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BT101 - Ecology, Biodiversity & Evolution-I

MSC ZOOLOGY

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Ecosystem

- Community of living organisms in conjunction of its non-living components
- Non-living components
- Interaction as a system between both components

Population is group of individuals belonging to same species occupying same space in particular time.

Community is group of populations occupying same space in particular time.

Control of Ecosystem

- **External**
Climate, topography
- **Internal**

Types of species, population size, disease, gene pool, reproduction rate. External factors are independent of internal factors.

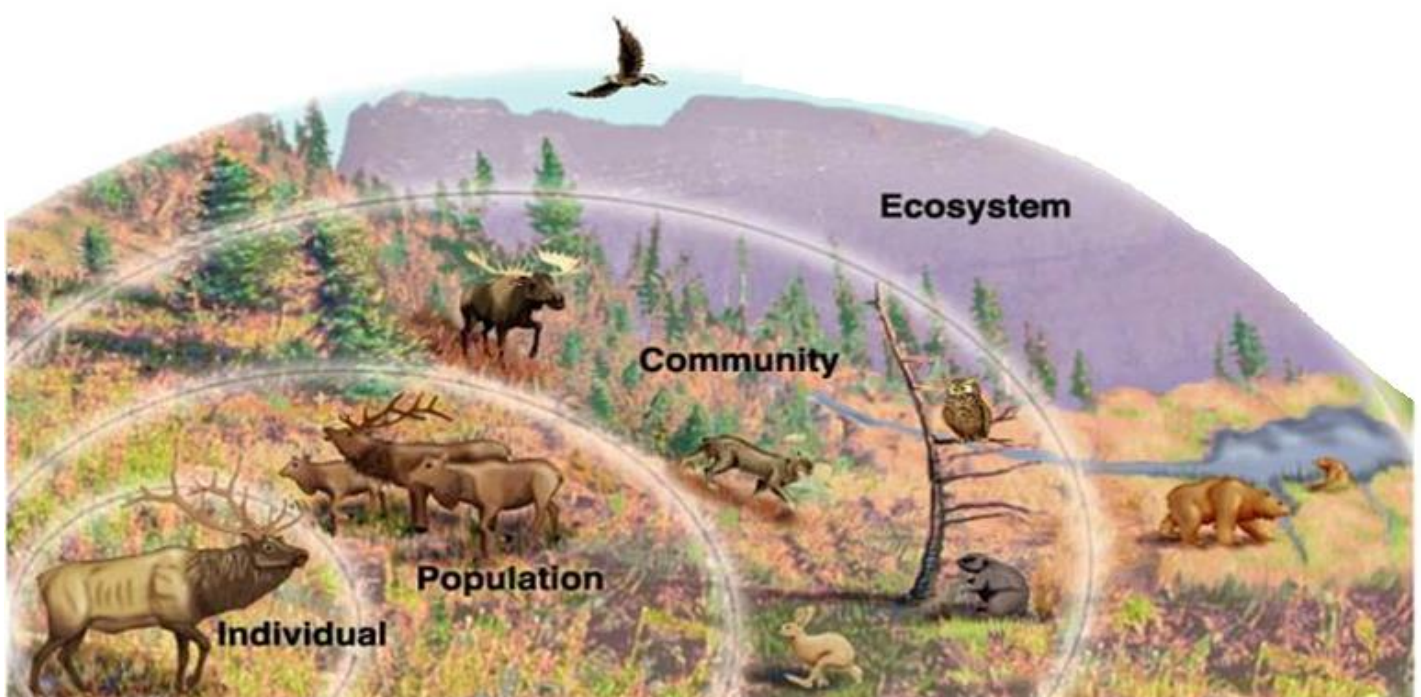
Biome

- Distinct biological communities
- Formed in response to specific external factors in that environment
- Internal factors are controlled by feedback loop

Example:

Population size is controlled by availability of resources.

- Ecosystem – a dynamic entity
- Subjected to disturbances and recovery (succession)



Flow of Energy in Ecosystem

Learning Objectives

- Introduction of energy dynamics in ecosystem. Use of energy by organisms. Type of useable energy

Energy

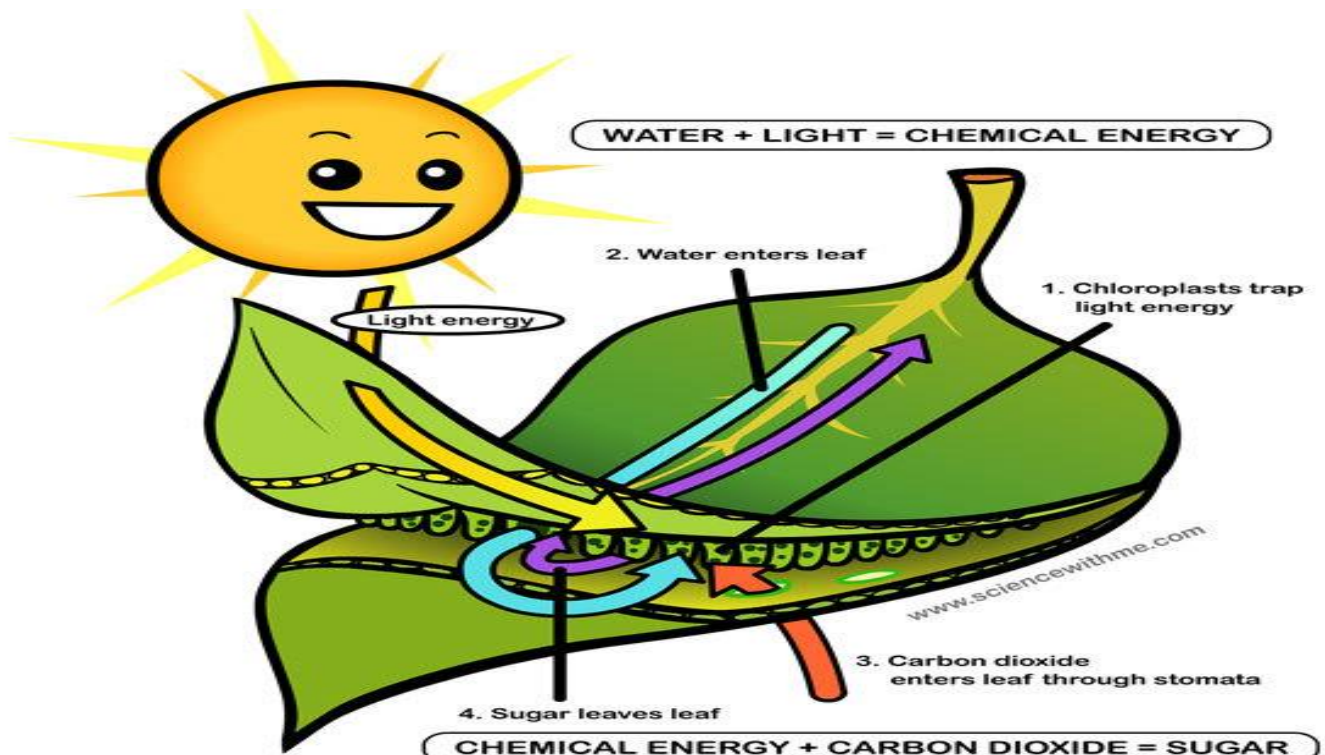
Energy exists in several different forms

1. Light
2. Chemical-bond energy
3. Motion
4. Heat

All organisms need energy to function

Principles

Energy is neither created nor destroyed in the biosphere. Organisms cannot convert heat to any of the other forms of energy. They only convert some chemical-bond or light energy to heat. Earth is an open system having constant and equal exposure to light. Plants use light energy in photosynthesis. They convert light energy into chemical bond energy. Animals use chemical bond energy to make organic molecules. Light and chemical-bond energy are partially converted to heat at every step. Heat is radiated into outer space at invisible infrared wavelengths. Earth's incoming and outgoing flows of radiant energy must be equal for global temperature to stay constant.



Learning Objectives

- **Concept of producers. Types of producers.** Photosynthesis. Chemosynthesis

Autotrophs

Synthesis of the organic compounds of their bodies from inorganic precursors such as:

- CO_2 , H_2O , NO_3

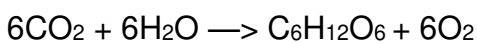
using energy from an abiotic source

- Light
- inorganic oxidation reactions

Types of Autotrophs

1. Photoautotrophs

- Photosynthetic organisms
- Examples: plants, algae, and cyanobacteria
- Photosynthesis

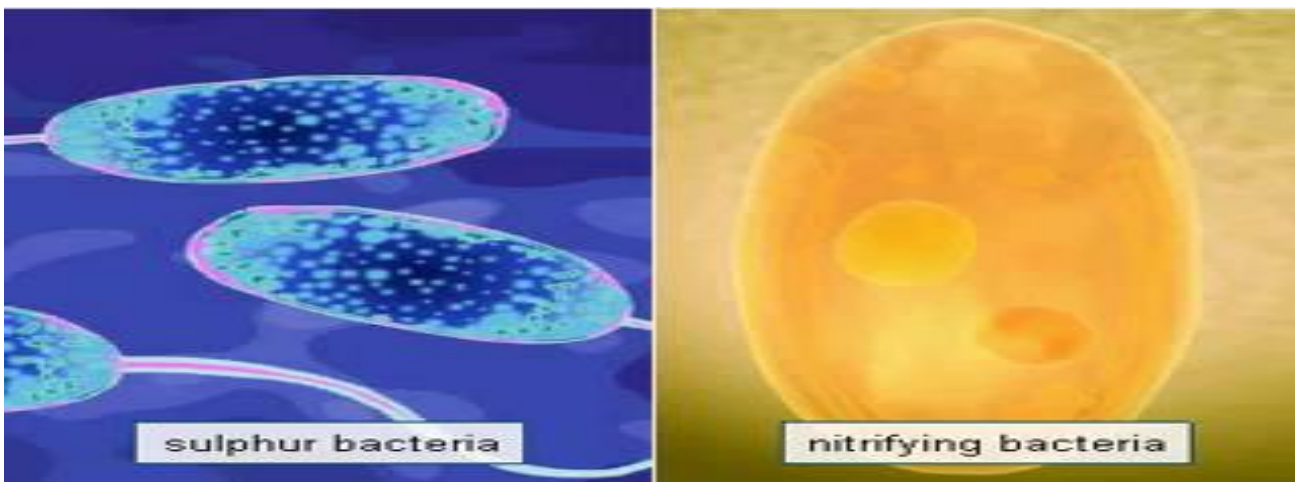


- Main input of free energy into the biosphere

2. Chemoautotrophs

- Occurs in dark habitats. They obtain energy by means of inorganic oxidation reactions. Convert toxic molecules into glucose

Example: Microbes, mussels



Learning Objectives

- **Concept of consumers. Types of consumers**

Heterotrophs

- Cannot synthesize organic compounds from inorganic precursors. Eat organisms from a different population for energy. Liberating chemical-bond energy for metabolic use in glycolysis, Krebs's cycle and electron transport chain

Example: Animals

Types of Consumers

- 1. **Herbivore**
- 2. **Carnivore**
- 3. **Omnivore**

1. Herbivore

- Primary food source is plant-based.

Examples: vertebrates as well as invertebrates

Digestive systems capable of handling large amounts of plant material. There are eight types of herbivory depending upon different feeding habits.

Feeding Strategy	Diet	Example
Algivores	Algae	krill, crabs, sea snail, sea urchin, parrotfish, surgeonfish, flamingo
Frugivores	Fruit	Ruffed lemurs
Folivores	Leaves	Koalas
Nectarivores	Nectar	Honey possum
Granivores	Seeds	Hawaiian honeycreepers
Palynivores	Pollen	Bees
Mucivores	Plant fluids	Aphids
Xylophages	Wood	Termites

2. Carnivore

Primary food source is animal-based.

Examples: vertebrates as well as invertebrates

- Digestive systems are more efficient in protein digestion.

2. Omnivore

Primary food source is both plant and animal-based.

Examples: human, bear, cockroach, chicken

- Digest carbohydrates, protein, fat, and fiber, and metabolize the nutrients

Types

- **Frugivores:** wolves and orangutans
- **Insectivores:** swallows and pink fairy armadillos
- **Granivores:** large ground finches and mice

Lecture 5

• **Decomposers**

Learning Objectives

- Concept of decomposers. Types of decomposers. Process of decomposition

Heterotrophs

Break down dead or decaying organisms. Absorb nutrients directly through chemical and biological processes without ingestion.

Types

- ✓ **Fungi**
- ✓ **Bacteria**

Fungi

- Primary decomposer . Release digestive enzymes by their hyphae. Absorb organic matter and release CO₂

Decomposition

1. Autolysis

Breaking down of tissues by the body's own internal chemicals and enzymes

2. Putrefaction

- Breakdown of tissues by bacteria. release compounds such as cadaverine and putrescine causing decaying odor. Proteolysis releases nitrogen and phosphorous
- **Carbohydrate breakdown**
- **- Aerobic by fungi and bacteria**
- **- Anaerobic by bacteria**

Anerobic degradation of lipids. Nucleic acids and bones degradation

Decomposition

- Plays important role in nitrogen and carbon cycles

Lecture 6

• Food Chain_Energy flows through trophic levels of ecosystems

Feeding Levels

Food energy passes through different sequence.

Example: plants → grass hopper → frog → snake → hawk

Many plant species eaten by insects.

Many insects species eaten by frogs

Trophic Level

Trophic level of an organism is position it occupies in a food chain.

Food Chain

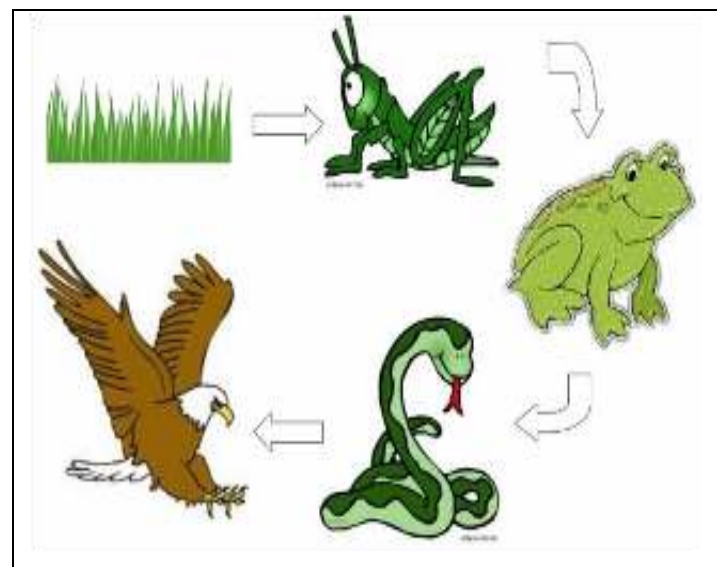
Linear network of links to pass energy in form of food. Simplified abstractions of real food webs, but complex in their dynamics

Feeding Levels

This complexity is organized by ecologists. Recognized limited number of feeding or trophic levels

Food Chain

Food energy passes through different sequence.



Level 1: Primary producer

Level 2: Primary consumer

Level 3: Secondary consumer

Level 4: Tertiary Consumer

Level 5: Apex Predator

A food chain also shows how the organisms are related with each other by the food they eat. Each level of a food chain represents a different trophic level. Food chain only follows a direct, linear pathway of one animal at a time.

Food Chain

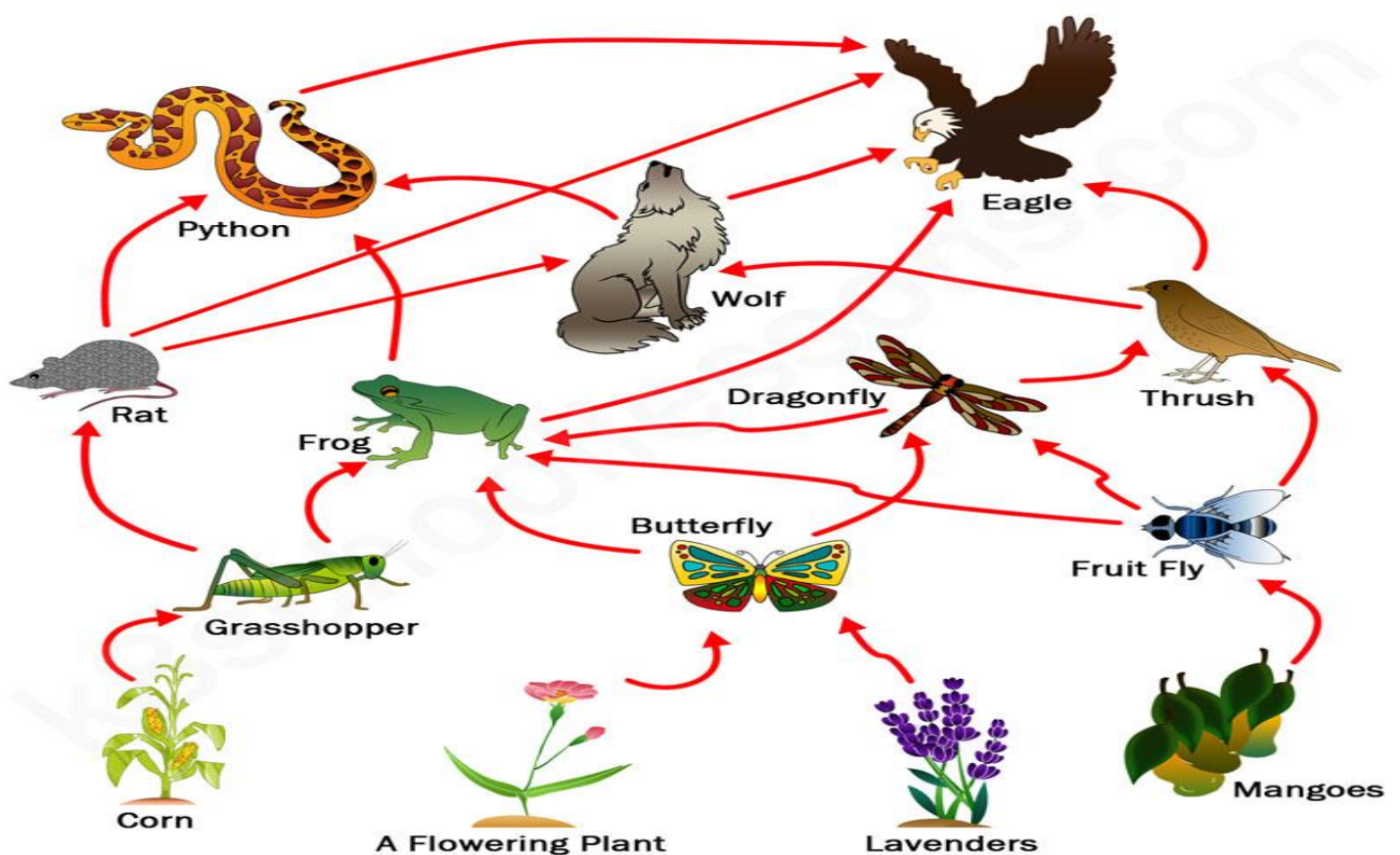
Detritivore and decomposers can be at trophic level as well. They return nutrients back in soil to be available for producers.

Lecture 7

• Food web

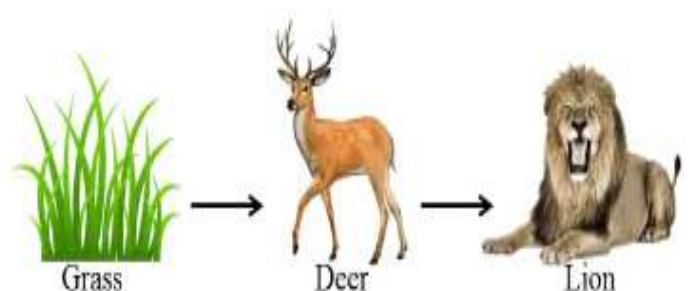
Food Web

Complexly interconnected food chains in an ecological community. Represent tiny portion of the complexity of real ecosystems



Consumer-Resource system

Direct or indirect balance between resources and consumption. Predators indirectly increase plant growth. They prevent overgrazing by suppressing herbivores. The net effect of direct and indirect relations is called trophic cascades.



Trophic Cascade

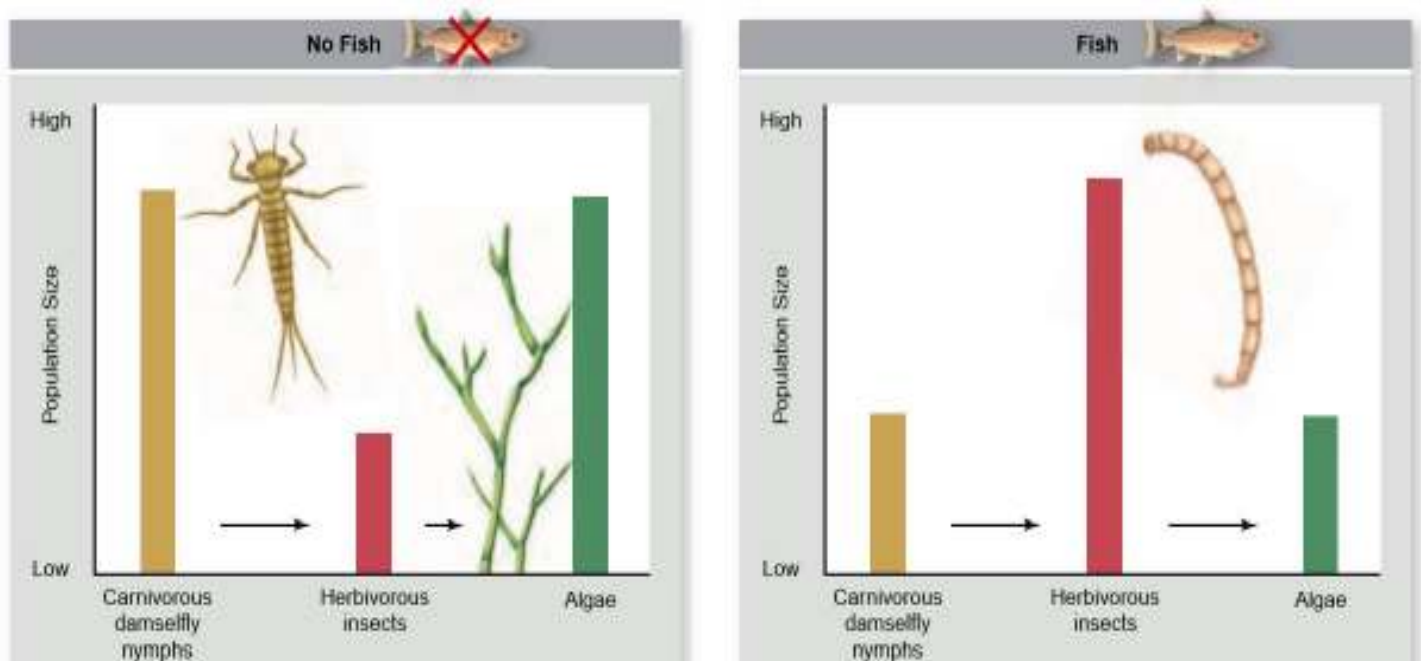
Powerful indirect interactions that can control entire ecosystems. Occurs when a trophic level in a food web is suppressed.

