

MUHAMMAD IMRAN

# BT101 - Ecology, Biodiversity & Evolution-I

MSC ZOOLOGY

Prepared by  
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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.

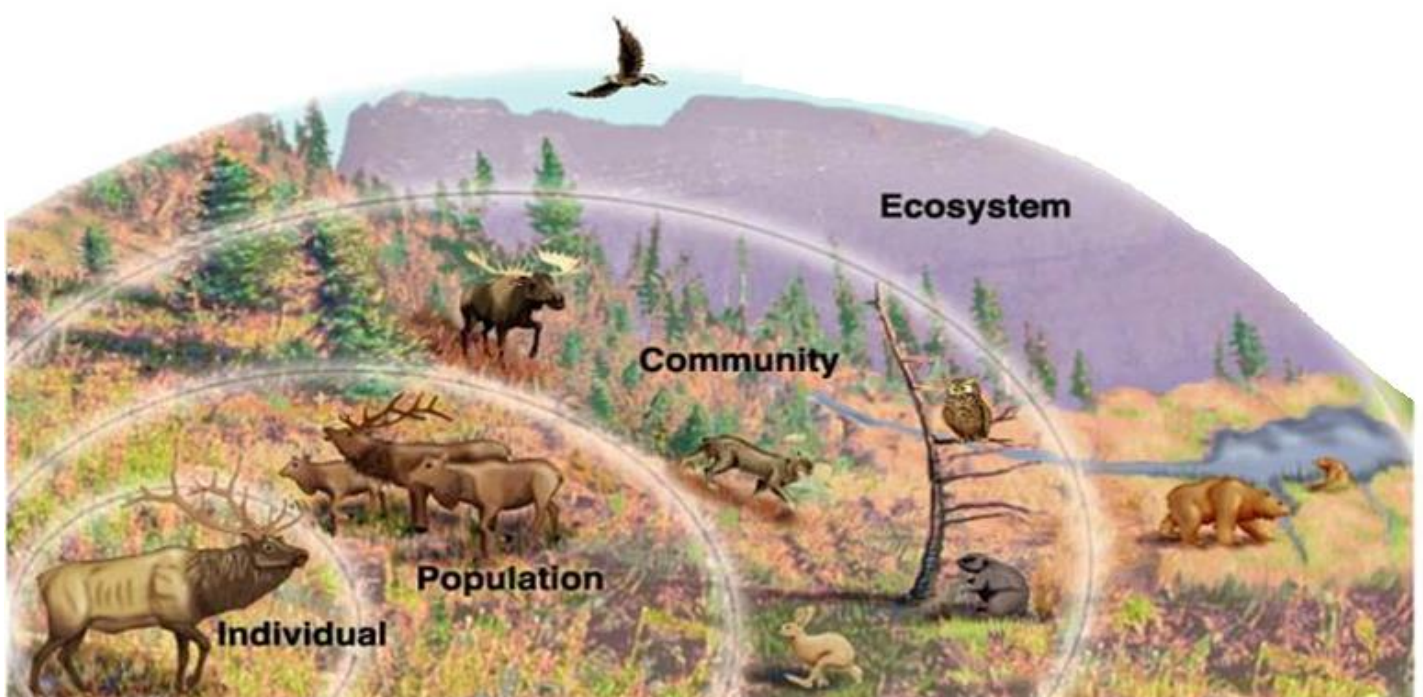
### Biome

- 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

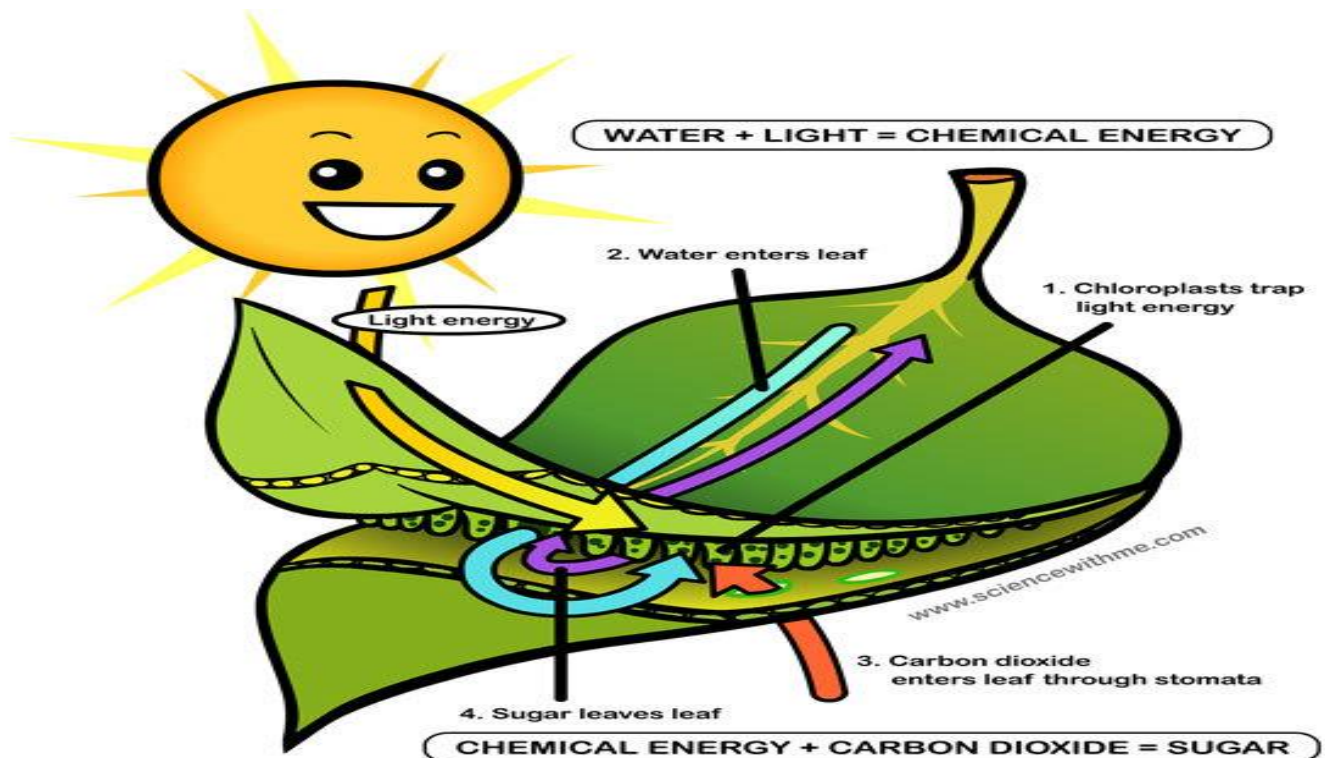
Energy exists in several different forms

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:

- $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{NO}_3$

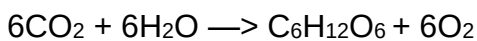
using energy from an abiotic source

- Light
- inorganic oxidation reactions

### Types of Autotrophs

#### 1. Photoautotrophs

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

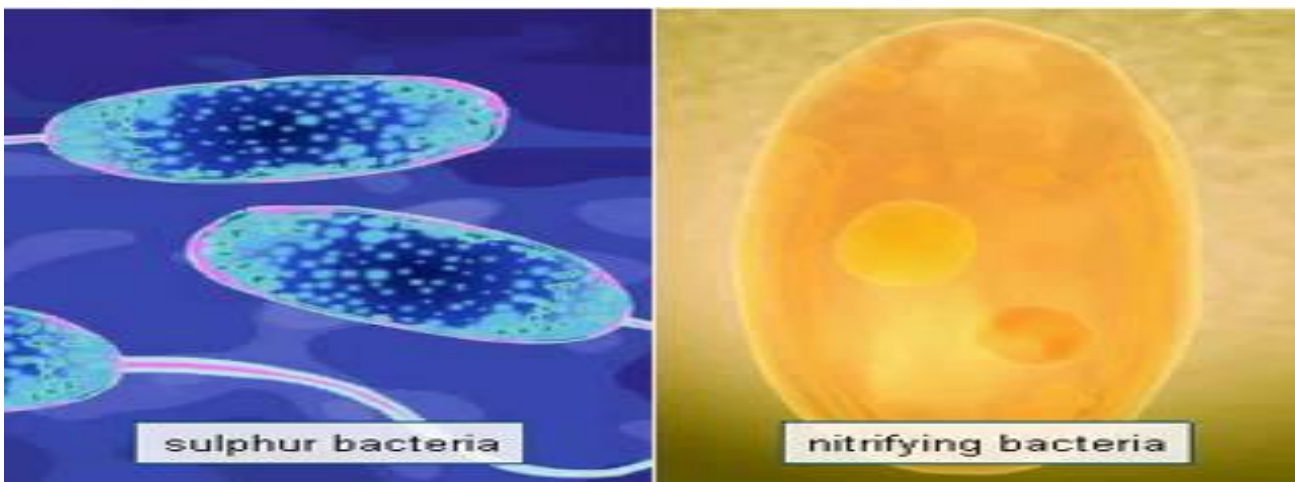


- Main input of free energy into the biosphere

#### 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 CO<sub>2</sub>

## 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

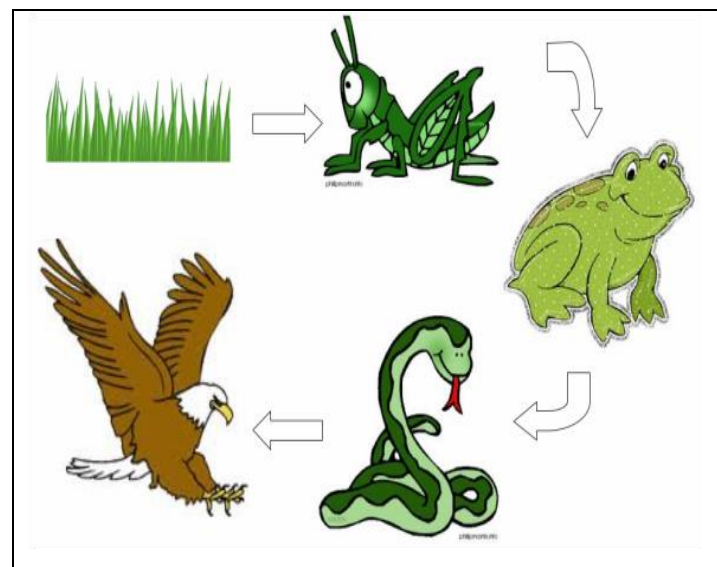
Linear network of links to pass energy in form of food. Simplified abstractions of real food webs, but complex in their dynamics

## 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

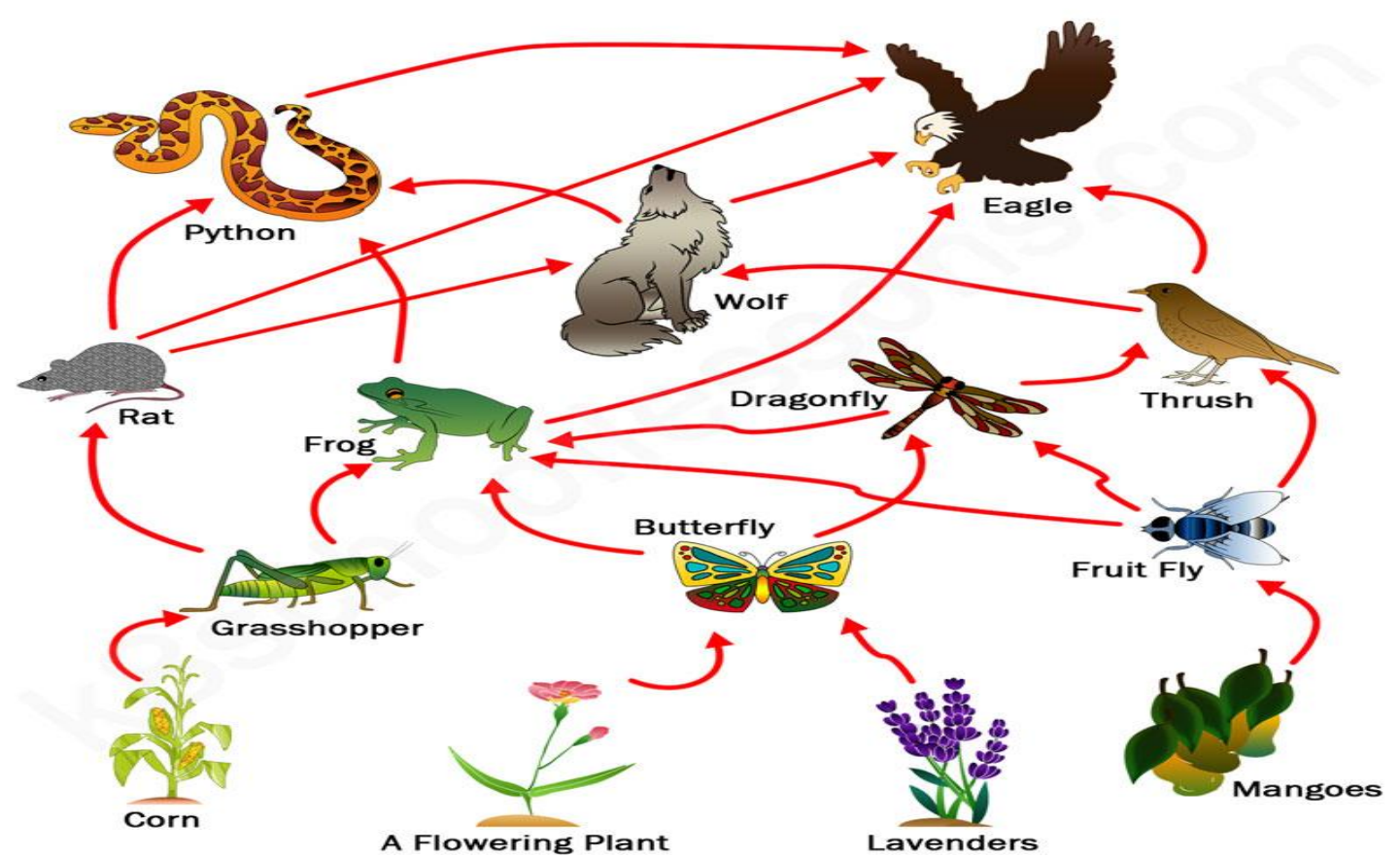
Detritivore and decomposers can be at trophic level as well. They return nutrients back in soil to be available for producers.

Lecture 7

• Food web

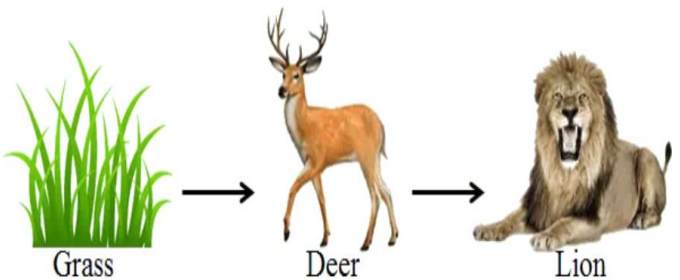
### Food Web

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

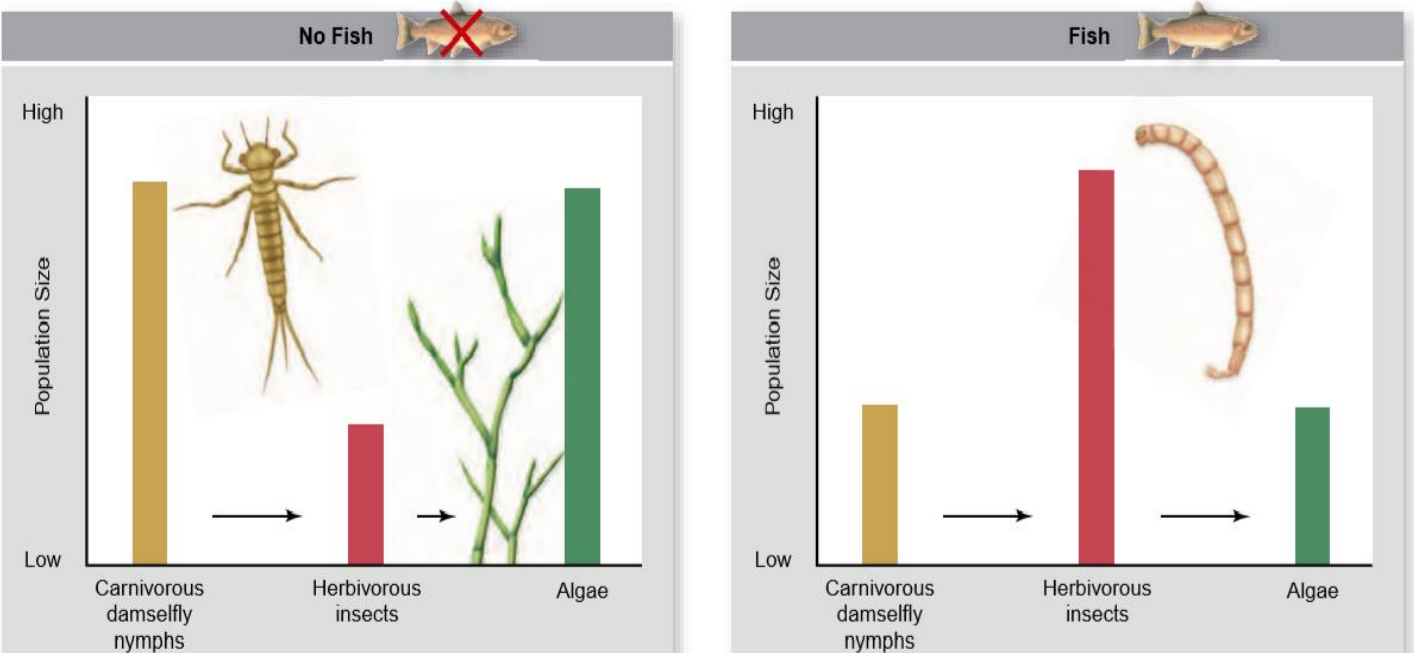
Powerful indirect interactions that can control entire ecosystems. Occurs when a trophic level in a food web is suppressed.

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

Impacts of climate and human activity on ecosystem

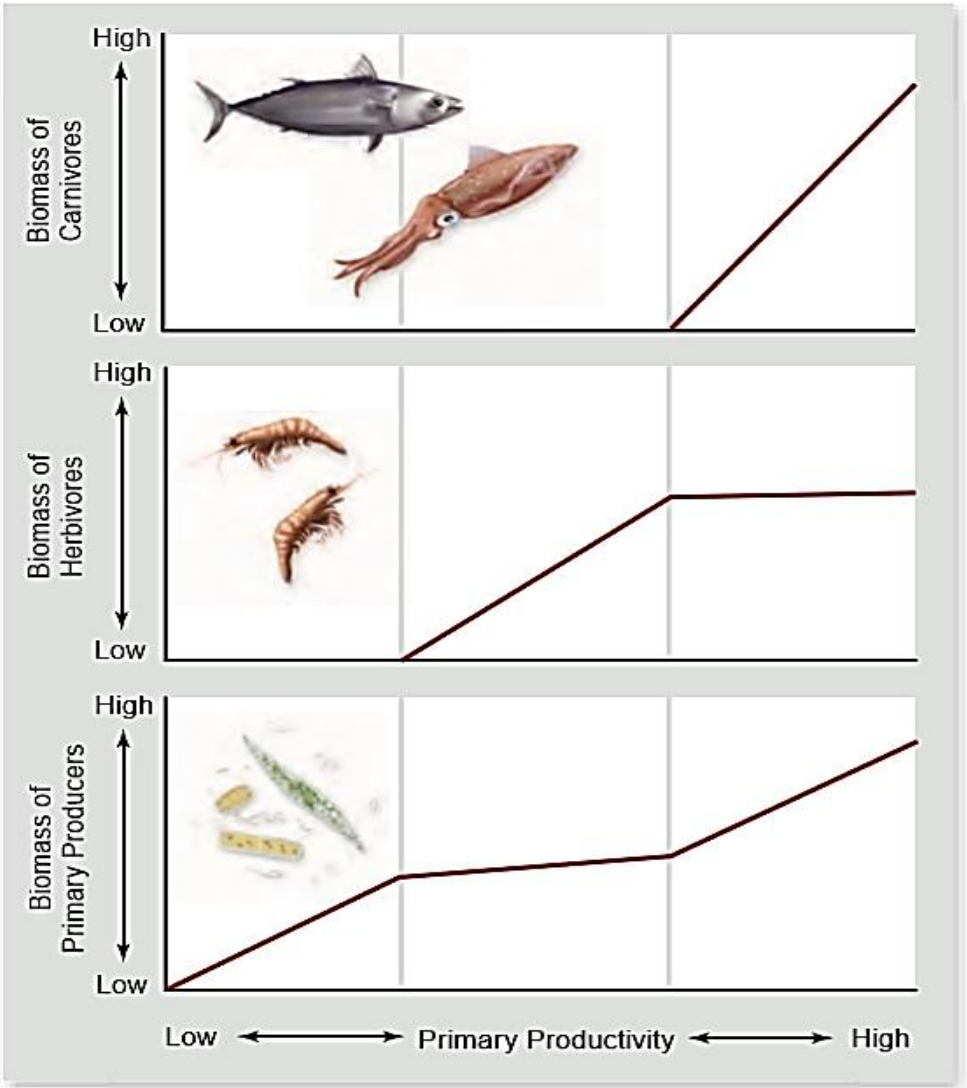
**1. Top-Down Effect**

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

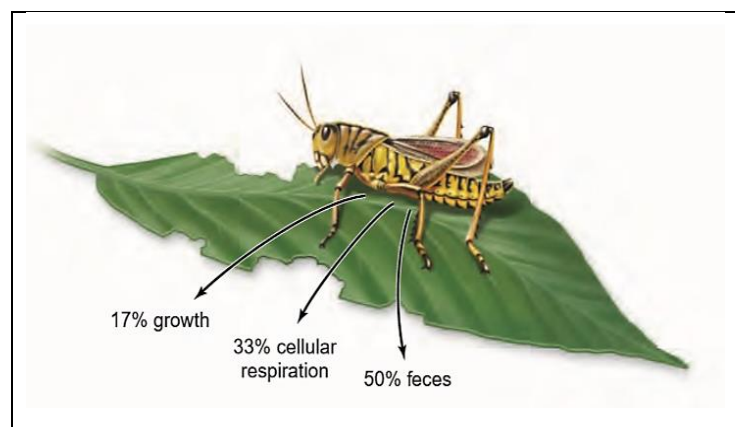
Small fraction of solar energy (1%) is consumed in photosynthesis. Transformed into chemical-bond energy. 99% solar energy is converted into heat.

