AP BIOLOGY NOTES ON ECOLOGY
(CHAPTERS 50 – 55)

CHAPTER 50 – INTRODUCTION TO ECOLOGY AND THE BIOSPHERE

YOU MUST KNOW:

- The role of abiotic factors in the formation of biomes.
- Features of freshwater and marine biomes
- Characteristics of the major terrestrial biomes

NOTES:

I. WHAT DOES ECOLOGY STUDY?

- **Ecology** – the Study of Interactions Between Organisms and the Environment
- Organisms all live in complex environment that include:
  a. **Abiotic** components – The nonliving components of the environment such as water, light, temperature, nutrients, soil.
  b. **Biotic** components – the living components of the environment such as other organisms as foods, other resources, or predators.
- These environmental factors limit the geographic range (distribution) and the abundance of species.

- Ecology is studied on several levels of organization
  - **Organism** – physiology, evolution, behavior of organisms in relation to environmental factors.
  - **Population** – interactions of individuals of the same species, living in the same environment
  - **Community** – studies the interactions of all living organisms that are living in the same area
  - **Ecosystem** – emphasizes energy flow and chemical cycling among organisms and the abiotic environment
  - **Biosphere** – includes the entire portion of Earth that is inhabited by life. Studies global effects of climate change, ozone depletion, mass extinction etc.

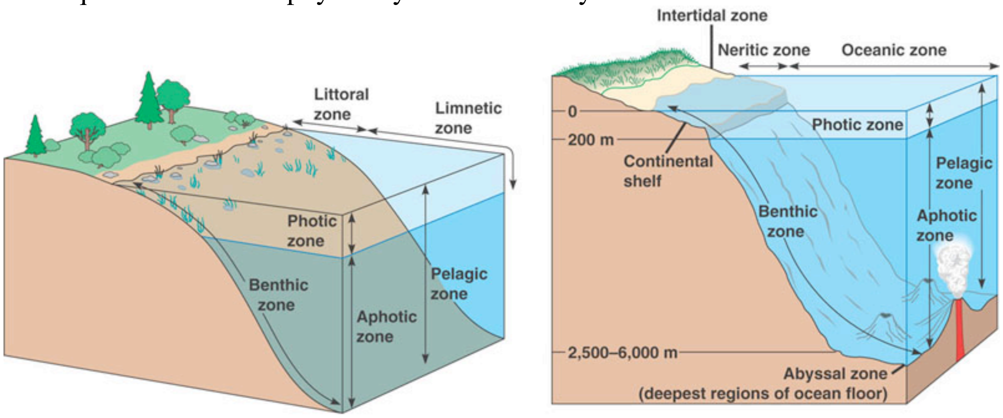
II. WHAT CAN LIMIT SPECIES DISTRIBUTION AND DISPERSAL?

- **Dispersal** – the movement of organisms from centers of high density or from center of origin to other areas.
- Dispersal can be two kinds:
  - Natural range expansions – organisms move into previously uninhabited areas as a natural way of expanding the population.
  - Species transplants – species artificially or accidentally introduced and reproduce in new location.
    – invasive species
    – Burmese python
- Factors that influence the distribution of species:
  - **Behavior and habitat selection** – Certain behaviors like mating, reproduction, nest building habits, etc. can eliminate habitats that otherwise would be very suitable. (ex. European corn borer only deposits its eggs on corn although they eat a wide variety of plants)
  - **Biotic Factors** – Some host species may be necessary for parasites to reproduce in new areas or pollination cannot occur without certain pollinator species, specific nutrient requirements may be necessary (ex. Koalas only eat eucalyptus leaves; parasites that cause malaria need the *Anopheles* mosquito to infect humans)
  - **Abiotic factors** – *Temperature* – affects biological processes such as germination or enzyme activities. *Water* – some organisms can tolerate only fresh water, while others only sea water (different osmoregulation). Terrestrial organisms face a constant threat of dehydration. *Sunlight* – Driving force of photosynthetic organisms and also influence the daily activities of other organisms (photoperiod regulation). *Wind* – influence temperature control, growth of plants and water loss. *Rocks and soil* – its composition, pH limit the distribution of plants and of the animals that feed on them.
  - **Climate** – Temperature, water, sunlight and wind are the major abiotic components of **climate** – the prevailing weather conditions in a particular area.

III. AQUATIC BIOMES

- **Biomes** – major types of ecological associations that occupy broad geographic regions of land or water.
- Aquatic biomes account for the largest part of the biosphere in terms of area. Ecologists usually distinguish between fresh water biomes (salt concentration is less than 1 %) and marine biomes (salt concentration is more than 3 %).

- Aquatic biomes are physically and chemically stratified:

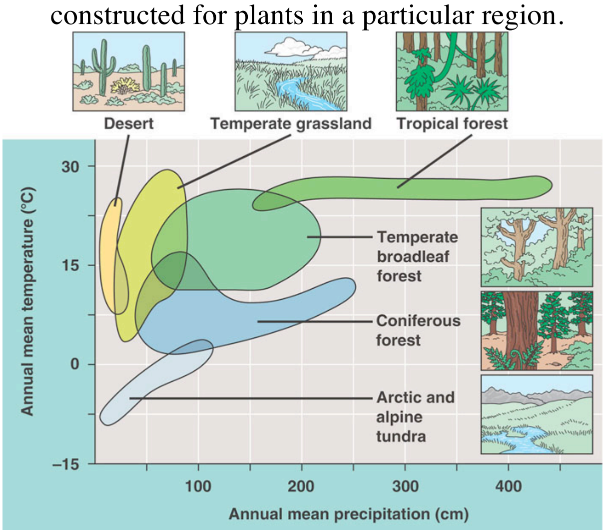


(a) Zonation in a lake (b) Marine zonation

- Light intensity decreases sufficiently because water and photosynthetic organisms absorb it.
  - **Photic zone –** has sufficient light for photosynthesis
  - **Aphotic zone –** does not have sufficient light for photosynthesis
  - **Benthic zone –** the bottom of all aquatic biomes, mostly made up of sand and organic and inorganic sediments. Mostly **detritus eaters** (organisms that eat dead, decomposing organic matter) live there and predators that eat them.
  - **Thermocline –** narrow zone of rapidly changing temperature that separates the warm upper and cold lower layers of lakes and oceans.
- Lakes are the most important standing water biomes. **Oligotrophic lakes** are deep lakes that are usually poor in nutrients (organic materials) but rich in oxygen with lower temperatures, and low phytoplankton concentration. **Eutrophic lakes** are shallower, rich in nutrients with lower concentration of oxygen and higher phytoplankton concentration.
- Aquatic biomes can be described by analyzing salinity, oxygen content, organic content, turbulence, light intensity, temperature

IV. TERRESTRIAL BIOMES:

- **Climographs** (plots of temperature and precipitation to show the distribution of various biomes) are mostly constructed for plants in a particular region.



