2020 WATER QUALITY–TRAINING HANDOUT
Overview of Competition

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DISCLAIMER - This presentation was prepared using draft rules. There may be some changes in the final copy of the rules. The rules which will be in your Coaches Manual and Student Manuals will be the official rules.

- **BE SURE TO CHECK THE 2020 EVENT RULES** for EVENT PARAMETERS.

TRAINING MATERIALS:

- **Training Power Point** presents an overview of material in the training handout
- **Training Handouts** presents introductory topic content information for the event
  This is a general training handout – there are also special handouts for each part of the competition including separate handouts for Freshwater and Estuary Ecology
- **Practice Activities** have sample problems for each area of the competition with answer keys
- **Sample Tournament** has sample problems with key
- **Event Supervisor Guide** has event preparation tips, setup needs and scoring tips
- **Internet Resource & Training Materials** are available on the Science Olympiad website at www.soinc.org under Event Information.
- **A Biology-Earth Science CD**, a **Water Quality CD (revised 2014 to include marine water quality)** and the **Division B and Division C Test Packets** are available from SO store at www.soinc.org

THE COMPETITION:
Student Handouts for each section of the competition

Part 1: Water Quality Information – apply ecological principles to Estuaries & Marine ecosystems
This section will use multiple choice, matching, fill-in-the-blank and/or short answers in areas such as

- aquatic ecology
- aquatic food chains and food webs
- population dynamics
- community interactions
- water cycle
- nutrient cycling
- aquatic chemistry and its implications for life
- potable water treatment
- waste water treatment
- watershed resource management issues
- sedimentation pollution
- exotic/invasive/harmful species
- human impacts

Part 2: Coral Reef Ecology – examine **coral reefs** and **the effects of pollution on reef ecosystems**.

Topics that may be included are
- **coral reef biology**
- **growth and reproduction**
- **zooanthellae**
- **reef fish communities**
- **reef ecosystem**
- **health indicators**
- **the importance of coral reefs**
- **problems associated with pollution**
- **management of reef systems**

Part 3: Water Monitoring and Analysis – Note: the Water Quality Index used for Freshwater does not apply to Marine Environments. Regions have their own marine water quality index

Data Interpretation and Procedural analysis
- salinity
- pH
- phosphates
- turbidity
- dissolved oxygen
- temperature
- nitrates
- fecal coliform
- total solids
- biochemical oxygen demand
- Aragonite Saturation– for marine especially coral reefs

Build and calibrate a salinometer (Hydrometer) <u>prior to the competition and use in competition</u>
- Test salt water
- 1-10%

Process skills:
- equipment use
- collecting and interpreting data
- measurements
- calculations
- classifying
- inferences
- variable analysis

Part I: General Principles of Aquatic Ecology

Aquatic Ecosystems

- Freshwater
- Lotic ecosystems – flowing water
  - Streams
  - Rivers
- Lentic ecosystems – still water
  - Ponds
  - Lakes
  - Wetlands
- Estuary ecosystems
- Marine ecosystems
  - Coral Reef Ecology

Review of Ecology Principles

- **Ecology** = the systematic study of how organisms interact with one another and with their environment
- Environment consists of both a living component, the **biotic** environment (other organisms) and a non-living component, the **abiotic** environment, e.g. physical factors such as soil, rainfall, sunlight, temperatures
- Ecology is an extremely complex and very diverse subject and it includes a variety of disciplines in addition to biology, e.g. geology, chemistry, physics, meteorology, and mathematics

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

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.