**Synthesized chemical-bond energy is consumed:**

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

**Availability to consumers**

- Tissues / Growth



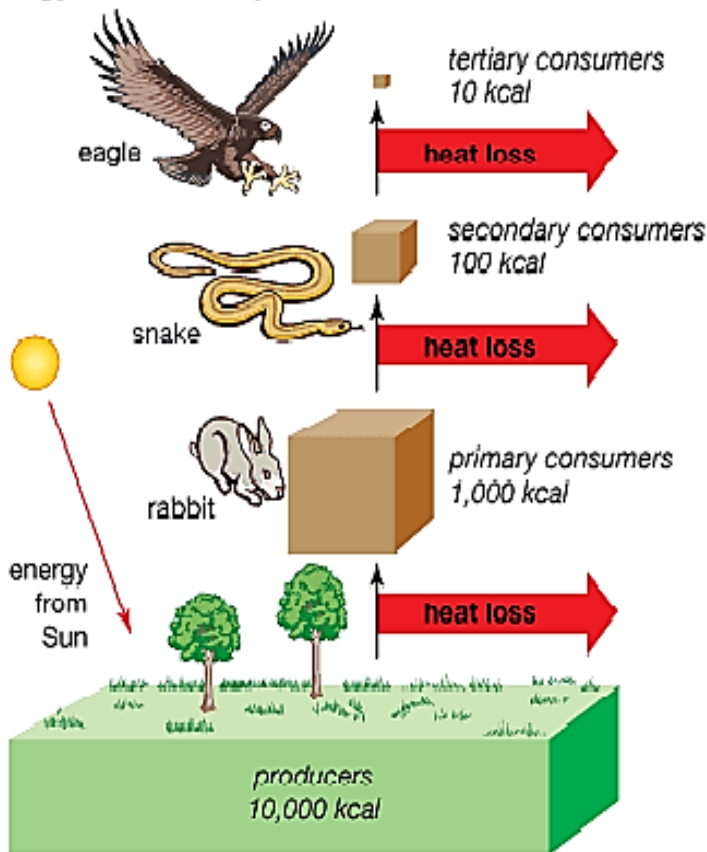
Chemical-bond energy is passed from one heterotroph trophic level to the next.

**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

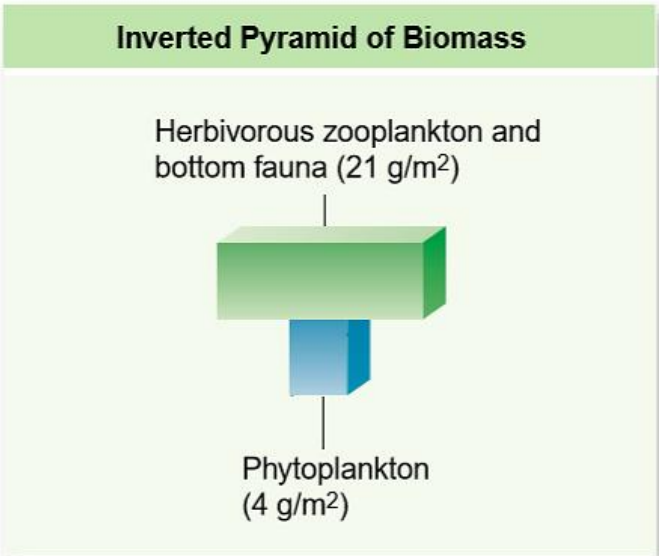
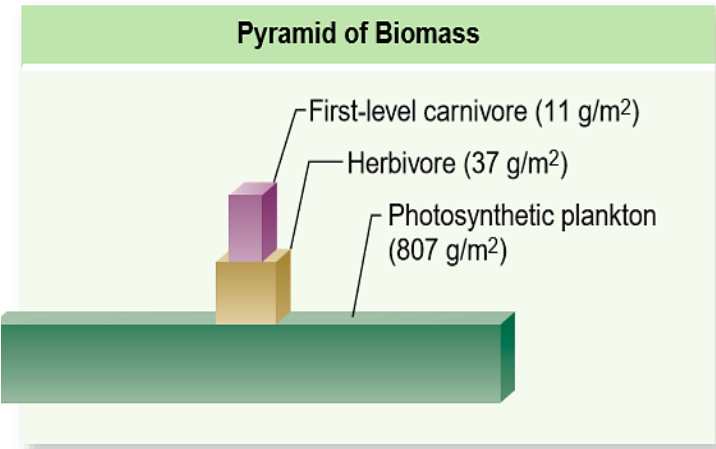
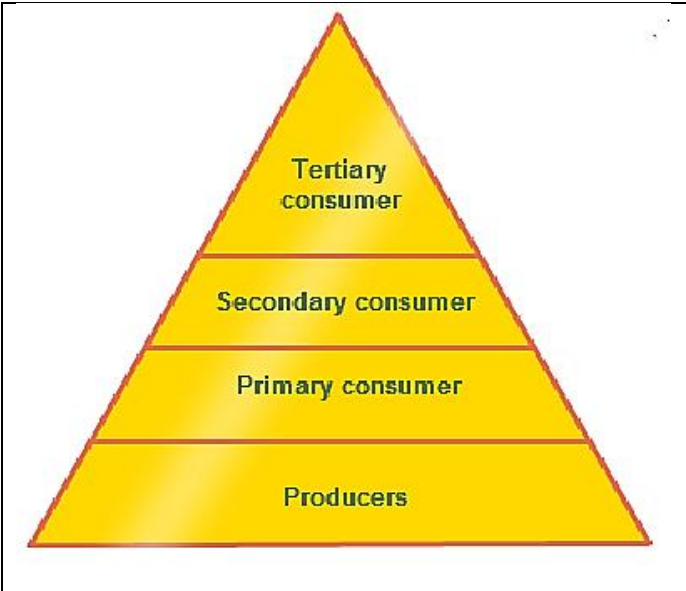
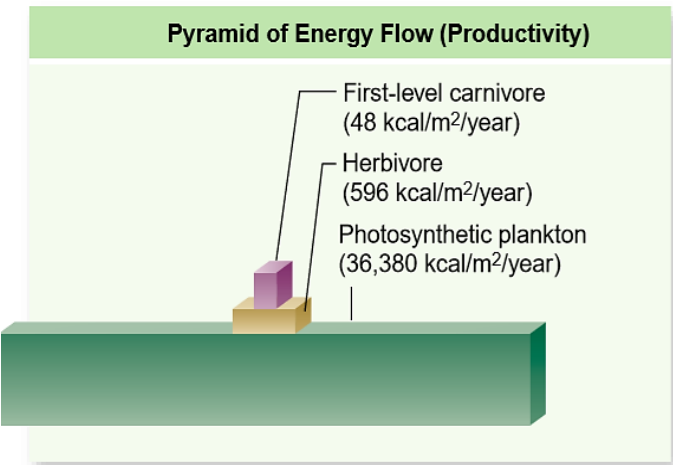
- **Wetlands and tropical rain forests:** 2000 g/m<sup>2</sup>/ year
- **Temperate forests:** 1200 - 1300 g/m<sup>2</sup>/ year
- **Savanna:** 900 g/m<sup>2</sup>/ year
- **Deserts:** 90 g/m<sup>2</sup>/ year

## Lecture 10

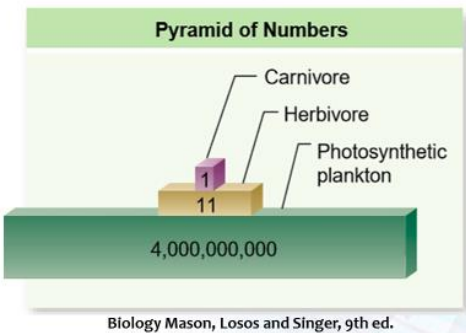
- Ecological pyramids illustrate the relationship of trophic levels

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**

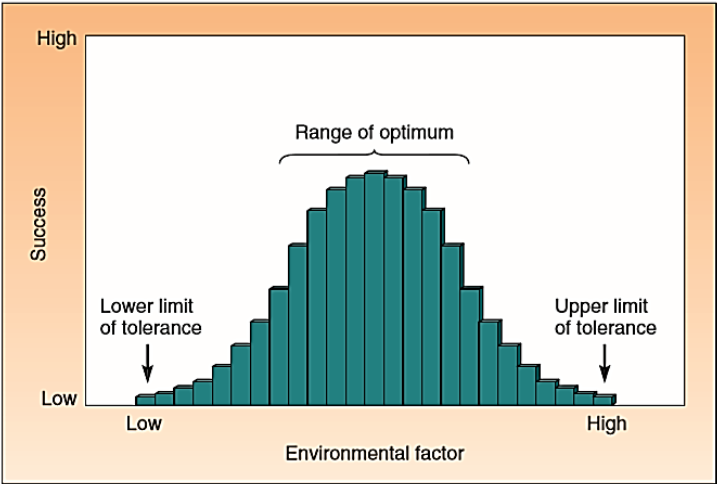
Natural environment where a species/organism lives

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<br>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

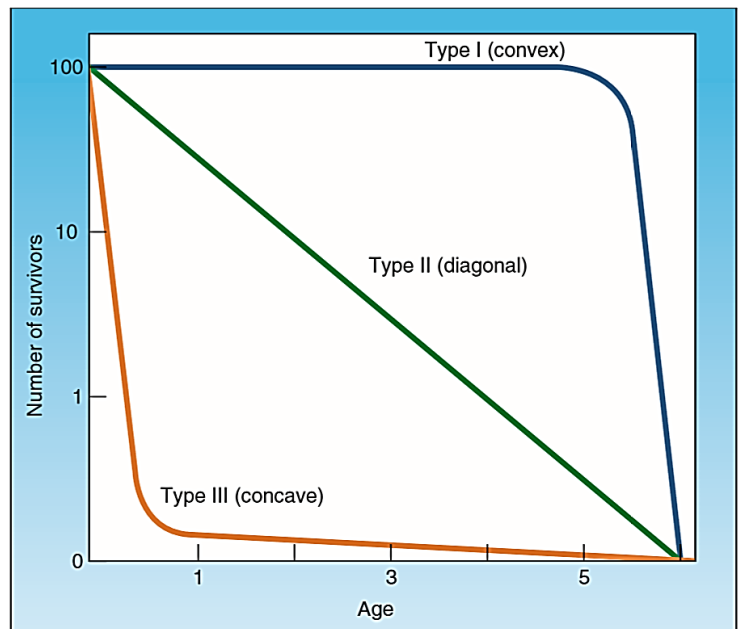
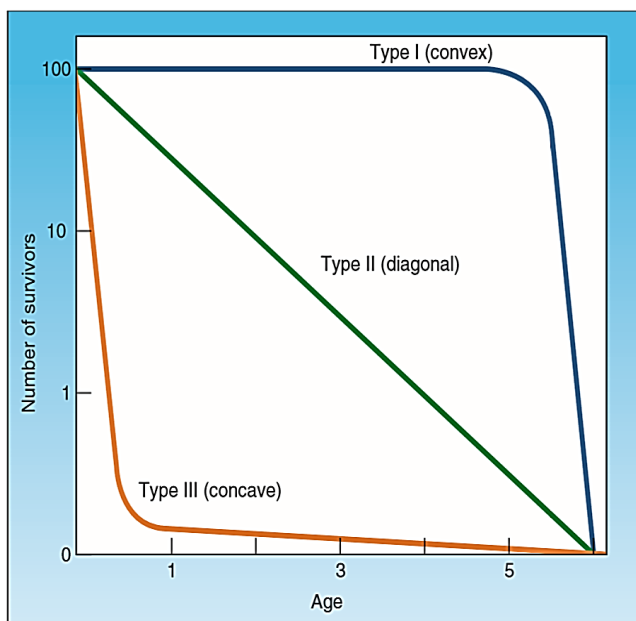
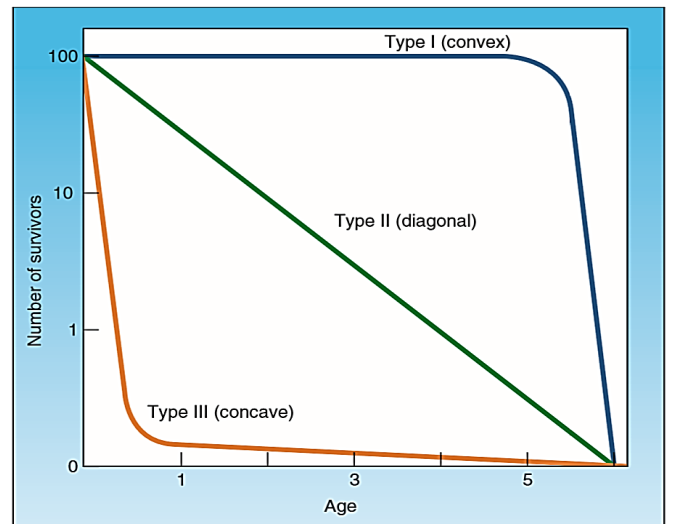
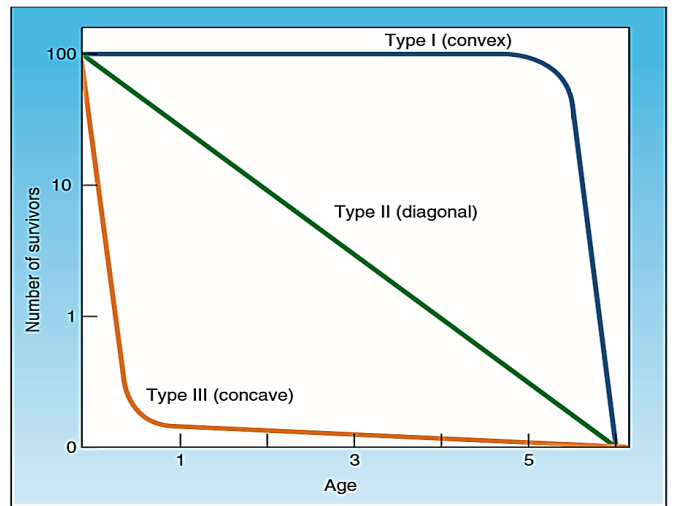
**Example:** Humans

#### 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

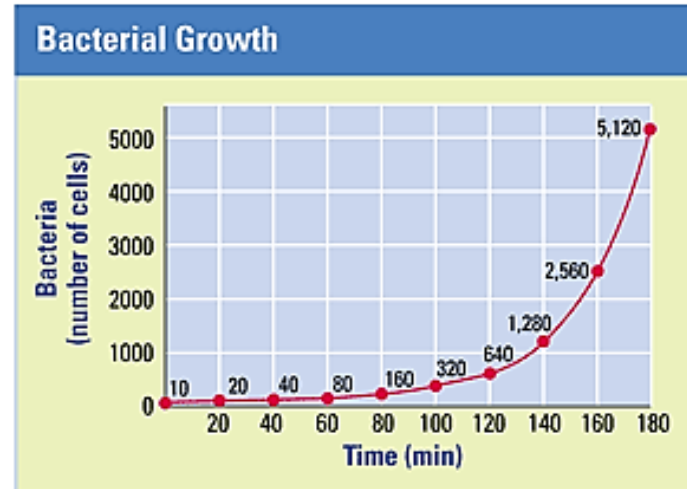
#### Types of Population growth

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

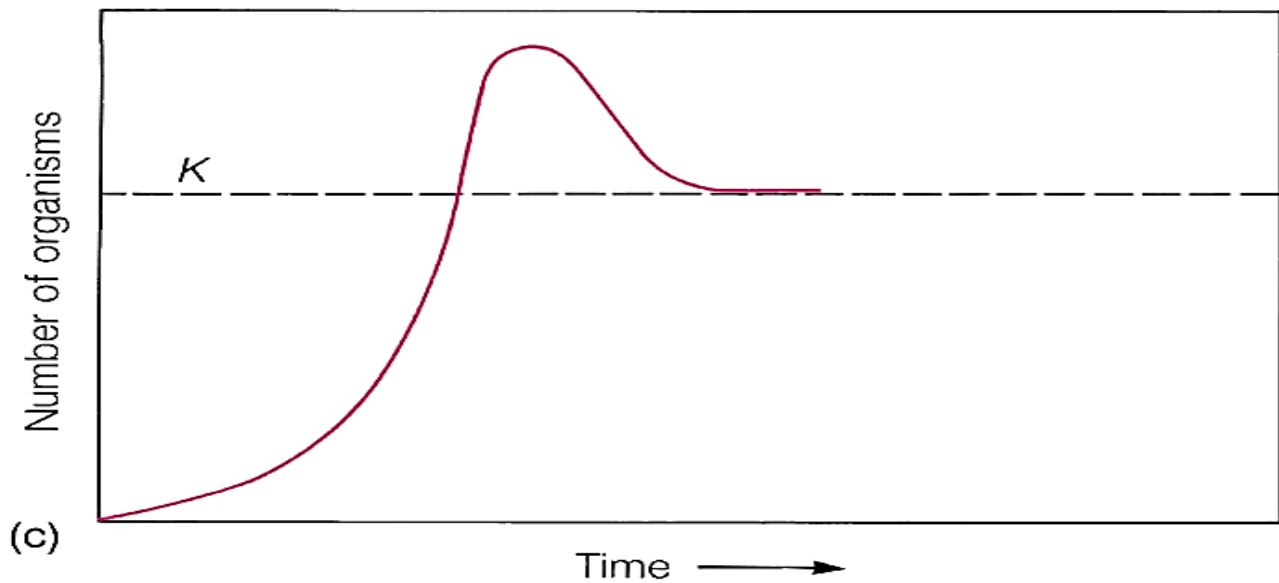
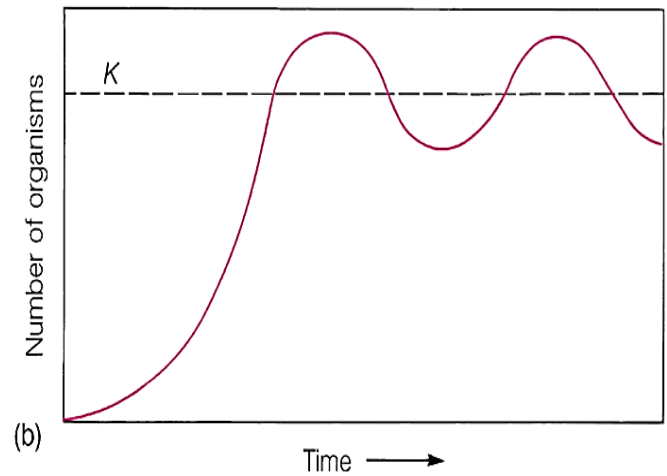
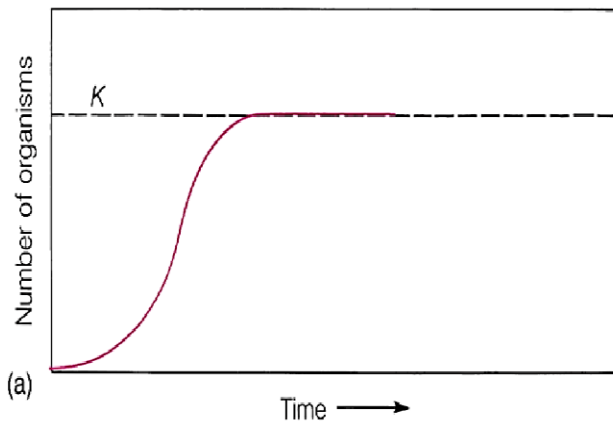
## • Logistics Population Growth

