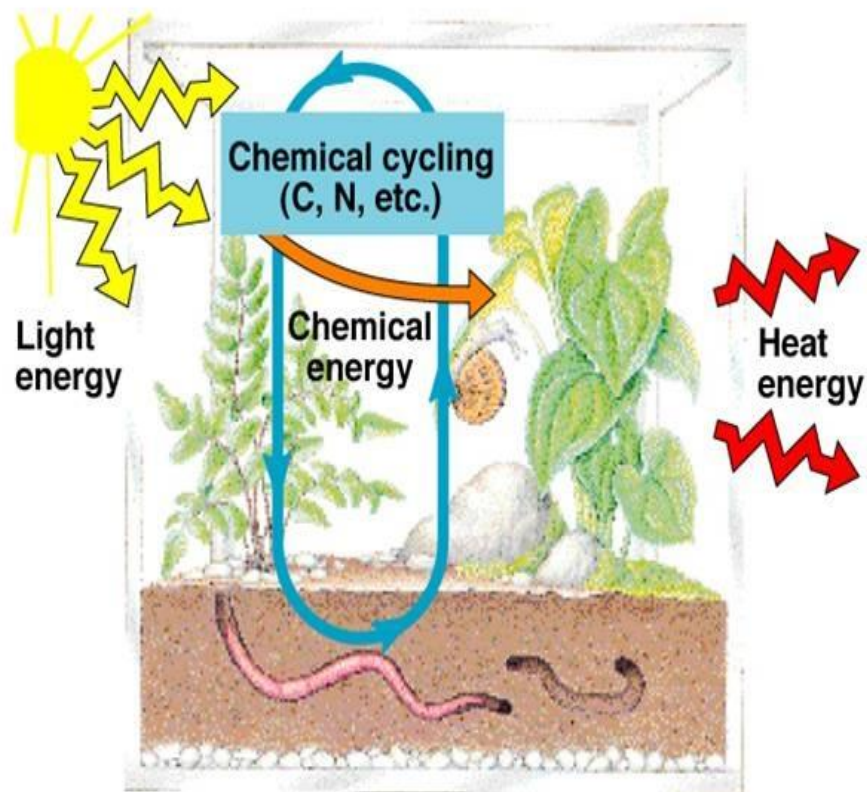


Energy flow through ecosystems

- **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. $\text{kg/m}^2/\text{yr}$
- 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