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
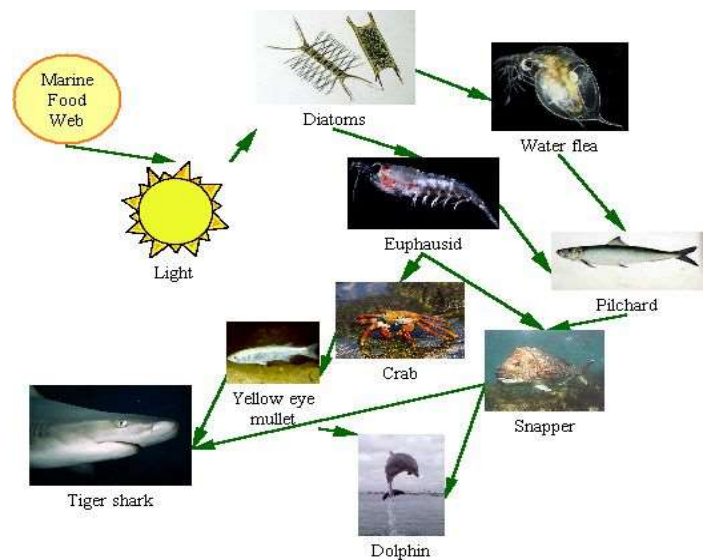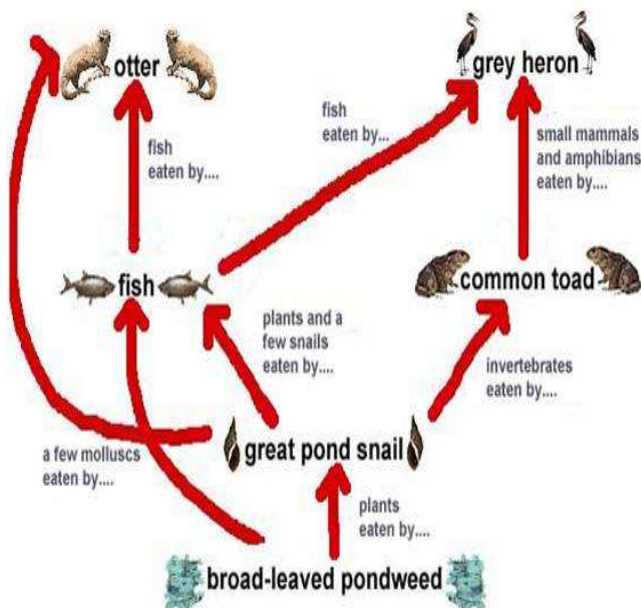
Structure of ecosystems

- 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**
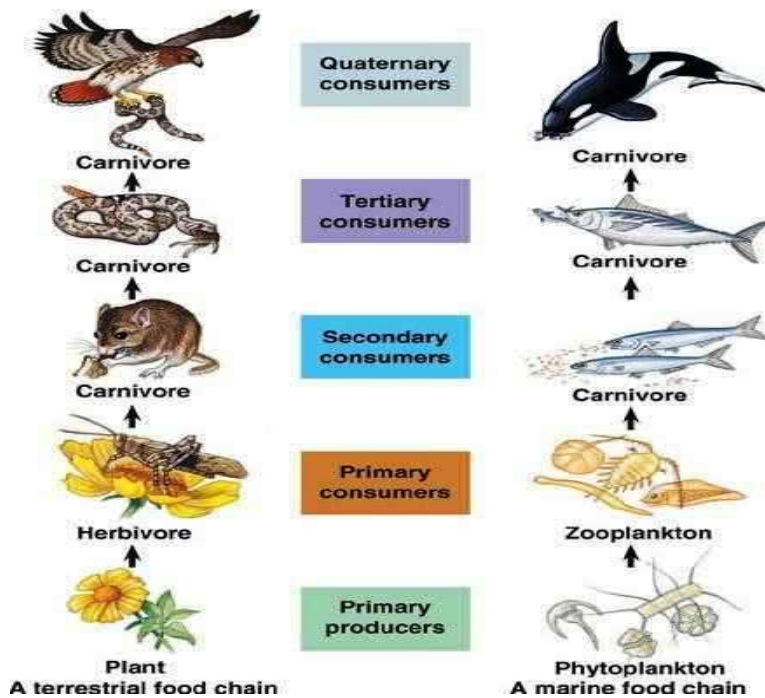
Food Web – many food chains in relation to each other