- 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

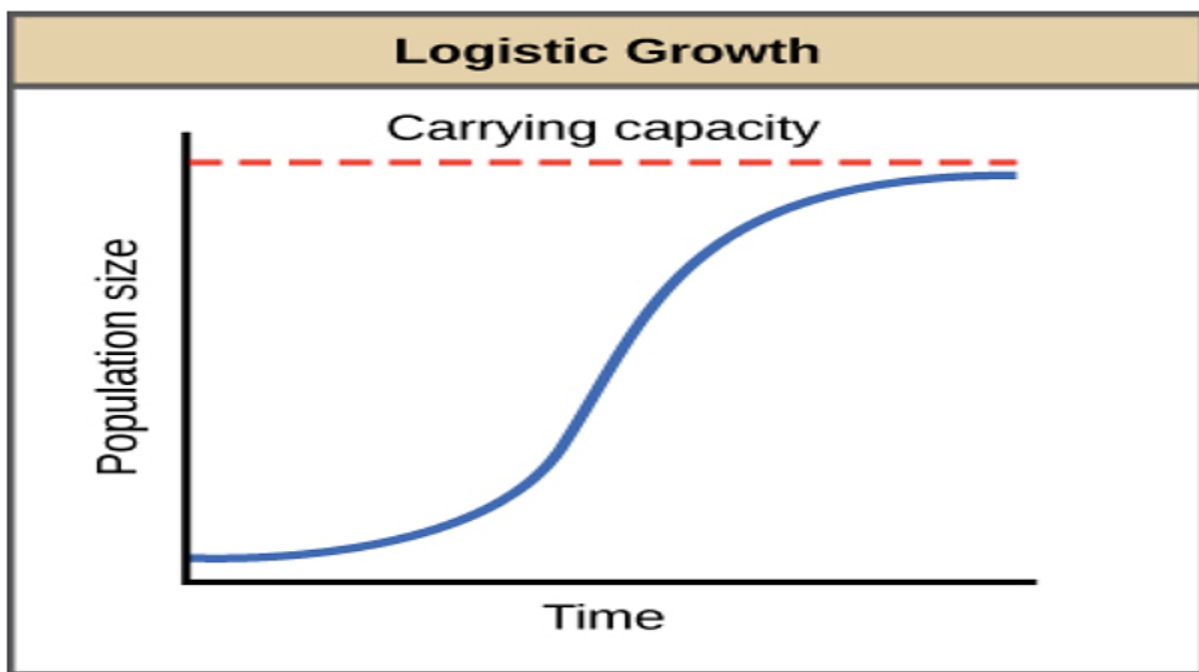
## • Population Regulation

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

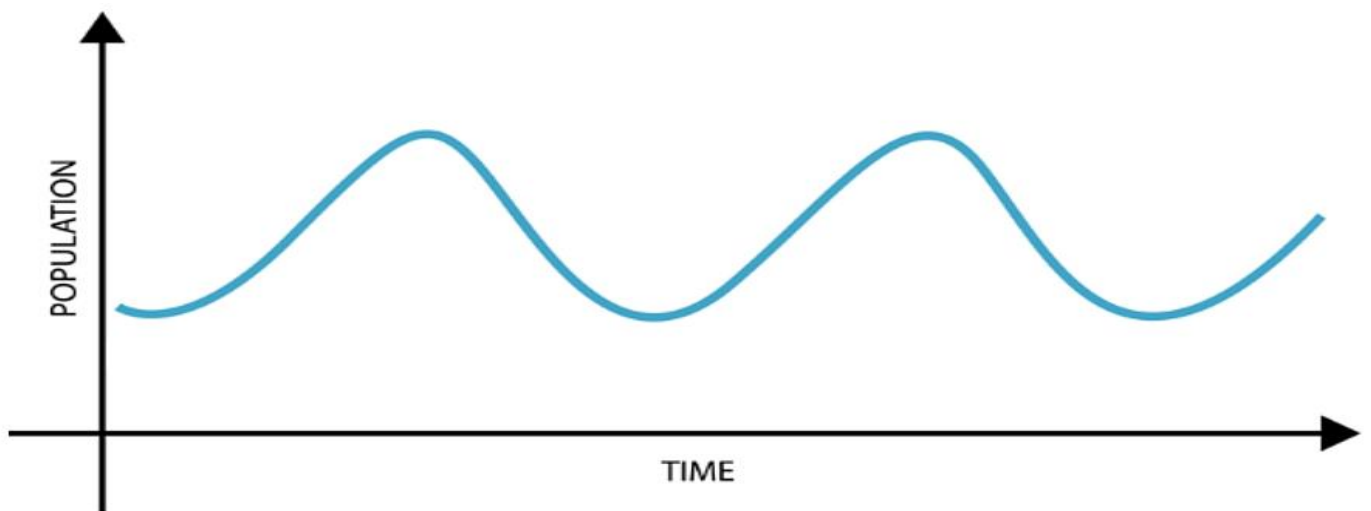
As an example, let's consider a wildfire that breaks out in a forest where deer live. The fire will kill any unlucky deer that are present, regardless of population size. An individual deer's chance of dying doesn't depend at all on how many other deer are around.

- 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

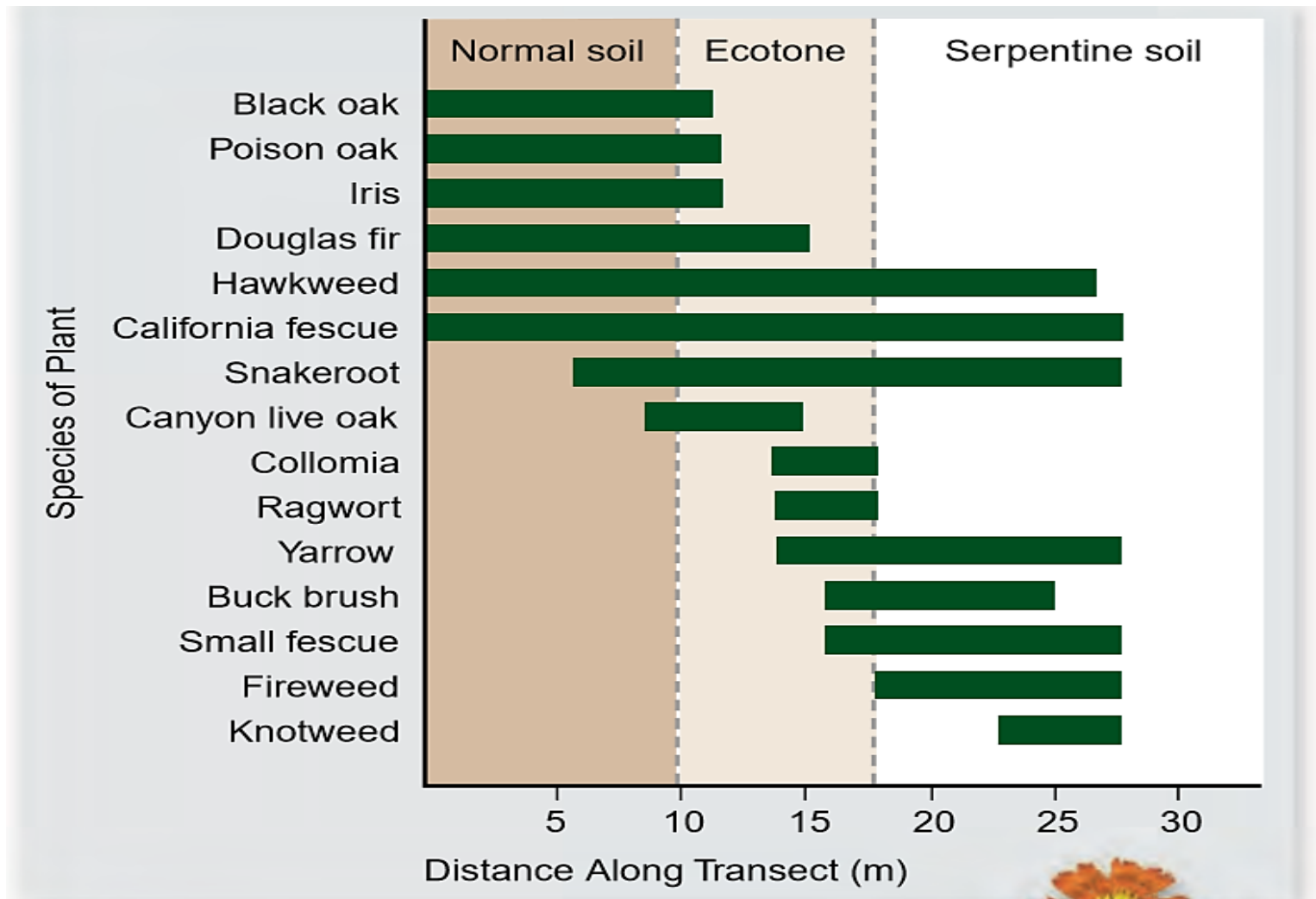
**Individualistic concept of communities**

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

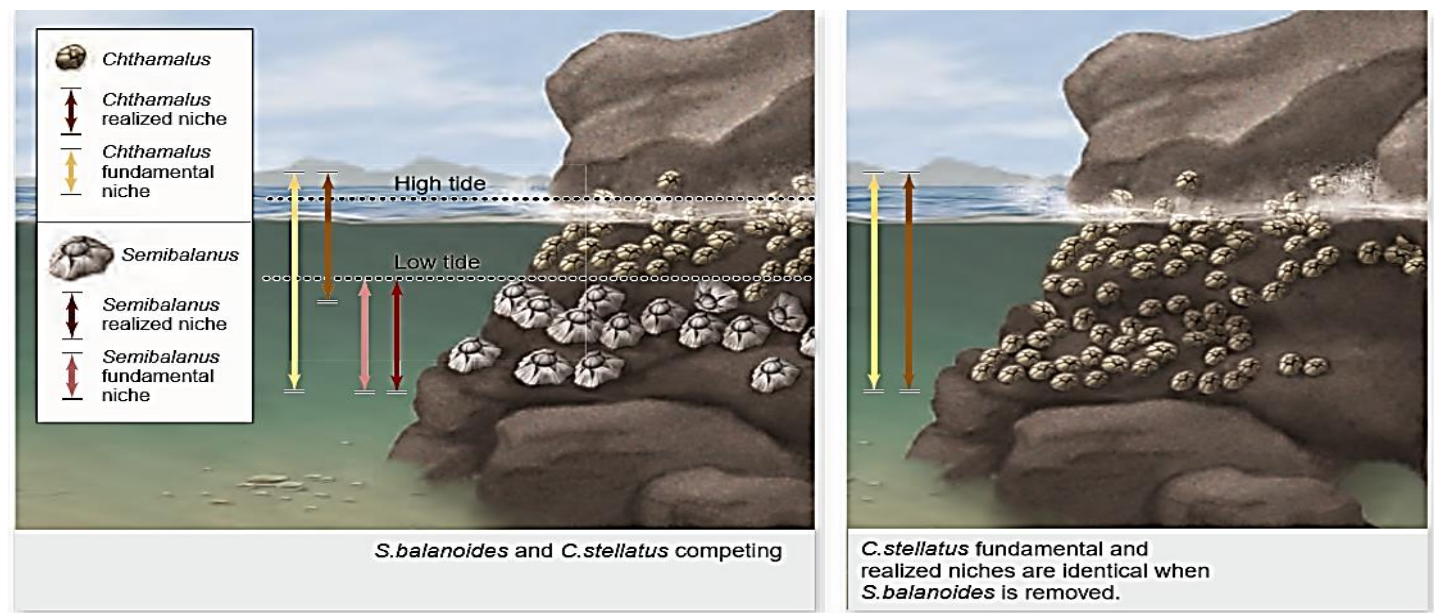
- Sometimes species cannot utilize their entire niche.
- Due to presence of other species competing for resources
- Interspecific competition, occurs between two species to use the same resources

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

- **Chemical defense**

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

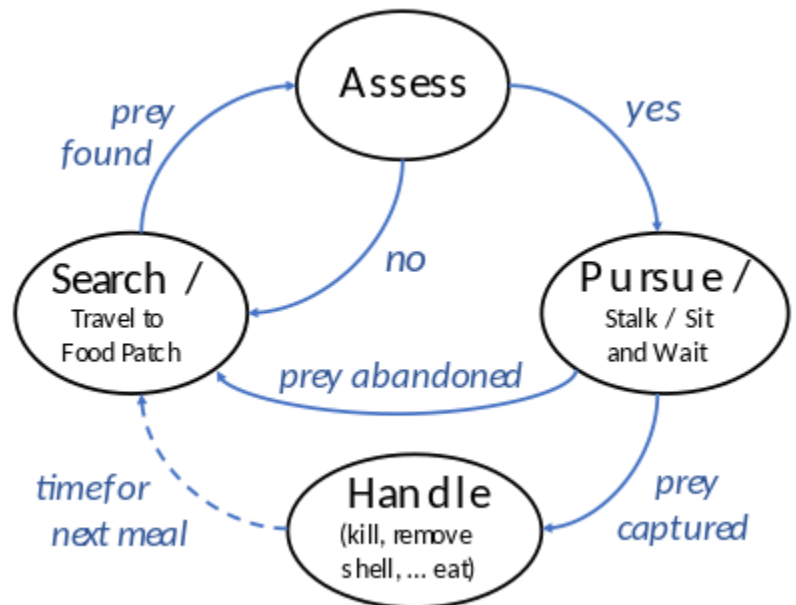


### Predation

- 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

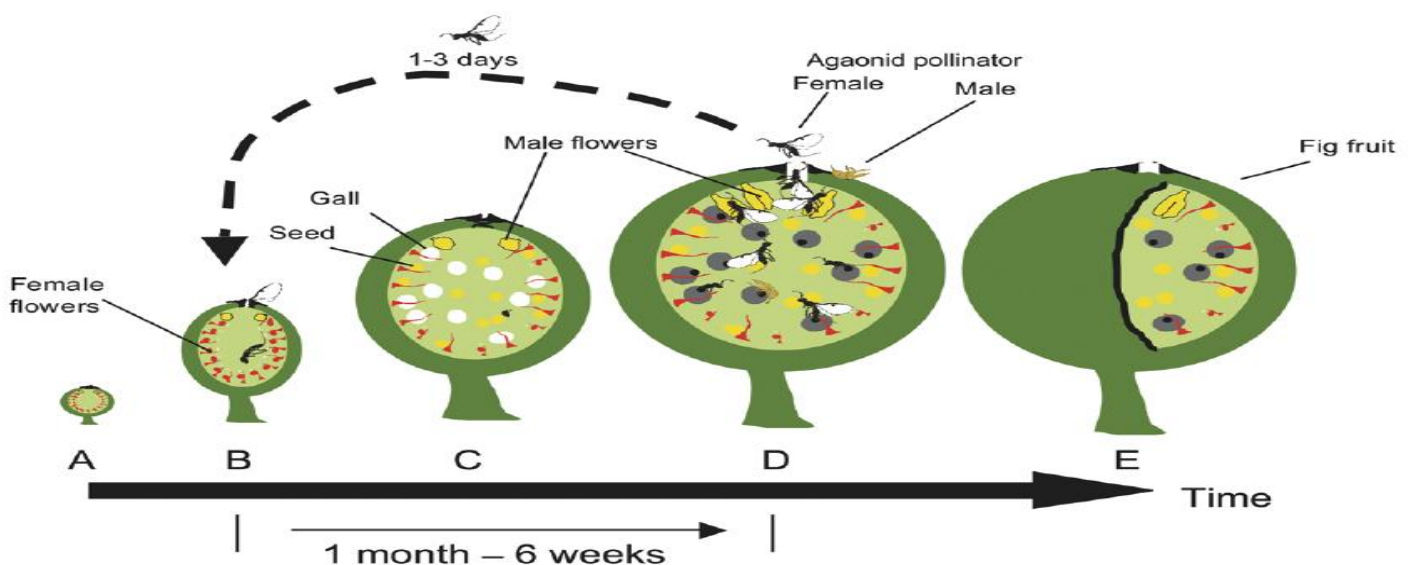
### Coevolution

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

### Mutualism

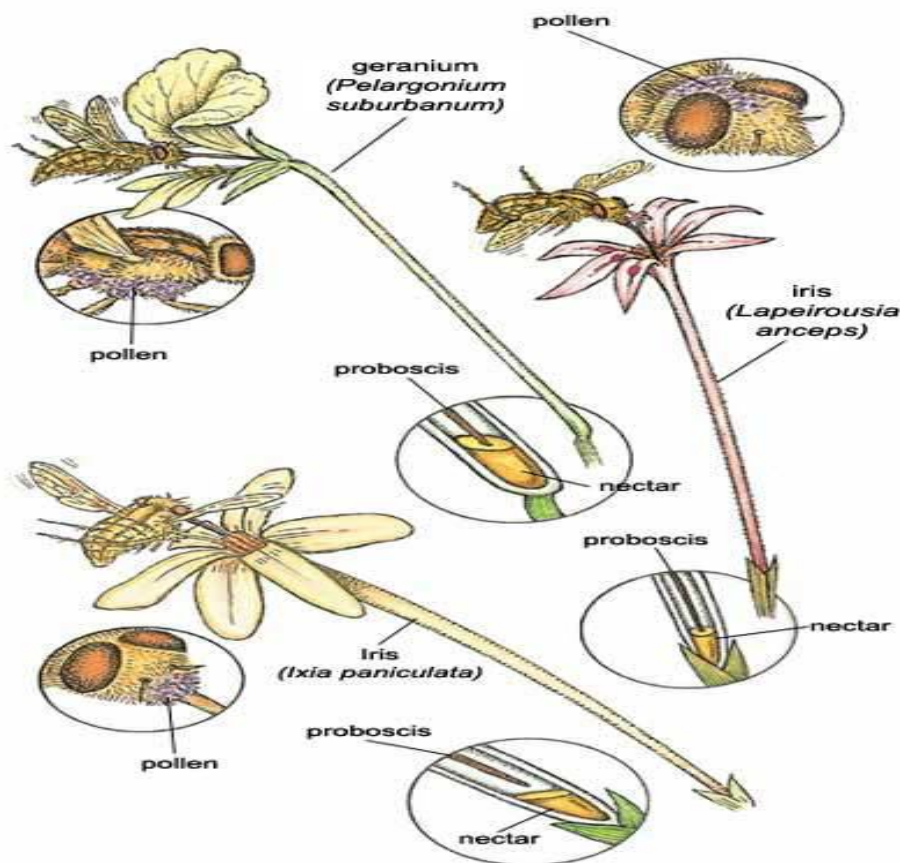
Both species coevolve to benefit each other in same habitat

- 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 hematophagic, 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

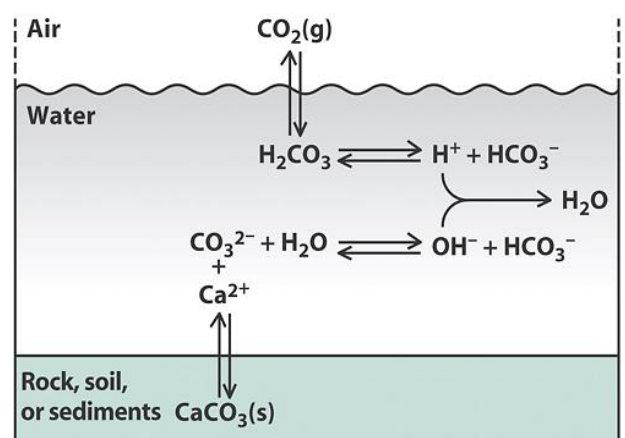
#### Composition of gases like solar nebula (disc of dirt and gases)

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 N<sub>2</sub>, CO<sub>2</sub> 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

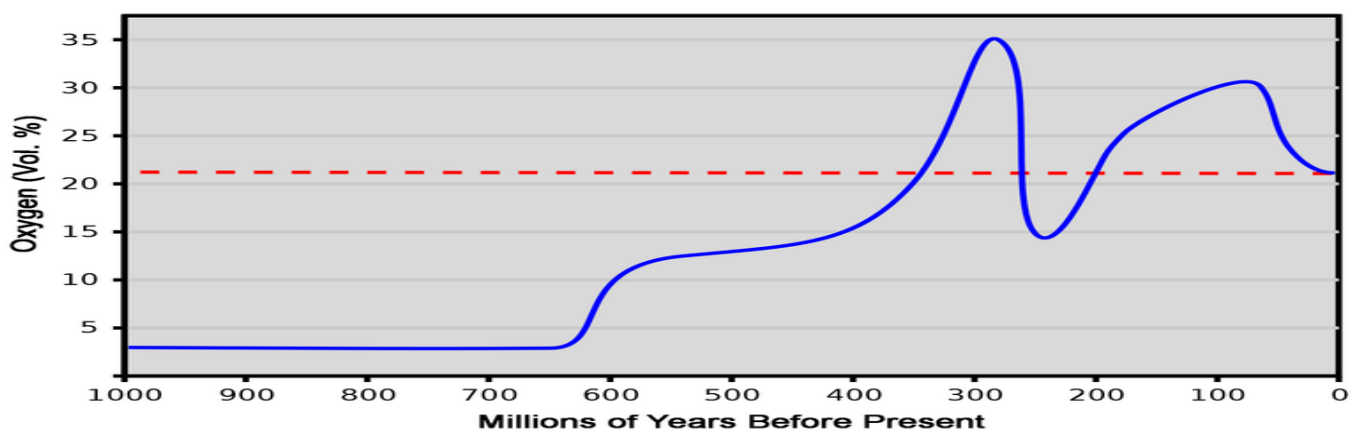
## • Atmosphere and its Evolution-2

### Evolution

#### 3. Third Atmosphere

- Constant rearrangement of continental plates
- Inflow and outflow of CO<sub>2</sub> from large continental carbonate stores
- O<sub>2</sub> synthesized in photosynthesis was being used in reducing materials
- Gradually, it was shifted to oxidizing atmosphere instead of reducing
- 541 million years ago, O<sub>2</sub> made stable 15% of atmosphere.