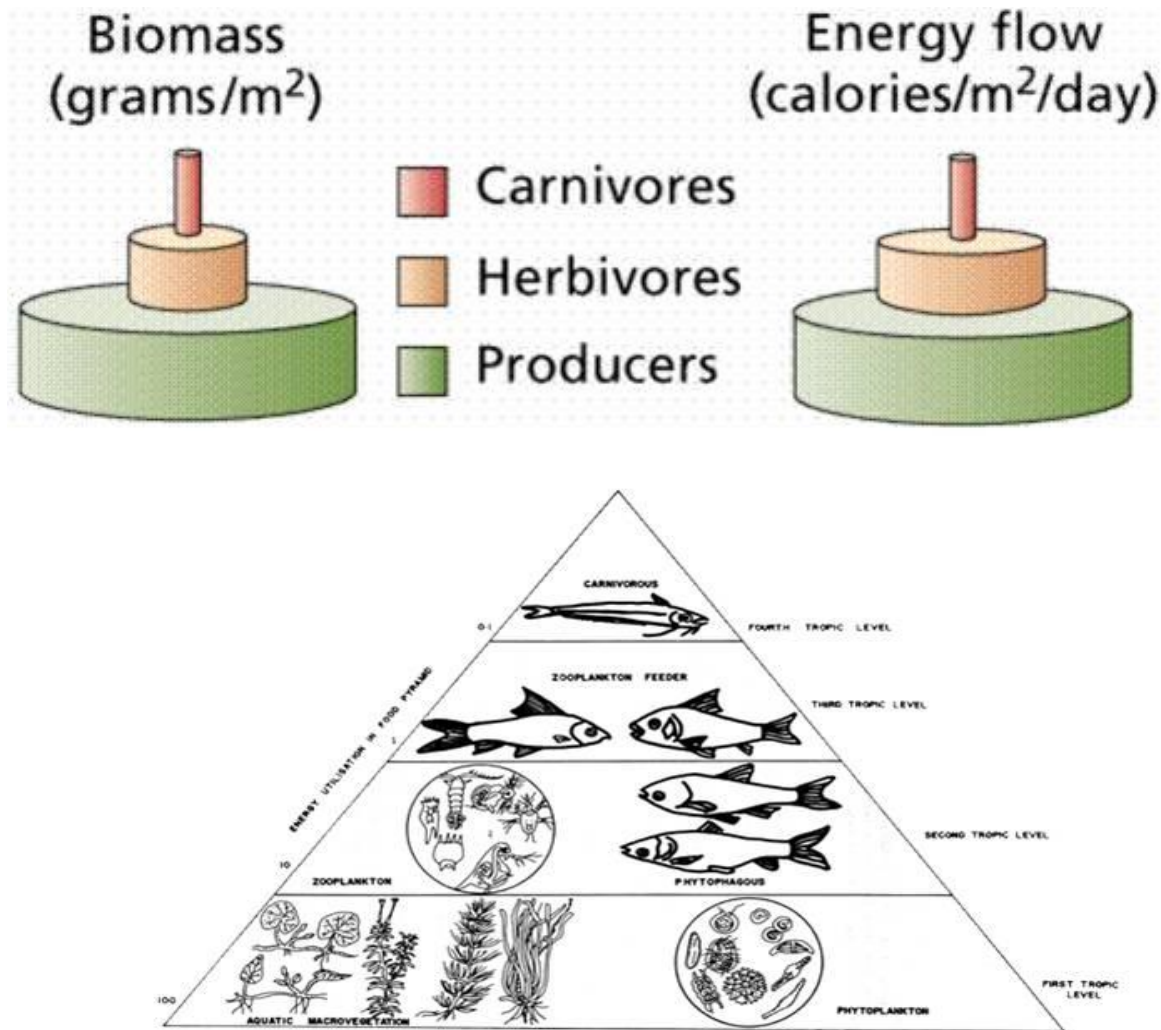


Numbers, Biomass and Energy Pyramids

Numbers Pyramids: Number of organisms at each trophic level ó it may be distorted by the size of the organisms ó some organisms are much larger than others