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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/m²/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
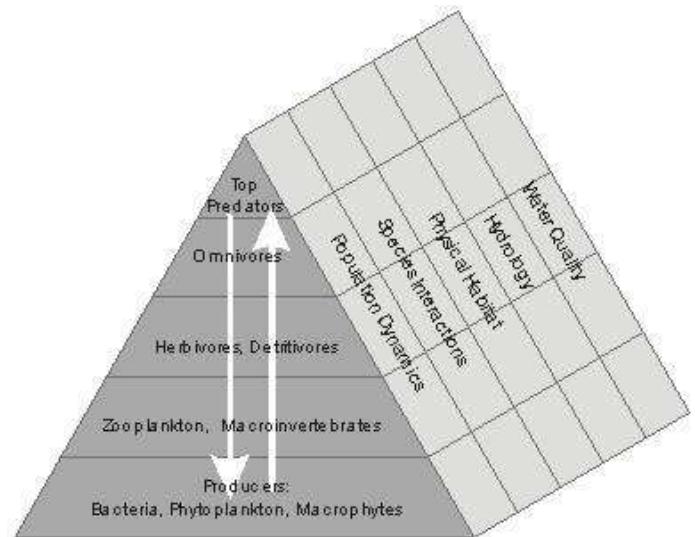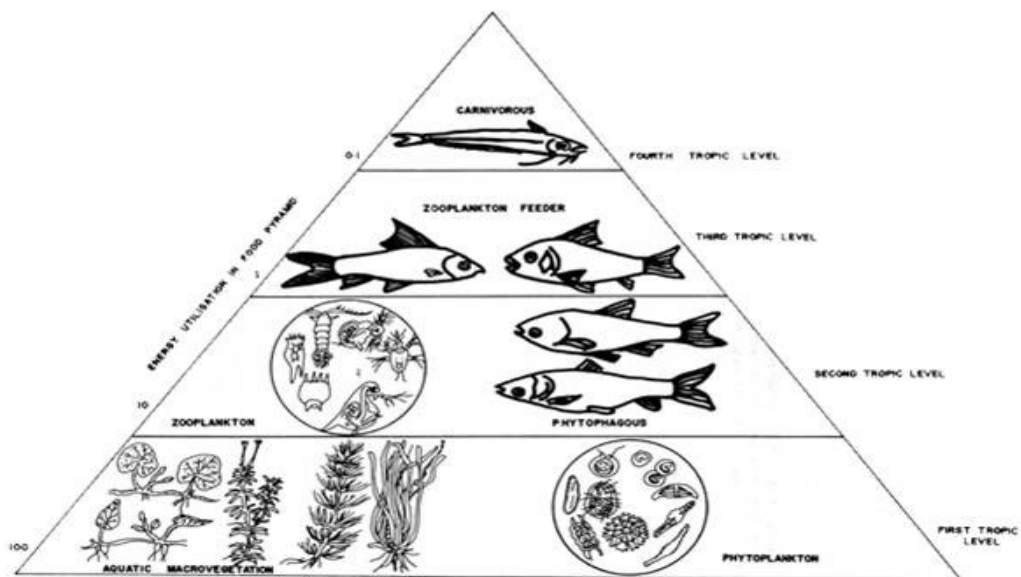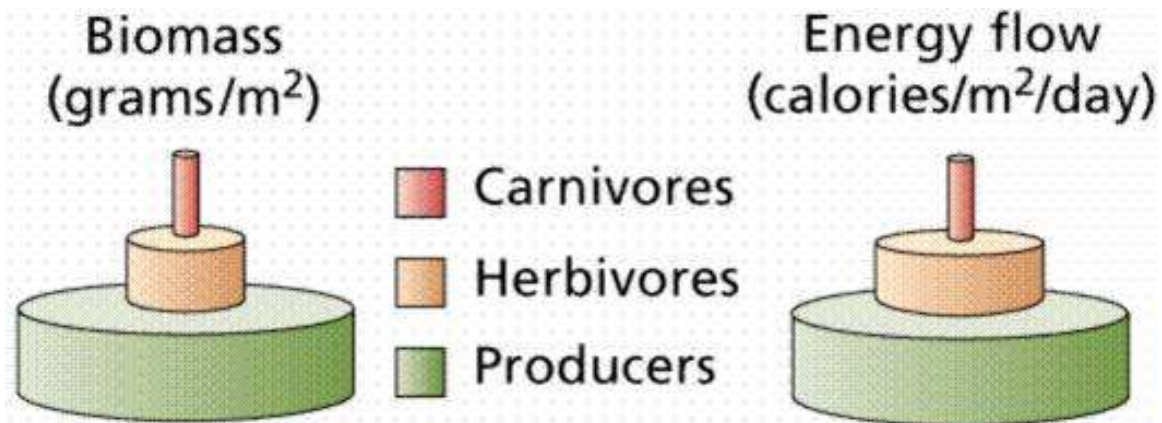
Energy vs. Nutrients