**Oxygen Content of Earth's Atmosphere**  
During the Course of the Last Billion Years



#### Reasons of fluctuations in O<sub>2</sub>

- Plants produced oxygen and consumed CO<sub>2</sub>
- Volcanic eruptions release sulfur into the atmosphere
- Sulfur oxidizes itself
- Reduces the amount of oxygen in the atmosphere
- Volcanic eruption also released CO<sub>2</sub>
- 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 (N<sub>2</sub>)
- 21% Oxygen (O<sub>2</sub>)
- <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

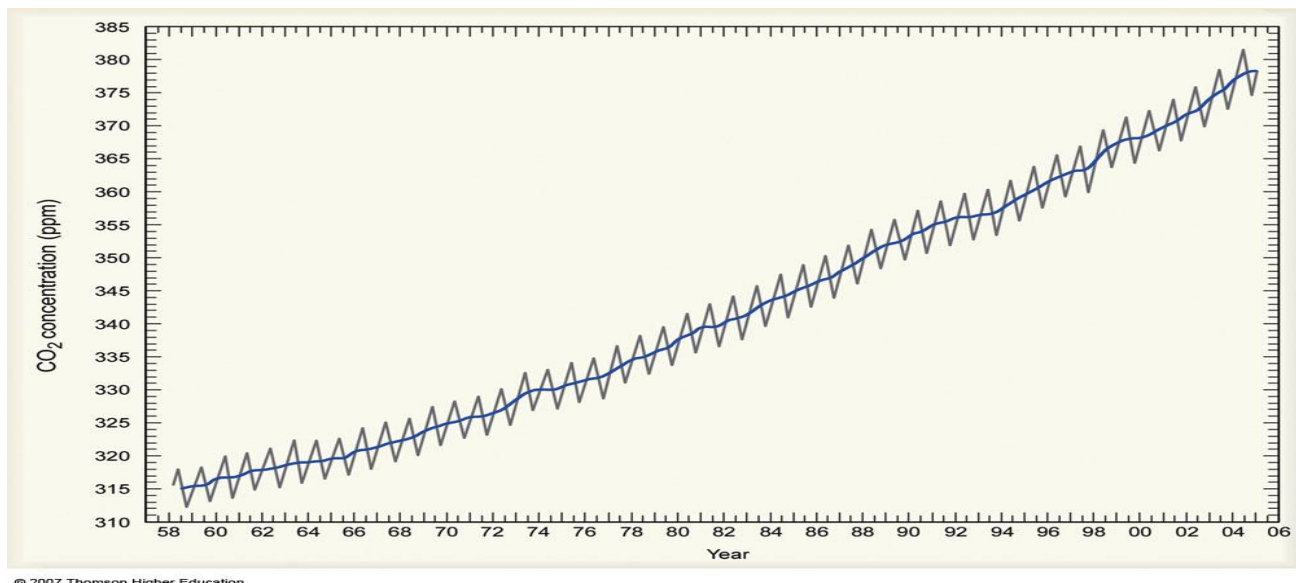
- **Water vapor (H<sub>2</sub>O):** 0 to 4%
- **Carbon Dioxide (CO<sub>2</sub>):** 0.038%
- **Methane(CH<sub>4</sub>):** 0.00017%
- **Ozone(O<sub>3</sub>):** 0.000004%

### Variable Water vapors

- Water vapor is invisible.
- Its not cloud droplets.
- 3<sup>rd</sup> 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 CO<sub>2</sub> 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 <sup>(A)</sup>    |                          |
|---------------------------------------|------------------|--------------------------|--------------------------|
| Name                                  | Formula          | in ppmv <sup>(B)</sup>   | in %                     |
| Nitrogen                              | N <sub>2</sub>   | 780,840                  | 78.084                   |
| Oxygen                                | O <sub>2</sub>   | 209,460                  | 20.946                   |
| Argon                                 | Ar               | 9,340                    | 0.9340                   |
| Carbon dioxide                        | CO <sub>2</sub>  | 400                      | 0.04 <sup>[9]</sup>      |
| Neon                                  | Ne               | 18.18                    | 0.001818                 |
| Helium                                | He               | 5.24                     | 0.000524                 |
| Methane                               | CH <sub>4</sub>  | 1.79                     | 0.000179                 |
| Not included in above dry atmosphere: |                  |                          |                          |
| Water vapor <sup>(C)</sup>            | H <sub>2</sub> O | 10–50,000 <sup>(D)</sup> | 0.001%–5% <sup>(D)</sup> |

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

- Exosphere:** 700 to 10,000 km (440 to 6,200 miles)
- Thermosphere:** 80 to 700 km (50 to 440 miles)[12]
- Mesosphere:** 50 to 80 km (31 to 50 miles)
- Stratosphere:** 12 to 50 km (7 to 31 miles)
- 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.

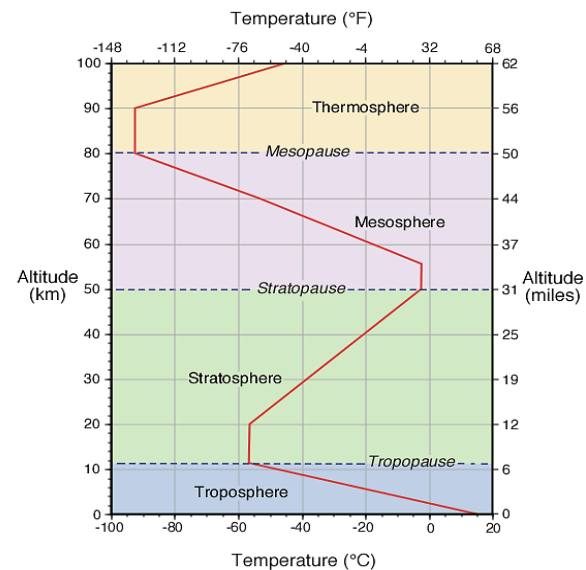
- Vapor pressure drops with decrease in temperature.
- Drop in vapor pressure is due to gravity.
- Pressure of the atmosphere is maximum at sea level and decreases with altitude.

### 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

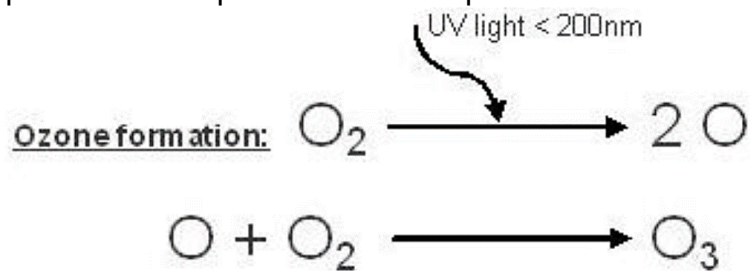
### Properties

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

Temperature increases by increase in altitude. Temperatures range from  $-51^{\circ}\text{C}$  near the tropopause to an average of  $-15^{\circ}\text{C}$  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:  $-15^{\circ}\text{C}$

## 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 CO<sub>2</sub> radiative emission
- Temperatures in the upper mesosphere fall as low as  $-101^{\circ}\text{C}$  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
- CO<sub>2</sub>, 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.  $\text{CO}_2$  is major source of carbon. Atmosphere contains about 750 billion metric tons of carbon in form of  $\text{CO}_2$ . Photosynthetic organisms take in  $\text{CO}_2$  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.

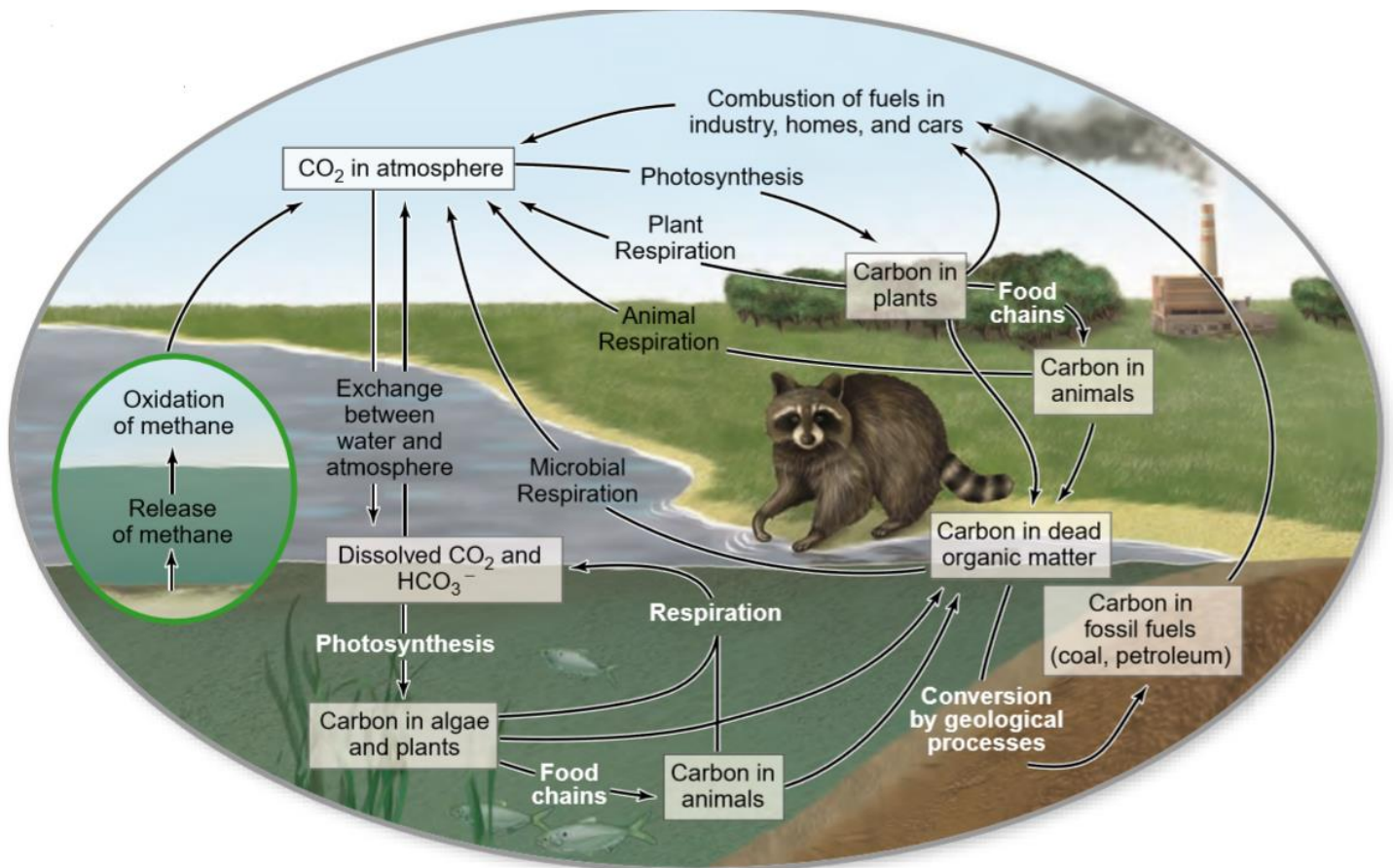
Respiration releases  $\text{CO}_2$  in air. Decaying organisms also produce  $\text{CO}_2$ .

$\text{CO}_2$  released in air is again available for plants. In aquatic ecosystem,  $\text{CO}_2$  reacts with the water to form bicarbonate ions. Dissolved  $\text{CO}_2$  and bicarbonates are used by algae and aquatic plants in photosynthesis.

Methanogens, for example, are microbes that produce methane ( $\text{CH}_4$ ) instead of  $\text{CO}_2$ .

Methane released in air is oxidized into  $\text{CO}_2$ . Amount of  $\text{CO}_2$  made by breakdown of organic compounds almost matches the amount of  $\text{CO}_2$  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

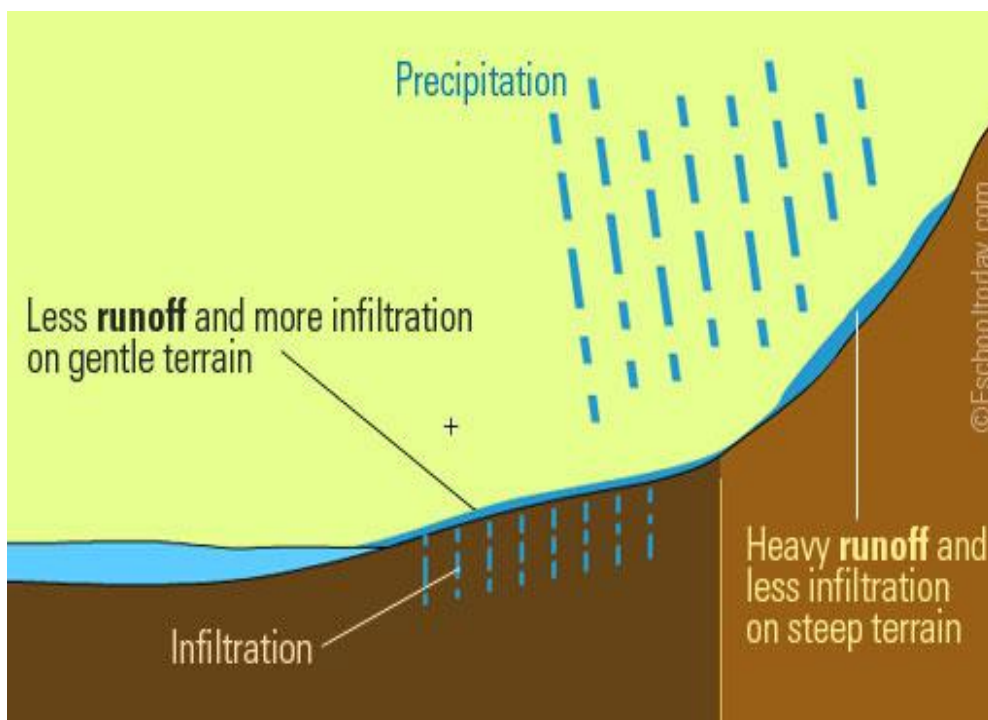
## Percolation (Infiltration)

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

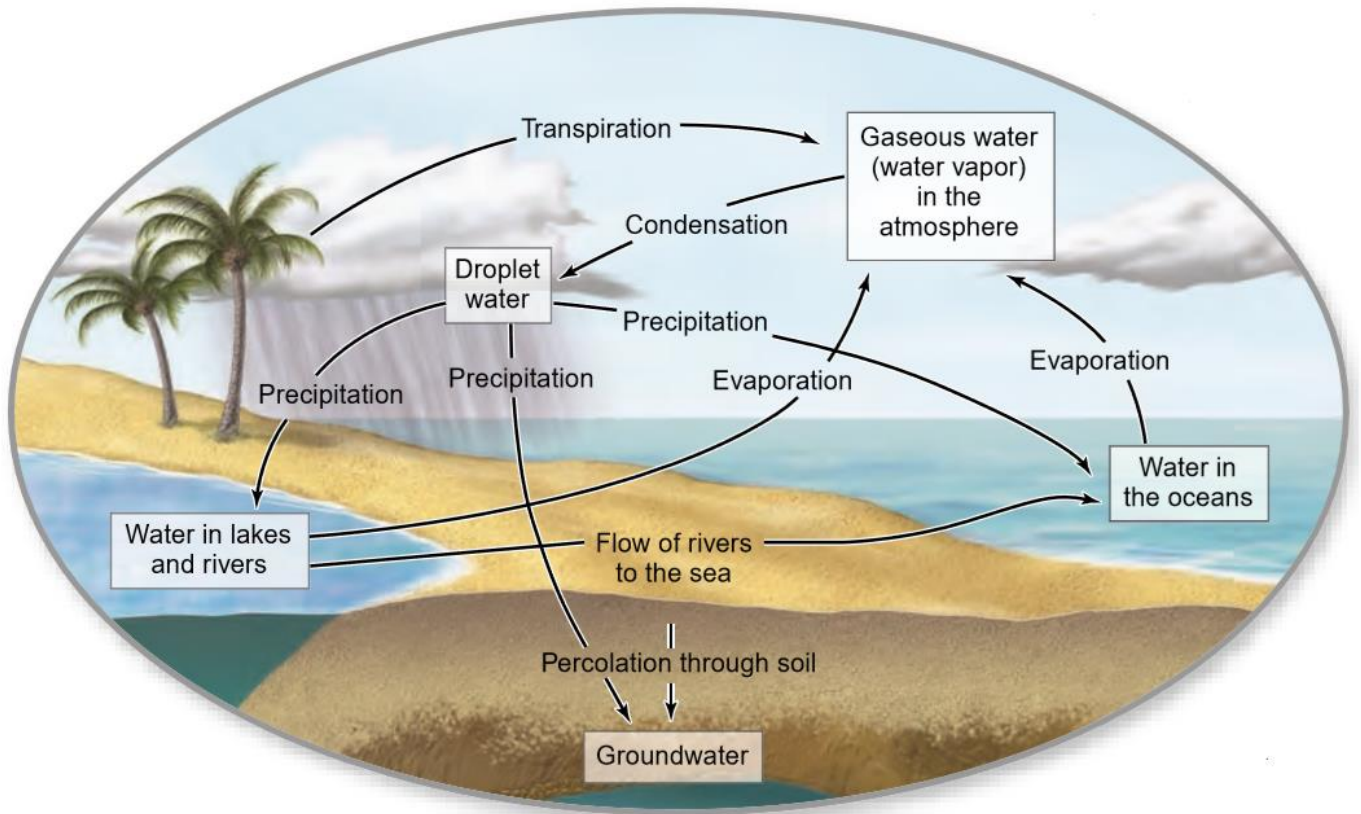
Water moves through the soil and rock layers. Many of the impurities in the water are filtered out. This filtering process helps clean the water.