Example: Removal of the top predator can alter the food web dynamics

Impacts of climate and human activity on ecosystem

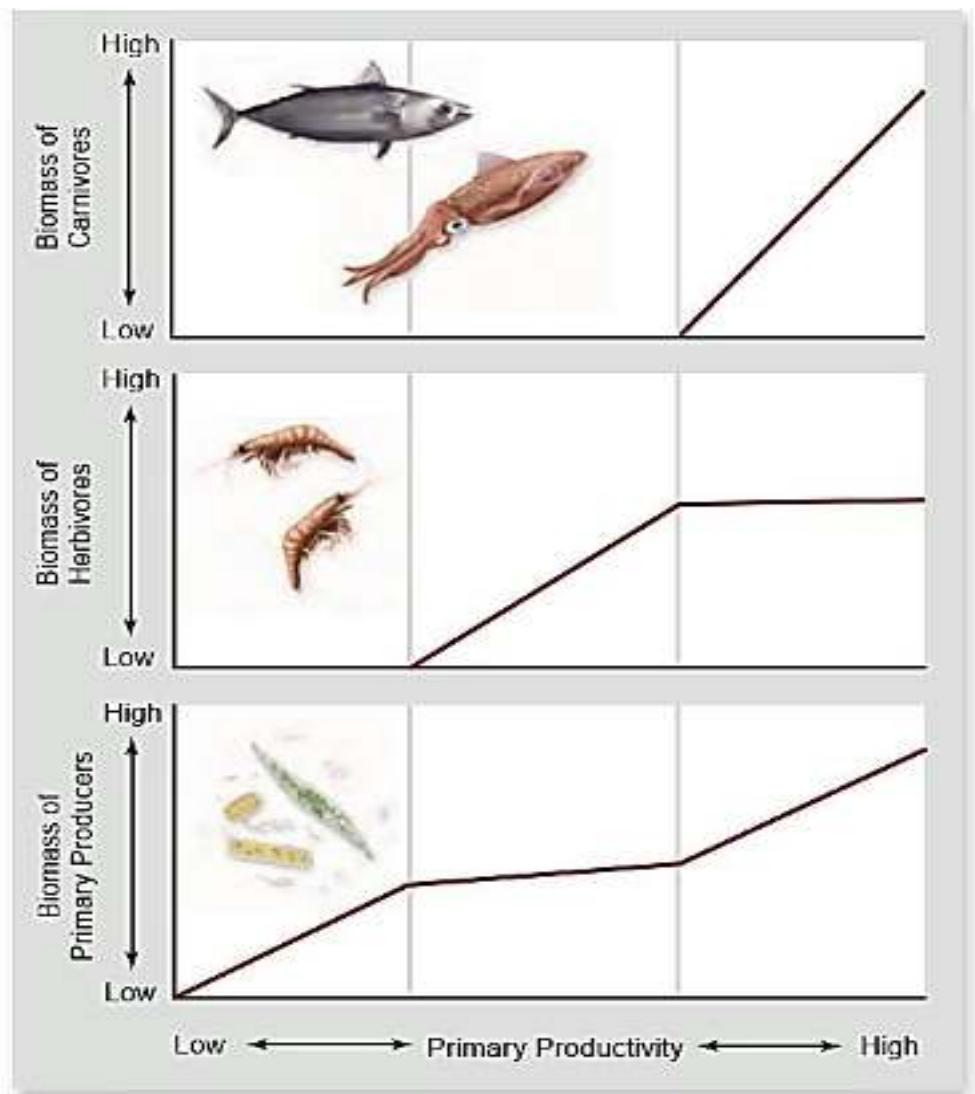
1. Top-Down Effect

Effect flows down through a trophic chain. From apex predator to lower trophic levels



2. Bottom-Up Effect

Effect flows up through a trophic chain. From primary producers to higher trophic levels



3. Species Level Cascade

Subset of the food-web dynamic is impacted by a change in population numbers

4. Community Level Cascades

Change in population numbers has a dramatic effect on the entire food-web

Example: Distribution of plant biomass

Lecture 8

• Trophic Levels & Productivity

Productivity of trophic level

Rate at which the organisms in the trophic level collectively synthesize new organic matter (new tissue substance). Energy is lost through respiration at every level.

1. Primary productivity (PP)

Organic matter produced by photosynthesis

- **Vascular plants;** major contribution in PP
- **Others;** algae, mosses, liverworts
- **PP is function of various factors;** water, temperature, soil

Gross primary production (GPP) is the amount of chemical energy as biomass that primary producers create in a given length of time.

1 a . Gross primary productivity (GPP)

Raw rate at which the primary producers synthesize new organic matter

1 b. Net primary productivity

= GPP – Respiration

- NPP varies with seasonal changes
- Measured in mass/unit area/year

Some fraction of this fixed energy is used by primary producers for cellular respiration and maintenance of existing tissues (i.e., "growth respiration" and "maintenance respiration"). The remaining fixed energy (i.e., mass of photosynthate) is referred to as **net primary production**. Some fraction of this fixed energy is used by primary producers for cellular respiration and maintenance of existing tissues (i.e., "growth respiration" and "maintenance respiration"). The remaining fixed energy (i.e., mass of photosynthate) is referred to as **net primary production**.

1. Secondary productivity

The rate that new organic matter is made by means of individual growth and reproduction in all the herbivores. Each heterotroph trophic level has its own secondary productivity.

Lecture 9

• How trophic levels process energy

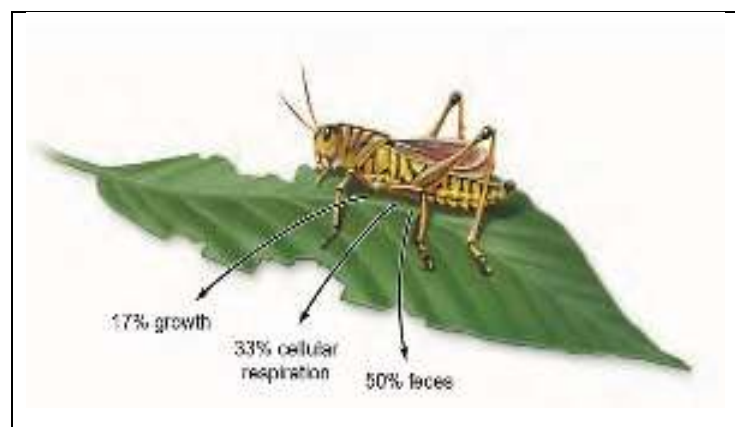
Small fraction of solar energy (1%) is consumed in photosynthesis. Transformed into chemical-bond energy. 99% solar energy is converted into heat.

Synthesized chemical-bond energy is consumed:

- Absorption of nutrients
- Growth (tissue formation)
- Body functions

Availability to consumers

- Tissues / Growth



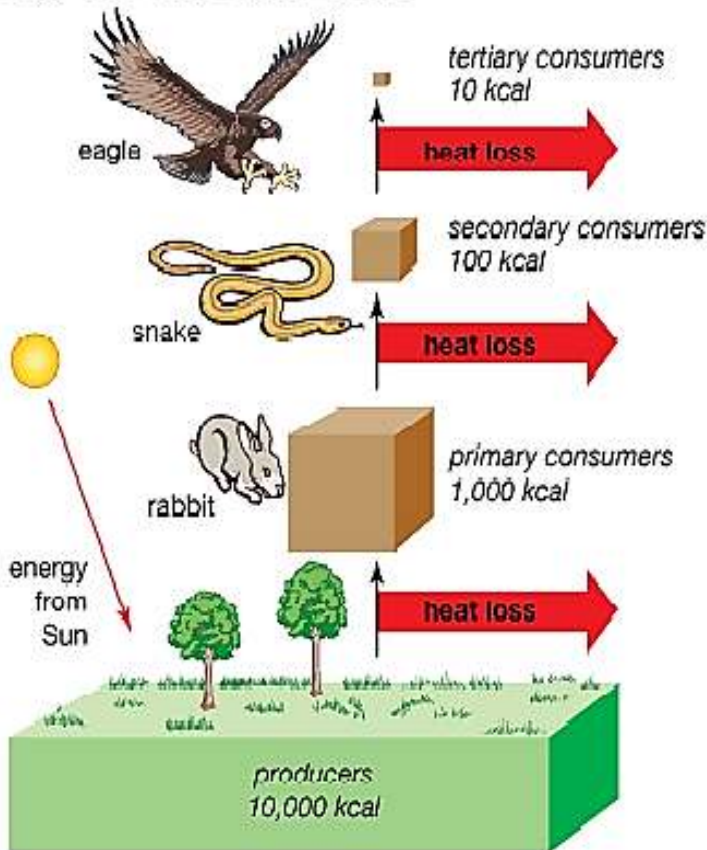
Chemical-bond energy is passed from one heterotroph trophic level to the next.

Loss of energy at every stage

1. Herbivore
2. Primary carnivore
3. Secondary carnivore

Loss of 90% energy from one level to next

Energy flow and trophic levels



Exponential decline of chemical-bond energy in a trophic chain limits:

- Lengths of trophic chains
- Number of top level carnivores

Top level carnivores have:

- large individual body sizes
- great individual energy needs

Variability in Net Primary Productivity between ecosystems

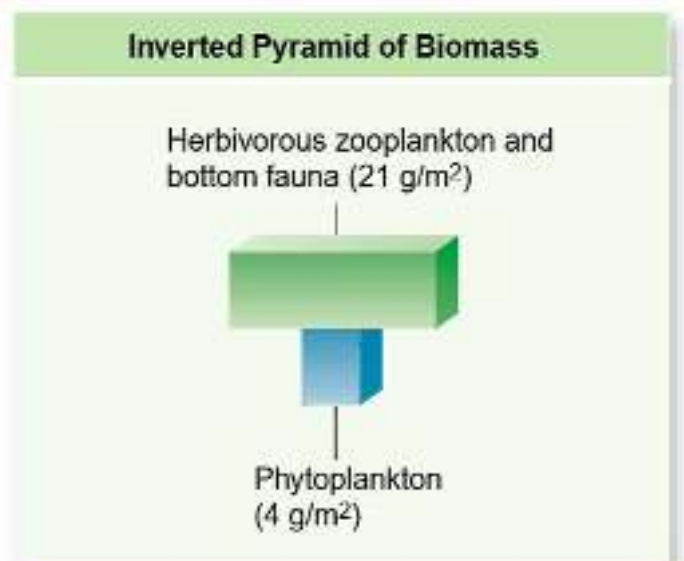
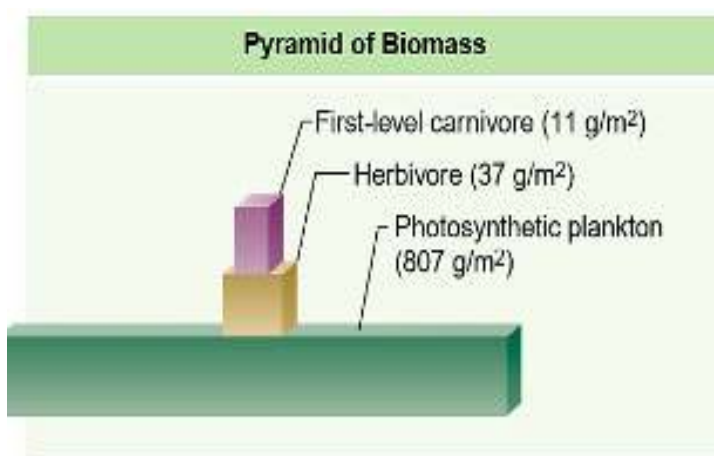
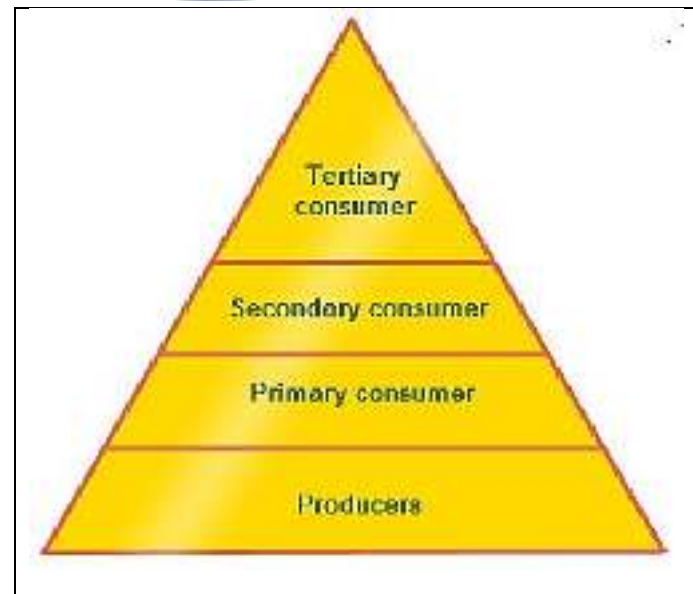
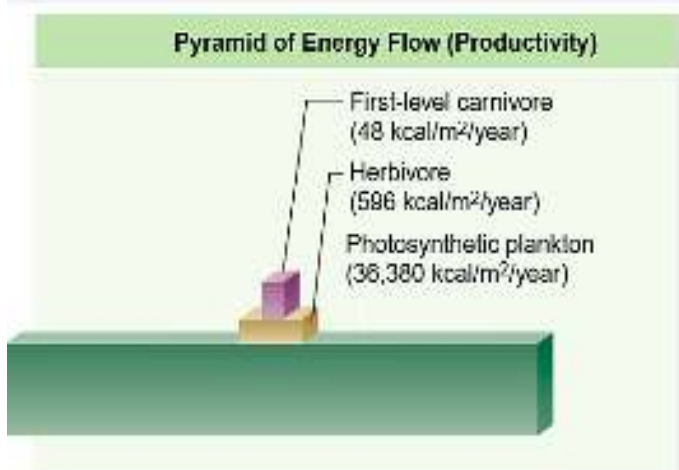
- **Wetlands and tropical rain forests:** 2000 g/m²/ year
- **Temperate forests:** 1200 - 1300 g/m²/ year
- **Savanna:** 900 g/m²/ year
- **Deserts:** 90 g/m²/ year

Lecture 10

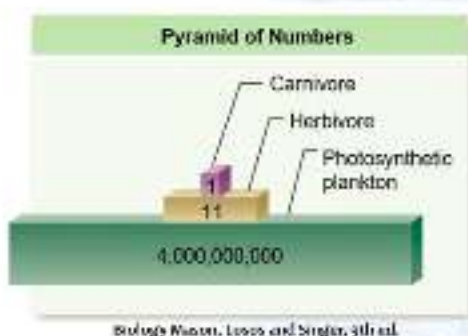
- Ecological pyramids illustrate the relationship of trophic levels

Flow of energy and decline of chemical-bond energy is represented by pyramids.

Trophic levels are boxes stacked on top of each other.
Width of box is proportional to productivity of that level.



Ecological Pyramids



Lecture 11

• Animals and their abiotic environment

Habitat

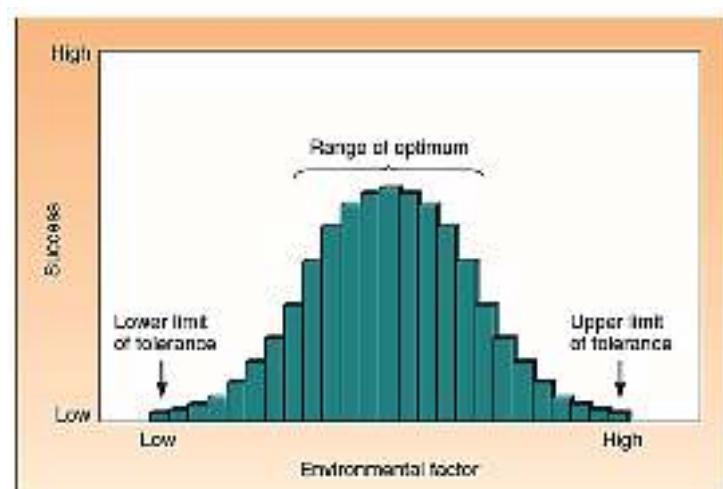
Natural environment where a species/organism lives

Where they find:

- Food
- Shelter
- Protection
- Mates

Habitat has two types of characteristics:

1. Abiotic/Physical



1. Abiotic Factors

2. Biotic/Biological

- Temperature
- Water
- Light
- Soil

- Tolerance range

At either limit, one or more essential functions cease

- Range of optimum

Highest success of animal

- Limiting factor

Factor out of tolerance range

- Taxis

Orientation towards a factor

Lecture 12

• Temperature

- Thermoregulation
- Inequality between heat loss and gain
- Harsh condition require adaptations
- Both ectothermic and endothermic animals have adaptations.

Torpor

Decreased metabolism. Lowered body temperature

Examples: Bats, Humming birds

Help in survival when not feeding

Hibernation

Decreased metabolism. Lowered body temperature. May last for weeks or months

Examples: Rodents, Shrews

Winter Sleep

Occurs in large animals. Large energy reserves. Quick restoration of activity

Examples: Bears

Aestivation

Survival in extended period of drying. Avoid temperature damage and dehydration

Examples: Insects, frog, turtle

Lecture 13

• Water & Light

Water is critical factor in homeostasis.

Animals lose water:

- Evaporation
- Excretion

Lost water must be replaced.

- Drinking
- Eating
- Avoiding dehydration

Adaptations

To avoid dehydration:

- Behavioral

Nocturnal mode, burrows/hides

- Physiological

Osmoregulation

Water Currents

- Affect animal distribution in water body.
- Generated by wind
- Convection currents
- Determine biodiversity and niche
- Movement of minerals and rocks

Convection currents transfer heat from one place to another by mass motion of a fluid such as water, air or molten rock. The heat transfer function of convection currents drives the earth's ocean currents, atmospheric weather and geology.

Adaptations

To cope with currents:

- Suckers
- Hooks / claws
- Body flattening
- Streamlining
- Discussed in "energy"
- Animal's response to light intensity
- Phototactic movement

- positive (Euglena)

- negative (Planaria, Earthworms)

Effects of Photoperiod

- Biological Clocks

- Diurnal

Distribution, sleep-wake cycle

- Annual

Reproduction, migration

Effects of Light

- Increase metabolism
- Pigmentation

Sexual dimorphism, camouflage

Sun as reference point in navigation during daily movement/migration

Increase in the number of individuals in a population

Reproduction

Population growth rate

- Rate at which the number of individuals in a population increases in a given time period.
- Species specific

Species	Rate of Reproduction
Bacteria	Every 20 minutes 3 million / 7 hours
House Fly	600 eggs / life time
Common Carp	300, 000 / year
Mouse	30 – 140 / year
Elephants	one / 5 – 6 years

Limiting factors regulate population size

- Rate of Birth
- Rate of Death/mortality
- Dispersal
- Food Resources
- Space to grow
- Environmental factors

Carrying Capacity (K)

- The maximum population size of the species that the environment can sustain indefinitely.
- Environment's maximal load
- Population size decreases above carrying capacity

Carrying Capacity

- Variable, may vary for different species
- May change over time due to a variety of factors including:
 - food availability, water supply, environmental conditions and living space
- Variety of tools to track the size of population
- Survivorship curve is one tool.
- It measures the proportion of individuals in a given species that are alive at different ages.

Survivorship Curve

- Y-axis is a logarithmic plot of numbers of survivors
- X-axis is a linear plot of age

Kinds of Survivorship Curve

Type 1 (Convex)

Populations survive to an old age, then die rapidly.

Unimportance of environmental factors in influencing mortality

Potential life span

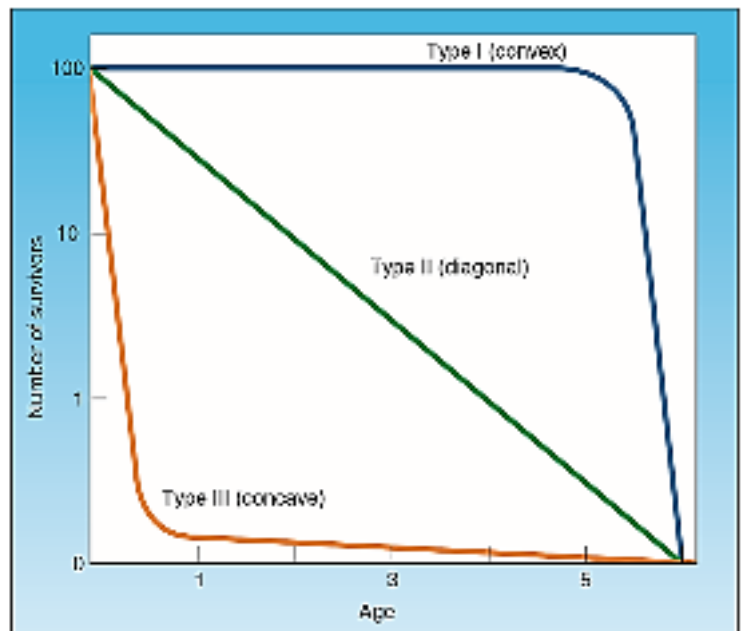
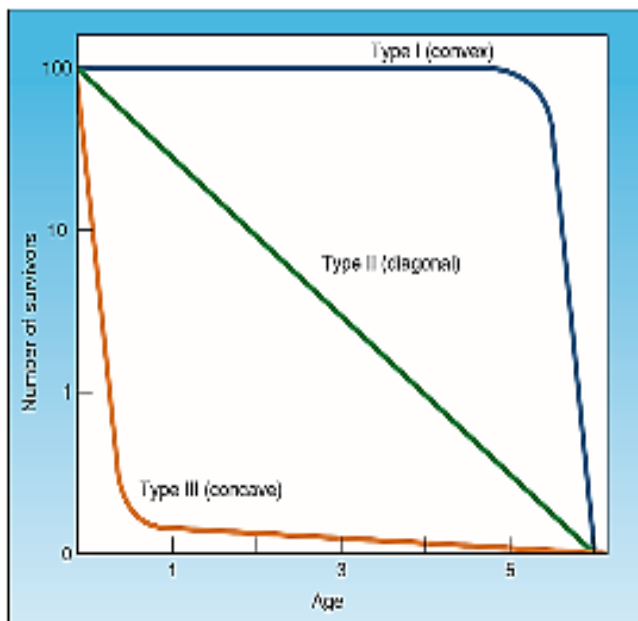
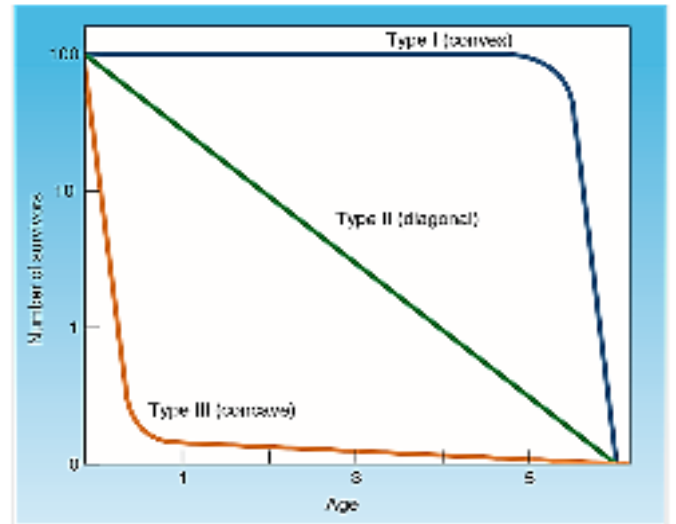
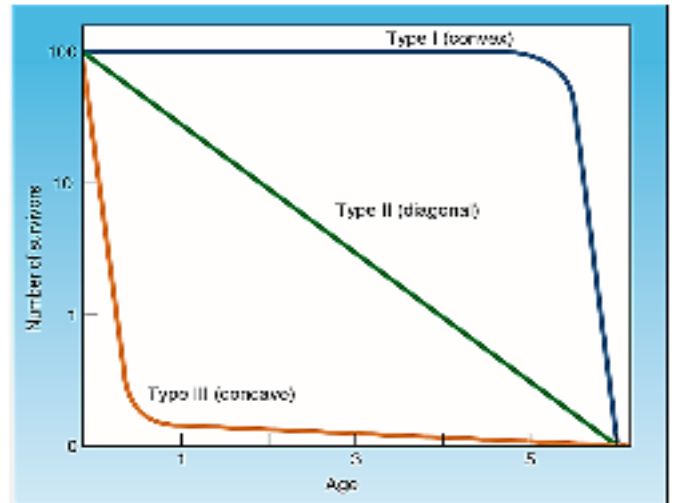
Example: Humans