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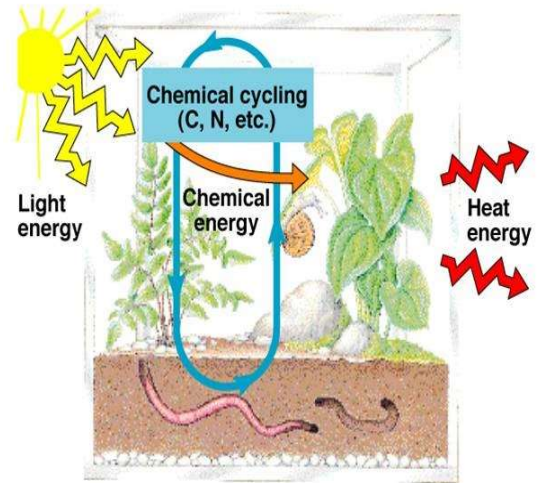
Biomass and Energy Pyramids

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
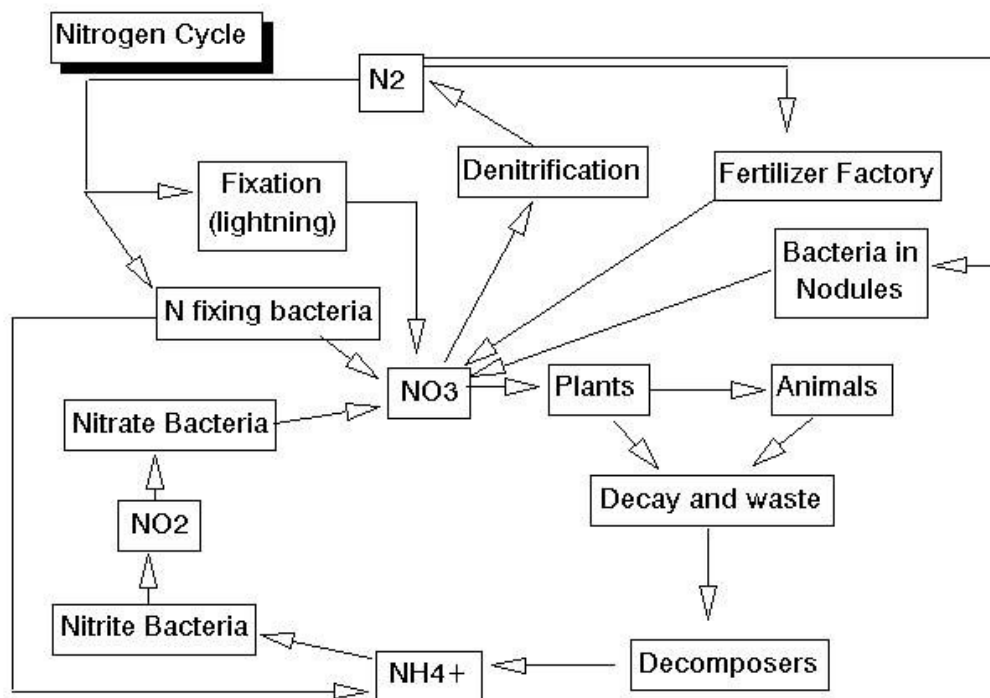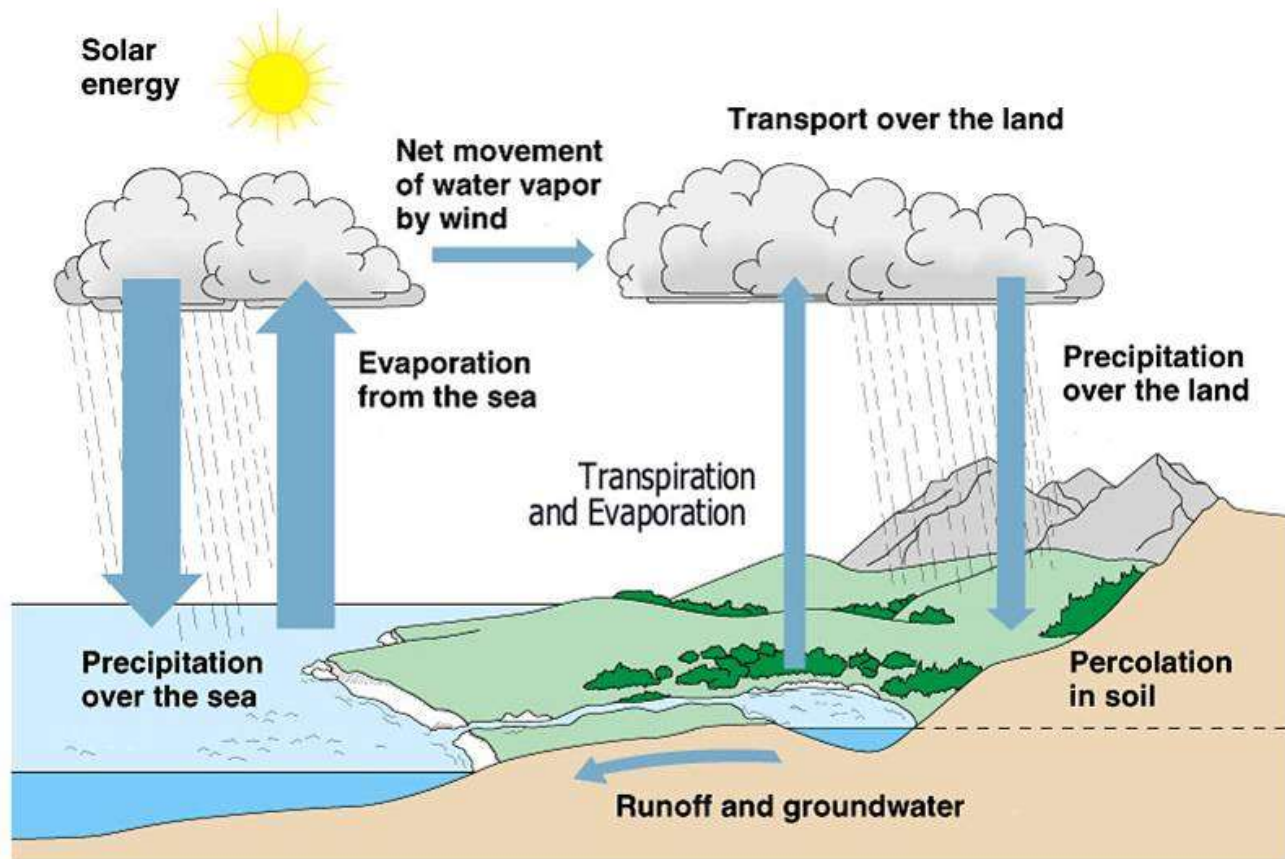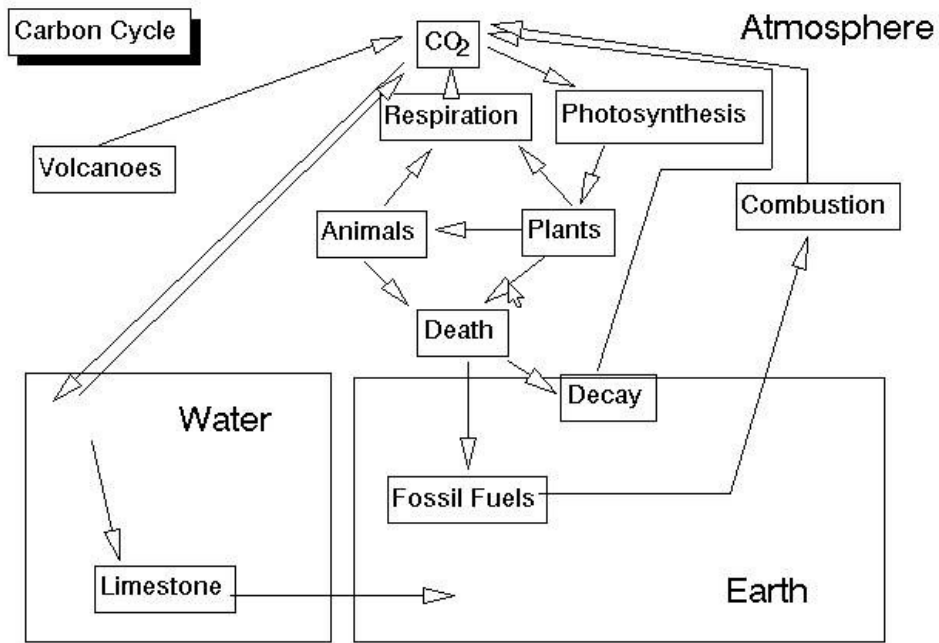
Weather and climate
- **Biome** = a large region of land characterized by the climax vegetation of the ecosystems within its boundaries
- The distribution and key features of biomes are the outcome of temperatures, soils and moisture levels (which vary with latitude and altitude), and evolutionary history
- **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