## 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 ( $\text{NH}_3$ ) and nitrate ions ( $\text{NO}_3^-$ ). Prokaryotic microbes can synthesize ammonia and nitrate from  $\text{N}_2$  in the atmosphere. It makes atmospheric nitrogen accessible to plants and algae. Other prokaryotes turn  $\text{NH}_3$  and  $\text{NO}_3$  into  $\text{N}_2$ , 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            | $3.9 \times 10^{15}$ | No              |
| Ocean → soluble salts | $6.9 \times 10^{11}$ | Yes             |
| Biomass               | $5.2 \times 10^8$    | Yes             |
| Land → organic matter | $1.1 \times 10^{11}$ | Slow            |
| → Biota               | $2.5 \times 10^{10}$ | Yes             |

Phases of Cycle

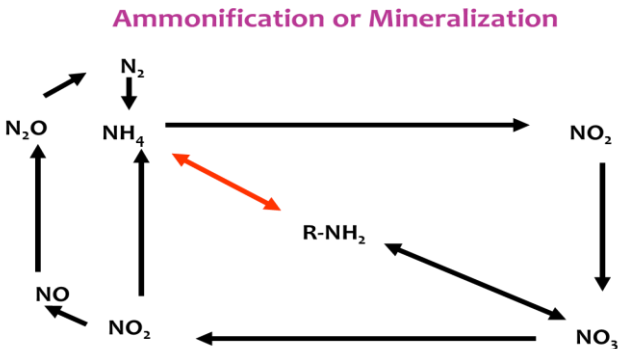
1. Ammonification/mineralization
2. Immobilization
3. Nitrogen Fixation
4. Nitrification
5. Denitrification

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

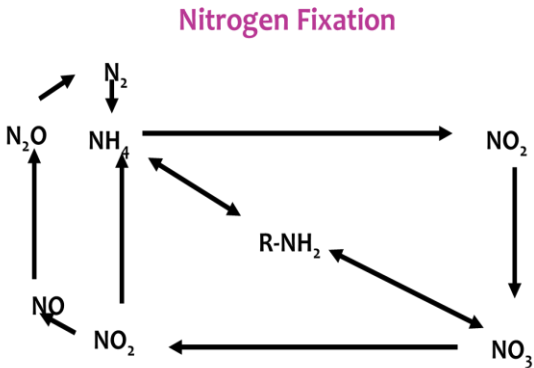
Immobilization

- 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
- $C/N < 20 \rightarrow$ Mineralization
- $C/N > 20 \rightarrow$ 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)



Microorganisms fixing Nitrogen

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

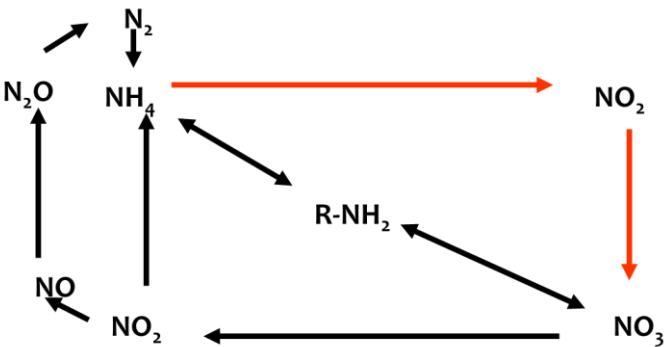
| N <sub>2</sub> fixing system | Nitrogen Fixation (kg N/hect/year) |
|------------------------------|------------------------------------|
| Rhizobium-legume             | 200-300                            |
| Cyanobacteria- moss          | 30-40                              |
| Rhizosphere associations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

Nitrification

Nitrification

Two step reactions that occur together :

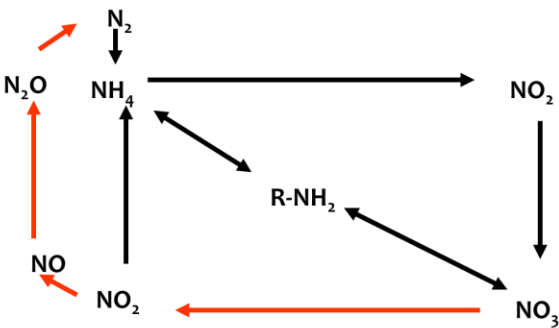
- 1<sup>st</sup> step catalyzed by *Nitrosomonas*  
 $2\text{ NH}_4^+ + 3\text{ O}_2 \rightarrow 2\text{ NO}_2^- + 2\text{ H}_2\text{O} + 4\text{ H}^+$
- 2<sup>nd</sup> step catalyzed by *Nitrobacter*  
 $2\text{ NO}_2^- + \text{O}_2 \rightarrow 2\text{ NO}_3^-$
- Optimal pH is between 6.6-8.0
- If pH < 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

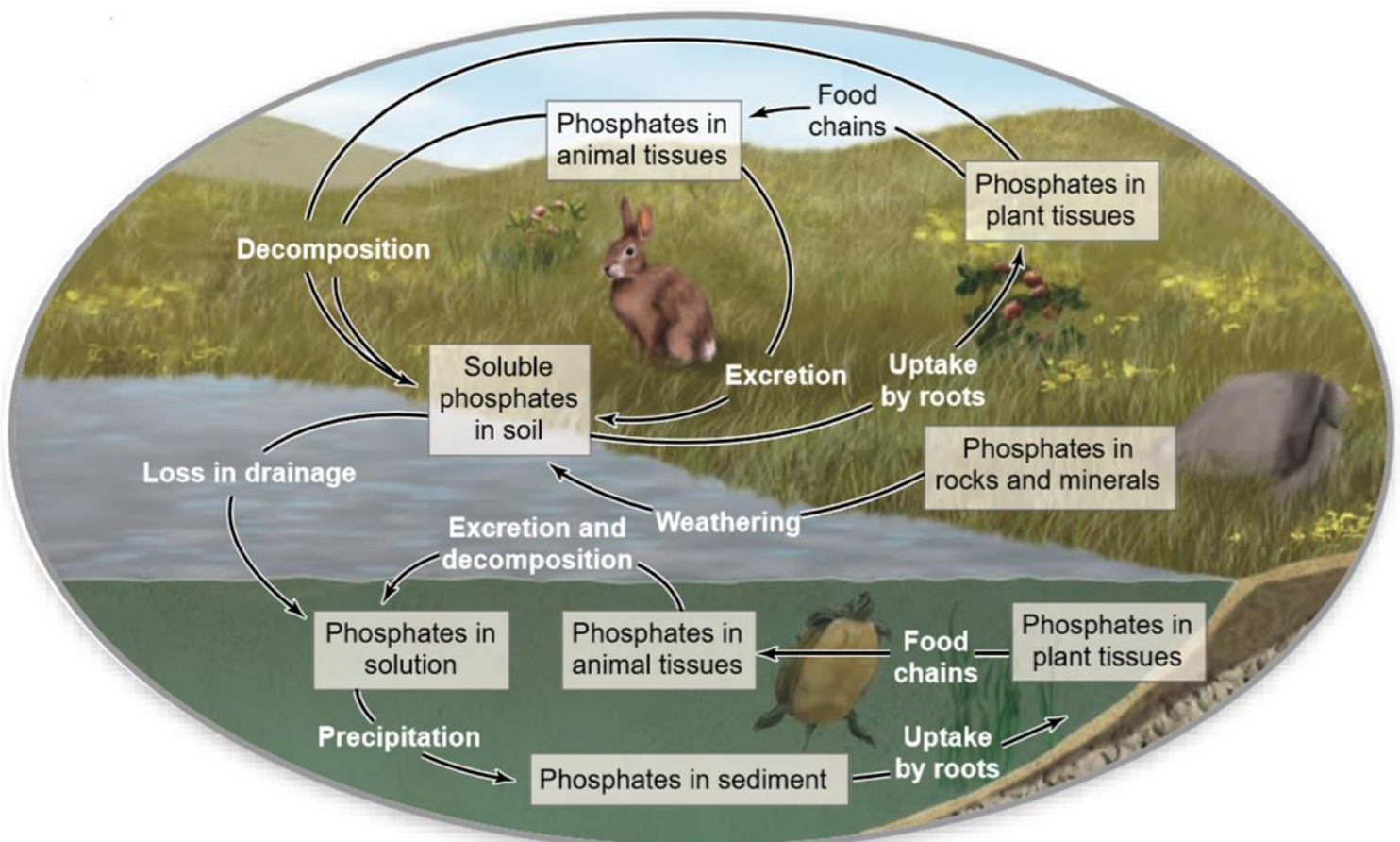


Phosphorus is important component of:

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

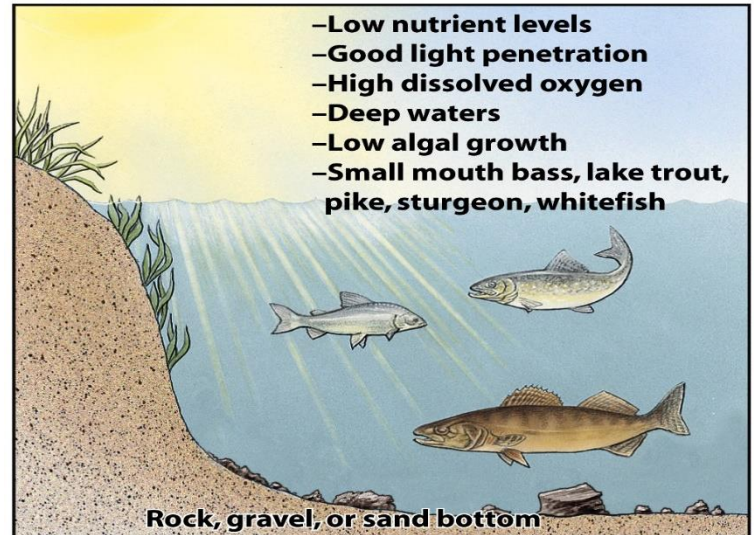
### **Sewage**

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

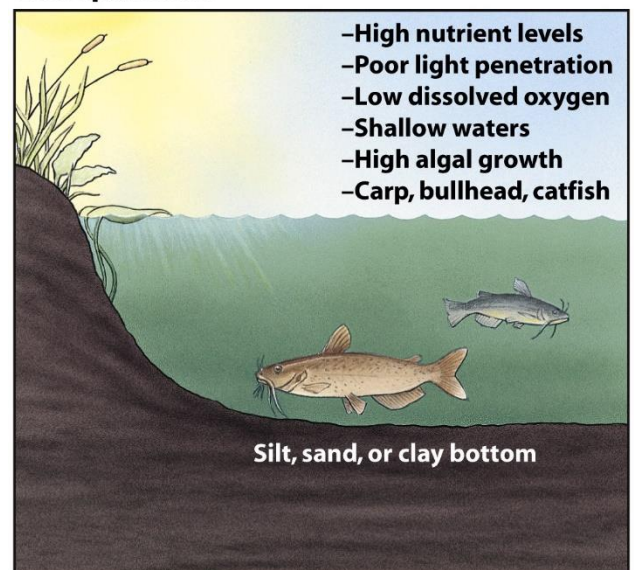
### **Causes serious environmental problems:**

- 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

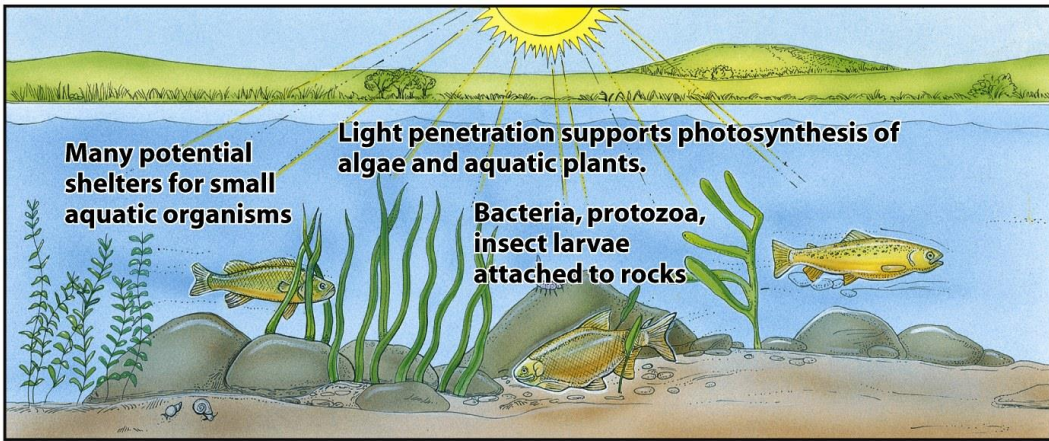


### Eutrophic lake

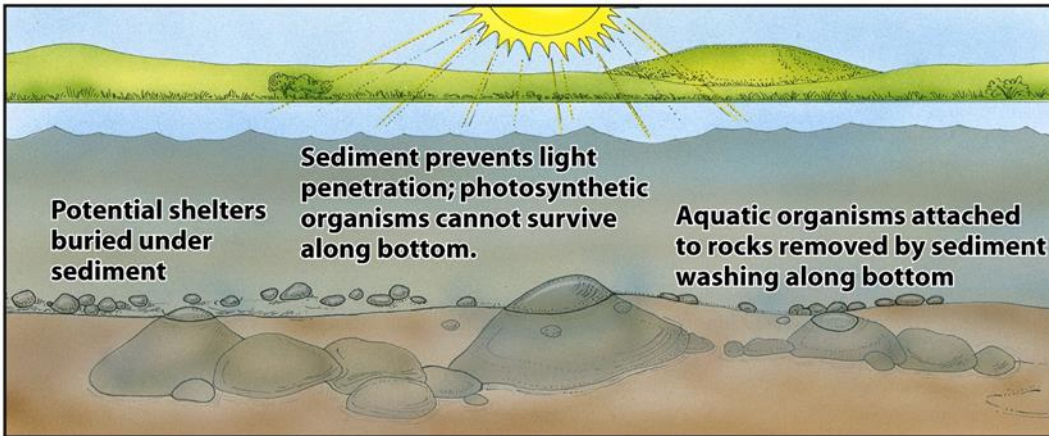


Erosion of agricultural lands, forest soils exposed by logging, degraded stream banks, overgrazed rangelands, strip mines, and construction

- 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 (CO<sub>2</sub>)
- Greenhouse gases

- **Hydrocarbons**

- Diverse group of organic compounds that contain only hydrogen and carbon (ex: CH<sub>4</sub>-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

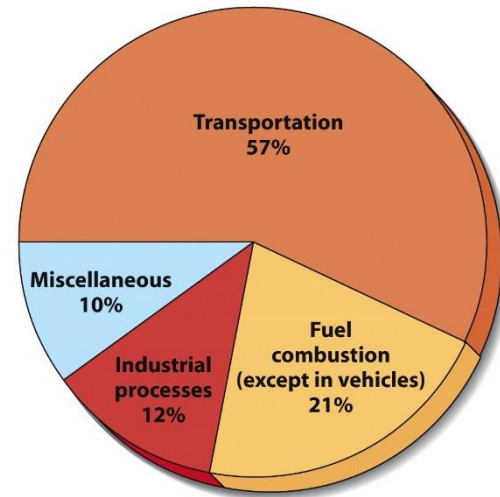
- **Two main sources**
  - Transportation
  - Industry
- Intentional forest fires is also high

### 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.

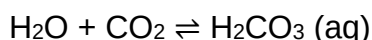
## Lecture 62

### • 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

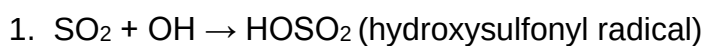
- Volcanic eruption releases  $\text{SO}_2$  in air.
- Nitrogen fixation adds  $\text{NO}_2$  in air.
- Electrical activity in the atmosphere such as lightning produces  $\text{NO}_2$ .
- Acid deposits in glacial ice.

##### Human Activities

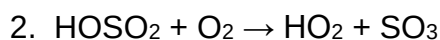
- Sulfur and nitrogen compounds from human sources
- Electricity generation, factories, and motor vehicles
- Greatest contribution by burning coal in power plants
- Gases can be carried hundreds of kilometers in the atmosphere before they are converted to acids and deposited.
- Taller factories funnels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

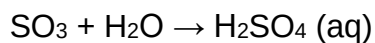


which is followed by:



### Chemical Processes

- Chemistry in cloud droplets
- In the presence of water, sulfur trioxide ( $\text{SO}_3$ ) 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 21<sup>st</sup> century

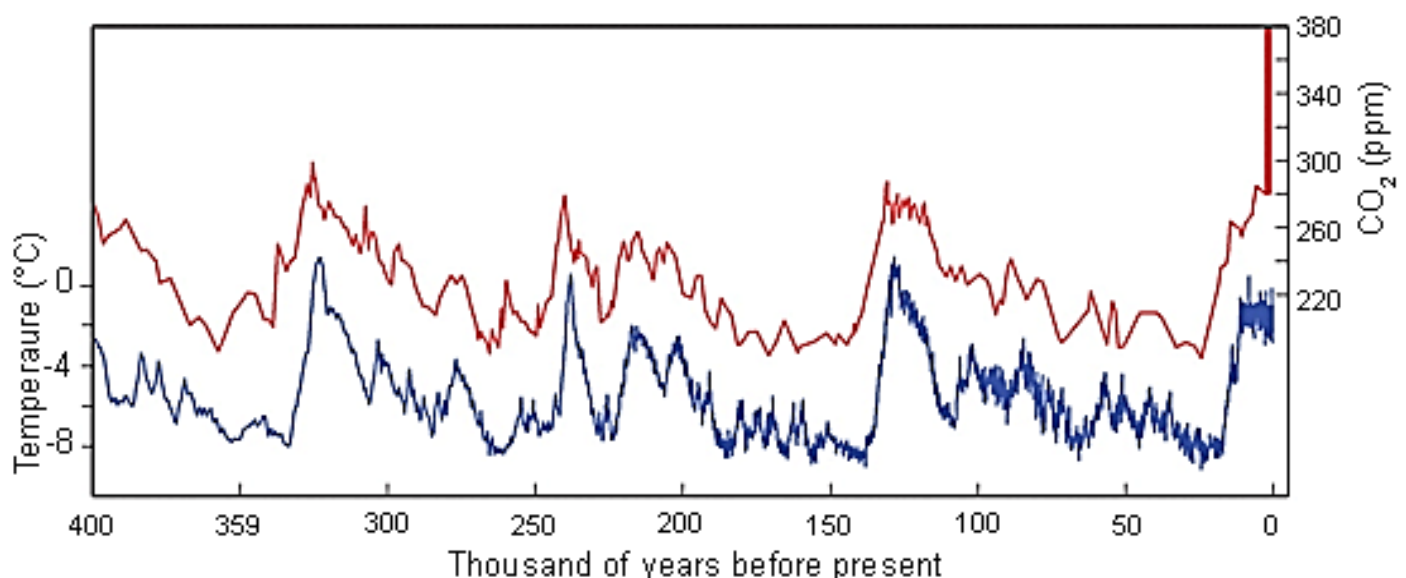


## Lecture 66

### • 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 CO<sub>2</sub> 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 CO<sub>2</sub> concentration is available only in the last few decade

Information about atmospheric CO<sub>2</sub> 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 H<sub>2</sub>O 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
  - CO<sub>2</sub> 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 CO<sub>2</sub> gas increases
    - Pulling CO<sub>2</sub> out of the atmosphere
    - The reduced atmospheric CO<sub>2</sub> 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 CO<sub>2</sub> gas decreases, allowing the CO<sub>2</sub> released by volcanism to build back up in the atmosphere. The increased CO<sub>2</sub> 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 21<sup>st</sup> 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 20<sup>th</sup> 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 CO<sub>2</sub> concentrations have led to an increase in dissolved CO<sub>2</sub>
- 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