Type II (Diagonal)

- Constant probability of death throughout lives
- Influence of environmental factors on mortality
- Mortality independent of age
- **Example:** birds, rodents

Type III (Concave)

- High juvenile mortality
- Influence of environmental factors and less resistance of juveniles on mortality
- Lower mortality in adults
- **Example:** Fish



Lecture 15

• Exponential Population Growth

Types of Population growth

1. Exponential

2. Logistic

Exponential Growth

- Resources are abundant.
- Remarkable potential to increase in number
- Exponential addition in population size
- Population may grow exponentially to certain time
- Ultimately limited by resource availability
- Formula of exponential growth
- $dN = rN$ N = Population size
- dt
- r = intrinsic rate of natural increase



Factors affecting reproductive rate

- Number of offspring produced
- Likelihood of survival to reproductive age
- Duration of the reproductive period
- Length of time to reach maturity
- Environmental factors

Lecture 16

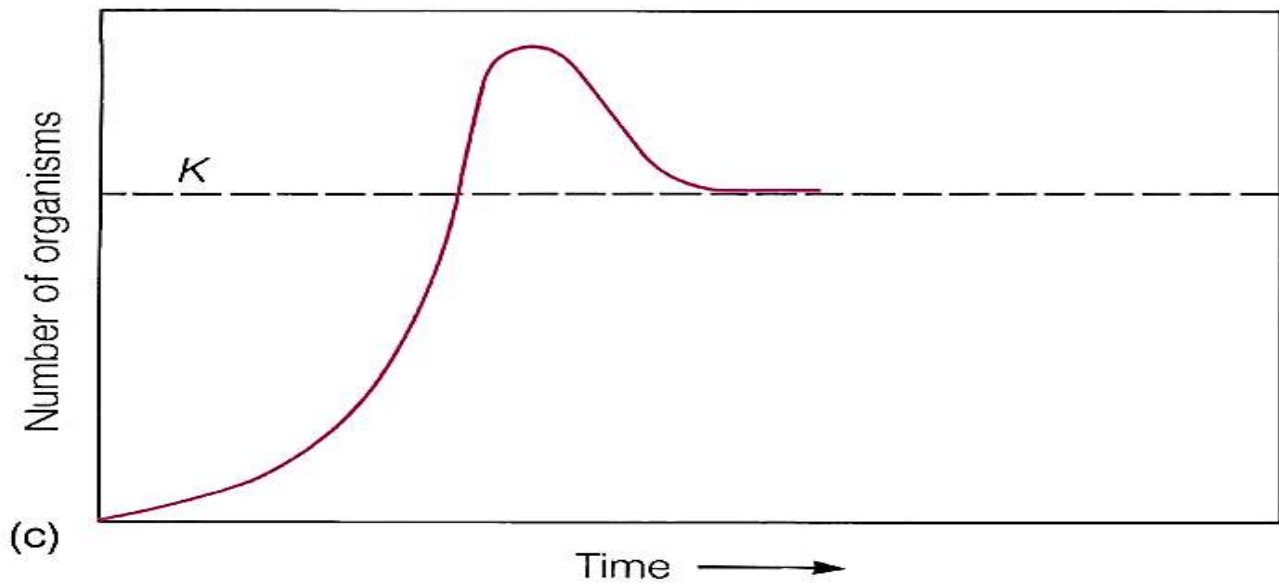
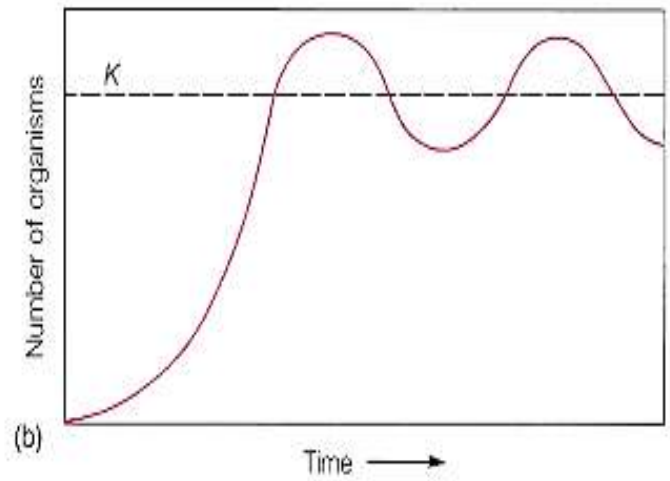
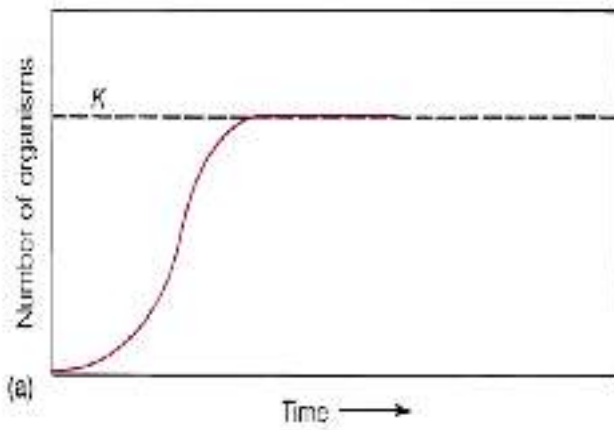
• Logistics Population Growth

- Carrying capacity of environment affect population growth.
- Environmental resistance
- Growth rate gets smaller as approaches the carrying capacity

Environmental factors affect population growth.

- Climate
- Food
- Space
- Competition

S - Shaped or Sigmoidal Curve



Formula

$$\frac{dN}{dt} = \frac{rN (K-N)}{K}$$

N = population size

dN / dt = change in population size per unit time

K = carrying capacity

r = intrinsic rate of natural increase

EXPONENTIAL GROWTH	LOGISTIC GROWTH
It occurs when resources are abundant.	It occurs when resources are limited.
Population passes well beyond the carrying capacity of the ecosystem.	Population doesn't grow beyond the carrying capacity of the ecosystem.
It produce J shaped curve.	It produce S shaped curve.
A stationary or stable phase is seldom achieved.	A stationary or stable phase is achieved.
It has two phases lag and log.	It has four phases lag, log, deceleration & steady .
It occurs in fewer organisms like lemmings, algal blooms, etc.	It is more common, example members of wildlife, yeast (a microscopic fungus), etc.

Lecture 17

• r and k selected species

r-selected species

- High growth rates
- Typically exploit less crowded ecological habitats
- Produce many offspring
- Relatively low probability of surviving to adulthood
- High reproductive rate supports their survival.
- Especially in unstable environment

Traits of r-selected species

- High rate of reproduction
- Small body size
- Early maturity onset
- Short generation time
- Ability to disperse offspring widely

Examples: bacteria, grasses, cephalopods, rodents

k-selected species

- Living at densities close to carrying capacity
- Typically are strong competitors in such crowded habitats.
- Invest more heavily in fewer offspring
- Relatively high probability of surviving to adulthood
- Survive in stable environment
- Ability to compete successfully for limited resources is crucial
- Populations of k-selected organisms typically are very constant in number.
- Close to the maximum that the environment can bear

Traits of k-selected species

- Large body size

- Long life expectancy
 - Production of fewer offspring
 - Often require extensive parental care until they mature
- Examples:** humans, whales, parrots, eagles

Lecture 18

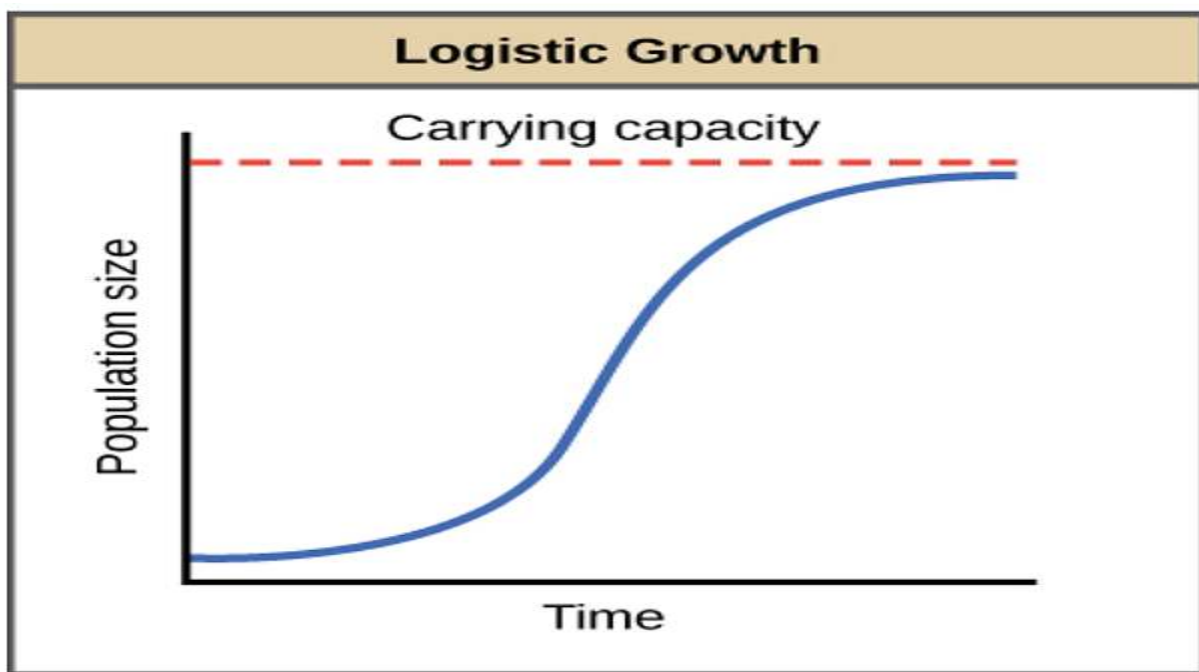
• Population Regulation

No indefinite growth of any population. Factors limit the population size and growth.

1. **Density dependent factors**
2. **Density independent factors**

Density dependent factors

- **Example:** Food



Competition within the population

When a population reaches a high density, there are more individuals trying to use the same quantity of resources.

Competition within the population

This can lead to competition for food, water, shelter, mates, light, and other resources needed for survival and reproduction.

Predation

Higher-density populations may attract predators who wouldn't bother with a sparser population. When these predators eat individuals from the population, they decrease its numbers but may increase their own.

Disease and Parasites

Disease is more likely to break out and result in deaths when more individuals are living together in the same place.

Waste Accumulation

High population densities can lead to the accumulation of harmful waste products that kill individuals or impair reproduction, reducing the population's growth.

Density Independent Limiting Factors

Affect per capita growth rate independent of density of population

- Natural disasters
- Severe weather
- Pollution

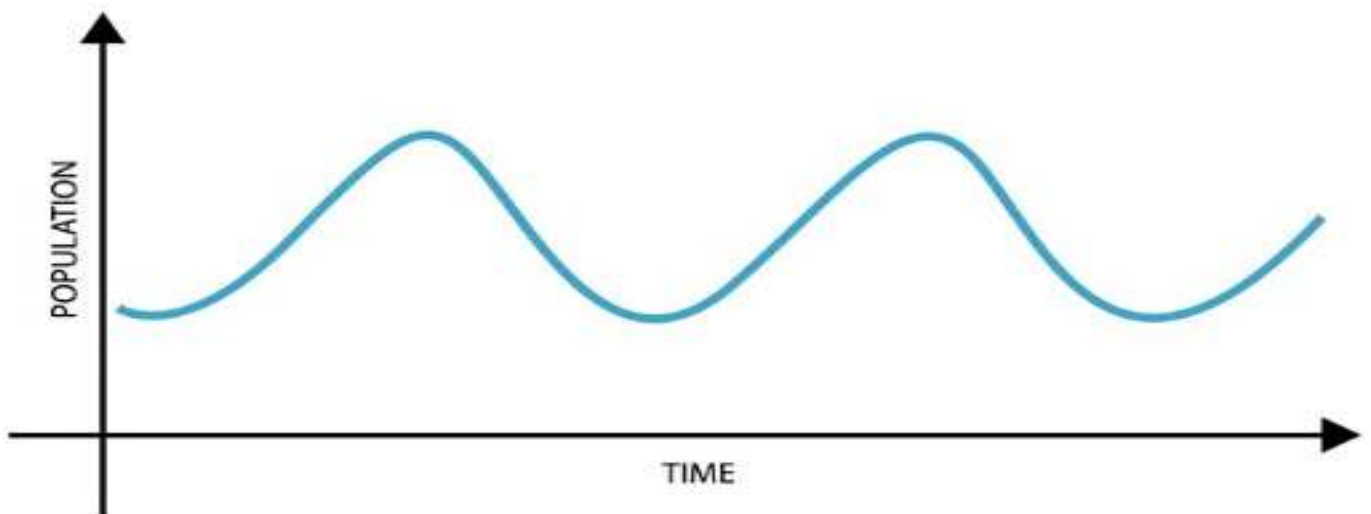
As an example, let's consider a wildfire that breaks out in a forest where deer live. The fire will kill any unlucky deer that are present, regardless of population size. An individual deer's chance of dying doesn't depend at all on how many other deer are around.

- Density Independent Limiting Factors
- Cannot regulate population at constant level
- They are accidental.
- Cause abrupt shift in population size
- May wipe out small population by sporadic event

Unlike density-dependent limiting factors, density-independent limiting factors alone can't keep a population at constant levels. That's because their strength doesn't depend on the size of the population, so they don't make a "correction" when the population size gets too large. Instead, they may lead to erratic, abrupt shifts in population size. Small populations may be at risk of getting wiped out by sporadic, density-independent events.

Collectively, density-dependant and independent factors create a different population growth curve.

- **Cyclic oscillations**



Cyclical oscillations are repeating rises and drops in the size of the population over time. oscillations are produced by interactions between populations of at least two different species. For instance, predation, parasite infection, and fluctuation in food availability have all been shown to drive oscillations.

Lecture 19

• Communities

- Group of species living in a habitat
- Plants, animals, fungi, protists, and prokaryotes that occur at a locality

Characterized by:

- Species richness
- Primary productivity

Concept about complexity of communities

- Individualistic
- Holistic

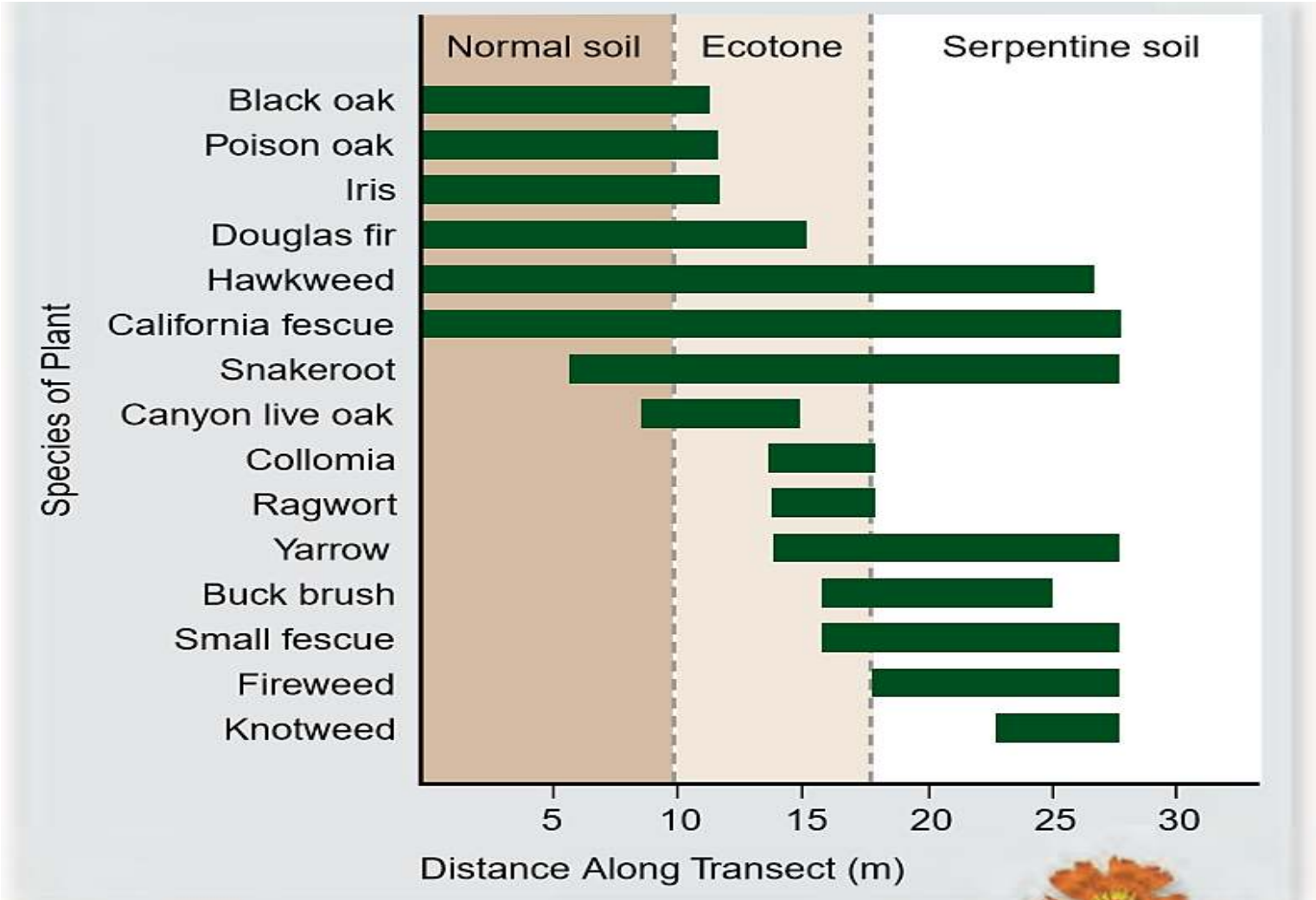
Individualistic concept of communities

Simple aggregation of species that happen to occur together at one place. Species appear and disappear according to their ecological needs. Structure of community varies with time

Hoslistic concept of communities

- Integrated and functioning as a whole unit
- Should stay the same through space or time
- Replaced by completely different communities with environmental changes
- Ecologists support individualistic concept.
- Community composition changes gradually across landscapes
- Some species appear and become more abundant.

Others decrease in abundance and eventually disappear.



Lecture 20

• The Ecological Niche

Each organism in a community confronts the challenge of survival in a different way. Occupies a specific functional role and place called its niche. The niche an organism occupies is the total of all the ways it uses the resources of its environment.

A niche may be described in terms of:

- Space utilization
- Food consumption
- Temperature range
- Appropriate conditions for mating
- Requirements for moisture

Other factors

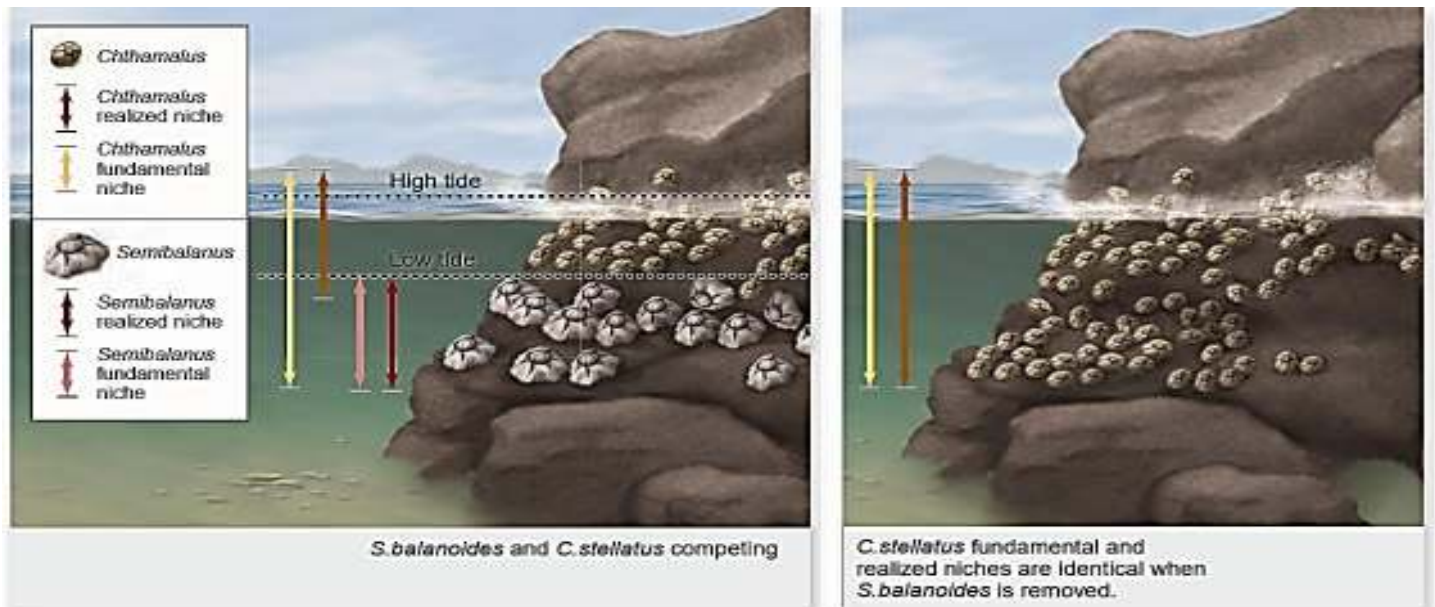
- Sometimes species cannot utilize their entire niche.
- Due to presence of other species competing for resources
- Interspecific competition, occurs between two species to use the same resources

Fundamental Niche

The entire niche that a species is capable of using, based on its physiological tolerance limits and resource needs.

Realized Niche

The actual set of environmental conditions, including the presence or absence of other species, in which the species can establish a stable population.



Competition among two species of barnacles. The fundamental niche of *Chthamalus stellatus* includes both deep and shallow zones, but *Semibalanus balanoides* forces *C. stellatus* out of the part of its fundamental niche that overlaps the realized niche of *Semibalanus*.

Lecture 21

• The Ecological Stability

Communities may begin in areas nearly devoid of life. The first community to become established in an area is called the pioneer community. Death, decay, new species and additional nutrients establish this community. Over thousands of years nutrients accumulate, communities established. Complex ecosystem becomes functional. Each successional stage is called a **seral stage**. Entire successional sequence is a sere. Dominant life-forms of a sere gradually make the area less favorable for themselves due to consumption of resources. But more favorable for organisms of the next **successional stage**. The final community is the **climax community**. It is different from the seral stages that preceded it because it can tolerate its own reactions. Complexity of ecosystem makes it more stable.

Types of Succession

Primary

Occurring in an environment in which new substrate devoid of vegetation and other organisms usually lacking soil

Secondary

An event reduces already established ecosystem.

Lecture 22

• Herbivory

Herbivory

- Consumers of plants
- Anatomically and physiologically adapted to eating plant material
- Mutualistic gut flora e.g. cellulose digesting bacteria
- Important role in food chain

Different feeding strategies

Major strategies:

1. Grazers
2. Browsers

1. Grazers

Feeds on plants such as grasses, soft flowering plants (forbs) and algae. Plants are not killed.