Biomass Pyramids: The total mass of all of the organism at each trophic level

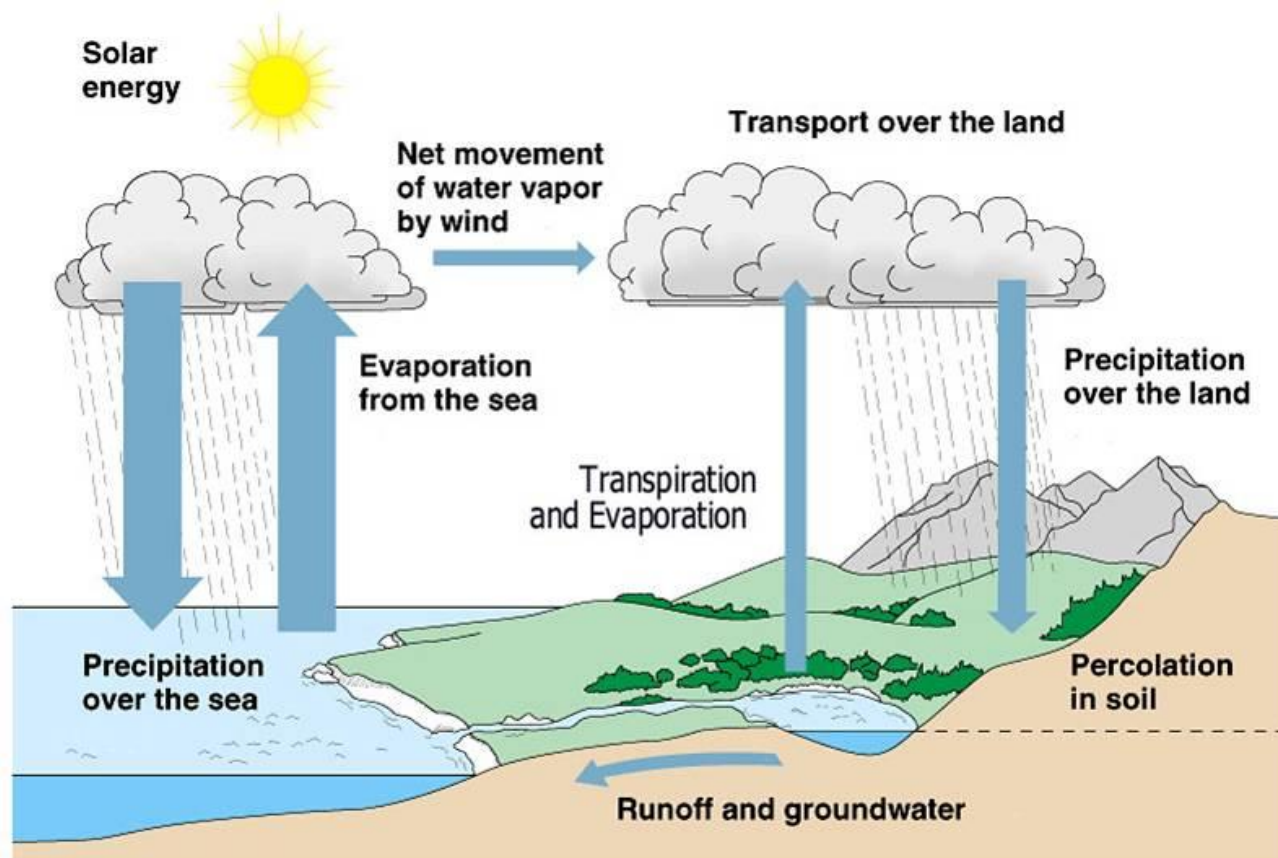
Energy flow: The amount of energy being used by all the organisms at each energy level



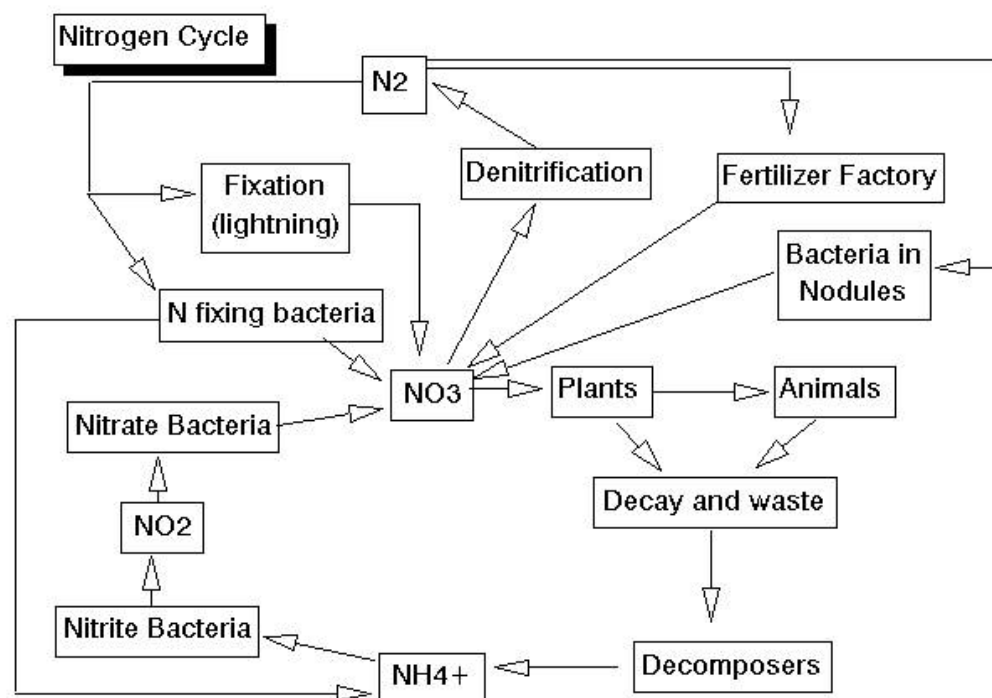
Ecological succession = a directional, cumulative change in the species that occupy a given area, through time