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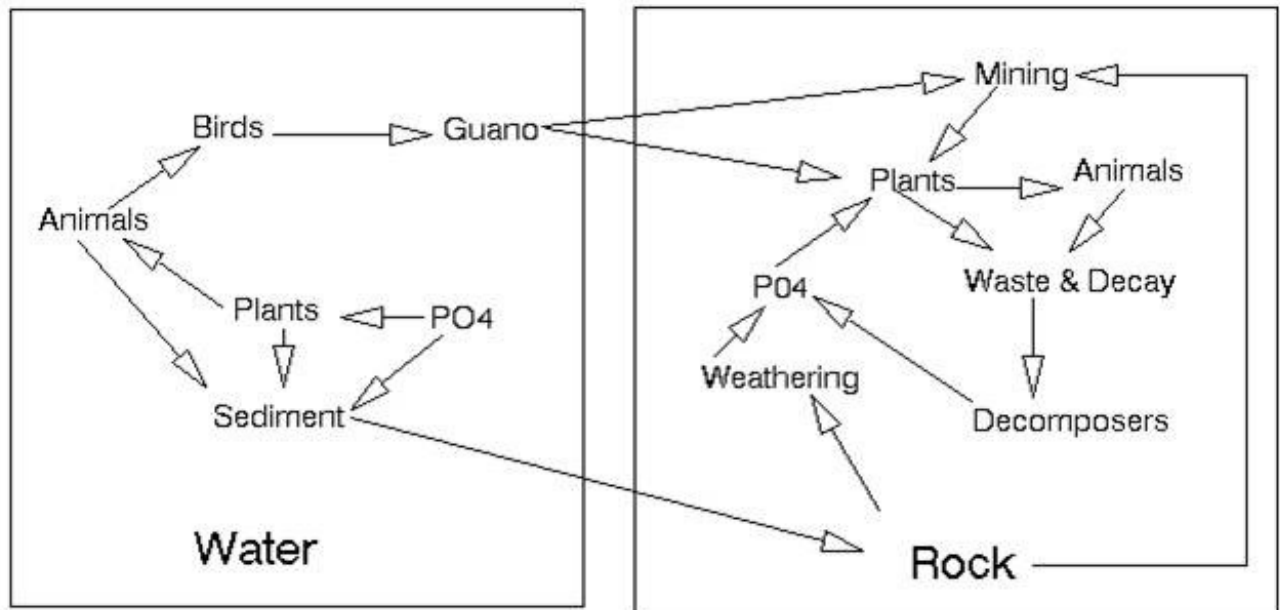In aquatic environments it is often the depth of light penetration that is the key factor.