Examples: Deer & Snails

Types of Grazing

1. Graminivory

Feeding primarily on grass. Specifically "true" grasses in family Poaceae

Examples: Horses, cattle, hippopotamus, grasshoppers

2. Coprophagy

Feeding on grass, forbs, leafy weeds, fruits, tree bark

Heavy grazing for half an hour of grazing period

Followed by half an hour of selective feeding

Example: Horses, cattle, hippopotamus, grasshoppers

- Later feeding in intervals
- Eat their or other species's soft feces (caecotrophs)

Example: Rabbit

2. Browsers

Feed on non-grass plant material

Leaves, soft shoots, twigs, fruits, woody plants such as shrubs

Examples: Goats, deer, giraffe, elephants

Herbivory

- **Over browsing**
 - Introduction of herbivores
 - Low productivity of native plants
 - Less predation pressure

Defense against Herbivory

1. Tolerance
2. Resistance
 - Physical/Mechanical defense

Thorns, hair, resins, silica deposits in cell wall, resins make plants inedible

- Chemical defense
 - Terpenes, phenols, alkaloids
 - Give bitter taste to plants
 - Affect nervous system of herbivore

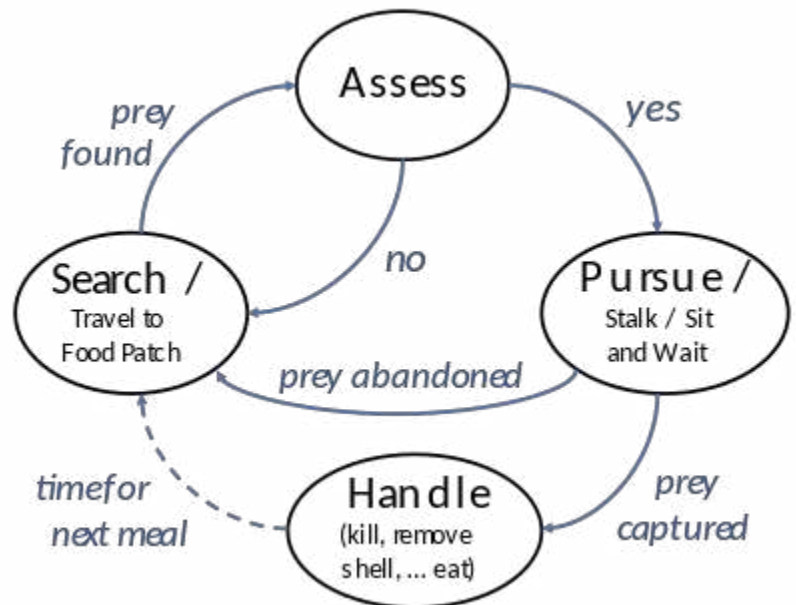


Predation

- One animal kills and eats another animal
- One is predator and other is prey
- Actively search for prey or sit and wait
- **Examples:** invertebrates such as jelly fish and insects
- Vertebrates such as lions
- To feed, a predator must search for, pursue and kill its prey.

These stages form a foraging Cycle.

1. Search
2. Assessment
3. Capture
4. Handling



Foraging Cycle

1. Search

- Sit and Wait method

- Suitable if the prey are dense and mobile
- Low energy requirement
- **Example:** Crocodiles, spiders, aquatic invertebrates, praying mantises

- Active foraging

- When prey is sedentary or sparsely distributed.
- Expends more energy.
- **Examples:** Sharks, sunfish, Insectivorous birds

Some switch between active foraging and sit & wait method.

Example: Plovers, shore birds, crappie fish

- Prey distributions are often clumped in form of patches.
- Predators respond by looking for patches.
- Albatross make foraging flights within the prey range of 700 – 3000 km.

2. Assessment

- Decide to kill or keep searching
- Decision depends on the costs and benefits
- Too small prey does not worth spending energy in capture.

Foraging Cycle

3. Capture

- **Pursuit predation**

Actively chasing fleeing prey

- **Ambush**
 - Sudden strike on nearby prey

- Adjusts its attack according to how the prey is moving.

3. Capture

- **Ballistic interception**
- Predator observes the movement of a prey
- Predicts its motion
- Works out an interception path
- Attacks the prey on that path

4. Handling

- Prey can be dangerous
- Sharp and poisonous spines
- Should be handled carefully
- Mostly predators tear the prey apart
- E.g. cat fish

Predation Strategies

- **Solitary predation**

e.g. hawks

- **Group predation**

e.g. wolves, hyenas

- **Physical adaptations**

Better vision, olfaction and auditory skills

Claws, sharp teeth, beaks, venom,

Lecture 24

• Competition

Animals compete for same resources in ecosystem.

1. Food
2. Space
3. Water
4. Light
5. Mates

Types of Competition

- **Intraspecific**

Between members of same species

- **Interspecific**

Between members of different species

Intraspecific Competition

- Same choice of resource
- Limited resources
- Reduction in fitness for individuals
- Follows logistic population growth curve

Types of Intraspecific Competition

1. Direct

- Results in fighting, stealing and ritualistic combats
- Expelling weak competitors from territory make them vulnerable.

2. Indirect

- Exploitative competition
- One depleting a shared resource
- Both suffering a loss in fitness as a result

Example: Bears catching fish near mouth of river

Inter-specific Competition

- Competition between individuals of different species
- Comparatively variety of resources
- Logistic population growth curve
- Negative impact on each other

Types of Inter-specific Competition

- **Direct**
- **Example:** Lions and Leopards
- **Indirect**

Example: Aphid- *Fordinae geoica* out-compete *F. formicaria* by 84%

Lecture 25

• Coevolution

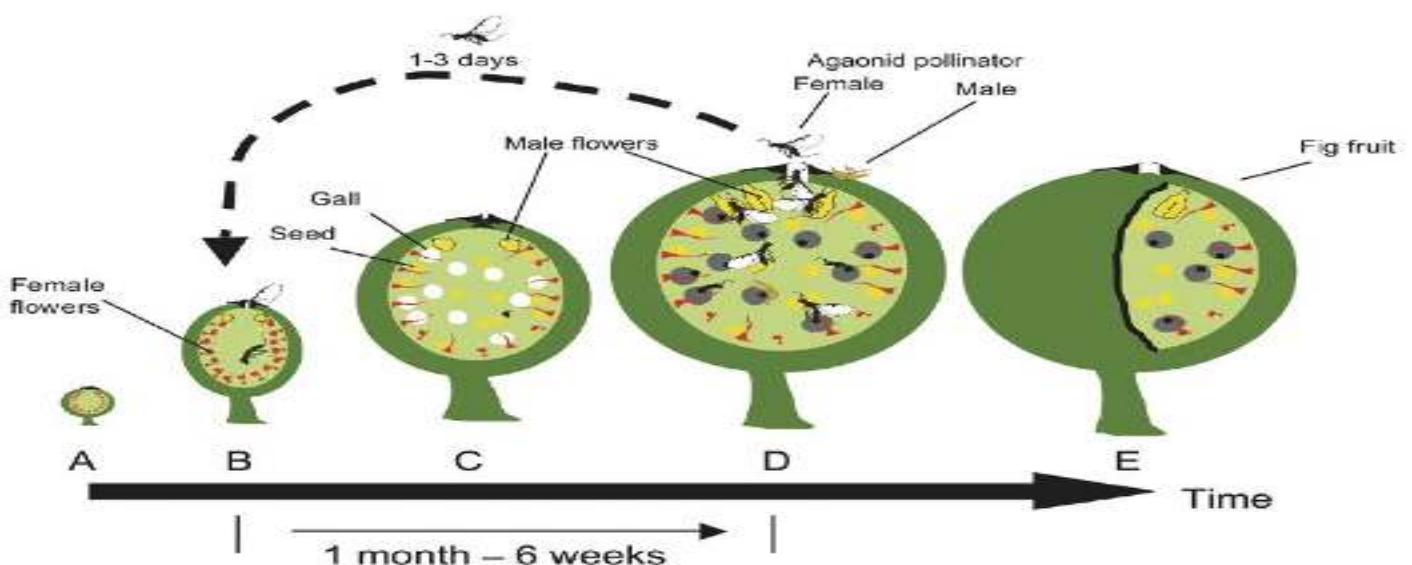
Coevolution

Two or more species living in same habitat, reciprocally affect each other's evolution. One exerts elective pressures on the other.

Mutualism

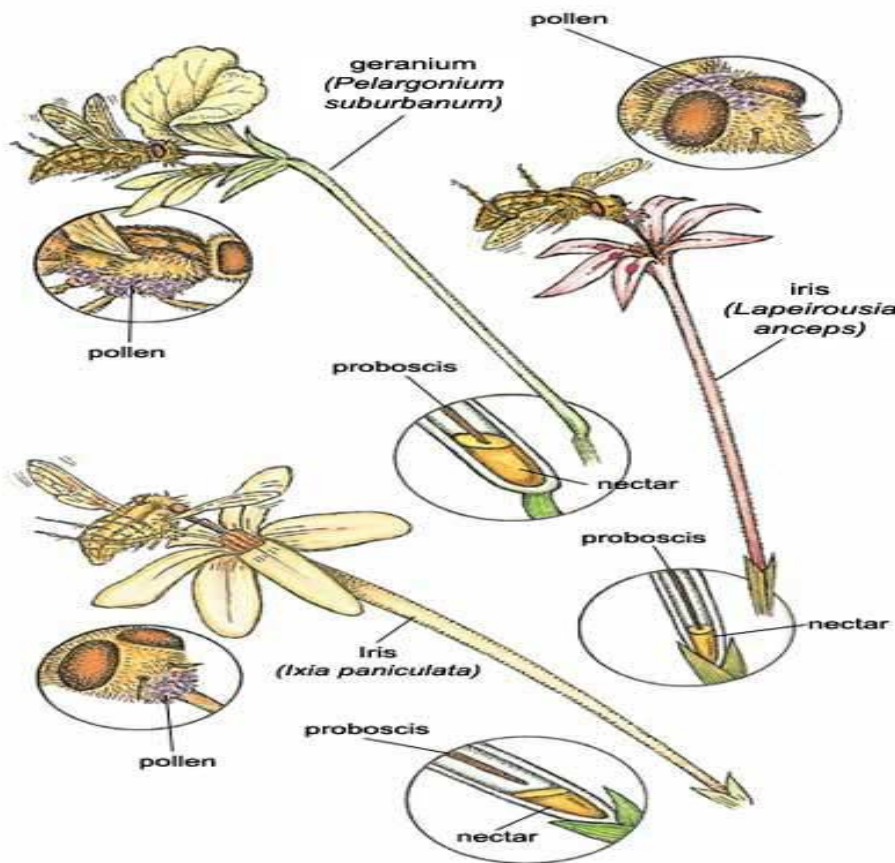
Both species coevolve to benefit each other in same habitat

- Fig – Wasp Relationship
- ~750 tropical fig species
- All of which depend entirely on wasps for pollination
- Figs are not fruits, they are specialized inflorescences with hundreds of unisexual flowers.
- Receptive figs produce scents that are specific to a particular pollinator species
- Shape of ostiole specific to head shape of particular wasp species (lock-and-key)
- Morphology of individual flowers specialized to a particular wasp species



Plant-pollinator coevolution

- Flies and moths have outlandish proboscises
- Extract nectar from similarly outlandish flowers



- Attina Ants grow fungi in their colonies
- They provide leaves as food for fungi (yeasts) and eliminate competition for them.
- Fungi produce nutritional “gongylidia”
- These are hyphal swellings. Gongylidia are harvested by ants to feed their larvae. Coevolution exists from 50 million years. Ants protect aphids from parasites and predators. Aphids produce honeydew, source of nutrition for ants. Specifically coevolved for ants

Lecture 26

• Symbiosis

Symbiosis

Relationship between two different species living together

Obligate or facultative

Types

1. **Mutualism**
2. **Commensalism**
3. **Parasitism**

Relationships can be obligate, meaning that one or both of the symbionts entirely depend on each other for survival. For example, in lichens, which consist of fungal and photosynthetic symbionts, the fungal partners cannot live on their own. Facultative means optional.

Mutualism

- Long-term relationship between individuals of different species
- Both individuals get benefit

Example: Hermit crab and sea anemone

Commensalism

- One species gain benefits while those of the other species is neither benefited nor harmed.

Example: Remora fish and Sharks

as in the remoras that ride attached to sharks and other fishes. Remoras feed on their hosts' fecal matter

Parasitism

- One species gain benefits other species is harmed
- Intimate contact (feed off host)
- Usually do not kill host (parasitoids do)
- Enhances fitness of parasite but reduces fitness of host

Parasitoid: wasp larvae eat caterpillar

Types of Parasites

1. Microparasites: reproduce inside host

Bacteria, viruses

2. Macroparasites: release juvenile outside host

E.g. trematodes

3. Endo parasites

Examples: Liver fluke, tape worm, nematodes

4. Ectoparasites

Examples: Ticks, mites, fleas, mosquito, lice

Lecture 27

• Parasitism

Parasitism

- One species gain benefits other species is harmed
- Host and Parasite
- Intimate contact (feed off host)
- Usually do not kill host (parasitoids do)
- Enhances fitness of parasite but reduces fitness of host

Parasitoid: wasp larvae eat caterpillar

Evolutionary strategies of Parasitism

1. Parasitic castrators

- Partly or completely damages the reproductive system of host
- Other systems are left intact
- Host's energy used for growth of parasites

2. Directly transmitted

- Do not need vector for transmission to host
- Single host life cycle

3. Vector transmitted

- Need a vector for transmission to final host
- Life cycle involves an intermediate host.
- Do not sexually reproduce in intermediate hosts

4. Parasitoids

- Mostly are insects

- Sooner or later kill their host

Types:

1. Idiobiont
2. Koinobiont

Idiobiont parasitoids

- Sting their prey on capture
- Either killing them outright or paralysing them immediately

Koinobiont parasitoids

- Flies as well as wasps
- Lay their eggs inside young hosts, usually larvae.
- Allowed hosts to grow
- Parasitoids emerge as adults, leaving the prey dead, eaten from inside

5. Micropredators

- Attacks more than one host
- Reducing each host's fitness
- Most micropredators are hematophagous, feeding on blood.

Types of Parasites

3. Endo parasites

- Examples: Liver fluke, tape worm, nematodes

4. Ectoparasites

- Examples: Ticks, mites, fleas, mosquito, lice

Lecture 28

• Camouflage-1

Camouflage

- Use of any combination of materials, coloration, or illumination
- Concealment from predators
- Also known as cryptic coloration

Principles of Camouflage

1. Crypsis

Objects hide and hard to see

2. Mimicry

Disguising them as something else

3. Motion dazzle

Using visual illusions

- Protect without hiding

Crypsis

1. Resemblance to surroundings

- Colors and patterns resemble a particular natural background
- Change their color if environment changes

Example: Egyptian nightjar, Parrot

2. Disruptive coloration

- Strongly contrasting, non-repeating markings such as spots or stripes
- It breaks up the outlines of an animal.
- Need other strategies for survival

Example: Leopard, Giraffe

3. Eliminating shadow

- Flattened bodies
- Sides thinning to an edge
- Animals habitually press their bodies to the ground
- Sides are fringed with white scales

Example: Horned Lizard

4. Distraction

- High-contrast markings which attract the predator's gaze
- Distract predator from recognizing whole prey
- Distract from identifying prey's outline
- Example: Bushbuck

Lecture 29

• Camouflage-2

4 Self Decoration

- Decorating with materials such as twigs, sand, or pieces of shell
- Break up their outlines
- Conceal the features of their bodies
- Match their backgrounds

Example: Decorator crabs

5. Changeable skin coloration

- Actively change their skin patterns and colours
- Change can be rapid or seasonal
- Chameleon rapidly changes its color.
- Arctic fox changes from brown or grey in the summer to white in the winter
- Use special chromatophore cells, fur molting to resemble their current background.

6. Countershading

- Shadow makes upper side darker and underside lighter
- Countershading graded color to counteract the effect of self-shadowing
- Creating an illusion of flatness
- Makes animal darker below and lighter above

Example: gazelles, grasshoppers, sharks, dolphins

Lecture 30

• Camouflage-3

7. Counter-illumination

- Producing light to match a background that is brighter than an animal's body
- Light-producing organs (photophores) scattered all over its underside

Example: hatchet fish, Firefly squid

- Illumination makes them lighter in color from below
- Eliminates shadow
- Protect them from predator

8. Transparency

- Few marine animals float near the surface are highly transparent
- Makes them invisible to predators at certain distance
- More efficient in deeper water

Example: Jellyfish

9. Silvering

- Transparency can be imitated by silvering
- It makes body reflective
- Light comes from above reflected by mirror like body
- Make fish invisible from the side

Example: Herring fish

Motion dazzle

Crypsis might be ineffective when animal moves

Motion makes it visible to predator

Rapidly moving bold patterns of contrasting stripes counteracts this risk

Example: Zebra

Due to optical illusion

Motion dazzle may degrade predators' ability to estimate the prey's speed and direction accurately

Giving the prey an improved chance of escape

Lecture 31

• Mimicry

- The resemblance of one species to another for protective or aggressive purposes
- Different from camouflage
- They imitate instead of hiding by camouflage strategies

Types of Mimicry

On basis of adopting different models to mimic:

1. Batesian Mimicry
2. Mullerian Mimicry

Batesian Mimicry

Association in which the members play two different roles

1. Model
2. Mimic

Model – a species which possesses the inherent protection, e.g. poisonous chemicals in insects e.g. Butterflies

The Mimic – a species which lacks the basic protection but through resembling the model superficially gains protection from predators

- **Model:** Monarch butterfly
- **Mimic:** Viceroy butterfly

Batesian Mimicry

- Mimics usually smaller than models
- Mimicry restricted to females
- One sex must stay the same to be recognizable
- Females do the choosing so males must be the original form
- Abundance of the mimic is limited by its effectiveness
- If too common then predators learn the wrong signal.

- Numbers increase to point of selective neutrality where benefit equals cost.
- Polymorphism is common
- If morph A is at selective neutrality
- New morph B, mimicking a different model, will be at a selective advantage

Mullerian Mimicry

- Distasteful species, that may or may not be closely related
- Share one or more common predators
- Mimic each other's honest warning signals, to their mutual benefit
- Predators learn to avoid all of them

In Müllerian mimicry, two equally noxious species evolve to look similar to each other. Now you would wonder why these species want to mimic each other when they both have good defenses; this question was asked by many, and the experts came up with an answer. Studies have shown that when two harmful species look alike, there are higher chances of repelling predators, and lesser fatalities. When a predator eats a noxious insect, it will begin avoiding it with experience. Another similar-looking harmful insect will automatically be safer from the predator without having to do much. It is easier to educate the predator faster by looking alike, than wasting time and increasing preying incidents.

- Polymorphism is infrequent
- Models tend to stay the same because there is a disadvantage in being different
- No limit to number of species participating
- Different colors depend on location and visibility
- Groups at different levels in tropical forest have different colors due to different light levels

Lecture 32

• Aposematism

Appearance of an animal that warns predators it is toxic, distasteful or dangerous.

Advertisement of signals

1. Color
2. Odours
3. Sound
4. Aggression

Function is to prevent attack.

Beneficial for both predator and prey, saving them from harm.

Types of Signals

Primary: Easily detectable (colors)

Secondary: invisible (ultrasonic noise for specific predator)

Primary Signals

Bright and high contrast colors

Patterns such as stripes

Effective colors are red, yellow, black and white

Colors resist changes in shadow and lighting.

Warning coloration evolves in response to:

- Background
- Light conditions
- Predator vision

Other visible signals

- Odour
- Sound

- Aggressive behavior

Examples:

Tiger moth: Bitter taste and ultrasonic sounds

Skunk: Noxious odour

Dart frog: Poison

Velvet ant: Sting and noise

he [honey badger](#)'s [reverse countershading](#) makes it conspicuous, [honestly signalling](#) its [ability to defend itself](#) through its aggressive temperament, and its sharp teeth and claws.

Examples:

Black widow spider: Neuro toxin

Honey badger: Aggressive

Prevalence

Both terrestrial and marine ecosystem

- Mostly insects

Marine animals

1. Nudibranch
2. Crown-of-thorns starfish

Iridescent blue rings on the mantles of the venomous octopus are considered by some to be aposematic

Lecture 33

• Atmosphere and its Evolution-1

- Atmosphere of Earth is the layer of gases
- Commonly known as air
- Surrounds the planet Earth
- Retained by Earth's gravity

Evolution

1. First Atmosphere

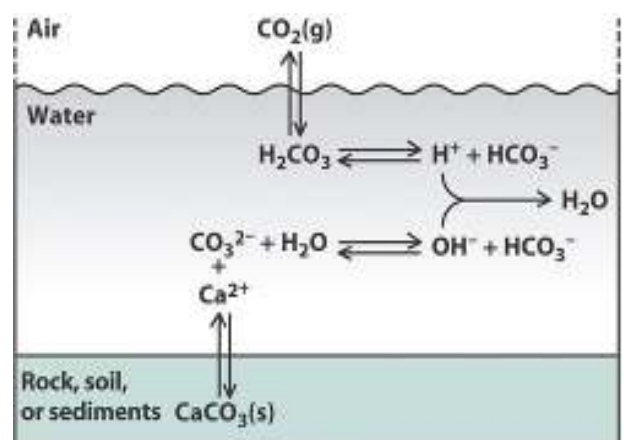
Composition of gases like solar nebula (disc of dirt and gases)

Aged 4 billion years ago

- Hydrogen
- Methane
- Helium
- Ammonia
- Water vapors

2. Second Atmosphere

- Outgassing from volcanism
- Supplemented by gases produced during heavy bombardment of Earth by huge asteroids
- Added N₂, CO₂ and inert gases
- Carbon-dioxide emissions dissolved in water
- Reacted with metals such as calcium and magnesium
- Formed carbonates that were deposited as sediments.
- Water-related sediments have been found
- Dated from as early as 3.8 billion years ago
 - billion years ago, molecular nitrogen formed



- Earth temperature was warm.
 - billion years ago, oxygen was developed
- Activity of photosynthesizing cyanobacteria
- Known as “Great Oxygenation Event”
- Activity of photosynthesizing cyanobacteria
- Known as “Great Oxygenation Event”

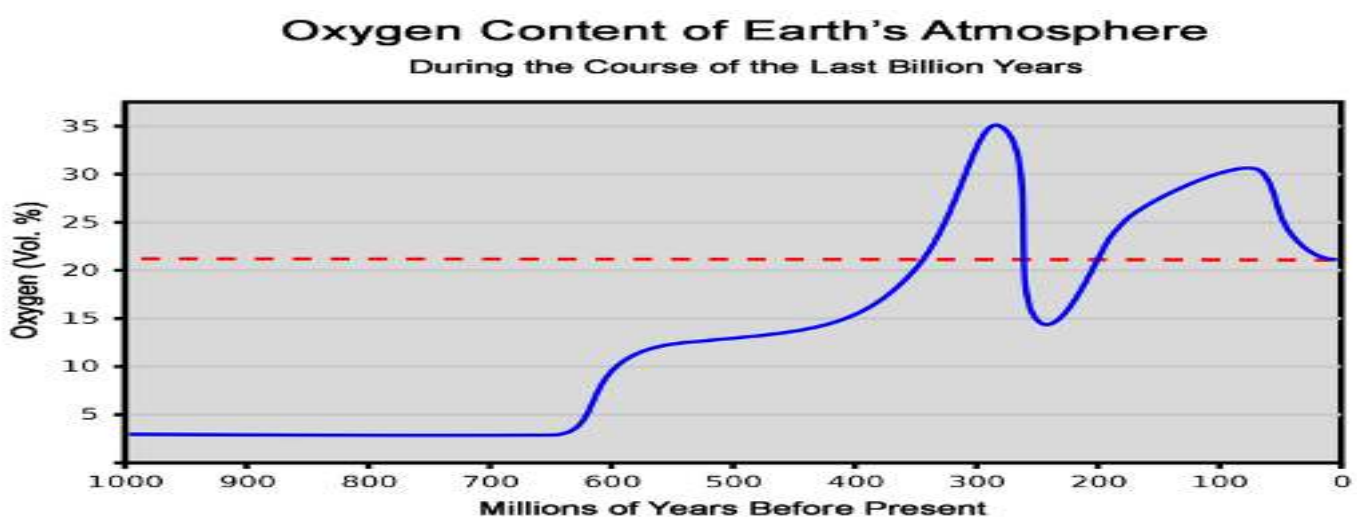
Lecture 34

• Atmosphere and its Evolution-2

Evolution

3. Third Atmosphere

- Constant rearrangement of continental plates
- Inflow and outflow of CO₂ from large continental carbonate stores
- O₂ synthesized in photosynthesis was being used in reducing materials
- Gradually, it was shifted to oxidizing atmosphere instead of reducing
- 541 million years ago, O₂ made stable 15% of atmosphere.