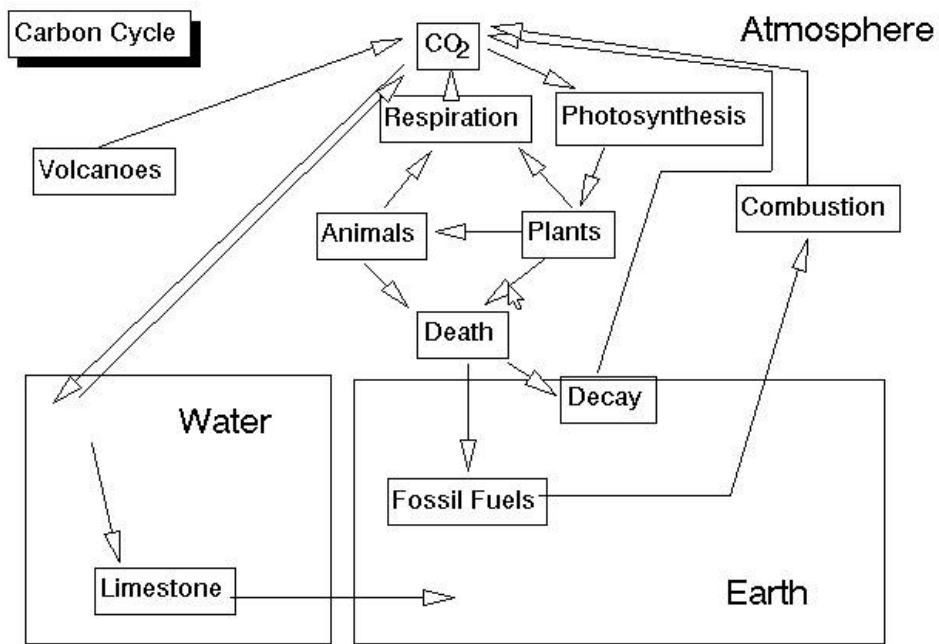
- **Primary succession** - starts from barren ground, e.g. new islands or de-glaciated areas
- **Secondary succession** - starts from disturbed areas, e.g. abandoned farm land or storm ravaged land
- Succession starts with a **pioneer community**, the first organisms to occupy an area
- Several **transitional 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.