Nutrient Recycling – Biogeochemical Cycles

Hydrologic (Water) Cycle

Carbon Cycle

Atmosphere

CO_2

Volcanoes

Respiration

Photosynthesis

Combustion

Animals ← Plants

Death

Decay

Fossil Fuels

Water

Limestone

Earth

Phosphorus Cycle

Birds → Guano

Animals

Plants ← PO4

Sediment

Water

Mining

Plants → Animals

PO4

Waste & Decay

Weathering

Decomposers
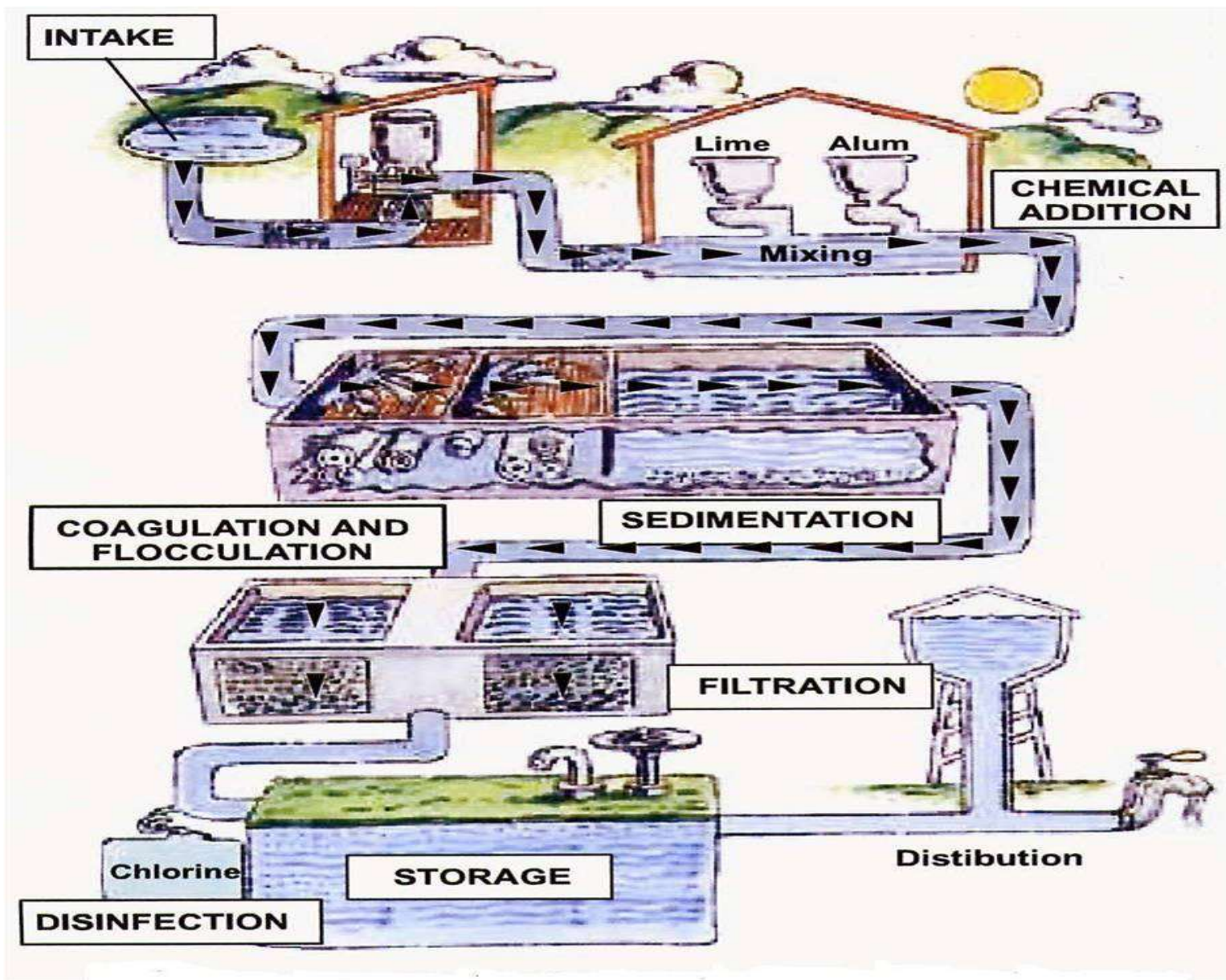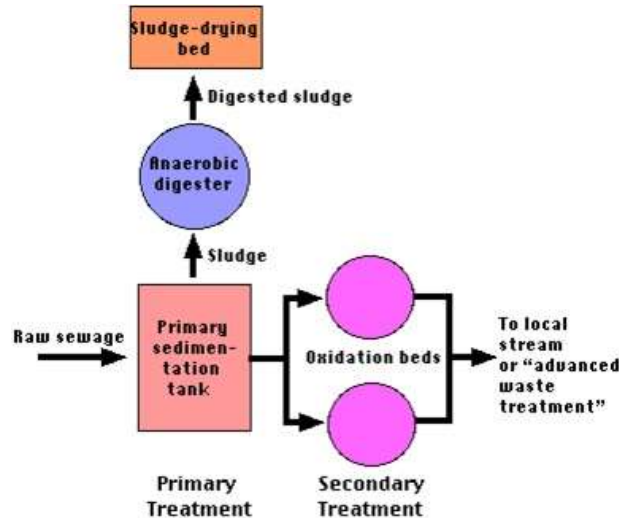
Rock