Reasons of fluctuations in O₂

- Plants produced oxygen and consumed CO₂
- Volcanic eruptions release sulfur into the atmosphere
- Sulfur oxidizes itself
- Reduces the amount of oxygen in the atmosphere
- Volcanic eruption also released CO₂
- Exact causes of fluctuations are unknown.

Lecture 35

• Composition of Atmosphere

Comprised of a mixture of:

1. Invisible permanent gases
2. Variable gases
3. Suspended microscopic particles

1. Permanent Gases

Form a constant proportion of the total atmospheric mass

2. Variable Gases

Distribution and concentration varies in space and time

3. Aerosols

Suspended particles and liquid droplets (excluding cloud droplets)

1. Permanent Gases

- 78% Nitrogen (N₂)
- 21% Oxygen (O₂)
- <1% Argon (Ar)

Relative percentages of the permanent gases remain constant up to 80 - 100km high. Turbulent mixing causes atmospheric composition to be fairly homogenous. Called as **Homosphere**

2. Variable Gases

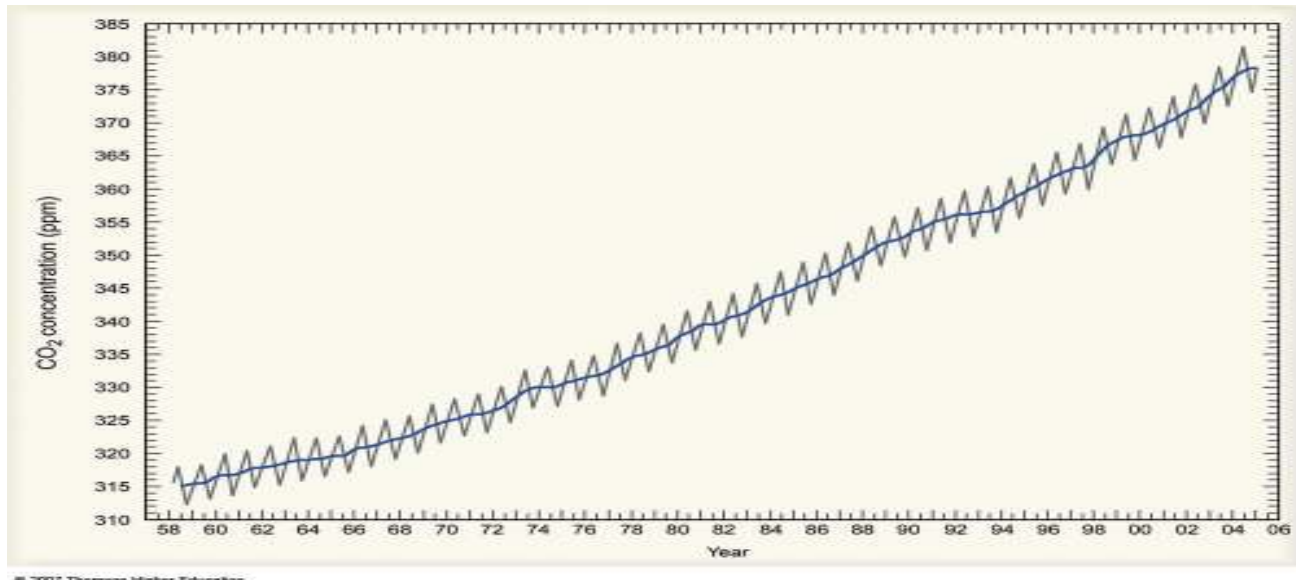
- **Water vapor (H₂O):** 0 to 4%
- **Carbon Dioxide (CO₂):** 0.038%
- **Methane(CH₄):** 0.00017%
- **Ozone(O₃):** 0.000004%

Variable Water vapors

- Water vapor is invisible.
- Its not cloud droplets.
- 3rd major component
- Surface percentages vary between <1% in desserts to 4% in tropics.
- Typical mid-latitude value is about 1-2%.

Variable Carbon Dioxide

- Small percentage of total atmosphere (380 ppm)
- But, very important green house gas



Mauna Loa Observatory CO₂ trace (annual variations embedded in the long-term record)

Variable Ozone

- Near the surface, ozone concentrations about 0.04-0.15 ppm
- In the upper atmosphere ozone concentration can reach ~15 ppm
- Upper atmospheric ozone is vital to blocking harmful radiation
- Ozone near the surface, however, harmful to life

Variable Methane

- Concentrations of about 1.7 ppm
- Extremely potent green house gas - 21 times more powerful by weight than carbon dioxide
- Unexpected increase in last 400,000 years
- Increase attributed to agriculture, industries, bio-mass and fossil fuel burning

3. Aerosols

- Small (or “tiny”) solid particles or liquid droplets (excluding clouds and rain)
- Aerosols can be man-made (anthropogenic) or naturally occurring (like ocean salt, dust, plant emissions)
- Aerosols are not synonymous with pollution

- Some aerosols are very beneficial and, in fact, are required for precipitation processes to occur.

Major constituents of dry air, by volume			
Gas		Volume ^(A)	
Name	Formula	in ppmv ^(B)	in %
Nitrogen	N ₂	780,840	78.084
Oxygen	O ₂	209,460	20.946
Argon	Ar	9,340	0.9340
Carbon dioxide	CO ₂	400	0.04 ^[9]
Neon	Ne	18.18	0.001818
Helium	He	5.24	0.000524
Methane	CH ₄	1.79	0.000179
Not included in above dry atmosphere:			
Water vapor ^(C)	H ₂ O	10–50,000 ^(D)	0.001%–5% ^(D)

Lecture 36

• Layers of Atmosphere-1

- Air pressure and density decrease with altitude

Temperature shows different patterns. It increases with altitude in some regions. Temperature is useful tool to distinguish atmospheric layers. Atmosphere can be divided into five layers. Highest to lowest

Layers of atmosphere

1. **Exosphere:** 700 to 10,000 km (440 to 6,200 miles)
2. **Thermosphere:** 80 to 700 km (50 to 440 miles)[12]
3. **Mesosphere:** 50 to 80 km (31 to 50 miles)
4. **Stratosphere:** 12 to 50 km (7 to 31 miles)
5. **Troposphere:** 0 to 12 km (0 to 7 miles)

Lecture 37

• Troposphere-1

- The lowest layer
- All weather conditions take place here. Conventional aviation takes place here.

It contains:

75% of the atmosphere's mass

99% of the total mass of water vapor and aerosols

Height

- 18 km (11 mi; 59,000 ft) in the tropics
- 17 km (11 mi; 56,000 ft) in the middle latitudes
- 6 km (3.7 mi; 20,000 ft) in the polar regions in winter.
- The total average height of the troposphere is 13 km.

Properties

- Composition of air is homogenous except water vapors.
- Temperature of the troposphere decreases with altitude.
- Ground absorbs most of the sun's energy
- It makes the lower levels of the atmosphere warm.
- Radiating of heat away from earth at the top of the atmosphere
- It results in the cooling of that part of the atmosphere.

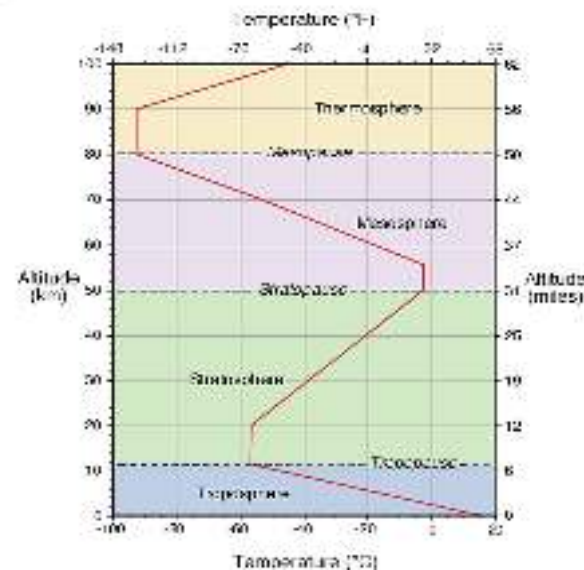
- Vapor pressure drops with decrease in temperature.
- Drop in vapor pressure is due to gravity.
- Pressure of the atmosphere is maximum at sea level and decreases with altitude.

Tropopause

- Boundary region between the troposphere and the stratosphere
- Temperature decrease with increase in altitude.

Height

- 17 kilometres (11 mi) above equatorial regions
- 9 kilometres (5.6 mi) over the polar regions



Lecture 38

• Stratosphere

- The second major layer of Earth's atmosphere
- Above the troposphere, and below the mesosphere

Height

- 20 km (66,000 ft; 12 mi) at equator
- 10 km (33,000 ft; 6.2 mi) at midlatitudes
- 7 km (23,000 ft; 4.3 mi) at the poles

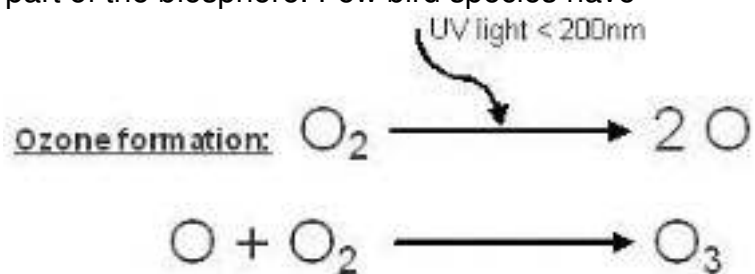
Properties

Low density/pressure of gases due to reduced gravity. Ozone is important gas.

Temperature increases by increase in altitude. Temperatures range from -51°C near the tropopause to an average of -15°C near the mesosphere

Increase in temperature is a result of the absorption of the Sun's ultraviolet radiation by the ozone layer. Speed of wind far exceed those in the troposphere, reaching near 220 km/h. Aircrafts fly near lower troposphere to take benefit of low air density and temperature optimizing fuel efficiency. Bacterial life survives in the stratosphere, making it a part of the biosphere. Few bird species have been observed in upper troposphere.

- Rüppell's vulture
- Bar-headed geese



Stratopause

- Boundary between stratosphere and the mesosphere
- Height: 50 to 55 kilometres high above the Earth's surface
- Pressure: 1/1000 of the pressure at sea level
- Temperature: -15°C

Lecture 39

• Mesosphere

- Layer, directly above the stratosphere and directly below the thermosphere
- Lower boundary is 50 to 65 kilometres
- Upper boundary is around 85 to 100 kilometres
- It is called as "near space".
- Temperature decreases with increasing height
- Due to decreasing absorption of solar radiation

- Rarefied, low dense atmosphere
- Increasing cooling by CO₂ radiative emission
- Temperatures in the upper mesosphere fall as low as -101°C varying according to latitude and season.
- Ionization starts here due to minimum gravity.
- Polar aurora is observed due to entry of solar winds.

Mesopause

- Boundary between the mesosphere and the thermosphere
- Height: 85 – 100 km
- Temperature: 100 – 102 $^{\circ}\text{C}$

Lecture 40

• Thermosphere & Exosphere

- Layer, directly above the mesosphere and below the exosphere
- **Height:** 80 km
- Extreme ultraviolet radiation causes photoionization/photodissociation of molecules, creating ions
- Known as ionosphere

Properties

Temperature increase with altitude due to absorption of highly energetic solar radiation. Temperature can raise 1700 $^{\circ}\text{C}$ or more. Highly diluted gas in this layer can reach 2,500 $^{\circ}\text{C}$ during the day. Temperatures will significantly drop if solar activity is limited. Ions are far apart to transfer heat through conduction. Around 160 kilometre, the density is so low that molecular interactions are too infrequent to permit the transmission of sound. Solar winds, extreme UV storms and atmospheric waves are observed here. Bombardment of particles is too intense to weaken the magnetic field on opposite end. Difficult to distinguish the boundary between thermosphere and exosphere. It is located directly above the thermosphere.

Thin, atmosphere-like volume surrounding a planet

Molecules are gravitationally bound to that body

Density is too low for them to behave as a gas by colliding with each other. Atmosphere thins out and merges with interplanetary space. Very little is known about it due to lack of research.

Lecture 41

• Benefits of Atmosphere

Atmosphere is responsible for sustaining life on earth. Without it, earth will be barren like moon and mars. Atmosphere is key element in survival of life.

Temperature

- Maintains the Earth's temperature
- Molecules of air gases absorb heat energy from sun.
- Conduction of heat energy by mixing of air
- CO₂, methane, nitrous oxide cause green house effect.

Protection against Radiations

- Protective shield against radiation and cosmic rays
- Bombardment of UV rays and particles from sun
- Ozone filters most of the UV rays.
- Gases also absorb cosmic rays, gamma rays and x-rays
- Prevent mutations

Physical Protection

Solar system is full of debris, small particles leftover from planetary creation or collisions in the asteroid belt. 100 tons of space debris strikes Earth every single day. Friction with atmospheric gases destroys them long before they reach the ground.

Weather and Water

- Atmosphere holds around 12,900 cubic kilometers of water at any given time.
- Responsible for water cycle
- Transfer water vapors from oceans to dry areas.
- Responsible for precipitation.
- Winds control weather.

Lecture 42

• Carbon Cycle

Carbon is main component of living organisms. 20% of human body is carbon by weight. CO_2 is major source of carbon. Atmosphere contains about 750 billion metric tons of carbon in form of CO_2 . Photosynthetic organisms take in CO_2 from the atmosphere

Synthesize the carbon containing organic compounds This process is sometimes called **carbon fixation**. Animals eat plants and make their own organic compounds. Production of energy by breakdown of these organic compounds in respiration.

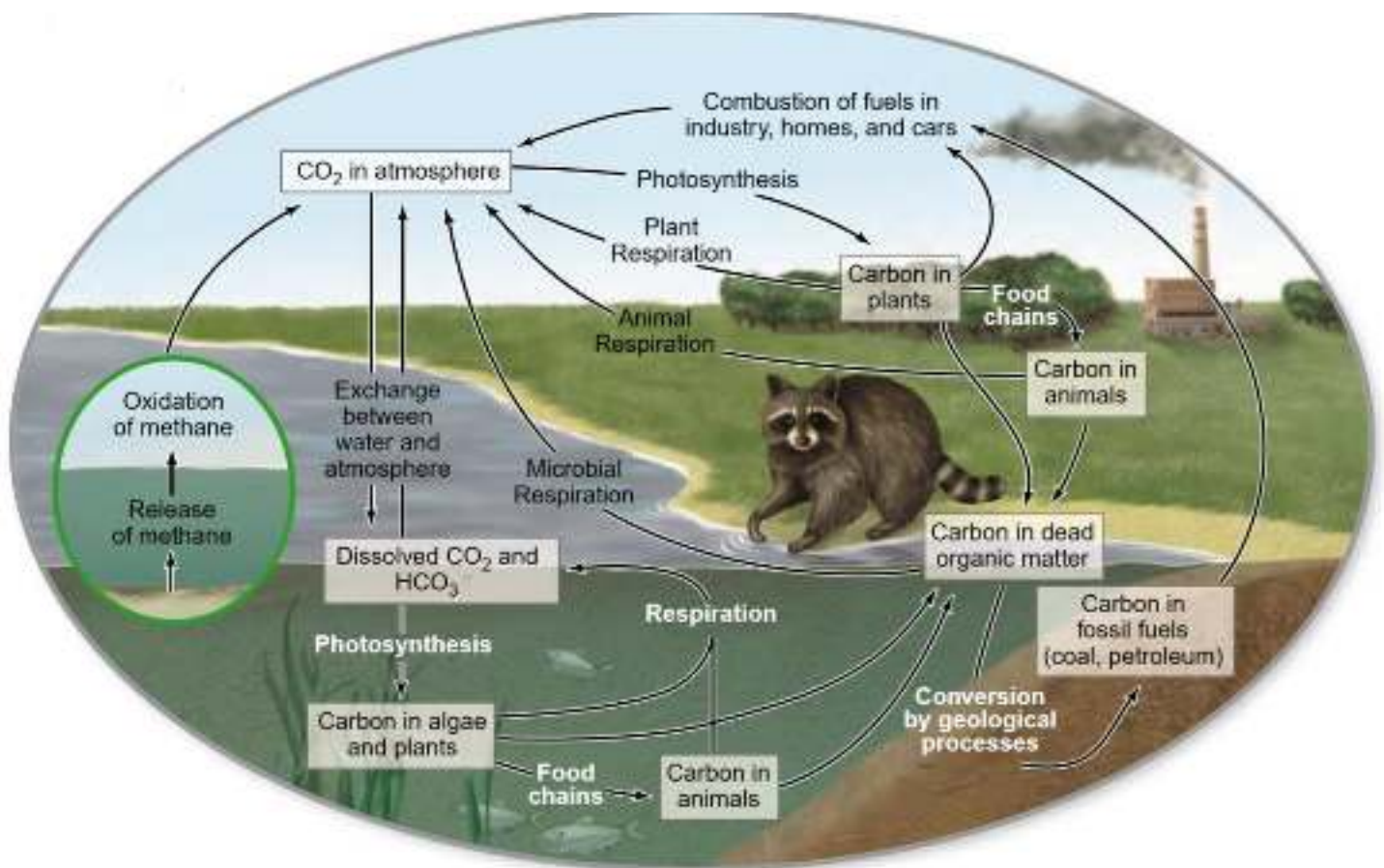
Respiration releases CO_2 in air. Decaying organisms also produce CO_2 .

CO_2 released in air is again available for plants. In aquatic ecosystem, CO_2 reacts with the water to form bicarbonate ions. Dissolved CO_2 and bicarbonates are used by algae and aquatic plants in photosynthesis.

Methanogens, for example, are microbes that produce methane (CH_4) instead of CO_2 .

Methane released in air is oxidized into CO_2 . Amount of CO_2 made by breakdown of organic compounds almost matches the amount of CO_2 used.

Small mis-matches can have large consequences.



Lecture 43

• Water Cycle -1

Life depends on the presence of water. Adult human body contains 60% of water by weight.

Water is compound which can be synthesized and broken.

Synthesis in aerobic respiration

Break down in photosynthesis

Rate of synthesis and breakdown is equal.

Evaporation

In evaporation, water changes from its liquid state to a gaseous state. Some of the water in the oceans and freshwater bodies, such as lakes and rivers, is warmed by the sun and evaporates. During the process of evaporation, impurities in the water are left behind. As a result, the water that goes into the atmosphere is cleaner than it was on Earth.

Condensation

- Opposite of evaporation
- Condensation occurs when a gas is changed into a liquid. When the water droplets formed from condensation are very small.
- They remain suspended in the atmosphere. These millions of droplets of suspended water form clouds in the sky or fog at ground level.

Precipitation

- Under right temperature and atmospheric pressure conditions
- Small droplets of water in clouds form larger droplets and precipitation occurs.
- The raindrops fall to Earth.

Surface Runoff

Much of the water that returns to Earth as precipitation runs off the surface of the land

Flows downhill into streams, rivers, ponds and lakes. Small streams flow into larger streams, then into rivers, and eventually the water flows into the ocean. Surface runoff is an important part of the water cycle. Much of the water returns again to the oceans, where a great deal of evaporation occurs.

Lecture 44

• Water Cycle-2

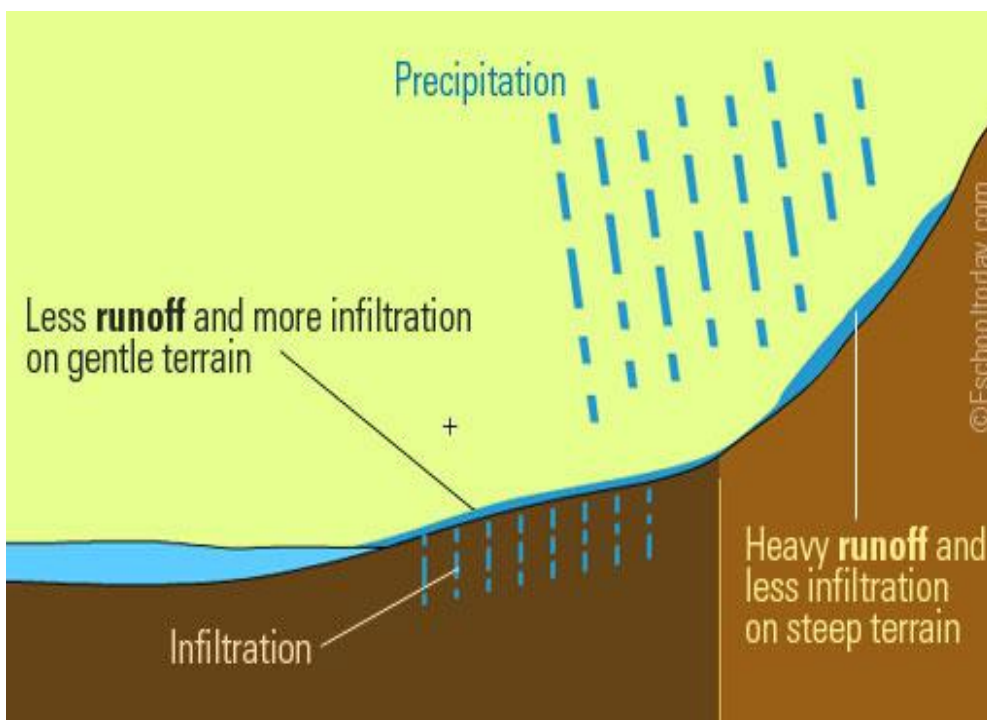
Percolation (Infiltration)

Percolation is an important process. Rain water soaks into (infiltrates) the ground, into the soil and underlying rock layers. Some of this water ultimately returns to the surface at springs or in low spots downhill. Some of the water percolates underground It is called **groundwater**.

Groundwater

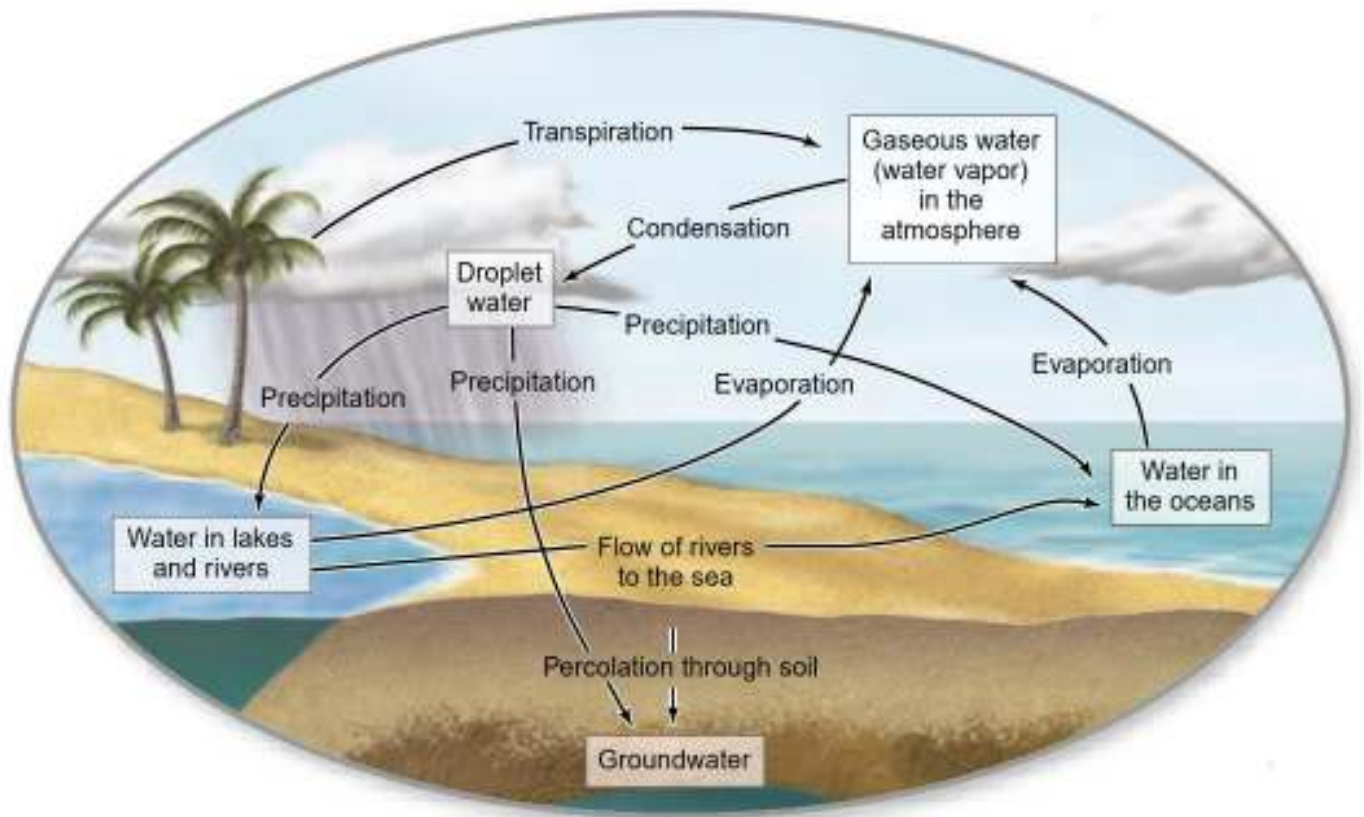
Water moves through the soil and rock layers. Many of the impurities in the water are filtered out. This filtering process helps clean the water.