Nutrient Recycling – Biogeochemical Cycles

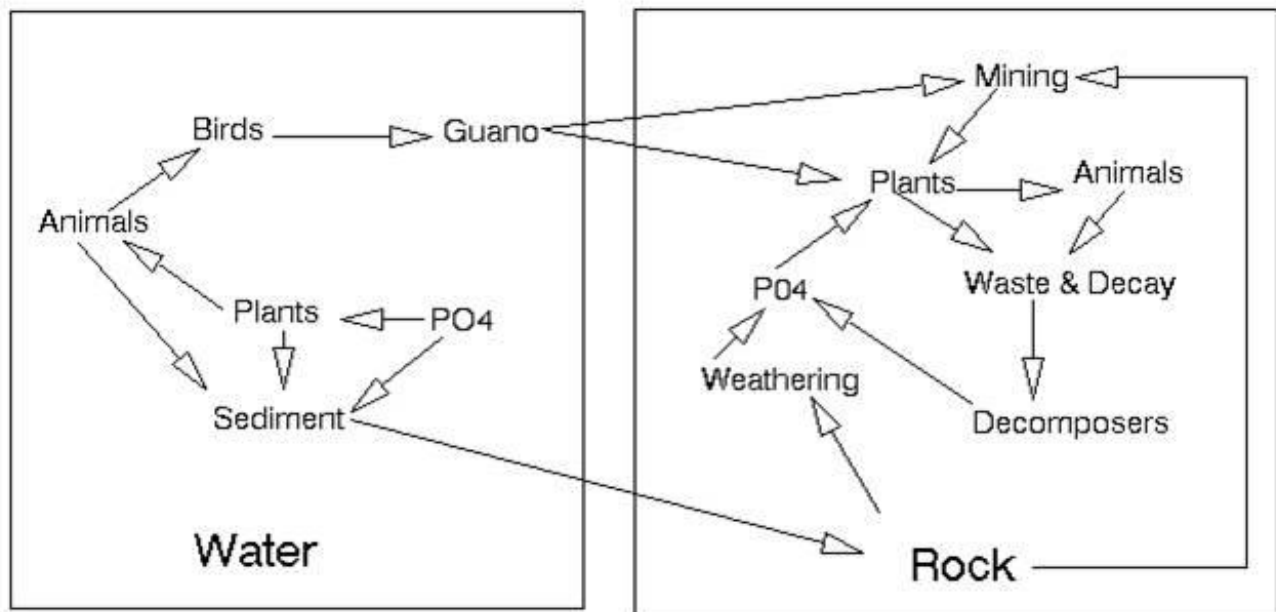


Hydrologic (Water) Cycle



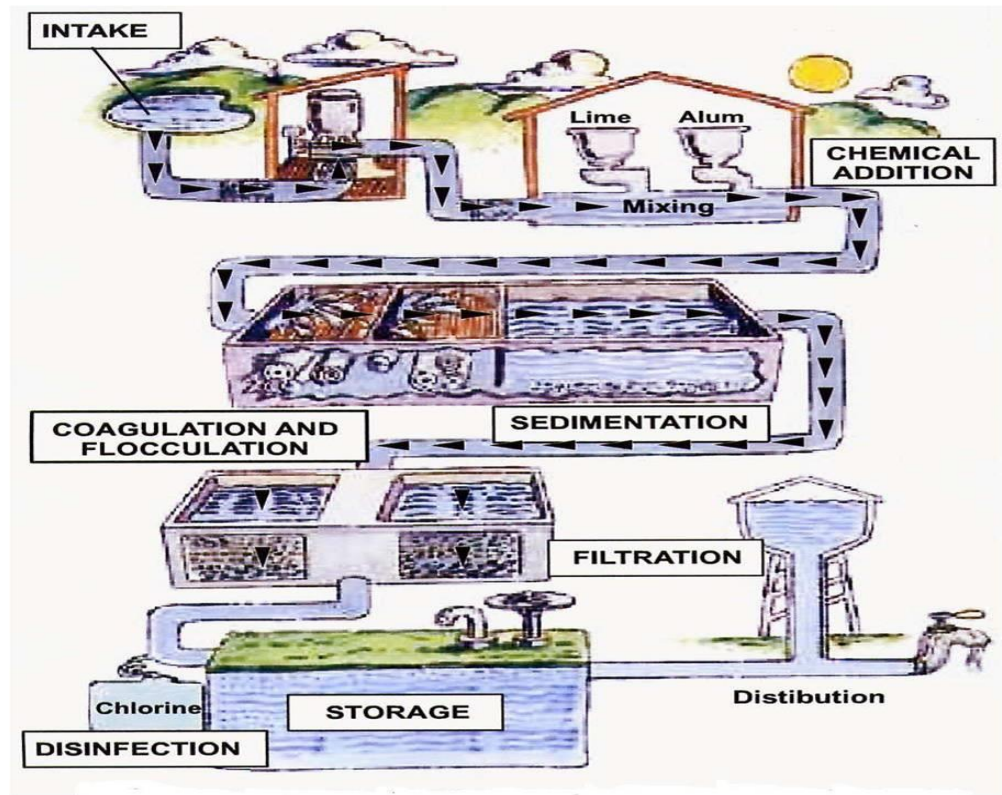


Phosphorus Cycle



Potable Water Treatment – making water safe for drinking

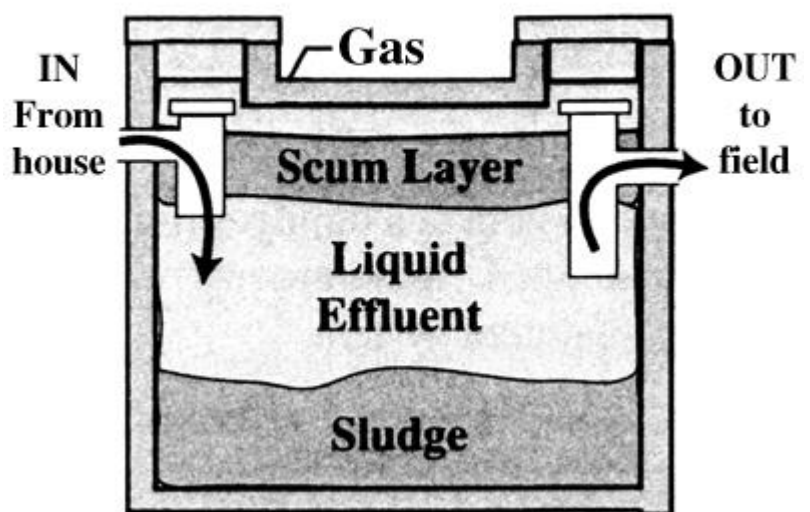
- Chemical addition of lime and alum to form sticky particles called floc that attract dirt particles
- Dirt and other particles are attracted by flock during flocculation and coagulation
- Sedimentation allows floc materials to sink to the bottom and be filtered out
- Filtration is accomplished by layers of sand, gravel, and/or charcoal
- Chlorine is added and the water is stored in tanks for the disinfection process to occur and the microbes to be killed



Septic Tank System

- Home septic tanks are miniature waste treatment facilities
- Household sewage is digested by anaerobic bacteria
- The solids settle to the bottom of the tank and the liquid effluent is carried to the drain field
- Water seeps out through holes in the tiles of the drain field where bacteria in the soil complete the breakdown process

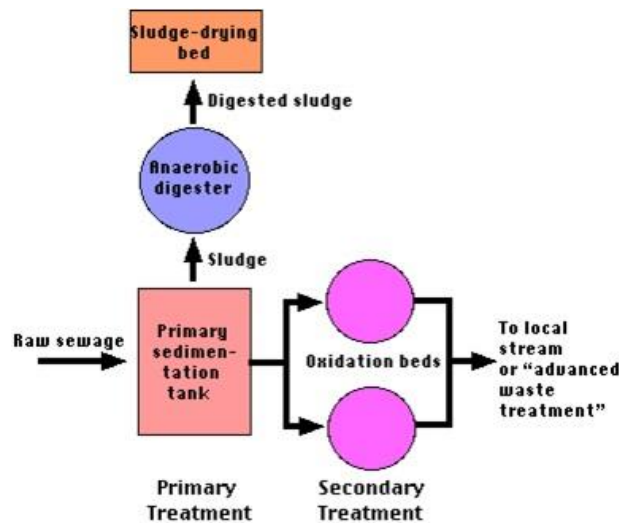
• *Section view of a septic tank*



Sewage Treatment

Microbes are used in sewage treatment for

- nutrient recycling
- methane recovery
- disease control



Primary treatment : The treatment step of sewage for physical removal of particles of large and small from the sewage through filtration and sedimentation

Secondary treatment or Biological treatment: After primary treatment, the primary effluent is passed into large aeration tanks where it is constantly agitated mechanically and air is pumped associated with fungal filaments to form mesh like structures). **BOD (biochemical oxygen demand)** -BOD refers to the amount of the oxygen that would be consumed if all the organic matter in one liter of water were oxidized by bacteria.

Activated sludge- Once the BOD of sewage or waste water is reduced significantly, the effluent is then passed into a settling tank where the bacterial flocs are allowed to sediment. This sediment is called activated sludge. **Anaerobic sludge digesters**- A small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum. The remaining major part of the sludge is pumped into large tanks called anaerobic sludge digesters where anaerobic bacteria and the fungi digest the sludge.

Methane is commonly produced in the sludge tank and it is often burned to fuel the treatment facility. The remaining sludge is burned or buried in a land fill and the fluid is recycled

Tertiary treatment of the fluid from the secondary treatment is cleansed of phosphate and nitrate products that could cause pollution before the water is returned to a natural water source.