Potable Water Treatment

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 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

Sewage Treatment

Microbes are used in sewage treatment for
- nutrient recycling
- methane recovery
- disease control

Sludge-drying
bed

↑ Digested sludge

Anaerobic
digester

↑ Sludge

Raw sewage → Primary sedimen-tation tank → Oxidation beds → To local stream or "advanced waste treatment"

Primary Treatment   Secondary Treatment

Primary treatment : The treatment step of sewage for physical removal of particles – 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 – 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.

Making A Simple Salinometer

| Materials | Water | Saltwater Solution |

Several types of salinometers can be made. The simplest is a hydrometer calibrated to read in % of salt concentration instead of specific gravity. Follow the instructions below to make and calibrate a simple salinometer. You will need to research how to make a known saltwater solution to use as a calibration standard.

Materials:
- soda straw
- modeling clay
- a fine-tipped permanent marker
- a tall clear container to hold the solution for calibrating your device
- salt for mixing one or more standard solutions
- water (tap water will work-distilled is better)

1. Mold a ball of modeling clay around one end of the straw. Make sure that the clay prevents water from leaking into the straw. Try to avoid forming pits or voids in the clay that can trap air.

2. Fill the container with water. Carefully insert the straw (clay covered end down) and add/remove clay until the straw floats at the maximum depth you wish.

3. Use the permanent marker to mark the depth where the salinometer floats in the water (0% salt solution).

4. Mix a saltwater solution of known concentration to use as a calibration standard. (10% is a good choice!)

5. Place the salinometer in the calibration standard and mark the level where it floats.

6. Interpolate/extrapolate from the two marks you have made to add additional lines on the scale. You can calibrate your device using additional standards at other concentrations to improve its accuracy.

You are not limited to this simple salinometer. Use your library, the internet, or other resources to research how to make a device with better accuracy and sensitivity.