Percolation (Infiltration) & Surface Runoff



Transpiration

Plants absorb water from the soil. Water moves from the roots through the stems to the leaves. Water reaches the leaves. Some of it evaporates from the leaves, adding to the amount of water vapor in the air. This process of evaporation through plant leaves is called transpiration. In large forests, an enormous amount of water will transpire through leaves.



Lecture 45

• Nitrogen Cycle - 1

Nitrogen is a component of all proteins and nucleic acids. A living organism is 16% nitrogen by weight. Atmosphere is 78% nitrogen by volume. Atmospheric nitrogen is in its elemental form. It cannot be used in this form by living organism. Ultimate source of nitrogen is nitrogen containing organic compounds synthesized by plants or by algae or other microbes. Two commonly used nitrogen sources are ammonia (NH_3) and nitrate ions (NO_3^-). Prokaryotic microbes can synthesize ammonia and nitrate from N_2 in the atmosphere. It makes atmospheric nitrogen accessible to plants and algae. Other prokaryotes turn NH_3 and NO_3^- into N_2 , making the nitrogen inaccessible. These activities balance the amount of accessible of nitrogen. All these processes form nitrogen cycle.

Sources of Nitrogen

- Lightning
- Inorganic fertilizers
- Nitrogen Fixation
- Animal Residues
- Crop residues
- Organic fertilizers

Forms of Nitrogen

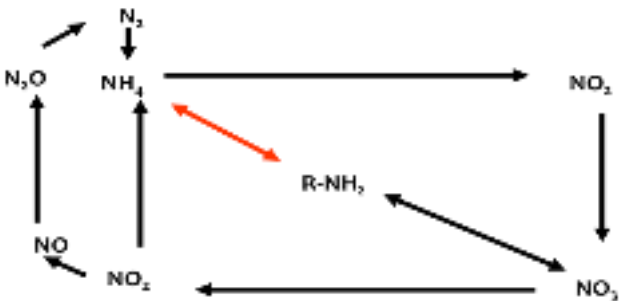
- Urea $\rightarrow \text{CO}(\text{NH}_2)_2$
- Ammonia $\rightarrow \text{NH}_3$ (gaseous)
- Ammonium $\rightarrow \text{NH}_4$
- Nitrate $\rightarrow \text{NO}_3$
- Nitrite $\rightarrow \text{NO}_2$
- Atmospheric Dinitrogen $\rightarrow \text{N}_2$
- Organic N

Nitrogen Reservoir	Metric tons nitrogen	Actively cycled
Atmosphere	3.9×10^{15}	No
Ocean → soluble salts	6.9×10^{11}	Yes
Biomass	5.2×10^8	Yes
Land → organic matter → Biota	1.1×10^{11} 2.5×10^{10}	Slow Yes

Phases of Cycle

1. Ammonification/mineralization
2. Immobilization
3. Nitrogen Fixation
4. Nitrification
5. Denitrification

Ammonification or Mineralization



Ammonification

- Decomposers: earthworms, termites, slugs, snails, bacteria, and fungi
- Uses extracellular enzymes to initiate degradation of plant polymers.

Microorganisms use:

Proteases, lysozymes, nucleases to degrade nitrogen containing molecules

Lecture 46

• Nitrogen Cycle -2

Immobilization

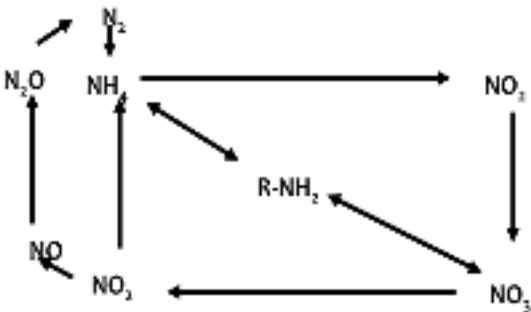
- The opposite of mineralization
- Happens when nitrogen is limiting in the environment
- Nitrogen limitation is governed by C/N ratio
- C/N typical for soil microbial biomass is 20
- C/N < 20 →Mineralization
- C/N > 20 →Immobilization

Nitrogen Fixation

- Energy intensive process :
- $N_2 + 8H^+ + 8e^- + 16\text{ ATP} = 2NH_3 + H_2 + 16\text{ ADP} + 16\text{ Pi}$
- Performed only by selected bacteria and actinomycetes
- Performed in nitrogen fixing crops

(ex: soybeans, legumes)

Nitrogen Fixation



Microorganisms fixing Nitrogen

- *Azobacter*
 - *Beijerinckia*
 - *Azospirillum*
 - *Clostridium*
 - *Cyanobacteria*
- Require the enzyme nitrogenase
 - Inhibited by oxygen
 - Inhibited by ammonia (end product)

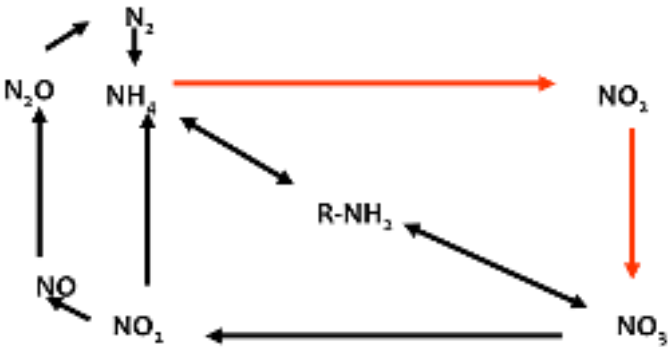
N ₂ fixing system	Nitrogen Fixation (kg N/hect/year)
Rhizobium-legume	200-300
Cyanobacteria- moss	30-40
Rhizosphere associations	2-25
Free- living	1-2

Nitrification

Nitrification

Two step reactions that occur together :

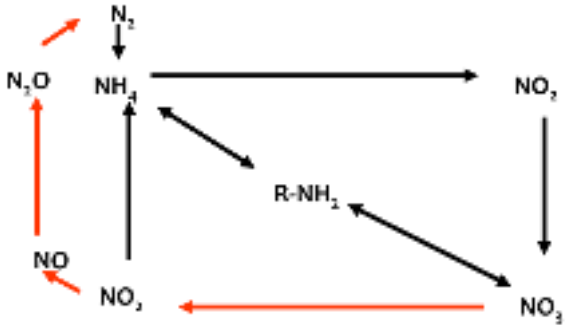
- 1st step catalyzed by *Nitrosomonas*
 $2\text{ NH}_4^+ + 3\text{ O}_2 \rightarrow 2\text{ NO}_2^- + 2\text{ H}_2\text{O} + 4\text{ H}^+$
- 2nd step catalyzed by *Nitrobacter*
 $2\text{ NO}_2^- + \text{O}_2 \rightarrow 2\text{ NO}_3^-$
- Optimal pH is between 6.6-8.0
- If pH < 6.0 → rate is slowed
- If pH < 4.5 → reaction is inhibited



Denitrification

- Removes a limiting nutrient from the environment
- Facultative anaerobic bacteria perform it.
- Oxidized nitrates are reduced.
- Glucose is electron donor.
- $4\text{NO}_3^- + \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{N}_2 + 6\text{H}_2\text{O}$
- Nitrate is the terminal electron acceptor
- Inhibited by oxygen
- Not inhibited by ammonia

Denitrification

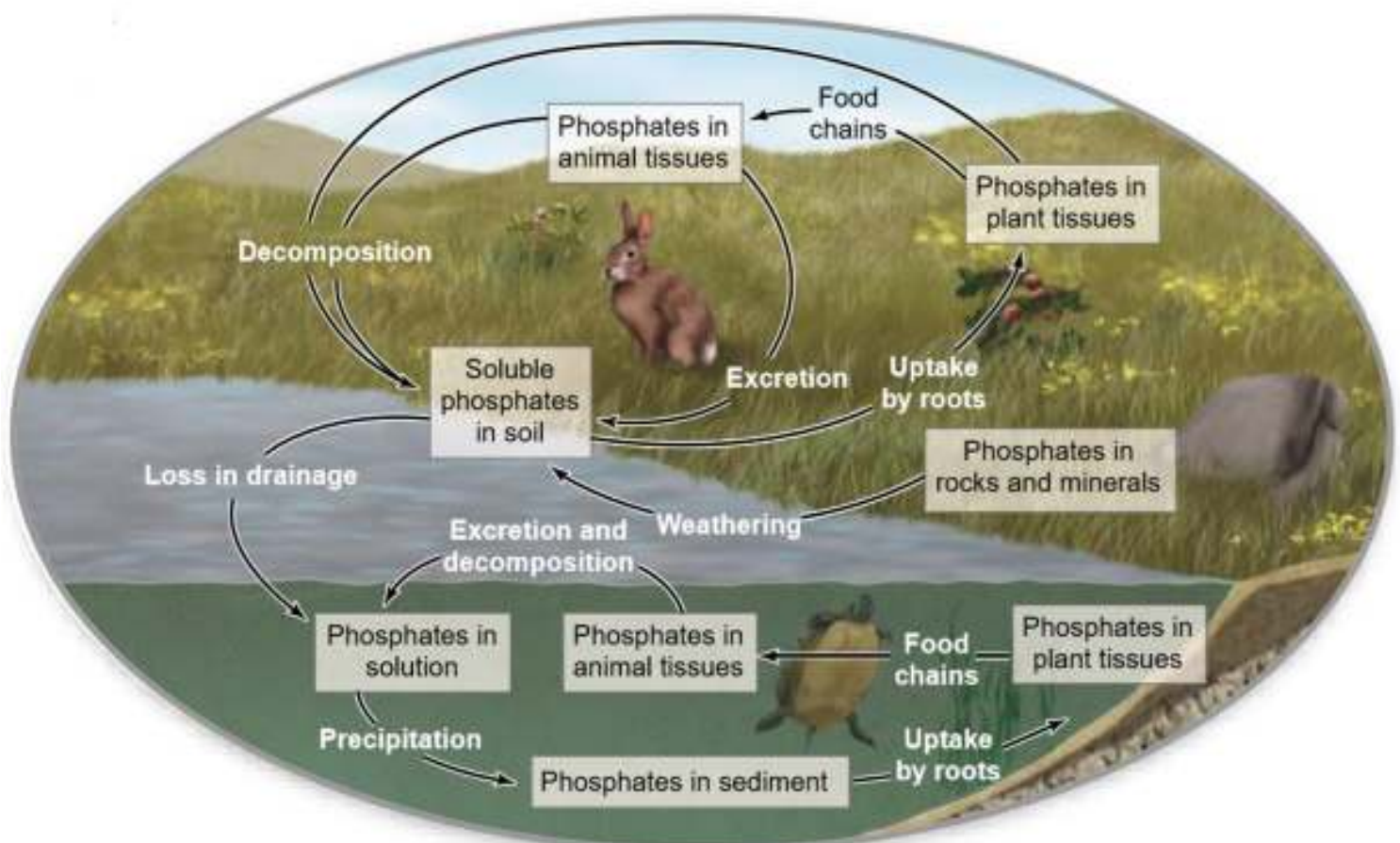


Phosphorus is important component of:

1. Nucleic acids
2. Membrane phospholipids
3. ATP

Phosphorus is mainly found in water, soil and rock in form of phosphates. The phosphorus cycle is the movement of phosphorus to and from between environment and organisms. Unlike to carbon and nitrogen, Phosphorus cannot be found in air in the gaseous state. Phosphate salts are released from rocks through weathering. Dissolve in soil water and will be absorbed by plants. This is the slowest cycle.

Animals absorb phosphates by eating plants or herbivores. When animals and plants die, phosphates will return to the soils or oceans again during decomposition. After that, phosphorus will end up in sediments or rock formations again, remaining there for millions of years. Eventually, phosphorus is released again through weathering and the cycle starts over. Like nitrogen, increased use of fertilizers increases phosphorus runoff into our waterways and contributes to eutrophication.



Extinction

- Termination of an organism or of a group of organisms (taxon), usually a species
- Moment of extinction is death of the last individual of the species. Capacity to breed and recover may have been lost before this point.
- Variety of causes, independently or in concert, are responsible for extinctions.
- Disruption of habitat
- Loss of ecosystem interactions e.g. disrupted food chain or web, symbiosis, predation
- Pollution
- Loss of genetic variation
- Catastrophic disturbances
- Natural or human-caused activities

- Disruption of ecosystem interactions is an important cause. One of the major disruptions is loss of habitat.

Percentage of Extinction of Species

Group	Habitat Loss
<i>E X T I N C T I O N S</i>	
Mammals	19
Birds	20
Reptiles	5
Fish	35

Habitat loss is the most important cause of modern-day extinction. Human activities are negatively affecting all types of habitat, from rain forest to ocean floor.

Natural habitats may be adversely affected by humans in three ways.

1. **Habitat destruction**
2. **Pollution**
3. **Habitat fragmentation**

Lecture 49

• Destruction of Habitat -1

A process in which natural habitat becomes incapable of supporting its native species. Organisms inhabiting there are displaced or destroyed reducing biodiversity. Human activities are responsible for this.

Causes

- Clearing habitats for agriculture and urban development
- Deforestation
- Mining
- Trawling
- Urbanization

Clearing habitats for agriculture and urban development

- Land clearing for agriculture is destructive.
- If extensive, it will bring irreversible changes.
- It will destroy whole ecosystem permanently.
- If 90% area is cleared, 50% of species will be lost.
- After clearing flora, fauna and topography, green house gas emissions, rise in soil salinity will damage it further.
- Land clearing should keep legislative regulation on its use.

Deforestation

About 31% of Earth's land surface is covered by forests. Removal of a forest or stand of trees from land which is then converted to a non-forest use.

Reasons of deforestation

- Agriculture
- Fuel
- Timber for building
- Pastures & Plantation
- Urban development

Insufficient reforestation has resulted in habitat damage, biodiversity loss, and aridity.

Impacts of Deforestation

- Global warming
- Tropical deforestation is responsible for approximately 20% of world greenhouse gas emissions.
- Decay or burning of wood release carbon in atmosphere.
- Carbon store in soil is also released.
- Water cycle
- Rate of transpiration by trees is reduced.
- Drier climate
- Low moisture in soil
- Less water available for plants.
- More erosion, flooding and land sliding
- Decline in biodiversity
- Cause of extinction
- Loss of genetic variations
- Affect interspecific interactions e.g. symbiosis

Impacts of Mining

- Mining needs removal of everything to get access to mine.
- It involves land clearing, deforestation and digging.
- Habitat is permanently damaged.
- It leaks pollutants.
- Water bodies are exposed to heavy metals and toxic minerals
- Water is pumped out to allow miners to work.
- Water level shrinks.

Impacts of Trawling

Trawling

- Pulling a fishing net through the water behind one or more boats
- Heavy catch of fish from wild.
- Using trawlers
- All wanted and unwanted animals are caught.
- Fishing gear towing at the bottom of sea damages sea bed.
- Including coral shattering, damage to habitats and removal of seaweed

Impacts of Urbanization

- Population shift from rural areas to urban areas
- Gradual increase in the proportion of people living in urban areas

Negative Impacts

- Deforestation
- Habitat destruction
- Habitat fragmentation
- Pollution

Lecture 50

• Habitat Fragmentation

- Habitat needs to be an intact body.
- Least interference is required to protect niches of organisms.
- Many species are too sensitive to tolerate changes in their niches.
 - e.g. insects
- Breaking up of one patch of habitat into several smaller patches
- Reduction in the total area of the habitat
- Isolation of one habitat fragment from other areas of habitat
- Decrease in the average size of each patch of habitat

Causes

- Fragmentation by different obstructions
- Volcanism, fire, climate change, deforestation, colonies, roads, water drains, noise, mining
- Population is divided into unconnected patches
- It affects biodiversity and population size in that habitat.

Edge Effect

- Proportion of the habitat that occurs on the boundary or edge, increases.
- Edge effects can significantly degrade a population's chances of survival.
- Changes in microclimate in edges are more dangerous than fragmentation itself.

In isolated fragments of rain forest, for example, trees on the edge are exposed to direct sunlight. As a result, these trees experience hotter and drier conditions than those normally encountered in the cool, moist forest interior, leading to negative effects on their survival and growth. In one study, the biomass of trees within 100 m of the forest edge decreased by 36% in the first 17 years after fragment isolation.

- Rainforests of Manaus, Brazil, First monkeys needing large area disappeared., then insects followed by insectivorous birds.

Edge Effect

- Population on edges are more exposed to sunlight.
- Parasites and predator effects can be more intense on edges.
- Plants are worst affected due to their immobility.

Lecture 51

• Effects of habitat fragmentation

Effects of Fragmentation

- Loss of biodiversity
- Threatening or extinction of species
- Genetic diversity is also fragmented.
- Small populations having smaller pool of fitness maintaining alleles to survive
- Gene flow and migration are reduced.
- Species do not migrate to fragments.
- Reproductive isolation and inbreeding
- It causes inbreeding depression.
- Inbreeding increases the level of homozygosity.
- Facilitating the expression of deleterious alleles that reduce the fitness
- It may result in local extinction.
- Genetic drift is increased.
- Random changes to the genetic make up of populations
- It leads to reductions in genetic diversity.
- Natural selection prefers large population size.
- Small population are weak in adaptations
- May be eliminated by the process of natural selection.
- Greatly affect the predator-prey dynamics of many species.
- By changing species diversity and population size
- Reduction in area of safe zones for prey making them vulnerable to predators
- It may increase their area of refuge on opposite

Lecture 52

• Invasive Species

Colonization, a natural process by which a species expands its geographic range, occurs in many ways.

Examples:

- Seed dispersal by birds
- Lowering of sea levels join two isolated land masses
- Flooding

Migratory animals carrying other animals as symbiotic or parasitic partners

Human activities are the major reason of invasion of species. Exotic Species are species that occur outside of their natural ranges because of human activity. An exotic species becomes invasive when it becomes established in its new environment and out competes native species.

Types of invasive species

1. Animals
2. Plants
3. Pathogens

They cause an imbalance in the natural environment. They outcompete the native species.

Zebra Mussel

- Originally from the Caspian and Black Sea.
- Accidentally introduced to the Great Lakes in 1988.
- Can harm other fresh water mussels
- Can block intake pipes for power plants
- Can cause problems for recreational activities.

Kudzu

- native to southern Japan and south east China.
- It occurs as an invasive species in the U.S.
- it is considered a noxious weed that climbs over trees or shrubs and grows so rapidly.
- It kills them by heavy shading.

Asian Tiger Mosquito

- Originally from Asia.
- Introduced to Hawaii in the late 1800's.
- Continental United States in 1985.
- Can be a vector for disease.
- Ex. West Nile Virus

Lionfish

- Native to the Pacific Ocean
- Introduced to the water around the United States in 1992 through the aquarium trade.
- Preys on native species.
- Has poisonous spines.
- Strategies and legislations about introduction of exotic species
- Protection of native species is of utmost priority.
- For purpose of conservation of native biodiversity

Lecture 53

. Overexploitation

- Over harvesting
- Harvesting a renewable resource to the point of diminishing returns
- Risk of extinction appears even when the species is initially very abundant.

Examples:

1. Passenger pigeons

2. Bison

in N. America

Cascade Effect

- Removal of apex predator in environment
- It leads to dramatic increase in their prey species.
- Unchecked prey can then overexploit their own food resources
- Shortage in food resources disturbs whole food web.
- Cascade of overexploitation at different trophic levels
- Population numbers dwindle, possibly to the point of extinction.

Example:

- Overhunting of sperm whale; an apex predator

Commercial Motivations

- International trade
- Furs
- Skin
- Bones
- Other body parts
- Trophy & Game hunting
- Hunting for food
- Medicines

Threatened species

- Chinchilla, vicuña, otter, and many cat species for fur
- Elephants for tusk
- Cod, bluefin tuna and swordfish fishing in N. America
- Mahogany trees in West Indies
- Cedar forests of Lebanon

Lecture 54

• Land pollution - 1

Pollution

Introduction of contaminants into the natural environment that cause adverse change. Undesirable change in physical, chemical, or biological characteristics of any component of the environment.

Pollution

Classified as:

1. Point source
2. Non point source

1. Point source

Single identifiable source of pollution

Example:

- Land fill
- Factory drain
- Sewages pipes

Non Point source

Resulting from many diffuse sources

Example:

- Sediment
- Nutrients
- Toxic contaminants and chemicals
- Pathogens

Types of Pollution

- Land
- Air
- Water
- Light
- Noise

Followed by industrial Revolution, natural habitats were destroyed and the environment was polluted.

Common problem worldwide

Direct result of the activities that humans engage in

Pollution of the Earth's natural land surface by industrial, commercial, domestic, and agricultural activities

Includes visible litter and waste along with the soil

The deposition of solid or liquid waste materials on land or underground can contaminate the soil and groundwater

Land pollution is comprised of:

1. Solid waste
2. Soil pollution

Solid Waste

- Semisolid or solid matter that are created by human or animal activities
- Disposed because they are hazardous or useless

Sources of solid waste

- Wastes from agriculture
- Wastes from mining
- Wastes from industries
- Solids from sewage treatment
- Ashes
- Garbage

Solid Pollution

- Caused by chemicals in pesticides
- Results from unhealthy methods of soil management.
- Harmful practices of irrigation methods.
- Causes

Lecture 55

• Land pollution -2

Sources

- Littering
- Herbicides, insecticides, and pesticides
- Construction debris and waste
- Mining waste
- Overcrowded landfills
- Deforestation
- Chemical and nuclear plants

- Industrial factories
- Oil refineries
- Human sewage
- Oil and antifreeze leaking from motor vehicles

Causes

- Increase in urbanization
- Increase in agricultural land
- Domestic waste
- Agricultural activities
- Industrial activities

Effects

- Exterminates wild life
- Vegetation that provides food and shelter is destroyed
- It can seriously disrupt the balance of nature, and, in extreme cases, can cause human fatalities
- Most pesticides kill or damage life forms other than those intended.
- Pesticides can damage crops; kill vegetation; and poison birds, animals, and fish
- Skin problems are often diagnosed due to land pollution.
- One of the leading causes for birth defects.
- Land pollution indirectly affects the respiratory system of human beings
- Can incur breathing problems and a number of diseases, which may affect the health of babies as well.
- Impact it has on the surrounding environments
- Every form of land pollution kills off the habitats of land animals as well as aquatic life
- The more we deplete these habitats the more the ecosystem is thrown out of balance.