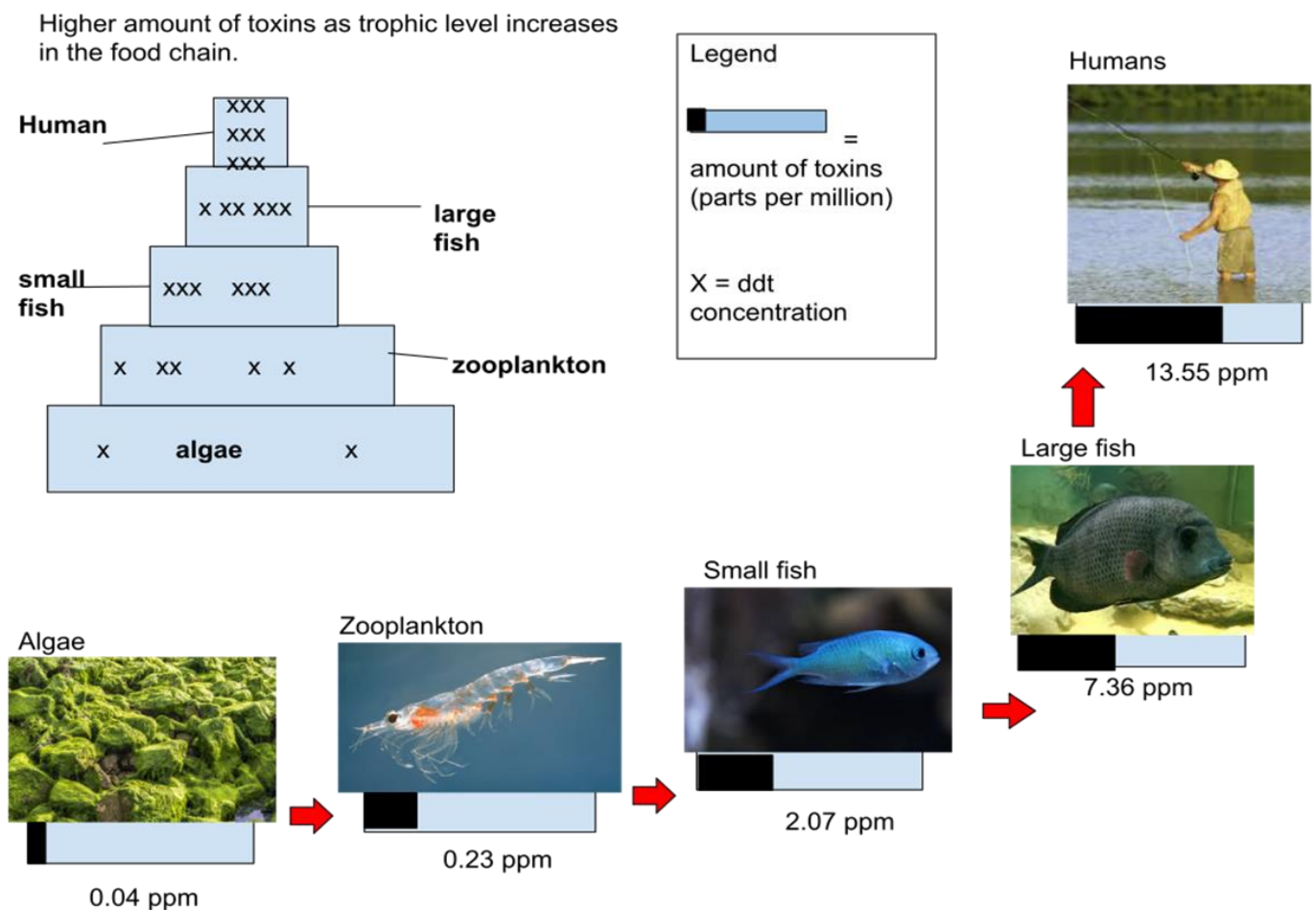
- Substance cannot be broken down by environmental processes

## 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

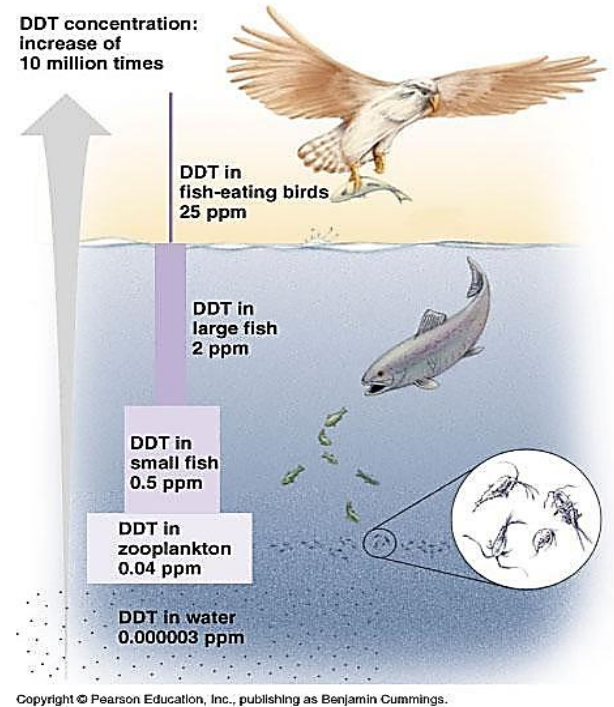
## DDT (Case Study)

- 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**

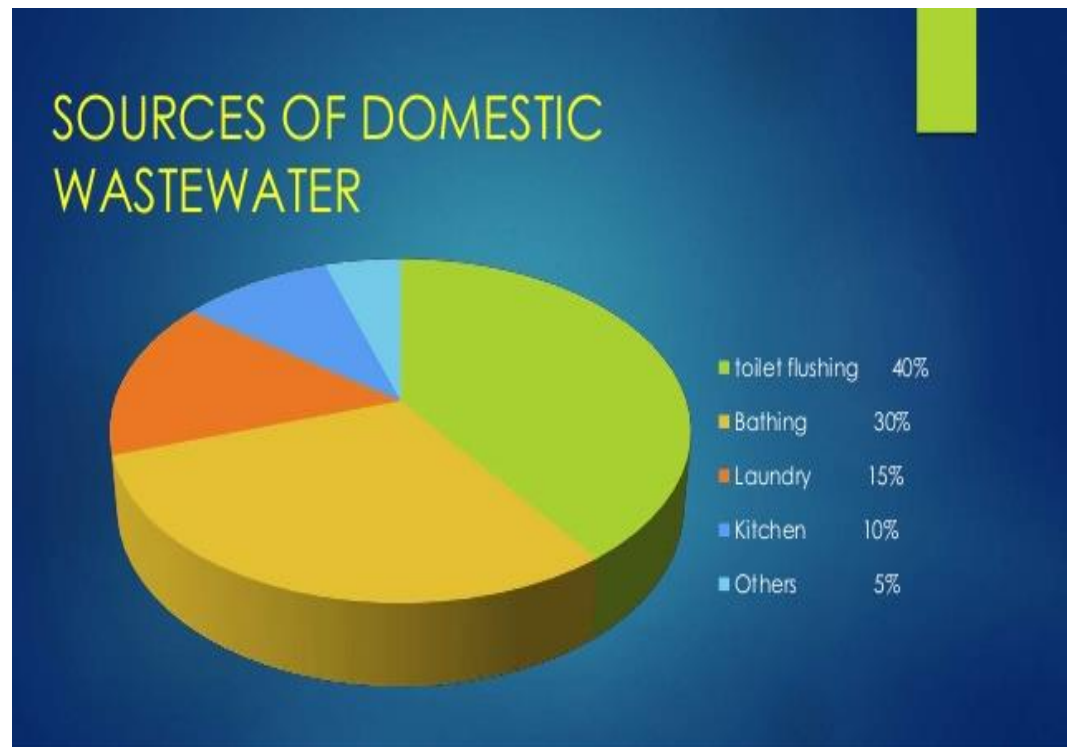
1. Gray water
2. Black water

#### **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

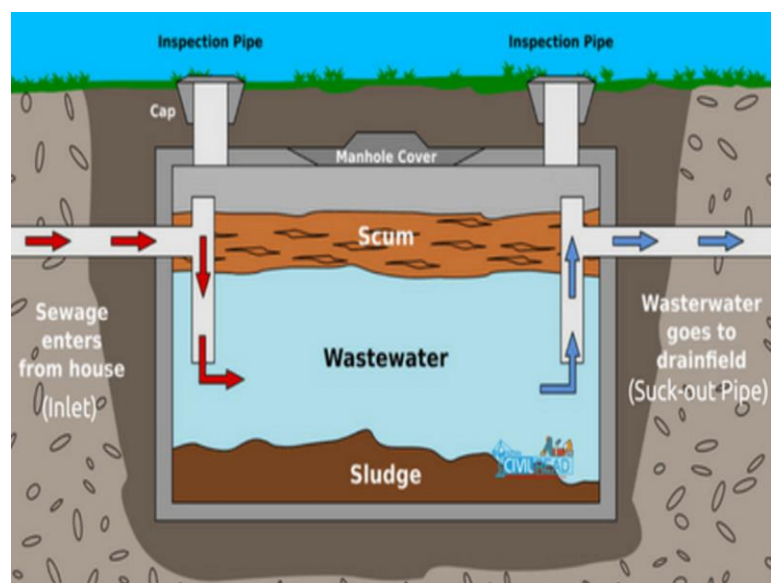
- Bacteria in sewage degrade organic matter
- Tank buried in ground to treat sewage from an individual home
- Wastewater flows into tank
- Solid material ("sludge") settles to bottom of tank
- Clean water flows out of tank into ground through subsurface drains

#### 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 17<sup>th</sup> 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

## Lecture 76

## • Evolution & Biogeography

### Biogeography

- Study of the geographic distribution of plants and animals
- Study the life-forms in different parts of the world have distinctive evolutionary histories
- Geographical regions have characteristic biotas. Closely related taxa tend to be closer together than more distantly related groups.
- Similar environments are found in different areas but the same species may not be found in all places where they could be
- Not closely related species in similar environments may appear similar due to convergence.

### Evidences

1. Regions with identical climate have different floras and faunas (Buffon's Law).

Cactaceae in North American deserts

Euphorbiaceae in southern African deserts

2. Geographic barriers closely associated with breaks between taxonomic groups.

3. Within a region, organisms are often closely related

- Across environmental gradients and lower taxonomic groups often show narrower distributions than higher.

### Disjunct Distribution

- A taxon with a disjunct distribution is one that has two or more groups that are related but considerably separated from each other geographically.

### Barriers

- Physical barriers
- Climatic barriers
- Biological barriers

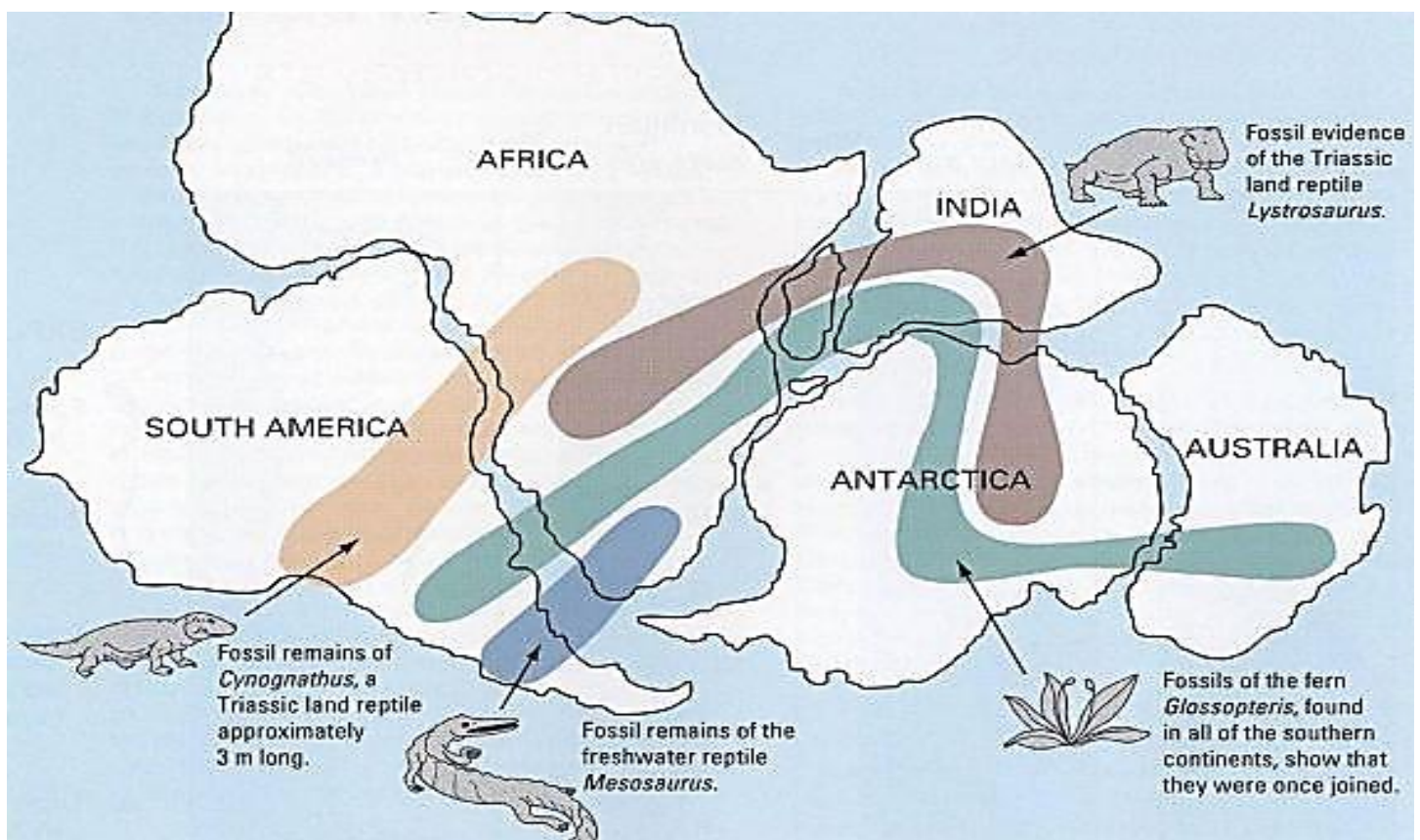
### Plate Tectonics

**Glossopteris Permian** – “fern”

**Mesosaurus** – Freshwater Permian Reptile

**Cynognathus** – Triassic land reptile

**Lystrosaurus** – Triassic land reptile



## Lecture 77

## • Evolution & Palaeontology

Paleontology is the study of fossils. It provides some of the most direct evidence for evolution. Fossils (to dig) are evidence of plants and animals that existed in the past and have become incorporated into the earth's crust.

**Nicolas Steno (1638-86) Father of geology and stratigraphy**

**James Hutton**

Evolution of earth must be old. Observable processes produce small changes that accumulate over time

**William Smith**

Different rock layers contain distinct fossils

## Fossil

Any preserved remains, impression, or trace of any once-living thing from a past geological age.

**Examples:** Bones, shells, exoskeletons, stone imprints of animals or microbes, objects preserved in amber, hair, petrified wood, oil, coal, and DNA remnants

- Emerging field of geology lead to a new concept of the age of the Earth.
- The history of the earth extends back through vast time periods.
- The processes at work today are the same as those that have been operating throughout the entire history of Earth.

**These concepts became known as:**

## Uniformitarianism or Actualism

**Georges Cuvier (1769-1832) proposed that:**

- Fossils resemble but are not exactly the same as modern species
- Many past species are extinct
- Mary Anning (1799 – 1847) discovered several marine fossils of Jurassic period.
- Darwin proposed his theory of natural selection based upon evidences from fossil record.
- Fossils provide the missing links between ancestor and descendants.

## Lecture 78

## • Evolution & Comparative Anatomy

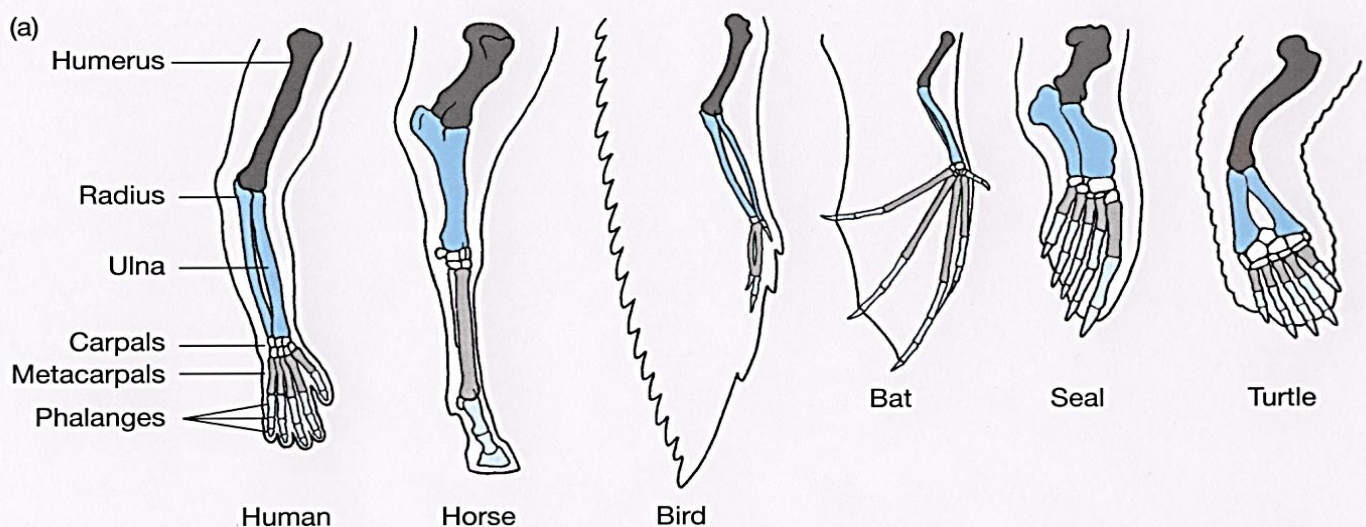
Comparative anatomy is the study of similarities and differences in the anatomy of different species. It is closely related to evolutionary biology and phylogeny (the evolution of species).

## Homology and Common Descent

- Divergent evolution
- Existence of shared ancestry between a pair of structures, or genes, in different taxa
- Once related lineages are reproductively isolated, evolution can lead to modifications of the basic plan.
- Forelimbs of vertebrates

T-6

Fig. 2.1 Structural homologies (a)



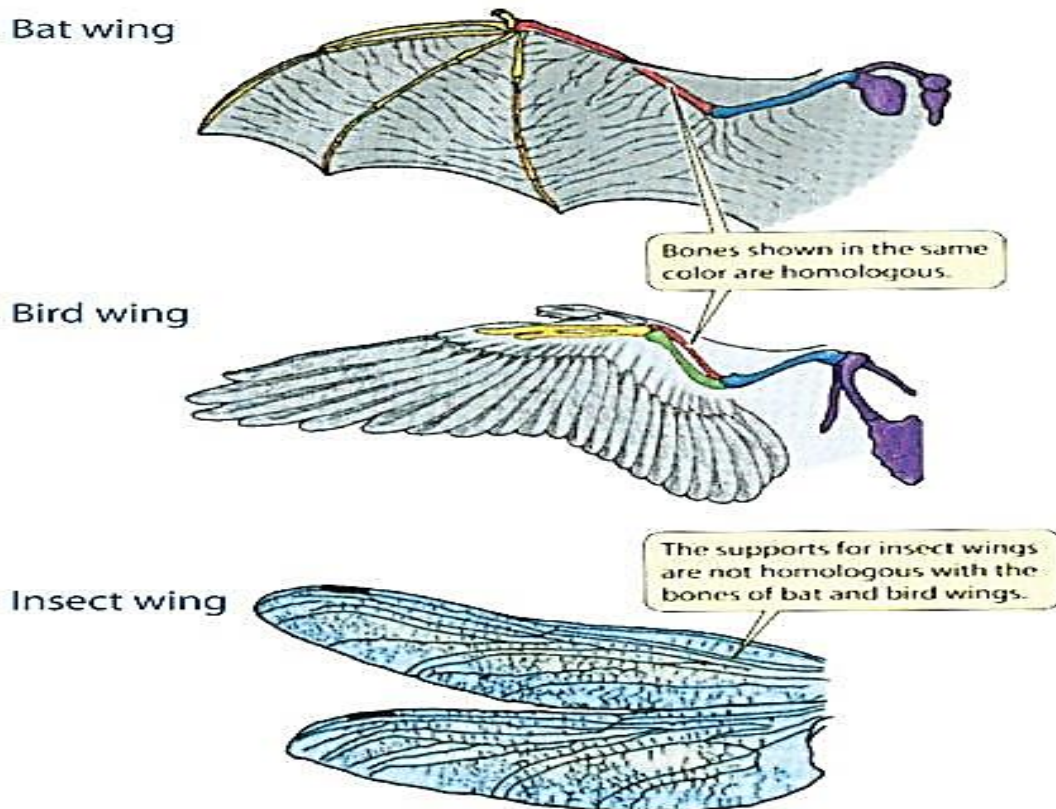
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- Evolution can be viewed as a series of bifurcations in a phylogenetic tree.
- All life can be traced back to a common ancestor.