- Annual means for temperature and rainfall are well correlated with the biomes that exist in different regions.
- Other factors that determine the type of terrestrial biome are the pattern of climatic variation, bedrock type, and soil type because they affect vegetation.
- General features of terrestrial biomes:
    - Named for major physical and climatic features and dominant vegetation
    - Include plants, microorganisms, fungi and animals
    - The shapes and sizes of plants define layering (ex. Canopy – low trees – shrubs – herbaceous plants – forest floor – root layer)
    - There is constant disturbance in biomes by various factors so they show patchiness and variety

CHAPTER 51 – ANIMAL BEHAVIOR

Notes:

I. Overview:

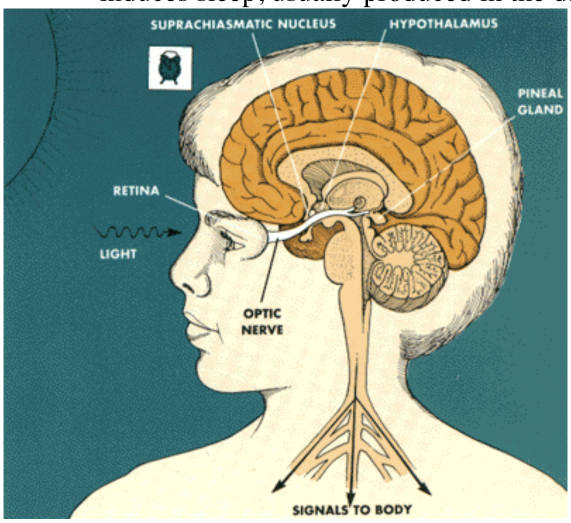
- **Animal behavior** – an action carried out by muscles or glands under control of the nervous system in response to a stimulus. These behaviors are determined by the physiological systems and abilities of the organism.
- Animal behavior is essential part of acquiring nutrients, finding a partner, keeping up homeostasis, raising young, etc.
- Because behavior is necessary for reproduction, it also influences and influenced by natural selection. Animal behavior is limited by the given set of genes that animals have but various mutations and changes in behavior can make the population more or less fit to survive in a given environment.

II. Basics of Animal Behavior (Handout p. 208-209 and 216-217) -- Animal behaviors can be attributed to two components:

- **Innate behavior** -- behavior determined by the "hard-wiring" of the nervous system. It is genetically predetermined, usually inflexible, a given stimulus triggering a given response. These behaviors frequently follow a classical, rigid pathway called a **fixed-action pattern (FAP)** where a releaser (some type of stimulus) triggers an operation of the **innate releasing mechanism** in the nervous system. This trigger results in the same set of actions every time the response is initiated. (Ex. Mating dances of birds triggered by the presence of a female; the egg rolling behavior of many waterfowl species; kelp gull chicks peck on a red spot on mother's beak to initiate regurgitation of food etc.)
    - Examples of innate behaviors:
        - **Reflexes** – knee-jerk reflex, withdrawal reflex
        - **Taxis –** movement in response to the direction of the stimulus toward (positive) or away (negative) from the stimulus
        - **Kinesis –** Random movement of the animal in no particular direction (Ex. Pill bugs move more when the humidity is low)
        - **Instincts (stereotyped behavior) –** more complex behaviors than reflexes that repeat the same way every time (Ex. Shaking water from wet fur, newly hatched sea turtles move toward the ocean)
- **Learned behaviors –** Results from experiences of the animal. Learned behaviors can modify innate behaviors. Learning behavior also may not follow the exact same pattern every time.
    - Examples of learned behaviors:
        - **Classical conditioning** – animals associate one stimulus with another (Ex. dog salivate when gets food, can be taught to salivate when hears a bell – Pavlov)
        - **Habituation** – response to the stimulus decreases when it is repeated with no apparent effect (Ex. Drug habituation in humans; harbor seals get used to hearing local killer whale calls and do not respond to it)
        - **Imprinting behavior** – during a critical period, an animal can adopt a behavior by latching on to the stimulus (Ex. Mallard chicks follow the first organism who they see right after hatching – Lorenz)
        - **Operant conditioning** – or trial and error learning – animal is rewarded or punished after chance behavior.

III. Timing of Animal Behavior (Review pp. 201-205)

- **Environmental cues**, such as day length, height of tides, temperature changes, plants and animals to establish or maintain patterns of activities use moon phases. Many life activities run in cycles, such as mating, birth, storage of food, migration, building body fat, sleeping patterns, hibernation.
- **Biological rhythms** can be direct response to environmental stimuli (**exogenous**) or can occur without environmental cues (**endogenous**). These endogenous components of biological rhythms are often called biological clocks. Endogenous rhythms continue even in the absence of environmental cues.
- To remain in synchrony with the environment, biological clocks need to reset at regular time intervals by external timekeepers. These are environmental cues that reset the clock.
- In humans the internal clock is made up of a set of cells in the midline of the brain (**suprachiasmatic nucleus – SCN).** Light from the eyes stimulates the nerve pathways that connect with this biological clock and helps to reset it. The SCN is connected to the **pineal gland** in our brain. This gland produces **melatonin** – a hormone that induces sleep, usually produced in the dark. Melatonin helps to realign our biological clocks.



- When we travel through time zones and our biological clock becomes misaligned from the real time in a given location, we get **jet lag.**

IV. Hibernation (Review sheet: p. 207)

- **Hibernation –** is a state of inactivity and metabolic depression in animals, characterized by lower body temperature, slower breathing, and/or lower metabolic rate.
- Hibernation is usually performed by animals to conserve energy during the winter months when food sources are limited. During hibernation the animal is also less responsive to environmental stimuli.
- Hibernation periods can vary between species (days, weeks and month)
- Animals prepare for hibernation by using environmental clues such as shortage of food, shorter days or cooler temperatures. They frequently build up energy storage as fat deposits.
- Some animals have reduced metabolic rates during the summer -- **estivation**

V. Animal Migrations (Review sheet 211-213)

- Migration is another important response to environmental change. True migration is when a group of animals travel from one well-defined area to another for a specific purpose such as breeding, overwintering, seeking food. -- migration of tundra swans
- Animals use a wide range of environmental cues to navigate and determine their position during migration. These cues include stellar (star formations) and solar cues, visible landscape features, wind direction, low frequency sounds generated by winds, polarized light, the Earth's magnetic field, smell of the sea etc.
- Navigation is also involved in **homing activities** (the ability of the animal to return to its home site or locality after being displaced).

VI. Animal Communication (Review sheet 219-225)

- **Communication** – the transmission of information between animals of the same species or sometimes-different species. Effective communication relies on being correctly understood so the messages conveyed between animals are highly ritualized (so easily interpreted). Communication can involve a range of signals such as visual, chemical, auditory and tactile signals. (*See examples in the handout)*

CHAPTER 52 – POPULATION ECOLOGY
Chapter objectives:

YOU MUST KNOW:

- How density, demographics and dispersion can describe a population.
- The differences between exponential and logistic models of population growth.
- How density-dependent and density-independent factors can control population growth.

NOTES:

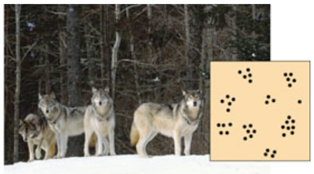
I. OVERVIEW:

This chapter is very abstract. To really understand and practice population ecology requires a lot of crunching numbers, fieldwork, calculations and reading graphs. We are just learning the basic key terms and some patterns and generalizations. Always know multiple examples where it applies.