Preventions

- People should be educated and made aware about the harmful effects of littering.
- Items used for domestic purposes ought to be reused or recycled.
- Personal litter should be disposed properly.
- Organic waste matter should be disposed in areas that are far away from residential places
- Use of pesticides should be reduced.

Lecture 56

• Water pollution - 1

- Any physical or chemical change in water that adversely affects the health of humans and other organisms
- Varies in magnitude by location
- Global issue
- Lack of disease-free water anywhere in the world

Categories

- Sewage
- Disease-causing agents
- Sediment pollution
- Inorganic plant and algal nutrients
- Organic compounds
- Inorganic chemicals
- Radioactive substances
- Thermal pollution

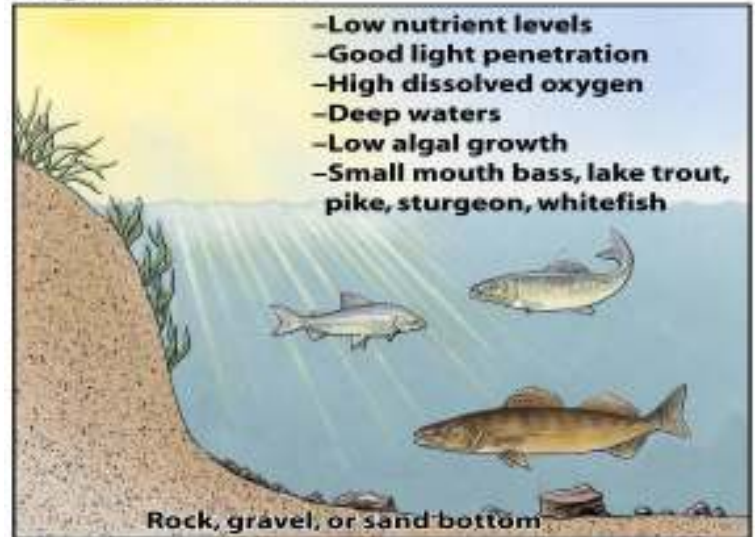
Sewage

- The release of wastewater from drains or sewers
- Includes human wastes, soaps, and detergents

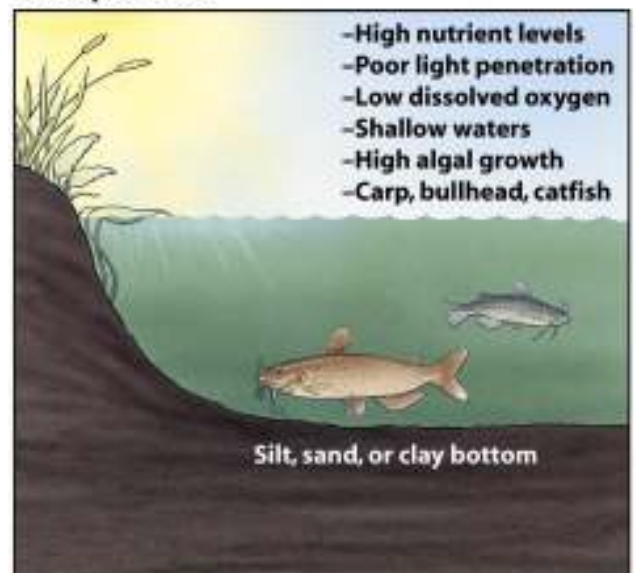
Causes serious environmental problems:

- Enrichment of nutrients
- Fertilization of a body of water by high levels of plant and algal nutrients (nitrogen and phosphorus)
- Increase in Biological Oxygen Demand (BOD)
- Amount of oxygen needed by microorganisms to decompose biological wastes
- As BOD increases Dissolve Oxygen (DO) decreases
- **Sewage- Eutrophication**
- **Oligotrophic**
 - Unenriched, clear water that supports small populations of aquatic organisms
- **Sewage- Eutrophication**
- **Eutrophic-**
 - Slow-flowing stream, lake or estuary enriched by inorganic plant and algal nutrients such as phosphorus
 - Often due to fertilizer or sewage runoff
- Disease-causing Agents
- Infectious organisms that cause diseases
 - Originate in the wastes of infected individuals
- Common bacterial or viral diseases:
 - Typhoid, cholera, bacterial dysentery, polio, and infectious hepatitis
- Sediment Pollution
- Excessive amounts of suspended soil particles
 - Originates from

Oligotrophic lake

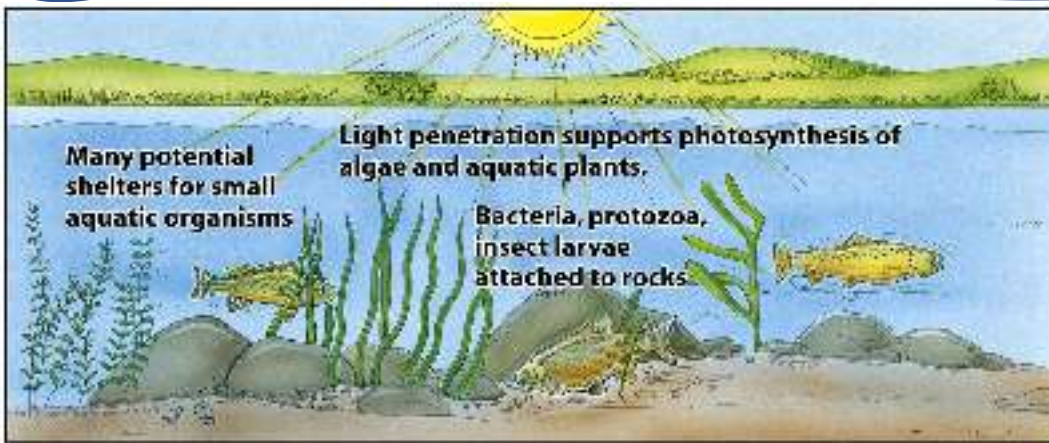


Eutrophic lake



Erosion of agricultural lands, forest soils exposed by logging, degraded stream banks, overgrazed rangelands, strip mines, and construction

- Sediment Pollution
- Problems
 - Limits light penetration
 - Covers aquatic animals and plants
 - Brings insoluble toxins into waterways



Stream ecosystem with low level of sediment



Same stream with high level of sediment

Lecture 57

• Water pollution - 2

Inorganic Plant and Algal Nutrients

Chemicals such as nitrogen and phosphorus that stimulate the growth of plants and algae

- Harmful in large concentrations

Sources:

- Human and animal wastes, plant residues, atmospheric deposition, and fertilizer runoff

Causes:

- Enrichment, bad odors, and a high BOD

Organic Compounds

- Chemicals that contain carbon atoms
 - Natural examples: sugars, amino acids, and oils
 - Human-made examples: pesticides, solvents, industrial chemicals, and PLASTICS

Inorganic Chemicals

- Contaminants that contain elements other than carbon
 - Examples: acids, salts, and heavy metals
- Do not degrade easily
- Lead
 - Found in old paint, industrial pollutants, leaded gasoline

Inorganic Chemicals

- Mercury
 - Mercury bioaccumulates in the muscles of top predators of the open ocean

Radioactive Substances

- Contain atoms of unstable isotopes that spontaneously emit radiation

Sources

- Mining
- Processing radioactive materials
- Nuclear power plants
- Natural sources

Thermal Pollution

- Occurs when heated water produced during industrial processes is released into waterways
- Organisms affected
 - Temperature affects reproductive cycles, digestion rates, and respiration rates
 - Warm water holds less DO than cold water

Water Pollution from Agriculture

- Agriculture is leading source of water pollution
 - Animal wastes and plants residues have high BOD
 - Chemical pesticides can leach into groundwater
- Almost all streams and rivers are polluted with agricultural pesticides.

Industrial & Municipal Wastes in Water

- Different industries generate different pollutants
 - Food processing plants- high BOD
 - Paper mills- High BOD and toxic compounds
- Few industries recover toxins before they go into the waste stream.

Lecture 58

• Air pollution - 1

Harmful or excessive quantities of substances including gases, particles, and biological molecules are introduced into Earth's atmosphere. It may cause diseases, allergies and even death of organisms. Both human and natural activities contribute.

Air Pollutants

Chemicals added to the atmosphere by natural events or human activities in high enough concentrations to be harmful

Two categories of air pollutants

1. Primary Air Pollutant
2. Secondary Air Pollutants

Primary Air Pollutant

- Harmful substance that is emitted directly into the atmosphere

Secondary Air Pollutant

- Harmful substance formed in the atmosphere
- Primary air pollutant reacts with substances normally found in the atmosphere or with other air pollutants.

Major Classes of Air Pollutants

- Particulate Material
- Nitrogen Oxides
- Sulfur Oxides
- Carbon Oxides
- Hydrocarbons
- Ozone

Particulate Material

- Thousands of different solid or liquid particles suspended in air
- **Includes:** soil particles, soot, lead, asbestos, sea salt, and sulfuric acid droplets

Dangerous for two reasons

1. May contain materials with toxic or carcinogenic effects
2. Extremely small particles can become lodged in lungs

Nitrogen and Sulfur Oxides

- **Nitrogen Oxides**
 - Gases produced by the chemical interactions between atmospheric nitrogen and oxygen at high temperature
 - Problems
 - Greenhouse gases
 - Cause difficulty breathing
- **Sulfur Oxides**
 - Gases produced by the chemical interactions between sulfur and oxygen
 - Causes acid precipitation

Lecture 59

• Air pollution - 2

Carbon Oxides and Hydrocarbons

Carbon Oxides

- Gases carbon monoxide (CO) and carbon dioxide (CO₂)
- Greenhouse gases

- **Hydrocarbons**

- Diverse group of organic compounds that contain only hydrogen and carbon (ex: CH₄-methane)
- Some are related to photochemical smog and greenhouse gases

Ozone

- **Tropospheric Ozone**

- Man- made pollutant in the lower atmosphere
- Secondary air pollutant
- Component of photochemical smog

- **Stratospheric Ozone**

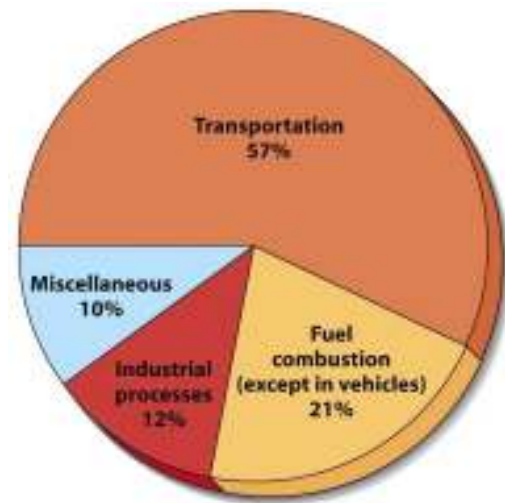
- Essential component that screens out UV radiation in the upper atmosphere
- Man- made pollutants (ex: CFCs) can destroy it

Sources of Outdoor Air Pollution

- **Two main sources**
 - Transportation
 - Industry
- Intentional forest fires is also high

Urban Air Pollution

- **Photochemical Smog**
 - Brownish-orange haze formed by chemical reactions involving sunlight, particulate susoension, nitrogen oxide, and hydrocarbons



Effects of Air Pollution

- Low level exposure
 - Irritates eyes
 - Causes inflammation of respiratory tract
- Can develop into chronic respiratory diseases

Lecture 60

• Light pollution

- Light pollution, also known as photo pollution
- Excessive, misdirected or obtrusive artificial light
- Major side-effect of urbanization
- It is blamed for compromising health, disrupting ecosystems and spoiling aesthetic environments.

Impacts

- The degradation of photic habitat by artificial light.
- The alteration of natural light levels in the outdoor environment.
- The alteration of light levels in the outdoor environment due to man-made sources of light.
- Indoor light pollution is such alteration of light levels in the indoor environment
- Due to sources of light, which compromises human health.
- The introduction by humans, directly or indirectly, of artificial light into the environment.

Humans

- Stress
- Headache
- Seasonal Affective Disorder

Ecosystem

- Ecosystem cycles of natural light

Animals

- Negative impacts on plant and animal physiology
- Sleep
- Foraging behavior
- Predation
- Reproduction
- Animal navigation
- Alter competitive interactions
- Change predator-prey relations

Example

- Reptiles are strongly affected by light pollution.
- Sea turtles like to build their nests in remote and very dark beaches.
- Coastal lights interfere with their ability to find safe nesting areas for their eggs.
- Artificial lights can confuse the baby turtles and take them to crawl away from the ocean into the roads or communities.

Lecture 61

• Noise pollution

Sound that is unwanted or disrupts one's quality of life is called as noise. When there is lot of noise in the environment, it is termed as noise pollution. Sound becomes undesirable when it disturbs the normal activities such as working, sleeping, and during conversations. It is an underrated environmental problem because of the fact that we can't see, smell, or taste it. World Health Organization stated that "Noise must be recognized as a major threat to human well-being"

Effects

- Noise pollution can damage physiological and psychological health.
- High blood pressure, stress related illness, sleep disruption, hearing loss, and productivity loss
- It can also cause memory loss, severe depression, and panic attacks.

Sources

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and streets cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Industrial noise also adds to the already unfavorable state of noise pollution. Loud speakers, plumbing, boilers, generators, air conditioners, fans, and vacuum cleaners add to the existing noise pollution.

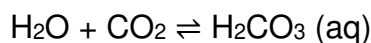
Lecture 62

• Acid Rain

Form of precipitation that is unusually acidic. It has elevated levels of hydrogen ions (low pH).

Deposition of a mixture

1. Wet (rain, snow, sleet, fog, cloud water and dew)
2. Dry (acidifying particles, dust and gases) acidic components
3. Unpolluted rain has an acidic pH, but usually no lower than 5.7.
4. This low pH is due to carbonic acid



5. Nitric acid is produced as result of lightening.

Causes

Natural

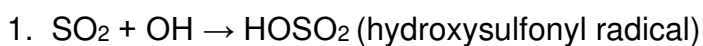
- Volcanic eruption releases SO_2 in air.
- Nitrogen fixation adds NO_2 in air.
- Electrical activity in the atmosphere such as lightning produces NO_2 .
- Acid deposits in glacial ice.

Human Activities

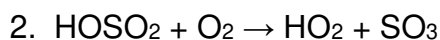
- Sulfur and nitrogen compounds from human sources
- Electricity generation, factories, and motor vehicles
- Greatest contribution by burning coal in power plants
- Gases can be carried hundreds of kilometers in the atmosphere before they are converted to acids and deposited.
- Taller factories funnels disperse smoke even farther.

Chemical Processes

- Gas phase chemistry
- In the gas phase sulfur dioxide is oxidized by reaction with the hydroxyl radical via an intermolecular reaction

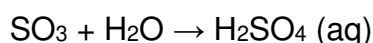


which is followed by:



Chemical Processes

- Chemistry in cloud droplets
- In the presence of water, sulfur trioxide (SO_3) is converted rapidly to sulfuric acid



- Nitrogen dioxide reacts with OH to form nitric acid
- $\text{NO}_2 + \text{OH} \rightarrow \text{HNO}_3$

Effects

- Not many things can grow in acidic conditions
- Low pH and high aluminum concentrations can damage or kill fish and aquatic populations
- At pH lower than 5 most fish eggs will not hatch and lower pH can kill adult fish.
- Soils can be damaged by the hydronium ion, which mobilizes aluminum and encourages leaching of minerals such as magnesium essential for plant life.
- Forests suffer from soil damage, however most food crops are unharmed because the nutrients lost are replaced in fertilizer.
- Monuments made of Calcium Carbonate (limestone and marble) will react with acid rain to form Gypsum
- Increases the oxidation rate of metals such as copper and bronze

Lecture 63

• Disruption of water cycle and coastal ecosystem

Stages of Water cycle

1. Evaporation
2. Transpiration
3. Condensation
4. Precipitation
5. Surface Run off
6. Infiltration

Deforestation

- Directly affects rate of transpiration
- Lesser volume of moisture in air by plants
- Increased rate of erosion due to weak support from root system.
- Making water in seas more muddy.

Pollution (Smog & Acid rain)

- Precipitation brings all the toxic chemicals in air back into surface runoff.
- Releasing them into water bodies.
- Infiltration of these chemicals adds toxicity in underground water.
- Toxic chemicals are recycled in water cycle through evaporation.

Coastal Ecosystems

- 3 billion people now live in coastal areas
- 1 thousand migrate to coastal areas in China each day
- 14 of the world's 17 largest cities are located along the coast

- To reclaim lands, mangroves and other wetland areas are destroyed.
- Coastal defences (dams and dykes) disrupt the natural function of waves and tides.
- Dredging of harbors damage reefs and produce sediments which also smother reefs
- Drains may deliver excess freshwater, solid waste and pollutants to coastal areas.
- Untreated sewage may be released in the sea causing pollution
- Over enrichment of nutrients in water causes eutrophication.
- Especially in estuaries
- Excessive growth of algae
- Depletion of oxygen in water disturbing flora and fauna

Lecture 64

• Greenhouse effect

The ground is heated by visible and (some) infrared light from the Sun. The heated surface emits infrared light. The majority of Earth's atmosphere (N_2 and O_2) are not good greenhouse gas. Carbon dioxide, methane, nitrous oxide and water vapors act as greenhouse gases. The small amount of greenhouse gases (H_2O , CO_2 , methane) traps (absorb and re-emit) the infrared radiation. Increasing the temperature of the atmosphere

Emission of Gases

CO_2

- 40% of carbon dioxide emissions stem from the burning of fossil fuels for the purpose of electricity generation.
- 20% and 13 % of carbon dioxide emissions comes from the burning of gasoline in internal-combustion engines of cars and trucks.
- Aviation causes 3.5% of global warming, and the figure could rise to 15% by 2050.
- Buildings structure account for about 12% of carbon dioxide emissions.
- 25% of carbon emissions by the burning and cutting of about 34 million acres of trees each year
- Water Vapors
- Causes about 36-70% of the greenhouse effect on Earth (not including clouds)

Methane

- Methane is more than 20 times as effective as CO_2 at trapping heat in the atmosphere.
- 145% increase in the last 100 years
- From sources such as rice paddies, bovine flatulence, bacteria in bogs and fossil fuel production
- In flooded fields, anaerobic conditions develop and the organic matter in the soil decomposes.

Nitrous oxide (N_2O)

- Naturally produced by oceans and rainforests

Man-made sources:

- Nylon and nitric acid production, the use of fertilizers in agriculture, cars with catalytic converters and the burning of organic matter

Lecture 65

• Ozone Depletion

O_3

- Gas composed of three atoms of oxygen
- Bluish gas that is harmful to breathe.
- Nearly 90% of the Earth's ozone is in the stratosphere.
- Ozone absorbs a band of ultraviolet radiation called UVB.

Ozone Depleting Substances

- Halocarbon refrigerants
- Solvents
- Propellants in aerosols
- Chlorofluorocarbons
- Hydro chlorofluorocarbons
- Methyl bromide
- Carbon tetrachloride
- Methyl chloroform

Effects

- Increased UV penetration
- Skin cancer in humans, basal and squamous cell carcinomas, have been strongly linked to UVB exposure.
- Malignant melanoma, lethal skin cancer related to UVA and UVB
- Cortical cataracts and UVB exposure
- Increased tropospheric ozone
- Increased production of vitamin D linked with UVB
- Cyanobacteria are sensitive to UV, indirectly affecting crops

- Ban on Use of CFCs since 1996

- Problem will be resolved by half of 21st century

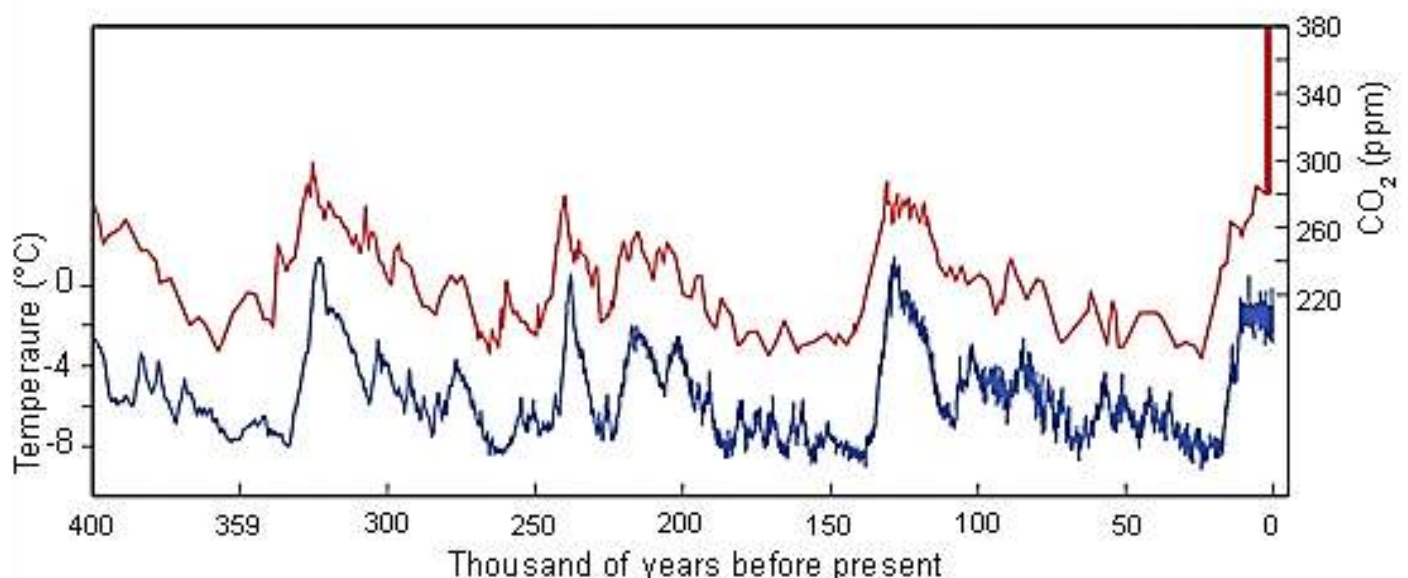


Lecture 66

• Global Warming

- There is a gradual increase in the average temperature of the Earth's atmosphere in the last 100 years.
- It has risen about 1°C since 1900.
- Sources: Greenhouse effect, pollution, deforestation
- The atmospheric concentration of CO₂ measured from Antarctic ice core data implies that Earth's climate has been pretty stable over the past 400,000 years.
- It also shows a rapid increase of about 30% in the past few centuries.
- From 270 ppm (parts per million) to 370 ppm

Figure 1: Changes in Carbon Dioxide and Temperature in the last 400,000 years



Precise measurements of atmospheric CO₂ concentration is available only in the last few decade

Information about atmospheric CO₂ concentration and temperatures in the past can be inferred by several different methods:

1. **Tree-ring**
2. **Deep ocean sediment**
3. **Ice core records**
4. **Corals**
 - Located high in mountains and in polar ice caps
 - Ice has accumulated from snowfall over many millenia.
 - Scientists drill through the deep ice to collect ice cores.
 - These cores contain dust, air bubbles, or isotopes of oxygen, that can be used to interpret the past climate of that area.
 - An increase in atmospheric temperature will lead to the increase in the water vapor content of the troposphere.
 - Because water vapor is a strong greenhouse gas, the increase in H₂O vapor in turn causes enhanced greenhouse effect.
 - Raising the temperature more
 - Higher atmospheric temperature will cause more evaporation of water.
 - Which leads to even higher temperature.
 - Clouds reflect sunlight
 - They decrease the solar energy input into Earth's atmosphere during the day
 - But they trap IR radiation from the Earth in night
 - CO₂ cycle is thermostat of earth.
 - If Earth warms up a bit, then:
 - Carbonate minerals formation in the oceans at a higher rate.
 - The rate at which the oceans dissolve CO₂ gas increases
 - Pulling CO₂ out of the atmosphere
 - The reduced atmospheric CO₂ concentration leads to a weakened greenhouse effect
 - That counteracts the initial warming and cools the planet back down.
 - If Earth cools a bit
 - Carbonate minerals formation slows down in the oceans. The rate at which the oceans dissolve CO₂ gas decreases, allowing the CO₂ released by volcanism to build back up in the atmosphere. The increased CO₂ concentration strengthens the greenhouse effect and warms the planet back up

Lecture 67

• Effects of Global Warming - 1

- **Physical Environmental Effects**
- **Effects on Biosphere**
- **Effects on Humans**

- Arctic sea ice shrinking

- Decrease in extent – 2.7% per decade since 1978
- Max. area of seasonally frozen ground decreased by 7% in Northern Hemisphere since 1900

- Global sea level rise

- Average rate of 1.8 mm per year (1961-2003)
- Likely sea level rise during the 21st century - 5 mm per year
- Low lying areas, small island states may disappear, salt water intrusion into aquifers, floods
- Low-lying coastal cities will be at the forefront of impacts

- Non-polar glaciers

- Widespread retreat during the 20th century

- Continental Precipitation

- Significant increase in North & South America, northern Europe, north & central Asia
- Drying in Mediterranean, southern Africa, parts of South Asia

Lecture 68

• Effects of Global Warming-2

- Extreme Weather

Frequency of drought, heat waves, typhoons, hurricanes and cyclones increased from 1960 until 2010. Extremely wet or dry events within the monsoon period have increased since 1980.