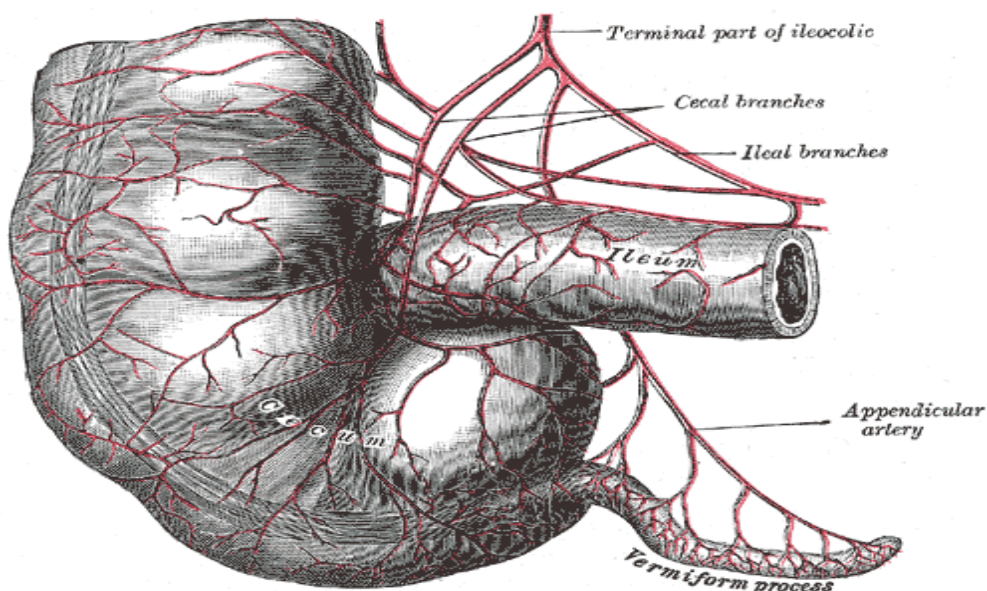
## Analogy

- Convergent Evolution
- Independent evolution of similar features in species of different lineages
- Creates analogous structures that have similar form or function but were not present in the last common ancestor of those groups



## Vestigial Organs

- Retention during the process of sexual reproduction of genetically determined structures or attributes
- That have lost some or all of their ancestral function in a given species.
- Vestigiality is loss of feature due to loss of its value in changed environment.
- The human vermiform appendix on the vestigial caecum.



- Blind cave fish has no eye
- Genes for functional eyes are still in their DNA

- Molecular biology has yielded a wealth of information on evolutionary relationships.
- Related animals have similar DNA derived from their common ancestor.
- Molecular biologists can estimate the elapsed time since divergence from a common ancestral molecule by looking for:
- Extraction and analysis of the structure of proteins from animal tissue, and compare the DNA of different animals
- Dissimilarities in the structure of related proteins and DNA
- By assuming relatively constant mutation rates

Genetic code of mRNA is universal.

|              |   | Second letter                            |                                      |                                            |                                           |                  |              |
|--------------|---|------------------------------------------|--------------------------------------|--------------------------------------------|-------------------------------------------|------------------|--------------|
|              |   | U                                        | C                                    | A                                          | G                                         |                  |              |
| First letter | U | UUU } Phe<br>UUC }<br>UUA } Leu<br>UUG } | UCU }<br>UCC } Ser<br>UCA }<br>UCG } | UAU } Tyr<br>UAC }<br>UAA Stop<br>UAG Stop | UGU } Cys<br>UGC }<br>UGA Stop<br>UGG Trp | U<br>C<br>A<br>G | Third letter |
|              | C | CUU }<br>CUC } Leu<br>CUA }<br>CUG }     | CCU }<br>CCC } Pro<br>CCA }<br>CCG } | CAU } His<br>CAC }<br>CAA } Gln<br>CAG }   | CGU }<br>CGC } Arg<br>CGA }<br>CGG }      | U<br>C<br>A<br>G |              |
|              | A | AUU } Ile<br>AUC }<br>AUA }<br>AUG Met   | ACU }<br>ACC } Thr<br>ACA }<br>ACG } | AAU } Asn<br>AAC }<br>AAA } Lys<br>AAG }   | AGU } Ser<br>AGC }<br>AGA } Arg<br>AGG }  | U<br>C<br>A<br>G |              |
|              | G | GUU }<br>GUC } Val<br>GUA }<br>GUG }     | GCU }<br>GCC } Ala<br>GCA }<br>GCG } | GAU } Asp<br>GAC }<br>GAA } Glu<br>GAG }   | GGU }<br>GGC } Gly<br>GGA }<br>GGG }      | U<br>C<br>A<br>G |              |

Sequencing of DNA and proteins help to accurately locate the similarities between different taxa. Transplantation of lost genes and other techniques like cloning help to understand evolution better.

Jean Baptiste LAMARCK 1744 – 1829

- Lamarck rejected fixity
- He proposed a theory of evolution which is attractive.
- However, it was eventually rejected because of the way inheritance works.
- But it is still considered a breakthrough.
- Theory of “inheritance of acquired characteristics or soft inheritance”
- Lamarck noticed that organisms adapted to a particular niche had well developed specialized organs
- For example a carnivore will have long canine teeth to grip its prey.
- Small non-functional organs (vestigial organs)

e.g. the appendix in humans, the internal hind limbs of whales and the internal legs of some species of snakes

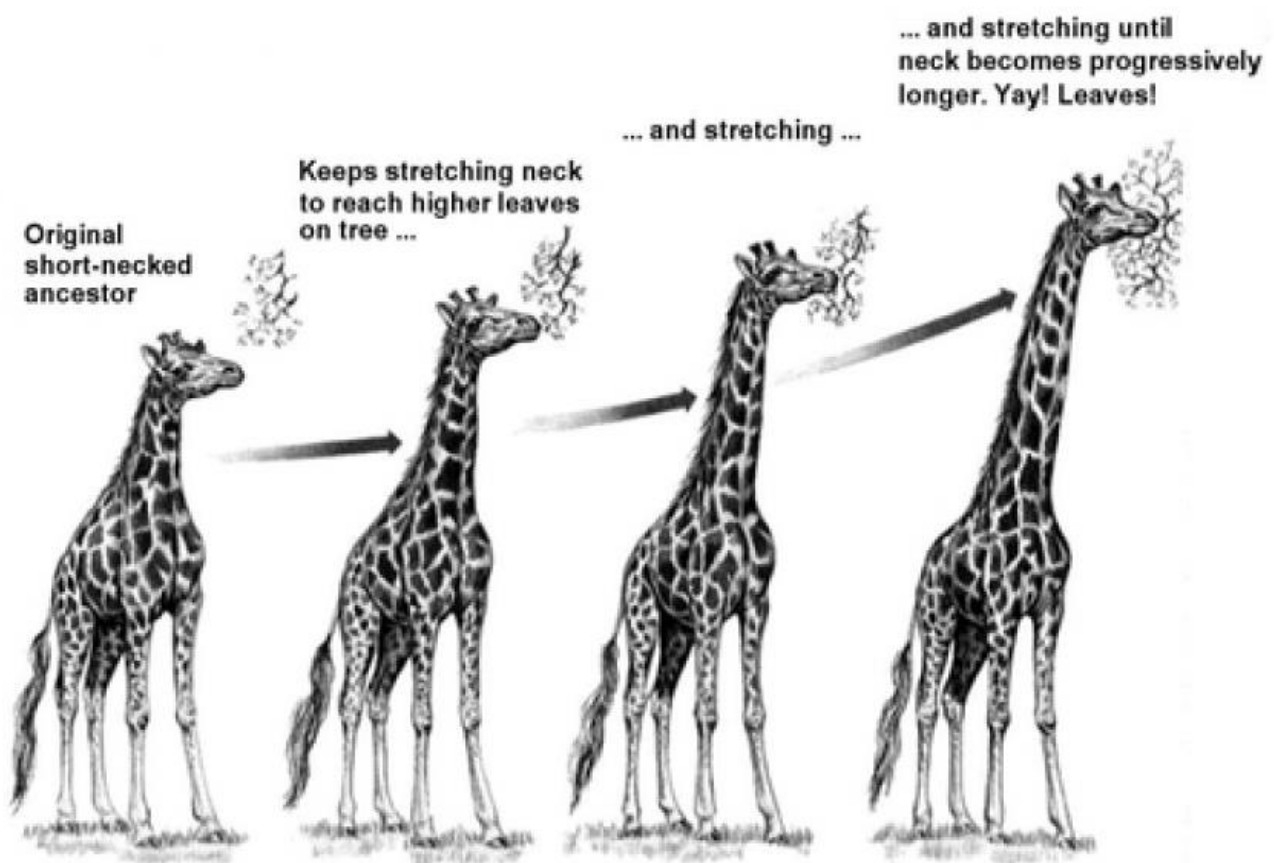
Comparative anatomy showed that these organs resembled those which were much more developed, with particular functions, in other species

### The Law of Use and Disuse

- He proposed that if an organ is used a lot it will develop and strengthen.
- If it is not used it will atrophy.
- He called this the law of use and disuse.

### The Inheritance of Acquired Characteristics

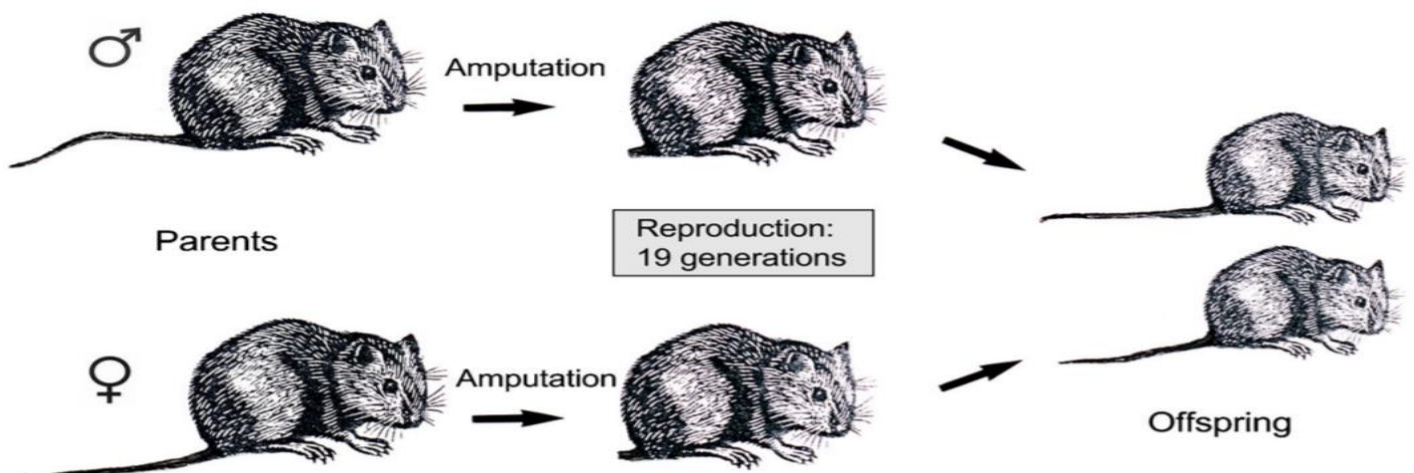
- If an organism developed a characteristic feature through adapting to a new way of life during its lifetime, it would pass this on to its offspring
- The classic example given is that of the giraffe's neck.
- As the giraffe's ancestors searched for a richer food supply they stretched to reach higher branches in trees.
- Thus their stretched bodies were passed onto their offspring.



**Lamarck's Giraffe**

### Rejection of Lamarckism

#### Weismann's theory of germ plasm (1896–1910)



- Characteristics acquired during the lifetime of a parent are not passed onto the offspring.
- Changes only in the germ cells/DNA are transferred to next generation.
- Modern genetics confirmed germ plasm theory.

## Lecture 81

### • History of Darwin and Voyage

**Charles Robert Darwin (1809–1882) in England.**

He joined school of medicine, Scotland in 1825 but he was not interested in being physician. Later he joined, Christ's College in Cambridge and graduated with honors in 1831. Instead of clergy training, he had been more involved in work of Cambridge's scientists, especially taxonomists. He made valuable contributions to beetle taxonomy. John Henslow nominated Darwin to serve as a naturalist on a mapping expedition that was to travel around the world. HMS Beagle set sail on December 27, 1831 on a 5-year voyage. Darwin helped with routine seafaring tasks and made numerous collections. Opportunity to explore tropical rain forests, fossil beds, the volcanic peaks of South America, and the coral atolls of the South Pacific. Most importantly, Darwin spent 5 weeks on the Galápagos Islands. A group of volcanic islands 900 km off the coast of Ecuador

Most revolutionary ideas came from his observations of plant and animal life on these islands.

On his return, it took " him 22 years to publish his history changing book " Origin of Species" in 1859.

## Lecture 82

### • Evidences of Theory of Natural Selection - 1

Darwin based his theory on many solid evidences from his observations and collected samples.

**Three major evidences:**

1. Geology
2. Fossil Evidences
3. Galápagos islands

**Geology**

- Darwin was impressed by Charles Lyell and James Hutton' s ideas of geology.
- Theory of uniformitarianism

**Theory states:**

Changes in the earth's crust throughout history have resulted from the action of uniform, continuous processes.

**Theory of uniformitarianism planted two ideas in Darwin's mind:**

- (1) The earth could be much older than 6,000 years.
- (2) If the face of the earth changed gradually over long periods, living forms also change during that time?

Gradual changes over the time with changing environment was foundation of theory of natural selection.

## Lecture 83

### • Evidences of Theory of Natural Selection - 2

**Fossil Evidences**

- Digging in riverbed of Pampas in Argentina
- Most of evidences of theory came from fossils

**He found fossil of:**

- Extinct hippopotamus like animal, now called Toxodon



- Horselike animal, Thoantherium

Horses had been present and had become extinct long ago in S. America.

They were introduced in 1500. There was sudden extinction without leaving descendant species.



- Giant extinct armadillo and present descendants
- Except for their large size, these fossils were very similar to forms Darwin found living in the region.
- Why would fossil remains and modern species found on the same continent resemble each other so closely?
- One species is replaced by an “allied” species geographically.
- Rhea in N. Argentina
- Replaced in south of the Rio Negro by a smaller, browner Rhea.

**He concluded:**

- Some species became extinct without leaving any descendants.
- Others became extinct, but not before giving rise to new species.
- Recent fossils are closely related to extant species.
- Adjacent layers in the fossil record contain similar organisms.

## Lecture 84

## • Evidences of Theory of Natural Selection - 3

### Galápagos Islands

Which are named after the large tortoises that inhabit them (Sp. galápagos, tortoise)

Darwin noticed that shapes of the tortoise shells from different parts of same Island differed. Tortoises from the drier regions had longer necks than tortoises from wetter habitats.

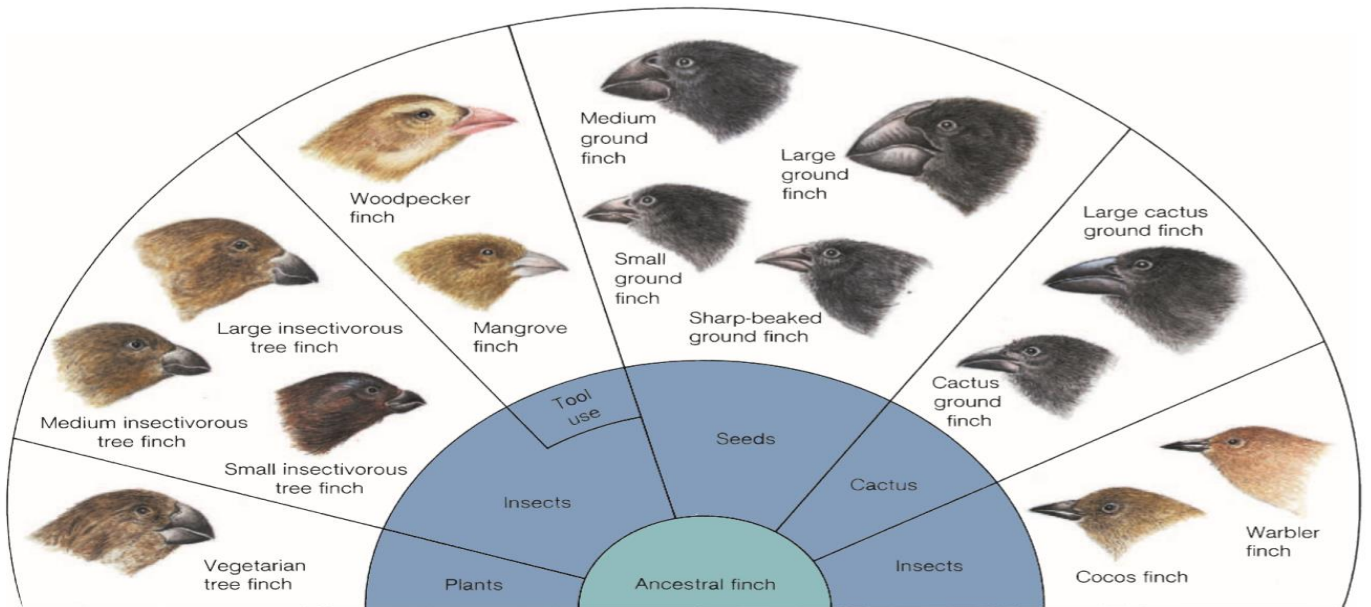
However, Islands’s tortoises were quite similar to each other and to the tortoises on the mainland of South America.

### Galápagos Finches

- Their similarities suggestive of common ancestry
- Chance arrival of a few finches probably set up the first bird populations on the islands.
- Early finches encountered habitat without other birds or predators.
- They were seed eaters and filled seed bearing habitats.
- 14 species of finches arose from this ancestral group.
- Each species is adapted to a specific habitat on the islands.

**The most obvious differences were in**

1. Dietary habits
2. Shape and size of bill



- Formation of new forms from an ancestral species, usually in response to the opening of new habitats.
- It is called adaptive radiations.

## Lecture 85

### • Theory of Natural selection-1

Based on his observations and collected data, Darwin proposed his theory of natural selection in form of "Origin of Species" in 1859.

**Theory has four major postulates.**

Each postulate describes the driving force behind evolution.

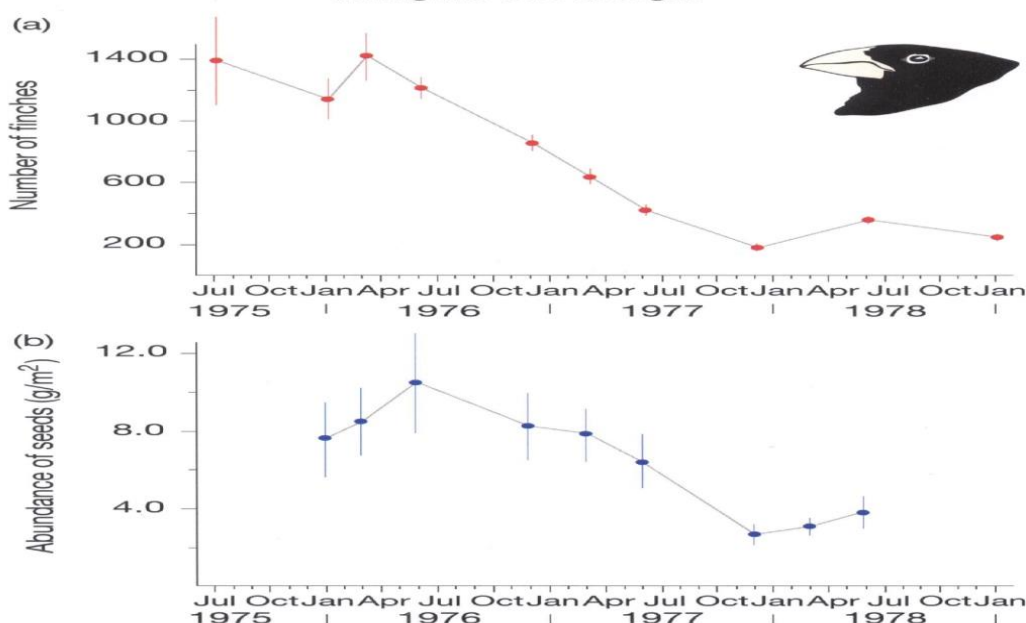
#### 1. Competition

- All organisms have a far greater reproductive potential than is ever realized.
- Example: Female sea star releases about 1 million eggs each season.
- What if all of these eggs were fertilized and developed to reproductive adults by the following year?
- Drastic increase in population size of each species
- Unimaginable resource problems in just a few years

**Limited resources and increasing population sizes create competition between individuals at:**

1. Intraspecific
2. Inter specific

T-15 Fig. 3.5 Decline of ground finch population and available seeds, during the 1977 drought