- **Population** – individuals of a species within a given area. They are distributed in space; vary in age and size → **population structure.**

II. POPULATION DENSITY AND DEMOGRAPHICS

- Members of the same population rely on the same resources, are influenced by the same environmental factors, interact and reproduce with each other.
- **Population density** – the number of individuals per unit area or volume (can be determined directly by counting or by sampling)
- **Population dispersion –** the pattern of spacing among individuals of the populations.
  - **a.** Patterns of distribution of various populations within a geographic range:
    - **Clumped** – the individuals aggregated in patches (ex. Plants, fungi, pack of wolves) because of patchy environmental conditions or food sources, carnivorous animals may be more successful of hunting in packs or herbivorous animals may be more successful of surviving attacks of carnivores in herds, mating behaviors also may call for clumped dispersion.
    - **Uniform –** the individuals in the population are evenly spaced (ex. Plants release chemicals that inhibit the germination and growth of other organisms, territoriality among animals, artificially planted trees)
    - **Random –** occurs in the absence of strong attractions or repulsions among individuals of the population. The position of each individual is fairly independent on the other individuals. (ex. Wind blown seed disposal for trees or other plants)



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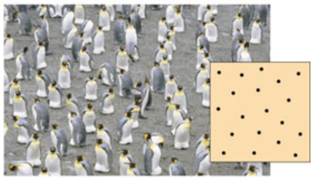

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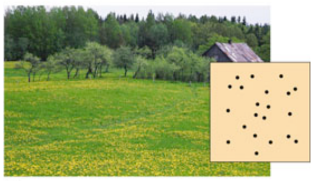

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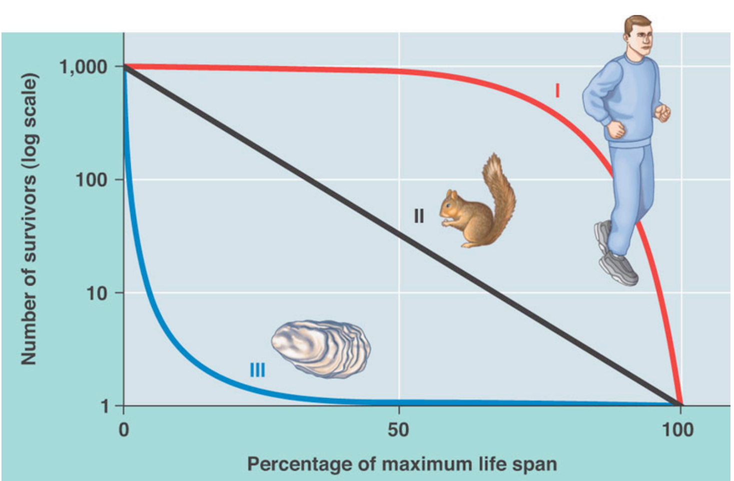
- **Demography** – the study of the vital statistics of populations and how they change over time – is also a useful way of describing populations.
  - **Life tables** – age-specific summaries of the survival pattern of a population. These tables follow the fate of a group of individuals of the same age (**cohort)** from birth until death. These are hard to construct for wild animals.

  - **Survivorship Curves –** A graph that plots the proportion or number of individuals in a cohort still alive at each age. Although survivorship curves are diverse, they usually follow one of three patterns:
    - **Type I** – flat at the start, reflecting low death rates during the early and middle years, than it drops steeply as death rates increase in old age (large mammals, humans).
    - **Type III** – drops sharply at the start because of high death rates for the young, but than flattens out as death rates decline for those few individuals that have survived to a certain age. Typically, these organisms have large number of offspring and very little care (oysters, many fish species)
    - **Type II** – Intermediate, with a constant death rate over the organism's life span (most rodents, some lizards, annual plants)

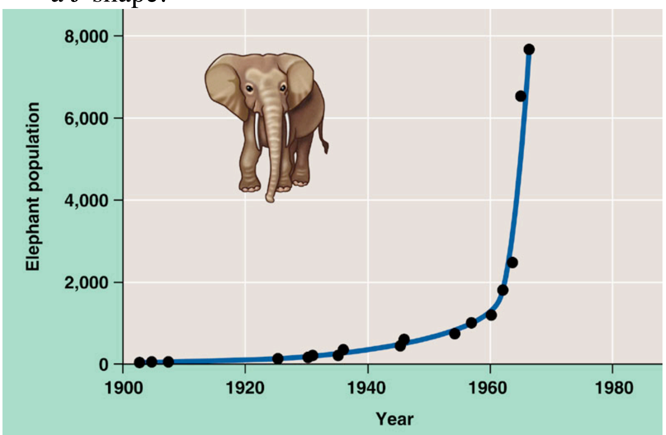


    - Most organisms have a mix of two types of survivorship curves.

III. THE EXPONENTIAL GROWTH MODEL

- Although populations have a tremendous capacity for growth, unlimited population growth does not occur indefinitely. Limited resources or other environmental factors will slow growth down.
- The growth of the population can be calculated by using:

  dN/dt = B-D (where N=population size; t = time; B= birth rate; D= death rate)
- In a hypothetical population that consists of only a few individuals with unlimited resources the population will increase with every birth if the immigration and emigration is ignored.
  a. **Zero population growth** occurs when the per capita birth and death rates are equal or r = 0
  b. **Exponential population growth** can occur if the population has abundant resources and free to reproduce at their physiological capacity. Under these conditions the per capita rate of increase can reach its maximum for the species. When the population is plotted over time the exponential growth curve has a J-shape.

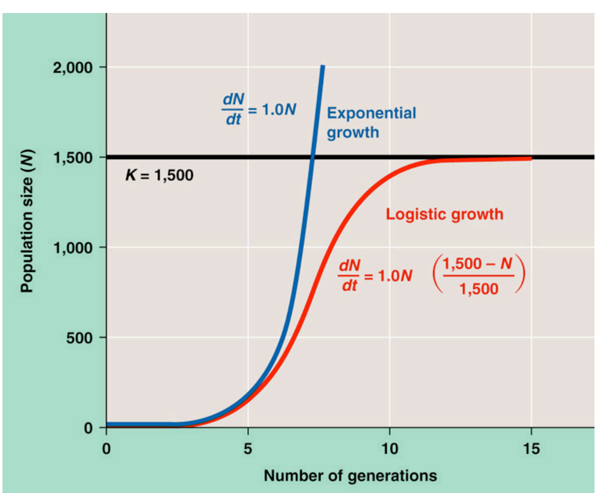


- This type of exponential growth occurs in populations that are introduced into a new or unfilled environment or whose numbers have been drastically reduced by a catastrophic event and are rebounding.
- During exponential growth the population number is:

  dN/dt = $\mathbf{r_{max}N}$ (where r_{max}= maximum per capita growth rate of the population)

IV. THE LOGISTIC GROWTH MODEL

- In nature, there is always a limit to the growth of a population. Because a habitat cannot support unlimited number of individuals. **Carrying capacity (K)** – is the maximum population size that a particular environment can support. It varies over space and time. Limited environmental resources lead to a lower per capita rate of increase (r).
- The **logistic population growth model** accounts for the carrying capacity of the environment when it calculates the per capita rate of increase.



- In most natural populations there is a lag time before the negative effects of an increasing population are realized. This may cause the population to overshoot its carrying capacity before settling down to a relatively stable density. Other populations may fluctuate greatly and it is even difficult to define the carrying capacity of those.
- Logistic growth is calculated by
  $dN/dt = r_{max} N (K-N/K)$ (where K is the carrying capacity of the population)

V. SELECTION FOR LIFE HISTORY TRAITS

- High and low population densities require very different reproductive and survival mechanisms (life histories):
  - **K – selection** – density dependent selection acts when population density is high, each individual has few resources. Competitive ability and efficient use of resources is favored.
  - **r** – **selection –** density independent selection acts when the population density is low, each individual has plenty of resources so rapid reproduction is favored.
- Genotypes that are most fit at low density do not have high fitness at high density.
- The K/r selection concepts have been criticized to be oversimplified.