Changes in ocean properties

- Increase in atmospheric CO₂ concentrations have led to an increase in dissolved CO₂
- Increase in ocean acidity
- Oxygen levels decrease because oxygen is less soluble in warmer water
- An effect known as ocean deoxygenation

Changes in Ecosystem

- Earlier timing of spring events
- Poleward and upward shifts in plant and animal ranges
- Expansion of deserts
- Ocean acidification threatens damage to coral reefs, fisheries, protected species, and other natural resources of value to society.

Impacts on Humans

- Changed precipitation patterns
- Warming of low latitudes
- Agricultural production
- Length of growing season will change.
- Droughts, extreme events will decrease yields
- Global economic inequality
- Biodiversity shifts – changes in crop varieties
- New pests and diseases
- Food security
- Thermal stress – heat waves, cold spells
- Extreme events, weather disasters (personal injuries, damage & disruption to infrastructure)
- Infectious diseases (malaria, dengue)
- Air pollution - impact of some air pollutants

Recent Climatic Trends in Pakistan (Department of Meteorology)

- Rise in mean temperature of 0.6-1.0°C in arid coastal areas, arid mountains and hyper arid plains.
- 0.5 to 0.7% Increase in solar radiation over southern half of country.
- 3-5% decrease in cloud cover in central Pakistan with increase in sunshine hours.

Recent Climatic Trends in Pakistan

- 5% increase in net irrigation water requirement with no change in rainfall.

Lecture 69

• Biomagnification

- Increasing concentration of toxic substance
- In the tissues of tolerant organisms at successively higher levels in a food chain
- It occurs as result of three activities.

- Concentration of the persistent toxins increases higher up the food chain.

1. Persistence

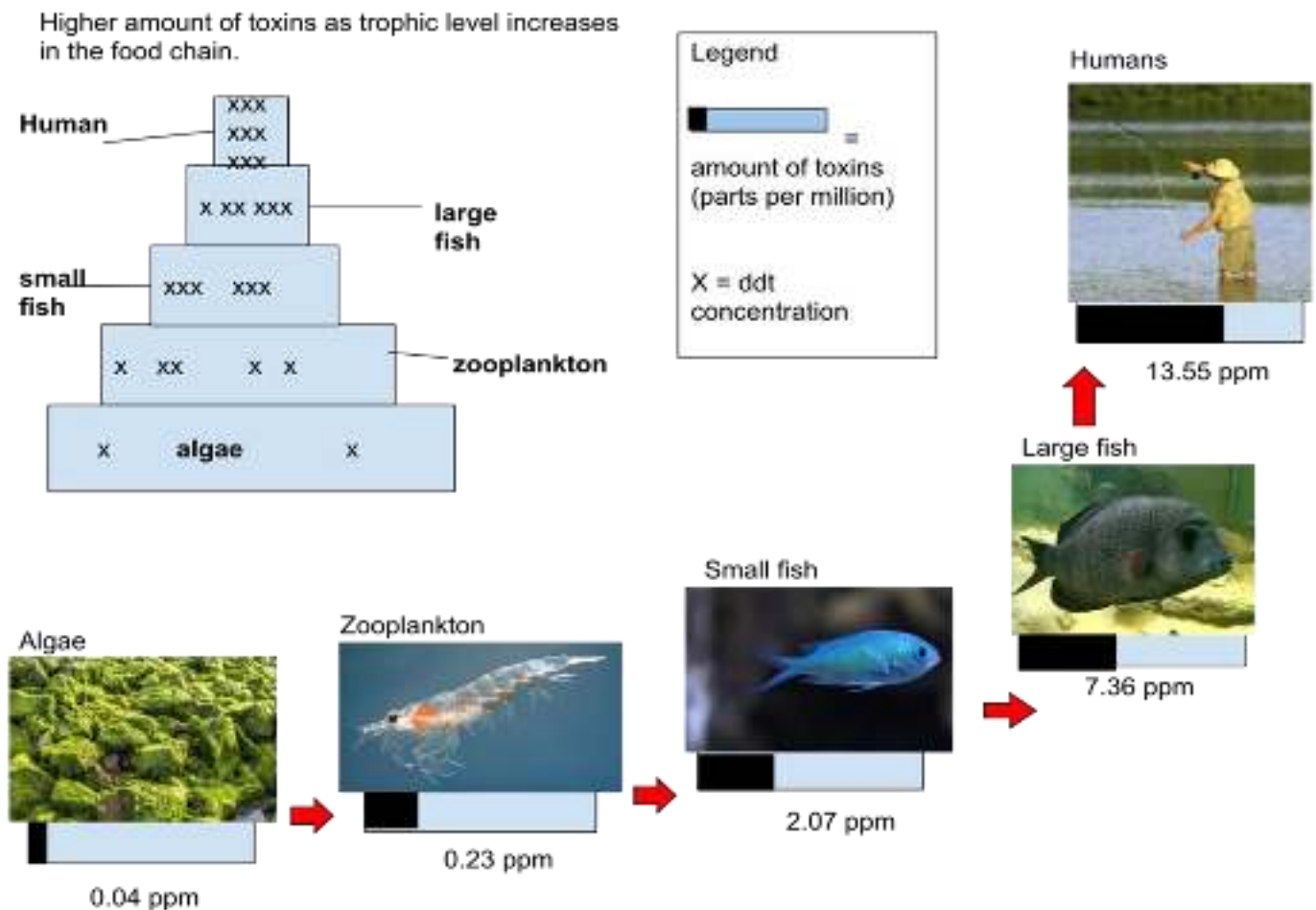
- Substance cannot be broken down by environmental processes

2. Food chain energetics

- Substance's concentration increases progressively as it moves up a food chain

3. Low or non-existent rate of internal degradation or excretion of the substance

- often due to water insolubility



Biomagnification

- Occurs across trophic levels (food chain).

Bioaccumulation

- Occurs within a trophic level
- Increase in the concentration of a substance in certain tissues of organisms' bodies due to absorption from food and the environment.

Bioconcentration

- Occurs when uptake from the water is greater than excretion

Pollutants that undergo biomagnification

- DDT (dichlorodiphenyltrichloroethane)
- Hexachlorobenzene (HCB)
- PCBs (polychlorinated biphenyls)
- Toxaphene
- Monomethylmercury

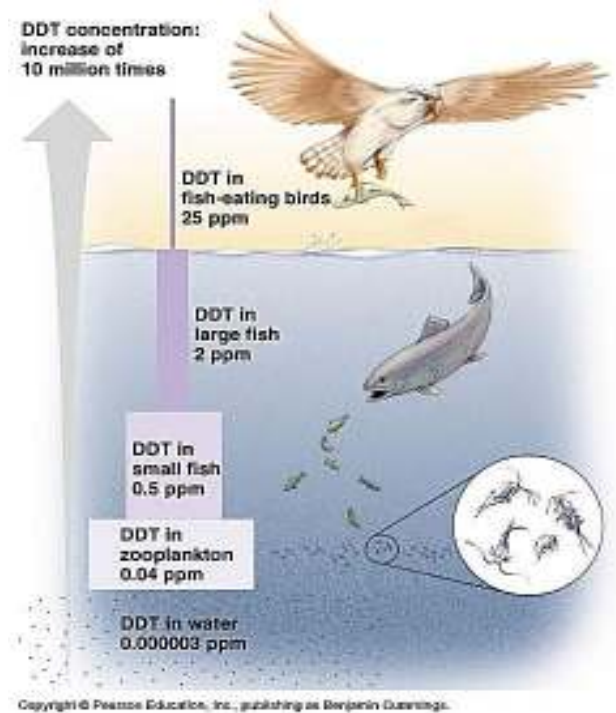
DDT (Case Study)

- Insecticide used to control malaria and typhus by killing mosquitoes and lice.
- Commonly used after WWII

- Inventor received Noble Prize
- Overused on crops as a pesticide
- Concentration of DDT increased 10 million times.

DDT (Problems)

- Egg shell thinning
- DDT interferes with metabolism of calcium
- Thin shells in predator birds such as osprey, bald eagles, brown pelicans
- Birds unable to incubate their eggs without breaking them.
- Acts as a hormone disrupter, mimics estrogen
- Has impacted sex ratio in some birds
- It has a half life of 15 year
- It takes 15yrs for its quantity to be $\frac{1}{2}$ its original
- If we start with 100 kg, we will still have ~ 1 kg after 100 years.
- Banned in US in 1972
- Still used overseas to prevent malaria especially in Africa
- It saves millions of lives annually in Africa.



Lecture 70

• Type of Wastewater

Wastewater

- Humans capture and divert a lot of the water for agriculture, industrial and municipal use.
- After the water is used, it is returned to the environment in a different condition, usually as dirty water (wastewater).
- Wastewater is any water that has been affected by human use.
- Wastewater is "used water" from these sources:
- Domestic, industrial, commercial or agricultural activities
- Surface runoff
- Storm water
- Sewer inflow or sewer infiltration

Components

- Pathogens
- Salts
- Acids
- Bases
- Metals
- Toxic inorganic compounds
- Organic matter
- Suspended solids

Types

1. Domestic wastewater from households
2. Municipal wastewater from communities (also called sewage)
3. Industrial wastewater from industrial activities
4. Agricultural wastewater from agricultural activities
5. Storm water

Domestic wastewater

- Flush toilets
- Sinks
- Dishwashers
- Washing machines
- Bath tubs
- Showers

Municipal wastewater

- Residential
- Shops
- Houses
- Offices
- Schools
- Hospitals
- Motor service stations
- Others

Industrial wastewater

- Huge water use in industrial activities
- Every industry uses water for chemical or physical processes.
- Quantity and quality depends on the type of industry.

Agricultural wastewater

- Irrigation
- Livestock watering and cleaning
- Aquaculture
- 69% to 90% of global fresh water use in agriculture
- Bulk of it is returned to the soil, waterways or discharged with added nutrients and contaminants

Storm wastewater

- Rainfall that flows over the ground surface
- It is created when rain falls on roads, driveways, parking lots, rooftops and other paved surfaces that do not allow water to soak into the ground.
- Stormwater runoff is the number one cause of stream impairment in urban areas.

Classification on basis of contamination

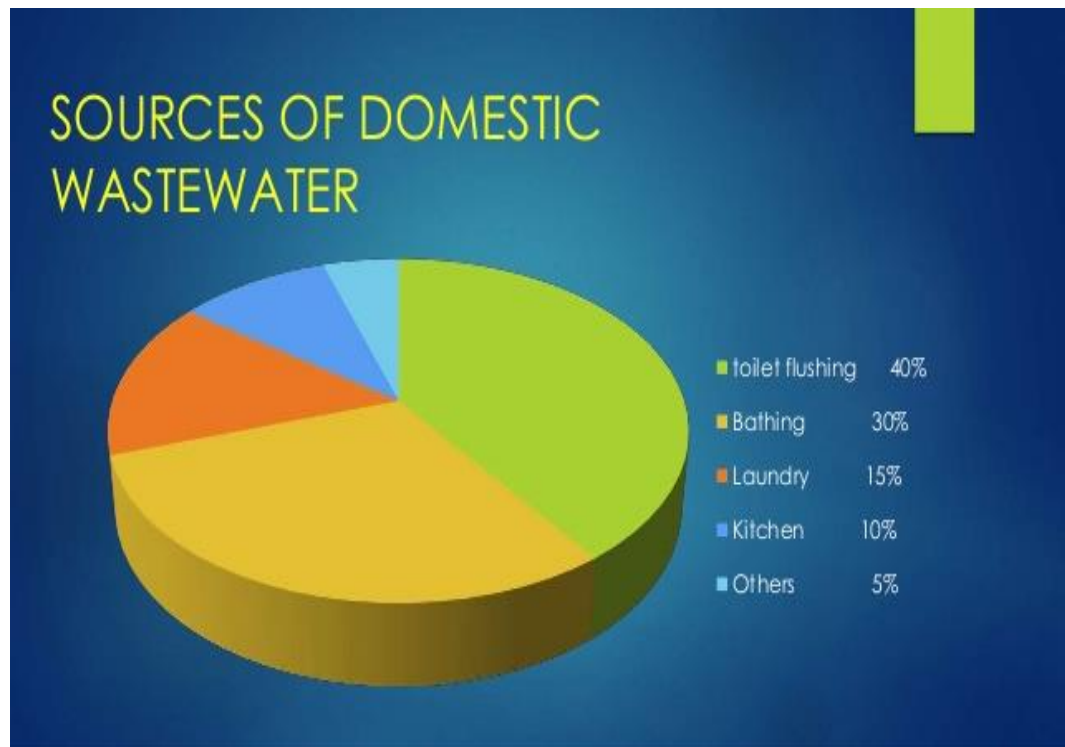
1. Gray water
2. Black water

Gray water

- Generated in households or office buildings from streams other than toilets
- Contains fewer pathogens
- Easier to treat and reuse onsite for:
 - Toilet flushing
 - Landscape or crop irrigation
 - Other non-potable uses

Black water

- Generated in toilets
- Contains pathogens
- Contain feces, urine, water and toilet paper from flush toilets
- Difficult to treat and recycle



Lecture 71

• Impacts of Wastewater on Environment

- All types of wastewater act as pollutant.
- Negative impacts on environment
- Industrial effluents may contain acids, alkalis, salts, poisons, oils and in some cases harmful bacteria.
- Mines, especially gold and coal mines, are responsible for large quantities of acid water.
- Agricultural pesticides, fertilizers and herbicides may wash into rivers and stagnant water bodies.
- Sewage as well as domestic and farm wastes were often allowed to pollute rivers and dams.

Non-persistent (degradable) Pollutants

- Domestic sewage
- Fertilizers
- Some industrial wastes
- Disease causing microbes
- These can be broken down by chemical reactions or by natural bacteria.
- Product of break down will be non-polluting substances such as carbon dioxide and nitrogen.
- If the pollution load is high, this process can lead to low oxygen levels and eutrophication.
- This damage is reversible.

Persistent Water pollutants

- Some pesticides (DDT, dieldrin)
- Some leachate components from landfill sites (municipal, industrial)
- Petroleum and petroleum products (Oil pollution)
- Heavy metals such as lead, mercury, cadmium
- Radioactive materials such as strontium-90, cesium-137, radium-226, and uranium
- High risk to the health of organisms
- Disturbance of food chain by affecting certain trophic levels
- This includes substances that degrade very slowly or cannot be broken down at all.
- They may remain in the aquatic environment for years or longer periods of time.
- The damage they cause is either irreversible or repairable only over decades or centuries.

Lecture 72

• Treatment of Wastewater - 1

Septic Tanks

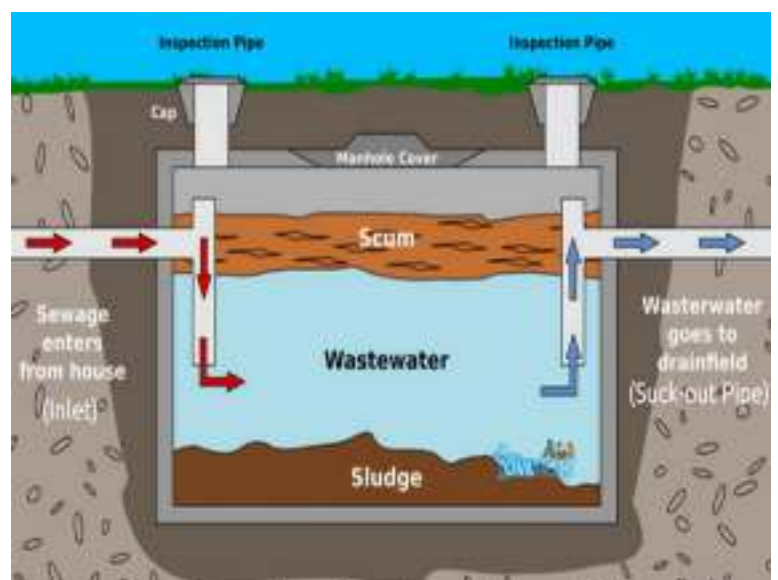
- Bacteria in sewage degrade organic matter
- Tank buried in ground to treat sewage from an individual home
- Wastewater flows into tank
- Solid material ("sludge") settles to bottom of tank
- Clean water flows out of tank into ground through subsurface drains

Lagoons (Stabilization Ponds)

- 3-5' deep
- Sunlight, algae, oxygen interact to clean wastewater

Conventional Sewage Treatment

Processes



1. Collection
2. Treatment

Collection

- Combined Sewers

Carry stormwater and wastewater

Separated Sewers

1. Sanitary Sewers
2. Storm Sewers

Conventional Sewage Treatment

Processes

1. Primary
2. Secondary
3. Advanced

Primary Treatment

Mechanical process

- Screening
- Grinding
- Grit Chamber (heavy particles - “grit”)
- Sedimentation Tank (suspended solids - “sludge”)
- Chlorination of effluent

Secondary Treatment

- Biological process
- Uses bacteria to remove organic matter dissolved in water (ODW) and lower BOD

Types

- Trickling Filter
- Activated Sludge

Secondary Treatment

- Secondary Treatment With Trickling Filters
- Effluent leaves sedimentation tank and flows through trickling filters
- Bed of stones 3-10’ deep through which sewage passes
- Bacteria gather on stones and multiply, consuming ODW
- Cleaner water trickles through pipes at bottom of filter for additional treatment

Lecture 73

• Treatment of Wastewater - 2

Secondary Treatment

- Secondary Treatment With Activated Sludge
- Effluent leaves sedimentation tank and is pumped to an aeration tank
- Effluent is mixed with air and sludge loaded with bacteria (“activated sludge”)
- Sludge contacts with raw sewage, and bacteria in the sludge then decompose the raw sewage, lowering ODW and BOD
- Activated sludge-sewage mixture is called mixed liquor
- Mixed liquor leaves aeration tank
- Flows to another sedimentation tank where suspended solids settle out for reuse as activated sludge

- Effluent is chlorinated
- Activated sludge in sedimentation tank is reused

Advanced Tertiary Treatment

- Physical and chemical processes that specific pollutants left in wastewater after primary and secondary treatment
- Extremely costly
- It cost twice as much to build a secondary treatment plant
- Bleaching to remove coloration
- Disinfection to kill pathogens
- Coagulation-sedimentation with alum
- Adsorption using activated charcoal
- Electrodialysis for salt removal

Lecture 74

• Protection of Endangered species

- Preserving populations and species in danger of decline or extinction
- There should be something left to be conserved.

Pristine Restoration

- In ecosystems where all species have been effectively removed
- Conservationists might attempt to restore the plants and animals that are the natural inhabitants of the area
- If these species can be identified.
- Focus is on reconstructing the processes that operated in the natural habitat.

The University of Wisconsin–Madison Arboretum has pioneered restoration ecology.

- a. The restoration of the prairie was at an early stage in November 1935.
- b. The prairie as it looks today. This picture was taken at approximately the same location as the 1935 photograph

Removing introduced species

- Sometimes the habitat has been destroyed by a single introduced species.
- In such a case, habitat restoration involves removing the introduced species.
- It is important to act quickly if an introduced species is to be removed.

Cleanup and Rehabilitation

- Habitats are seriously degraded by chemical pollution.
- They cannot be restored until the pollution is cleaned up.
- **Example:** Nashua River in New England
- Cleaned up after being heavily polluted by dye plants.

Captive Breeding Programs

- Recovery programs
- Particularly focused to on one or a few species
- Sometimes involve direct intervention in natural populations to avoid an immediate threat of extinction.
- It might be successful or failed effort.
- The Hawaiian goose was practically extinct in the wild
- 12 birds were taken into captivity
- A population of 9000 was released back into the wild
- The rats eat the eggs and the nestlings of the geese.
- Pere David's deer was a native species of China
- In 1865, 18 were taken into zoological collections

- Meanwhile it became extinct in the wild
- By 1981 there were 994 individuals scattered through zoological collections.

National Parks

First the area that is suitable for the creation of a reserve has to be identified and delimited. This requires surveys to collect data on key species. Property may have to be expropriated.

A legal framework may need to be set up to control human activities in the area. If part of the area has been degraded due to bad land use it may need restoring. Alien species that have penetrated the area may need excluding or eliminating. Constant management will be needed to maintain the habitat of the species being conserved. This may mean arresting natural succession.

Examples in Pakistan

1. Hingol national park
2. Kirthar national park
3. Chitral national park

Lecture 75

• Evolution

- Change in the heritable characteristics of biological populations over successive generation
- These characteristics are the expressions of genes.
- Which are passed on from parent to offspring during reproduction.
- Variations come from evolution and causes biodiversity.

History of Evolution

1. Classical
2. Medieval
3. Pre-Darwinian
4. Darwinian Revolution
5. Modern Synthesis

History of Evolution

1. Classical

- All living things were related and that they had changed over time.
- One type of organism could descend from another type.

2. Medieval

- Fixed natural possibilities
- Life forms are fixed
- Aristotle added that new types of living things could come to be.

3. Pre-Darwinian Period

- Began in 17th century
- Explanation of natural phenomena in terms of physical laws
- John Ray introduced the term “Species”
- Linnaeus in 1735 explicitly recognized the hierarchical nature of species relationships.
- Introduction of five kingdom classification
- Buffon suggested that species could degenerate into different organisms.
- Erasmus Darwin proposed that all warm-blooded animals could have descended from a single microorganism.
- First evolutionary scheme was proposed by Jean-Baptiste Lamarck in 1809.
- He proposed the theory of changes/mutations over the time.
- It was a break from the concept of fixed creation but faced strong resistance.

4. Darwinian Revolution

- Malthus (1798) proposed that population growth creates a struggle for resource.
- Darwin influenced by Malthus's ideas, proposed the ground breaking "Theory of natural selection" in 1859.
- Huxley applied Darwin's ideas to humans, using paleontology and comparative anatomy.
- Gregor Mendel proposed the laws of genetics in 1865.
- Weismann made the important distinction between germ cells and somatic cells.
- He demonstrated that heredity passes through the germ line only.
- De Vries proposed that hereditary material is in nucleus and transferred to cytoplasm.

5. Modern Synthesis

It connected natural selection and population genetics, based on Mendelian inheritance, into a unified theory that applied generally to any branch of biology. Watson & Crick model of DNA in 1953.

Evidences of evolution are based upon:

1. Biogeography
2. Paleontology
3. Comparative Anatomy
4. Molecular Biology