VI. POPULATION REGULATIONS

A. Population Density and Population Change:

- **Density independent factors –** the birth and death rate changes but independently from the size of the population (natural catastrophe)
- **Density dependent factors –** The birthrate falls with rising density (ex. Lynx population decreases if not enough hares are available)

B. Density Dependent Population Regulation

- This is an example of negative feedback mechanism (*review)*—at increased densities the birthrate declines or the death rate increases or both. Mechanisms that cause this:
  a. Competition for resources
  b. Territoriality
  c. Health (increased transmission rate of a disease)
  d. Predation
  e. Toxic metabolic wastes
  f. Intrinsic factors (physiological factors that drop reproduction – later maturation, aggressive interactions among individuals)

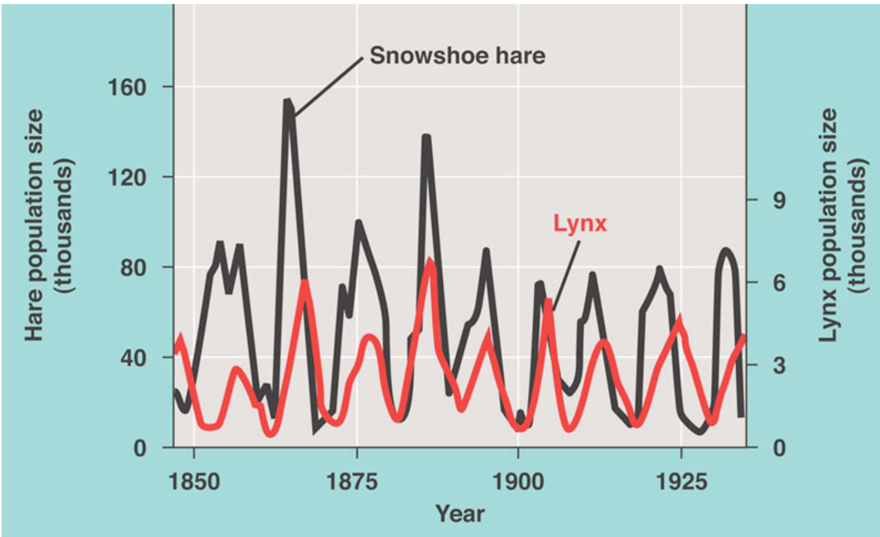
C. Population Dynamics – focuses on complex interactions between biotic and abiotic factors that cause variations in population size.

- Over time all populations show fluctuations in numbers.
- Fluctuation of numbers of large mammal populations can be caused by harsh winter or increasing predator numbers, but they are usually seem to be relatively stable:

  - Smaller, invertebrate animals can have an even more fluctuating population number. Environmental factors affect them even more, more predators or even in some cases cannibalism can decrease the population while laying very large number of eggs can quickly increase the population numbers:

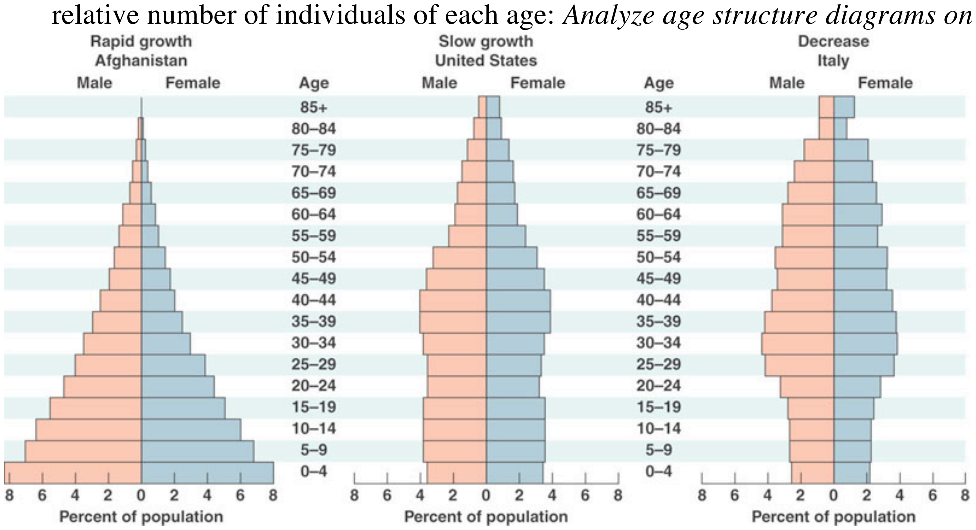
D. Population Cycles:

- Many populations increase and decrease at unpredictable intervals, but others go through regular cycles of boom-and-bust cycles (ex. Hare and lynx populations)



VIII. HUMAN POPULATION GROWTH:

- Human population went through and unprecedented boom in numbers since 1650. This growth cannot be sustained for very long in other populations. Although human population still grows, the rate of growth decreased. This decrease in the rate of growth is due to diseases (AIDS) and voluntary population control.
- Population dynamics vary by region to region or by country to country.
    a. Some populations are stable with high birth rate and high death rate
    b. Others are stable with low birth rate and low death rate
    c. Others go through **demographic transition** from a. to b.
- One important demographic variable in present and future growth trends is a country's **age structure** – the relative number of individuals of each age: *Analyze age structure diagrams on the book's CD-ROM Activity 52.6*



- These age structure diagrams not only predict population growth trends but also predict future employment, education and social issues.
- It is hard to determine the **global carrying capacity** for humans. **Ecological footprint –** the aggregate land and water area needed to sustain the people of a nation, is one measure of how close we are to the carrying capacity of Earth. At more than 6 billion people, the world is already in ecological deficit.

CHAPTER 53 – COMMUNITY ECOLOGY
YOU MUST KNOW:

- The difference between a fundamental niche and a realized niche
- The role of competitive exclusion in interspecific competition.
- The symbiotic relationships of parasitism, mutualism, and commensalisms with examples.
- The impact of keystone species on community structure.
- The difference between primary and secondary succession.

I. OVERVIEW OF THE CHAPTER:

- **Community** – an assemblage of populations of various species living close enough for potential interaction.
- Ecologists define the boundaries of a particular community to fit their research question.

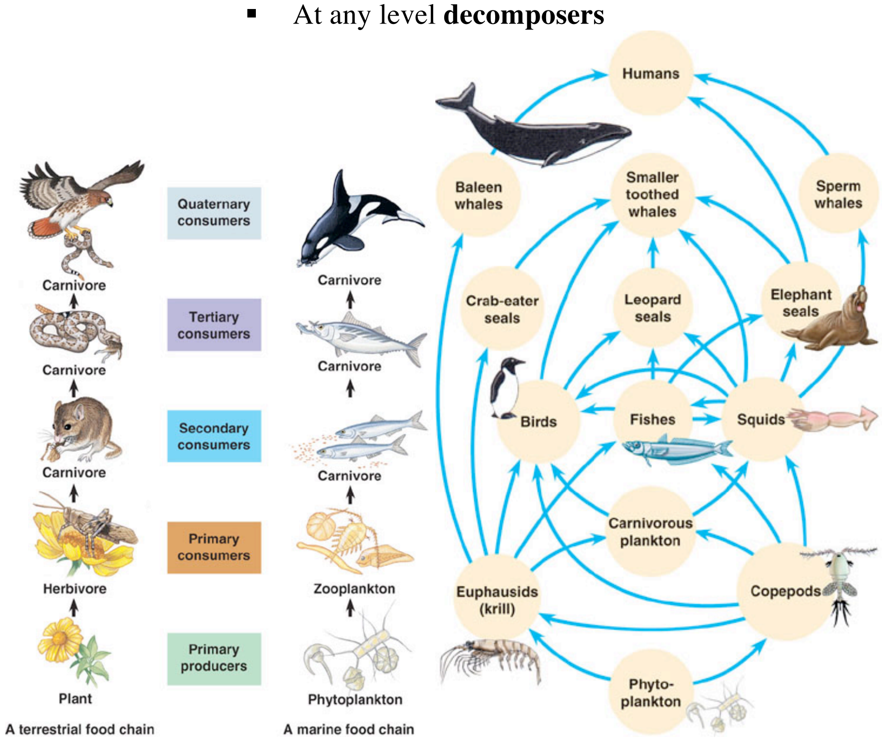
II. COMMUNITY INTERACTIONS:

- The sum total of a species' use of the biotic and abiotic resources in its environment is called the species' **ecological niche**. As a result of competition, a species' **fundamental niche**, which is the niche potentially occupied by that species, may be different from its **realized niche** that is the niche the species actually occupies.
- Ecologists refer to these relationships as **interspecific interactions**. There are several types of these interactions:
    - **Interspecific competition** – occurs when species compete for a particular resource that is in short supply (ex. Garden plants and weeds for soil and water). The results of this competition are detrimental for both species (-/-). Strong competition can lead to the local elimination of one of the two competing species – **competitive exclusion principle**. Even slight advantage in using resources more efficiently can result in a reproductive advantage for one species and drive the other to extinction. At times two species that compete for resources will evolve differently from each other so they do not compete for the same resources any more and they can coexist in the same community – **resource partitioning.**
    - **Feeding relationships (Predation and herbivory)** – +/- interaction between species in which one species, the predator, kills and eats the other, the prey. Both predators and prey developed important adaptations through natural selection for survival (*Know examples)*. Herbivores and plants also have adaptations to avoid being eaten or benefit from it and also to be more successful plant eaters. *(Also need to know examples)* Interesting morphological and physiological adaptations also developed to be more successful in the feeding relationships:
        - **Cryptic coloration** (camouflage) – Ex. Canyon tree frog
        - Mechanical and chemical defenses – Ex. Skunks, porcupines
        - **Aposematic coloration** (warning coloration) – Ex. Poison arrow frog
        - **Batesian mimicry –** harmless (palatable) species mimics a harmful one – Ex. Hawkmoth larva mimics green parrot snake
        - **Mullerian mimicry –** 2 or more unpalatable (poisonous) species resemble each other – Ex. Various wasp species – This is a good example of **convergent evolution**
    - **Symbiotic relationships:**
        - **Parasitism** – (+/-). **Parasite** benefits, **host** is being harmed. Can be **endoparasites** (organisms that live within an other organism) or **exoparasites** (organisms that live on the outer surface of the host). **Parasitoidism** – organisms lay eggs within or on a living host. *You must know examples*. Parasites can seriously limit growth in the host population.
        - **Infectious diseases** (+/-). **Pathogens** or disease causing agents are typically small microorganisms (bacteria, viruses, prions, protists, fungi). *You must know one example of each*. Pathogens can also seriously limit population growth in the infected populations.
        - **Mutualism** (+/+) – Ex. Ants and acacia trees, N-fixing Rhisobium bacteria and legumes.
        - **Commensalism** (+/0) – Any close relationship would influence both organisms in most cases, so it is hard to find examples of this relationship. Ex. Egrets and water buffalo, whales and barnacles.

- **Coevolution** – reciprocal evolutionary adaptations of two interacting species. This has to be a genetic change in one of the parties to follow another change in the other organism.

III. COMMUNITY STRUCTURE:

- Two fundamental features of community structure:
  - **Species diversity** – variety of different kinds of organisms that make up the community. It is composed of **species richness** – total number of different species and **relative abundance** – the proportion of each species to the total number of individuals. Various sampling techniques are used to determine species diversity.
  - **Trophic structure** or feeding relationships. Food chains describe the transfer of materials and energy from one organism to the next. The typical order:
    - **Primary producers** (mostly photosynthetic plants or algae)
    - **Primary consumers** (mostly herbivores)
    - **Secondary consumers** (carnivores)
    - **Tertiary consumers** (carnivores)
    - **Quaternary consumers** (carnivores)
    - At any level **decomposers**



- More realistic representations of feeding relationships are **food webs**

- Food chains are usually relatively short and rarely have more than four links. There are two hypotheses why:
  - **Energetic hypothesis** – limited by the inefficiency of energy transfer, so by the end of the chain the energy content of organisms is very low.
  - **Dynamic stability hypothesis** – long food chains are less stable than short ones. It would take more time to recover after a disturbance for top predators in a long chain.

IV. Species with Larger Impact:

- **Dominant species** – those species in a community that are the most abundant or collectively have the highest **biomass** (total mass of all individuals in a population). The dominant species set a control over the type and distribution of other species but replacing it with another dominant species may not result in significant change in the community.
- **Keystone species** – They are not necessarily the most abundant species in a community but they exert strong control on community structure by their crucial ecological roles. Ex. Sea otter is a key stone predator in the kelp forests. Once their numbers are decreasing, the number of sea urchins increases and the kelp density decreases.

- **Foundation Species –** Organisms that cause physical changes in the environment through their behavior or through their large collective biomass. Ex. Beaver.

IV. DISTURBANCE AND COMMUNITY COMPOSITION:

- According to the new view on biological communities, the **nonequilibrium model** describes them better – communities are constantly changing after being buffered by disturbances.
- **Disturbance** is an event, such as a storm, fire, flood, drought, overgrazing, or human activity that changes a community, removes organisms from it, and alters resource availability.
- Human disturbance because of farming, development, climate change and pollution is the most serious and most widespread of all disturbances.
- **Ecological succession** – The process in which a disturbed area may be colonized by a variety of species, which are in turn replaced by still other species. There are two types of ecological successions:
  - **Primary succession** – a virtually lifeless area without soil such as a new volcanic island or rubble (moraine) is gradually become inhabited. Organisms: autotrophic prokaryotes → lichens, mosses → grasses → shrubs → trees → climax community (this process may take hundreds or thousands years)
  - **Secondary succession –** when soil is present from a previously existing community (ex. Cleared forest). Organisms: herbaceous plants → woody shrubs → trees → climax community (Takes less time to develop).
- By altering soil properties, pioneer plants allow new plant species to grow, the new plants alter the environment in other ways.

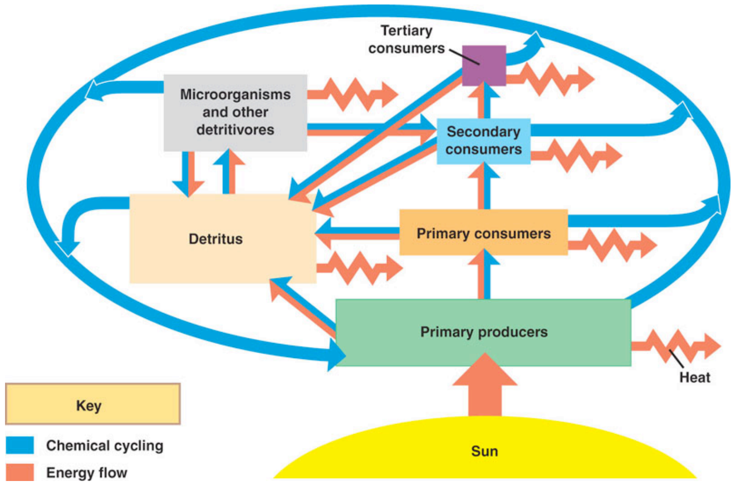
CHAPTER 54 – ECOSYSTEMS

YOU MUST KNOW:

- How energy flows through the ecosystem by understanding the terms in bold that relate to food chains and food webs.
- The difference between gross primary productivity and net primary productivity.
- The carbon and nitrogen biogeochemical cycles.

I. OVERVIEW:

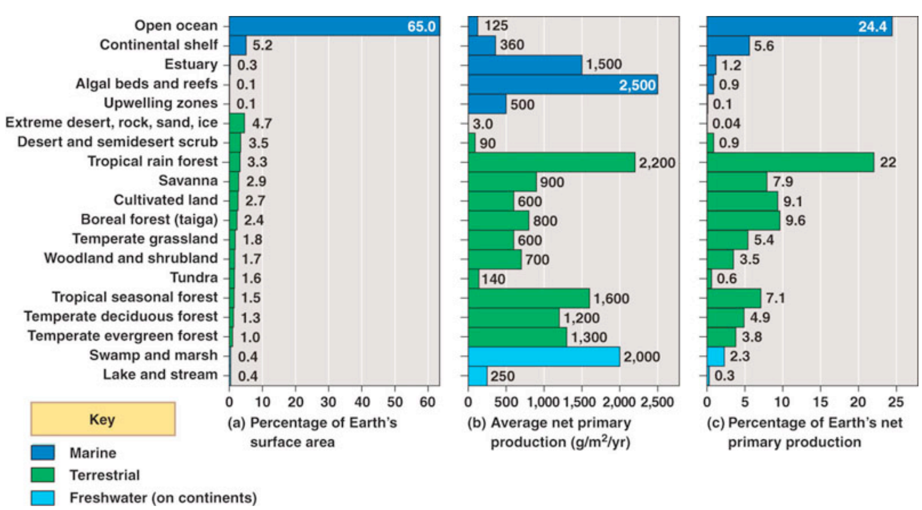
- **Ecosystem** – consists of all living organisms in a community as well as the abiotic factors with which they interact.
- Ecosystems' dynamics involve energy flow and chemical cycling. Energy flows through the ecosystems while matter cycles within them.
- By grouping species in a community into trophic levels, we can follow the flow of energy and the movement of chemical elements.
- Energy flow is guided by physical laws:
  - **Principle of conservation of energy** – energy cannot be created or destroyed but only transformed. In living systems the source of energy is the sun and the energy is either stored in organic compounds, reflected back from surfaces or is lost as heat.
  - **Second law of thermodynamics** – energy conversions cannot be completely efficient because some energy is always lost as heat.



- Decomposers break down the organic material in an ecosystem and transfer the chemical elements into inorganic forms to abiotic reservoirs such as soil, water and air.

II. LIMITS OF PRIMARY PRODUCTION:

- **Primary production –** the amount of light energy converted to chemical energy by autotrophs during a given period of time.
- Solar energy is absorbed, scattered or reflected back by various surfaces or by the atmosphere. Bare ground and bodies of water absorb or reflect most of the incoming energy and make it useless for living organisms. Mostly the red and blue wavelength of the visible light range is used for photosynthesis but only 1 % of the visible light will really be converted to chemical energy.
- **Gross primary production (GPP) –** the total primary production in an ecosystem, which is the amount of light energy that is converted to chemical energy by photosynthesis per unit time. The units used are $J/m^2/yr$ or $g/m^2/yr$.
- **Net primary production (NPP) –** is equal to the gross primary production minus the amount of energy used by primary producers for respiration. The units used are $J/m^2/yr$ or $g/m^2/yr$.
- The net primary production is the value of energy that will be available to the consumers in an ecosystem.
- Different ecosystems vary considerably in their net primary production and in their contribution to the total net primary production of the Earth:



- Limitations of primary production in marine and freshwater ecosystems:
  - Light is a key variable – as the light is moving down in the photic zone of the ocean or a lake most of it is absorbed by the water and does not reach into the deeper areas of water (aphotic zone)

- Nutrients can also limit primary production. The most common elements that are limiting factors are nitrogen, phosphorous and iron. However, if there is too much nitrogen or phosphorous in the water it results in **eutrophication** (algal bloom of cyanobacteria) that substantially decreases the oxygen concentration in the water and kills most fish species.

- Limitations of primary production in terrestrial and wetland ecosystems:
  - Large-scale limiting factors are temperature and moisture that control primary production. These factors and their effect on the environment can be measured by **actual evapotranspiration** – the annual amount of water transpired by plants and evaporated from the landscape measured in millimeters.

  - On the local scale the limiting factor can be the mineral nutrient content of the soil. The limiting minerals are usually nitrogen and phosphorous.

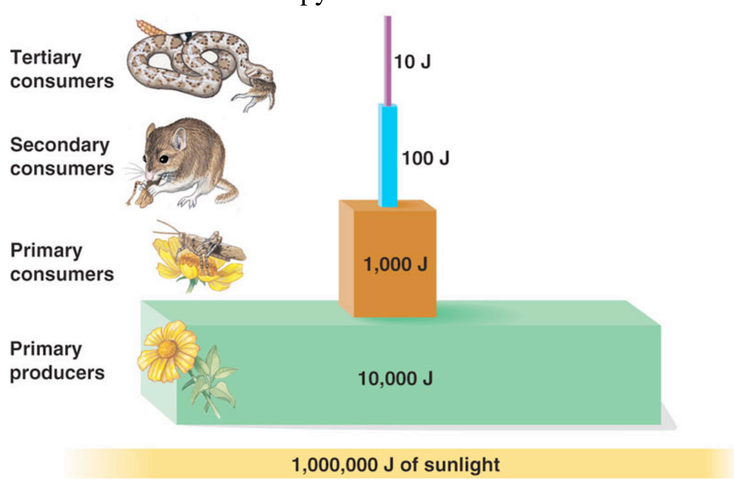
III. ENERGY TRANSFER BETWEEN TROPHIC LEVELS:

- **Secondary production –** the amount of chemical energy in consumers' food that is converted into their own biomass during a given time period. Much of the primary production in not used by consumers.
- We can measure the efficiency of animals as energy transformers by using the following equation:

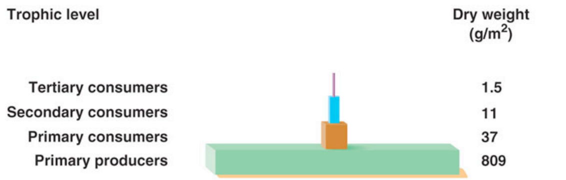
Production efficiency = net secondary production / assimilation of primary production

Where assimilation consists of the energy that is used for growth, reproduction and cellular respiration.

- **Production efficiency** is only a fraction of the energy stored in food and not used for respiration.
- Birds and mammals have the lowest production efficiency because of the upkeep of constant body temperature – 1 – 3 %, fish that are ectotherms have 10 %; insects have a 40 % production efficiency.
- **Trophic efficiency** – the percentage of production transferred from one trophic level to the next. Trophic efficiencies are always lower than production efficiencies and only range about 5 – 20 %. Trophic efficiency is expressed in three ways:
  - **Pyramids of production** – shows the loss of energy on each trophic level where primary producers always form the base of the pyramid.



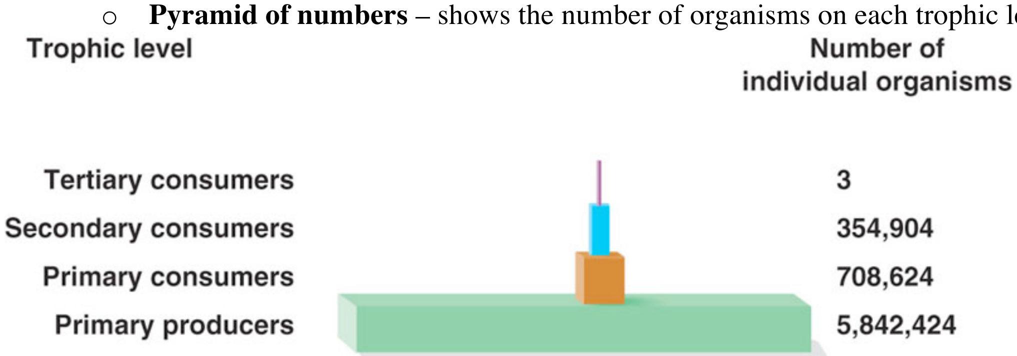
  - **Pyramids of biomass –** each tier represents the total dry weight of all organisms in one trophic level. Most biomass pyramids narrow sharply as we move up to the top-level carnivores, however, some aquatic ecosystems have inverted biomass pyramids because of the short turnover time of phytoplankton.



(a) Most biomass pyramids show a sharp decrease in biomass at successively higher trophic levels, as illustrated by data from a bog at Silver Springs, Florida.

(b) In some aquatic ecosystems, such as the English Channel, a small standing crop of primary producers (phytoplankton) supports a larger standing crop of primary consumers (zooplankton).

- **Pyramid of numbers** – shows the number of organisms on each trophic level:

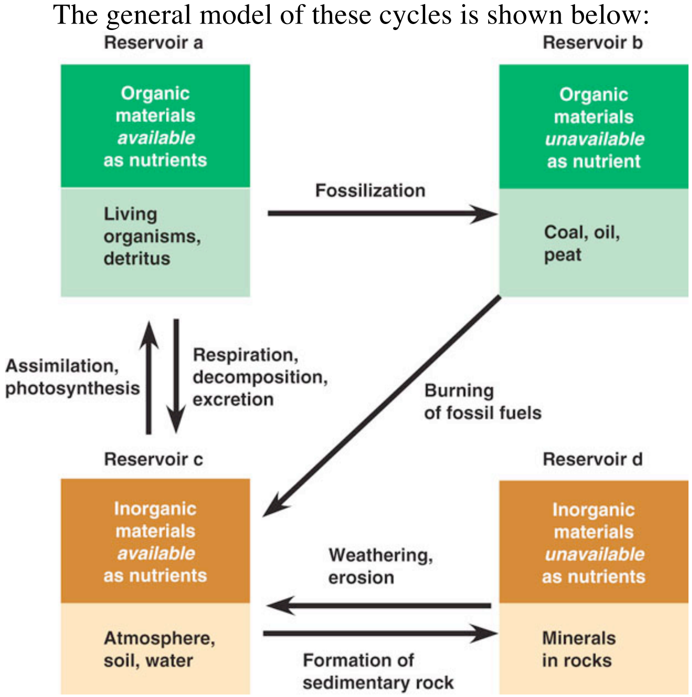


- The dynamics of energy flow has serious implications on the human population as well. More people can be fed efficiently with grains and vegetables than with meat.

IV. BIOGEOCHEMICAL CYCLES:

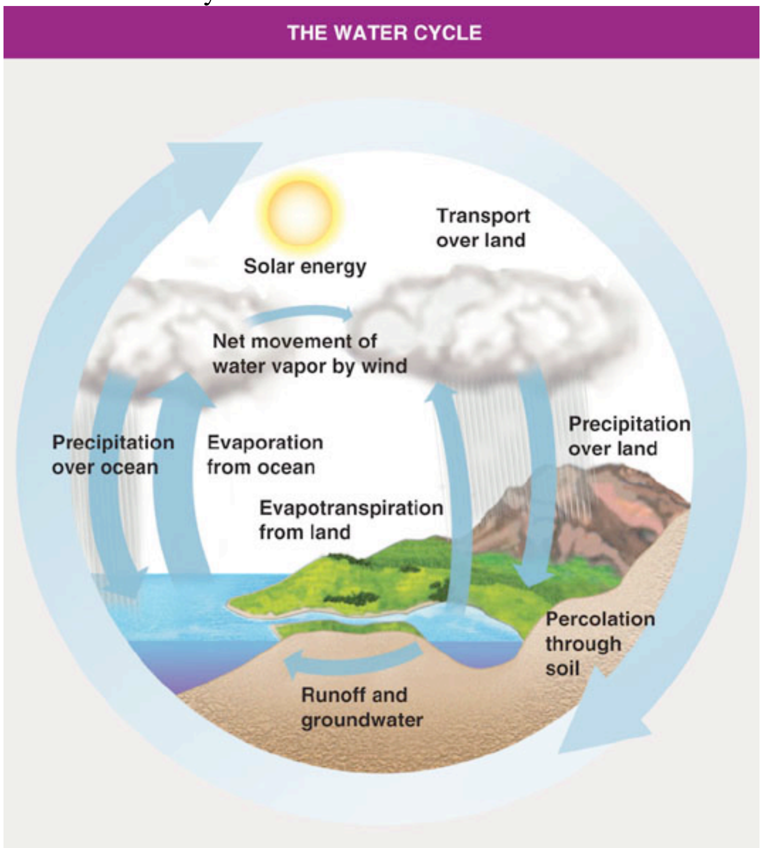
Chemical elements only available in limited amounts in ecosystems so these essential elements must be recycled between the biotic and abiotic environment – **biogeochemical cycles**

The general model of these cycles is shown below:



The following four cycles are the most studied and most important for living organisms:

- The Water Cycle



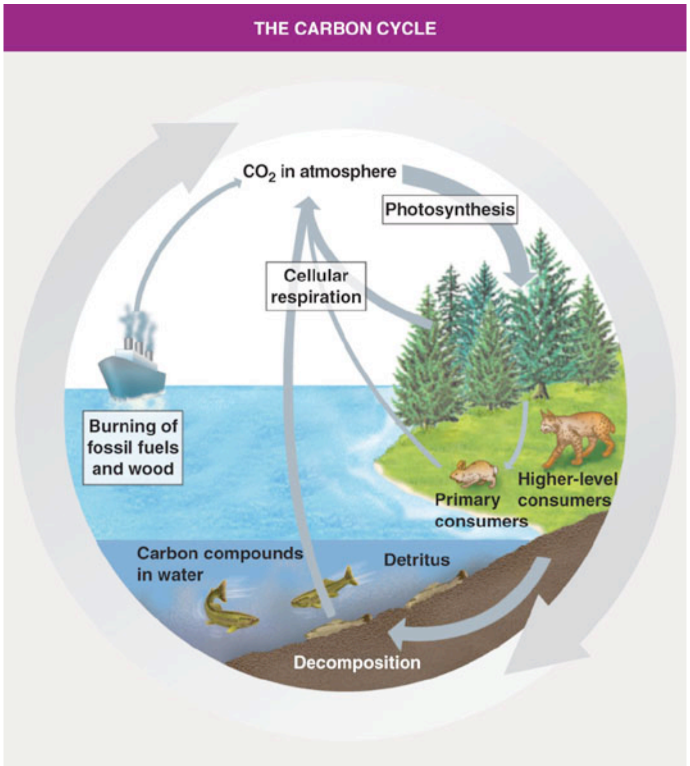
Water is essential to all organisms and its availability influences the rate of ecosystem processes, especially the primary production and decomposition

Forms available: Mostly liquid water

Reservoirs: The oceans (97%), glaciers and polar ice caps (2%), lakes, rivers, groundwater (1%), atmosphere (negligible)

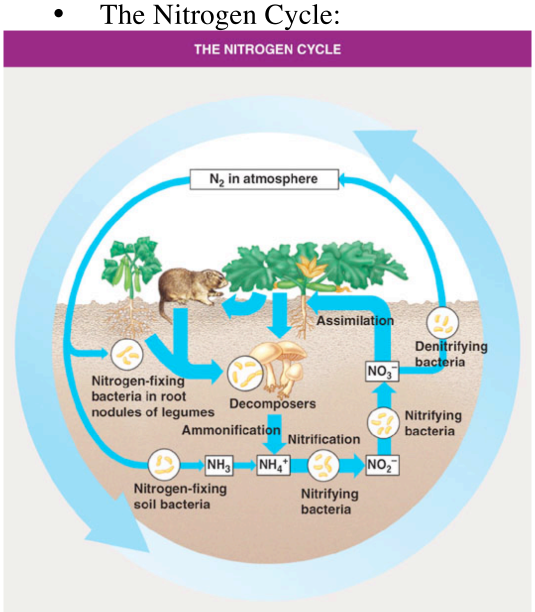
Key processes: evaporation of liquid water by solar energy, condensation of water vapor into clouds and precipitation, transpiration by terrestrial plants

- The Carbon Cycle:



- Carbon is the main element in every organic compound
- Forms available to life: Primary consumers convert CO_2 into organic molecules
- Reservoirs: fossil fuels, soil, sediments, dissolved carbon compounds in the oceans, organisms' biomass, atmosphere, sedimentary rocks (slow turn over)
- Key processes: photosynthesis, cellular respiration, volcanoes, burning fossil fuels

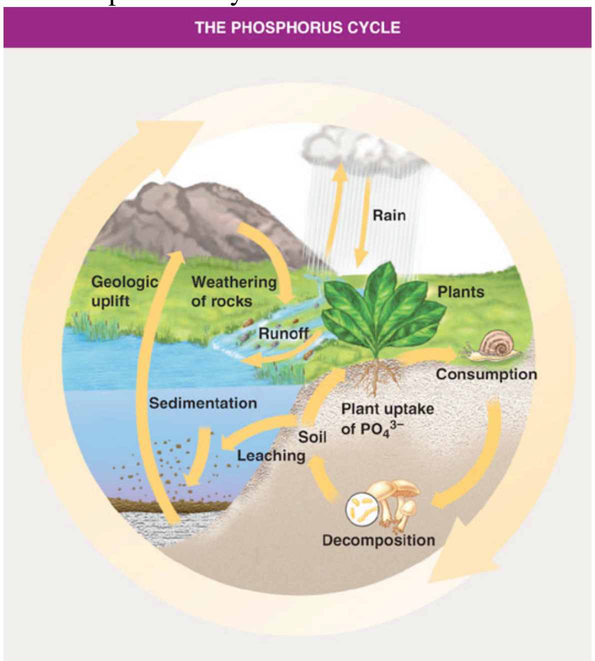
- The Nitrogen Cycle:



- Component of amino acids (proteins) and nucleic acids
- Forms available for life: Plants and algae can utilize ammonium (NH_4^+) and nitrate (NO_3^-), some bacteria also can utilize ammonium, nitrate and nitrite (NO_2^-), and animals can only utilize organic nitrogen sources.
- Reservoirs: atmosphere, soil, sediments, dissolved in surface and groundwater, biomass

- Key processes: **Nitrogen fixation** (the conversion of N_2 by bacteria to soluble inorganic forms); **ammonification** (decomposes organic nitrogen to NH_4^+); **nitrification** (ammonium is converted to nitrate by nitrifying bacteria); **denitrification** (under anaerobic conditions, denitrifying bacteria converts nitrate to nitrogen gas)

- Phosphorous Cycle:



- Phosphorous is a major component of nucleic acids, phospholipids, ATP and other nucleotides, mineral constituent of bones and teeth
- Forms available for life: plants into organic molecules can convert Phosphate (PO43-).
- Reservoirs: sedimentary rocks, soil, dissolved in oceans, biomass, guano
- Key processes: weathering rocks washes into waters, organic molecules – food web.

THE SECTION BELOW WILL BE DISCUSSED IN PLACE OF CHAPTER 55
V. HUMAN DISTURBANCE ON THE NUTRIENT CYCLES:
A. Problems with Nutrient Enrichment:
- People can move nutrients from one area to an other, enriching one and deplete an other
- Farm soil may run off into streams
- When natural vegetation is cleared from an area, nutrients can easily run off
- **Cultural eutrophication** --

B. Acid Precipitation
- **Acid precipitation** – rain, snow, sleet or fog that has the pH of 5.6 or lower.
- It forms when wood, coal or other fossil fuels are burned and produce sulfur and nitrogen oxides. These oxides react with water and form sulfuric and nitric acid that fall to the Earth with precipitation.
- Acid precipitation lowers the pH of aquatic ecosystems and affects the soil chemistry of terrestrial ecosystems. It leaches important minerals out of the soil and plants. It prevents the normal formation of shellfish shells and kills pH sensitive fish.
- In industrial countries, acid precipitation decreased in recent years.

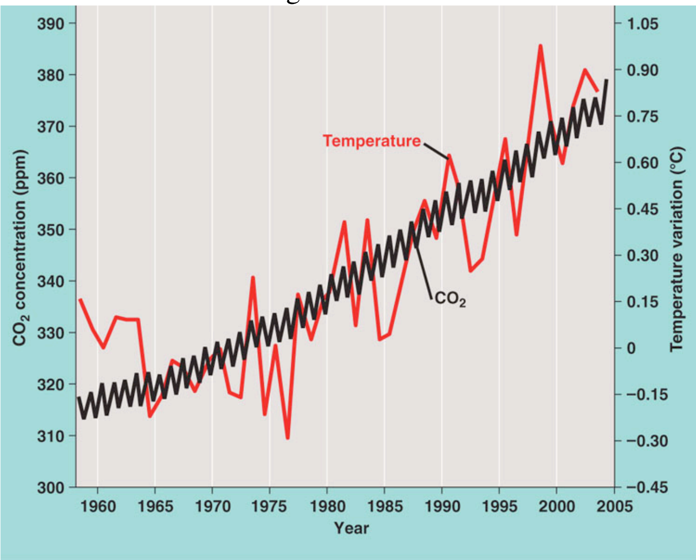
C. Toxins in the Environment
- Humans release thousands of chemicals into the environment, many of them did not exist in nature before. Organisms take in these toxins with nutrients and water. As we move up on the levels of a food web, toxins become more and

more concentrated – **biological magnification**. As a result, top level carnivores tend to be most severely affected by toxic compounds in the environment.

- Many toxins do not break down easily so they persist in the environment for decades or even longer.
- In some other instances, harmless substances can have toxic breakdown products or two or more chemicals can interact in the environment and can produce harmful effect together.

D. Atmospheric CO_2

- Since the industrial revolution, the concentration of atmospheric CO_2 levels has been increasing as a result of burning fossil fuels with a higher rate and due to the increased deforestation.



- There are several consequences of this increase:
  - Increased vegetation but with more C_3 than C_4 plants
  - **Greenhouse effect** – water vapor and CO_2 traps the infrared radiation that is reflected back from the Earth's surface. As a result, more heat is trapped and global warming occurs.
  - Global warming has many effects on the earth's weather patterns, ocean currents and can cause flooding of the coastal areas.

E. Depletion of Atmospheric Ozone

- Ozone is necessary to prevent living organisms from harmful UV radiation coming from the sun. It is located on the lower part of the stratosphere.
- The ozone layer has been gradually thinning since the 1970's because of the introduction of CFC's (chlorofluorocarbons) that were widely used. Chlorine from CFC's moved up to the stratosphere and changed ozone into oxygen in a chain reaction where chlorine is gained back at the end. As a result, one chlorine atom can react with hundreds of ozone molecules.
- Low levels of ozone result in increased skin cancer rate and increased cataracts in humans, while other living organisms will also have seriously damaged DNA with unforeseen consequences.

F. Loss of Biodiversity

- Loss of habitat of many living organisms because of the overpopulation by humans
- Biological magnification can poison organisms on the top of the food chain (top predators)
- Global climate change alters the pH, salinity, CO_2 concentration in the ocean, alter the temperature and precipitation in terrestrial ecosystems.