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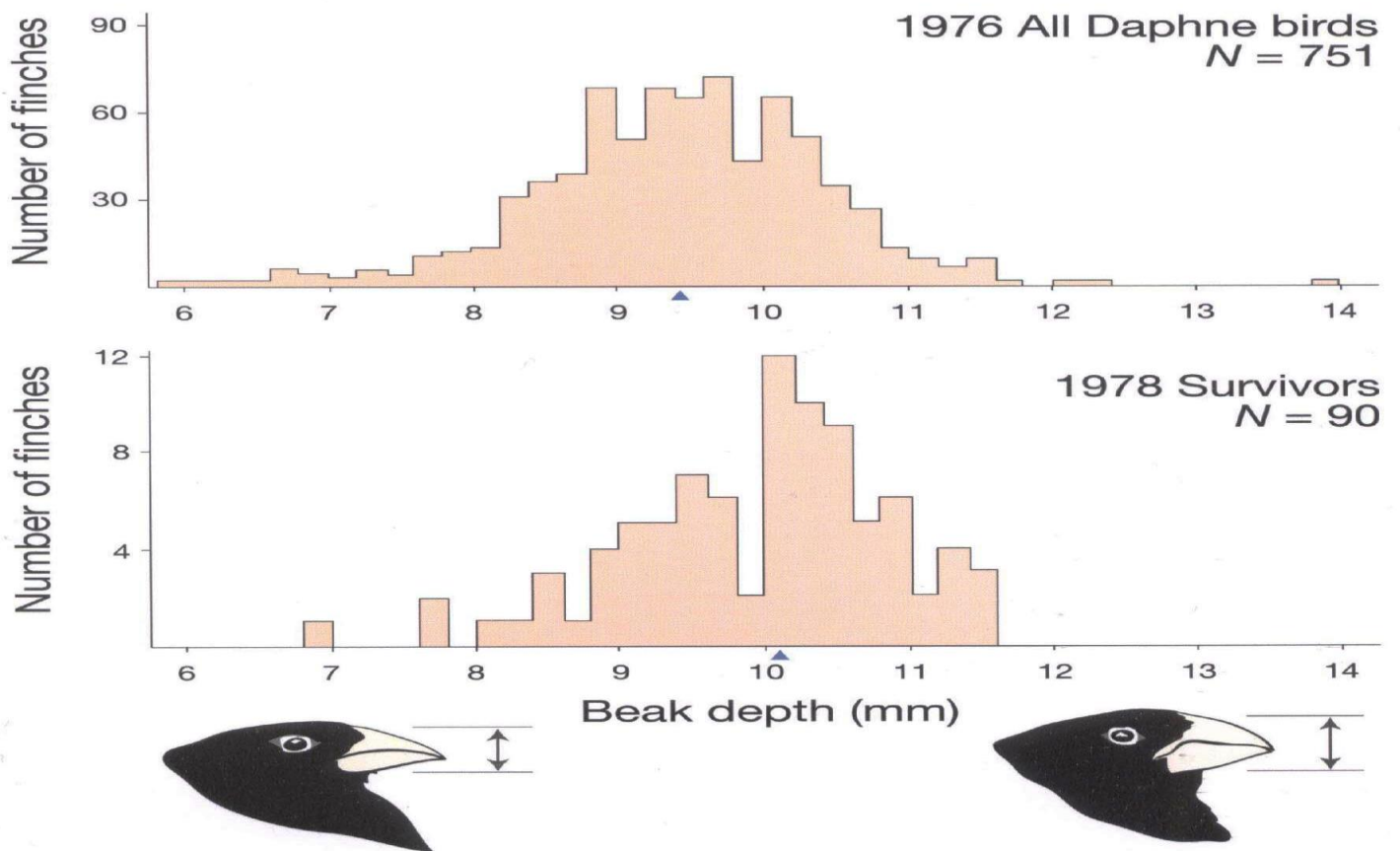
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## 2. Variations

- Individuals vary in traits directly related to their ability to survive and reproduce
- Inherited variations arise by random mutation.
- Seldom are any two individuals exactly alike.
- Variations can be advantageous or harmful.
- May be neither helpful nor harmful
- Variations can be passed on to offspring.

## DIFFERENTIAL SURVIVAL

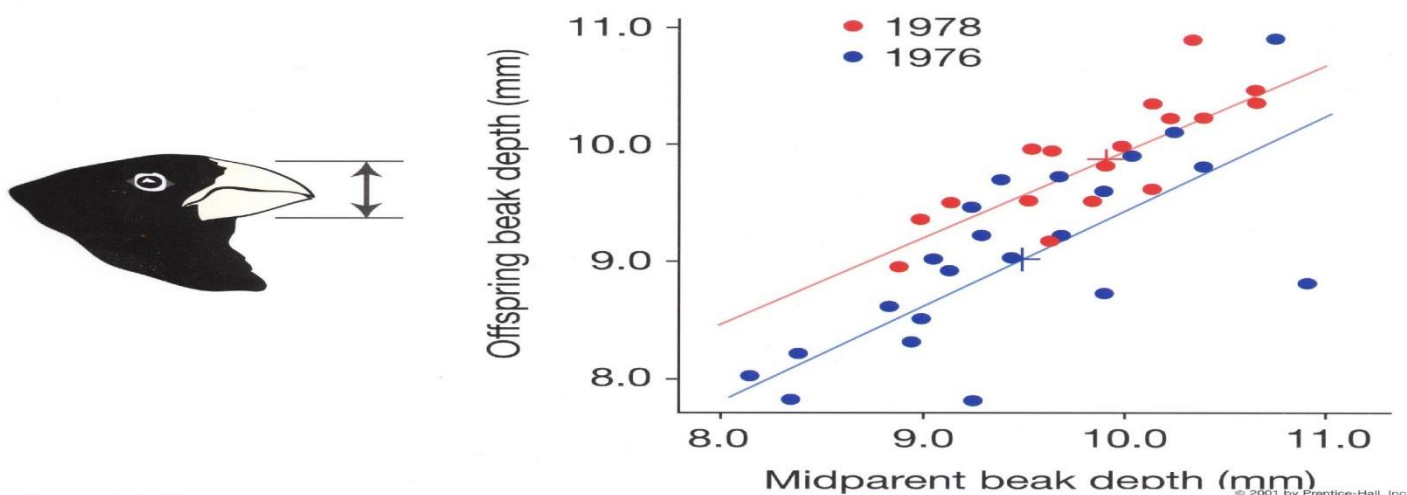
Fig. 3.6 Beak depth before and after natural selection



## VARIATION & HERITABILITY

T-14

Fig. 3.4 Heritability of beak depth in *Geospiza fortis*



- Mendel later suggested that genes are responsible for traits.
- Inheritance is carried out by transfer of genes.
- Independent assortment of alleles and crossing over bring variations.
- This confirmed the second postulate of Darwin.

**3. Survival of the Fittest**

- Because resources are limited, existence is a constant struggle.
- Higher rate of population growth causes depletion of resources.
- Therefore, many individuals die.
- Darwin reasoned that the individuals that die are those with the traits (variations) that make survival and successful reproduction less likely.
- Traits that promote successful reproduction are said to be adaptive.
- **Survival of the fittest**

**4. Transfer of adaptive traits to next generation**

- Adaptive traits are perpetuated in subsequent generations.
- Organisms with maladaptive traits are less likely to reproduce
- Maladaptive traits become less frequent in a population and eventually are eliminated.
- Process of selection is called as “Natural Selection”.
- Change in environment (climate, food shortage, other stressors) lead to extinction of ill-adapted species.

**Alfred Russel Wallace (1823-1913)**

- Co-discoverer of theory of natural selection
- Collection of data and specimens from amazon and Malay archipelago

**He proposed:**

- Population pressure on resources
- Variations in response to environmental changes

Both Wallace's and Darwin's papers were published in the Journal of the Proceedings of the Linnean Society in 1859.

**Differences from Darwin's theory**

- Every evolutionary modification was a product of selection.
- Therefore, had to be adaptive for the organism.
- However, Darwin did not insist on finding adaptive significance for every modification.

- **Adaptations are defined as:**
- Characteristics that increase the potential of an organism or species to successfully reproduce in a specified environment.
- Adaptation occurs when a change in a phenotype increases an animal's chance of successful reproduction.
- Change in environment is the force behind adaptations.
- It may result in the evolution of multiple new groups.
- To exploit the changed environment
- Adaptation is confused with fitness or adaptedness.

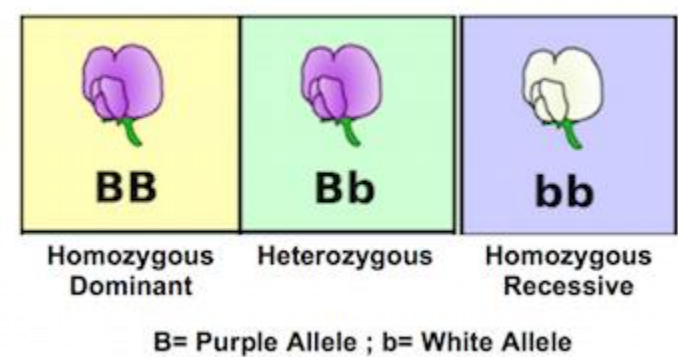
**Adaptedness or fitness:**

is a measure of the capacity for successful reproduction in a given environment.

- Not every characteristic is an adaptation to some kind of environmental situation.
- Neither adaptations lead to perfection.

- Genes of all traits are present in a population in form of alleles.

Example:



Stock of different genes in an interbreeding population is called as gene pool. This gene pool is transferred to next generation. But there can be outflow or inflow of genes in gene pool.

This change in gene frequency is called as genetic drift. The process of genetic drift is analogous to flipping a coin.

- Higher the number of trials, closer to ratio of 50:50.
- Smaller the number, disproportionate ratio like 70:30.

Chances of incorporation of two adaptive alleles into gametes is equal. Gamete sampling from small population may show unusual proportions of alleles in next generation.

- This is due to chance event like meiosis.
- These chance events may result in increasing or decreasing the frequency of alleles.

|                           | Loss of genetic diversity through genetic drift | Substitution of a new allele for an existing allele through genetic drift |
|---------------------------|-------------------------------------------------|---------------------------------------------------------------------------|
| Parental generation       | AA Aa Aa aa                                     | AA Aa Aa aa                                                               |
| Parental gametes          | $\frac{4}{8}$ A A A A<br>$\frac{4}{8}$ a a a a  | $\frac{3}{8}$ A A A<br>$\frac{1}{8}$ A'<br>$\frac{4}{8}$ a a a a          |
|                           | Chance selection of 8 gametes ↓                 | Chance selection of 8 gametes ↓                                           |
| F <sub>1</sub> generation | Aa Aa aa aa                                     | Aa A'a aa A'a                                                             |
| F <sub>1</sub> gametes    | $\frac{2}{8}$ A A<br>$\frac{6}{8}$ a a a a a    | $\frac{1}{8}$ A<br>$\frac{2}{8}$ A' A'<br>$\frac{5}{8}$ a a a a a         |
|                           | Chance selection of 8 gametes ↓                 | Chance selection of 8 gametes ↓                                           |
| F <sub>2</sub> generation | Aa aa aa aa                                     | A'a A'A' aa aa                                                            |
| F <sub>2</sub> gametes    | $\frac{1}{8}$ A<br>$\frac{7}{8}$ a a a a a a    | $\frac{3}{8}$ A' A' A'<br>$\frac{5}{8}$ a a a a a                         |

- In small populations, inbreeding is also common.
- Genetic drift and inbreeding are likely to reduce genetic variation within a population.

## Lecture 90

## • Effects of Genetic Drift

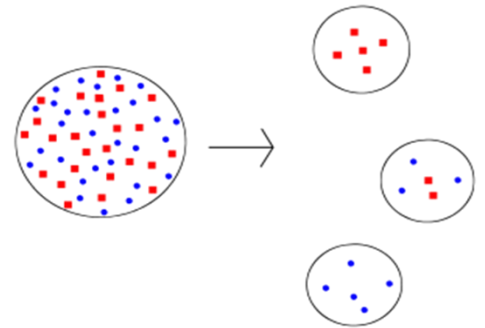
Two special cases of genetic drift have influenced the genetic makeup in a population.

1. **Founder Effect**
2. **Bottleneck Effect**

### Founder Effect

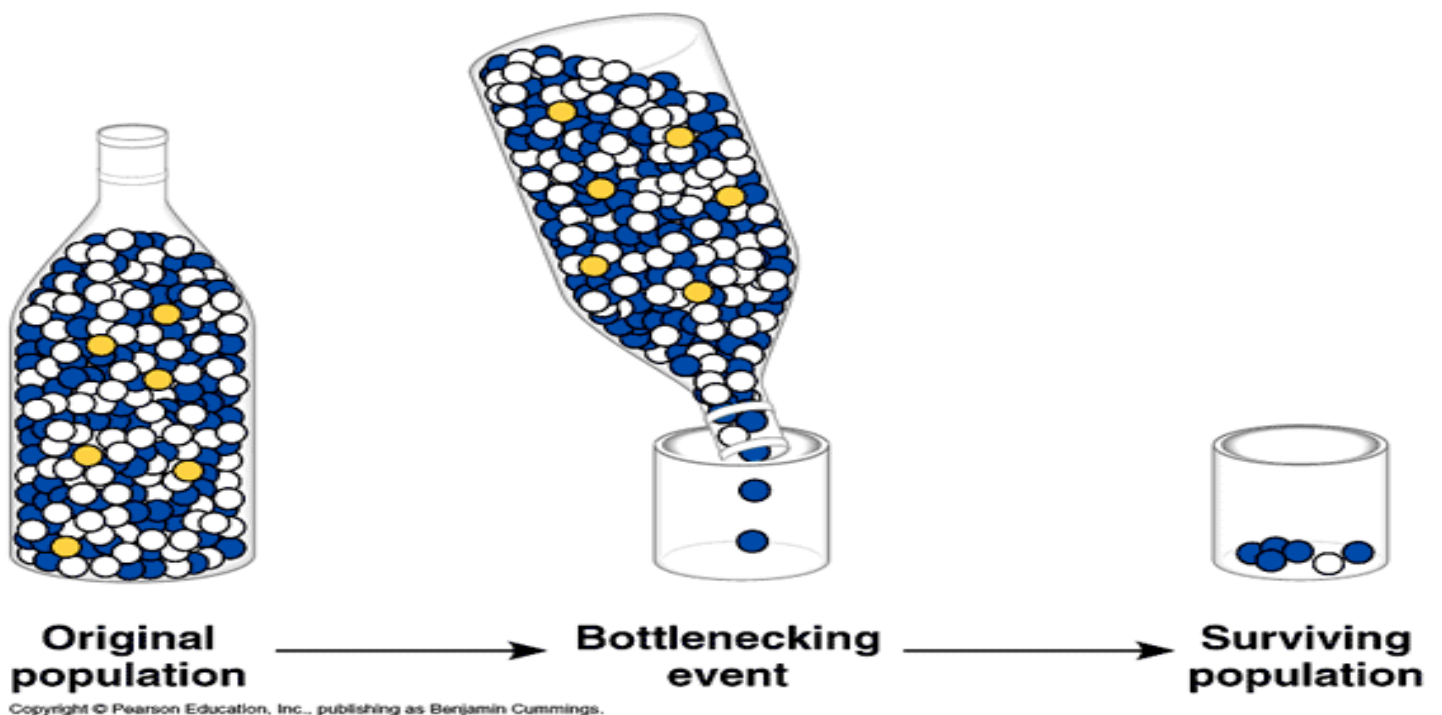
- When a few individuals from a parental population colonize new habitats.
- The new colony that emerges from the founding individuals is likely to have a distinctive genetic makeup
- Far less variation than the larger population

Founder effect: The original population (left) could give rise to different founder populations (right).



### Bottleneck Effect

- It occurs when number of individuals in a population is drastically reduced.
- Mostly by any disaster e.g. natural catastrophe, over hunting, habitat damage
- Survivors have gene pool not representing the initial population.



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- Decreases in genetic diversity make populations less likely to withstand environmental stress.
- More susceptible to extinction
- Decreases in genetic diversity make populations less likely to withstand environmental stress.
- More susceptible to extinction

## Lecture 91

## • Conditions of Natural Selection

### Conditions of natural selection

- Three conditions must be met for natural selection to occur.

#### 1. Variation must exist among individuals in a population.

Natural selection works by favoring individuals with some traits over individuals with alternative traits. If no variation exists, natural selection cannot operate.

## 2. Variation among individuals must result in differences in the number of offspring surviving in the next generation.

- Because of their phenotype or behavior
- Some individuals are more successful than others in producing offspring.
- Although many traits are phenotypically variable, individuals exhibiting variation do not always differ in survival and reproductive success.

## 3. Variation must be genetically inherited.

- For natural selection to result in evolutionary change, the selected differences must have a genetic basis.
- Not all variations has a genetic basis. It can be environmental.
- Even genetically identical individuals may be phenotypically quite distinctive if they grow up in different environments.
- When phenotypically different individuals do not differ genetically, no evolutionary change will have occurred.

## Lecture 92

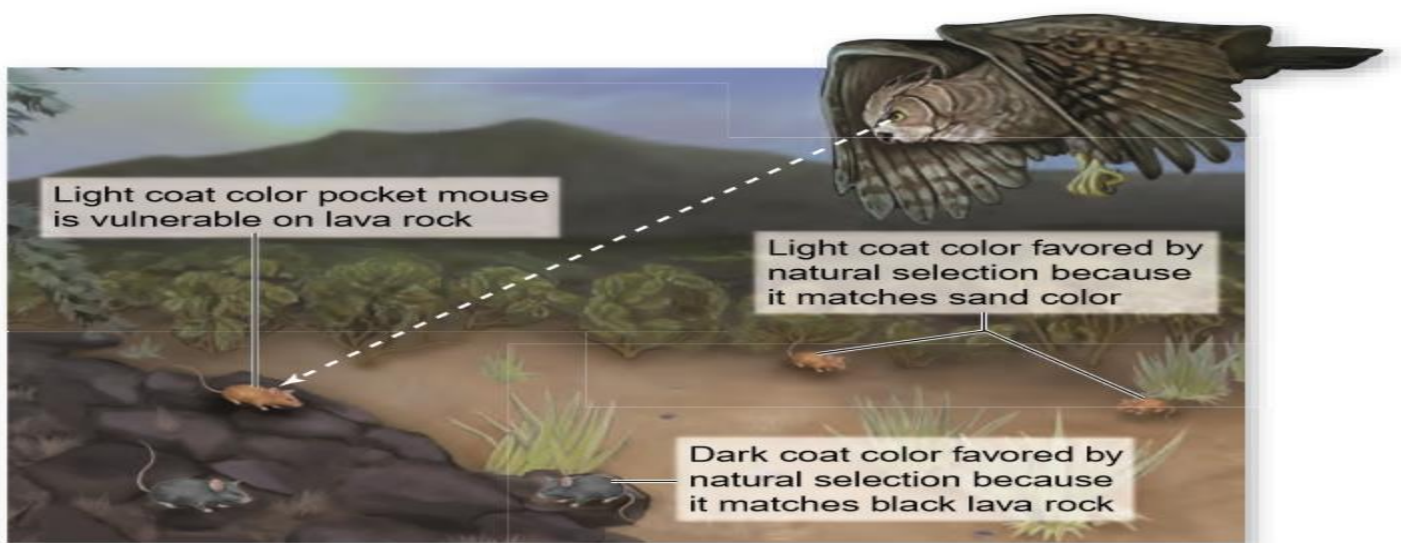
## • Selection for Surviving Adaptations

The result of evolution driven by natural selection is that:

Populations become better adapted to their environment. Many instances of adaptation involve genetic changes that decrease the probability of capture by a predator.

Example:

- **Black rocks formation in America South-west**
- **Black coat color supports animal to mimic the background.**
- **Lizards, rodents, and a variety of insects dwelling there are dark in color.**



Natural selection helps to adapt in different climate.

- Same trait but different intensity of expression

Example:

- **Enzyme lactate dehydrogenase**
- Catalyzes the conversion of pyruvate to lactate
- Different allele frequency in mummichog fish population in North and South.
- Form of enzyme in mummichog populations in North are better catalyst at low temperatures.
- As compared to south
- At low temperatures, individuals with the northern allele swim faster
- Survive better, than individuals with the alternative allele.

## Pesticide and microbial resistance

- The widespread use of insecticides has led to the rapid evolution of resistance in more than 500 pest species.

### Example: Housefly

- Resistance allele at the *pen* gene decreases the uptake of insecticide.
- Alleles at the *kdr* and *dld-r* genes decrease the number of target sites, thus decreasing the binding ability of the insecticide.
- That's how natural selection helps to survive better in environment.

## Lecture 93

### • Fitness and its Measurement

#### Fitness

- Fitness is quantified as reproductive success
- The number of surviving offspring left in the next generation.
- The most fit phenotype is simply the one that produces, on average, the greatest number of offspring.

#### Example:

##### Two phenotypes of toads

1. **Green**
2. **Brown**

Green leave average 4 offsprings

Brown leave average 2.5 offsprings

- By custom, the most fit phenotype is assigned a fitness value of 1.0.
- Fitness of the green phenotype would be  $4.0/4.0 = 1.000$
- Fitness of the brown phenotype would be  $2.5/4.0 = 0.625$ .
- The difference in fitness would therefore be

$$1.000 - 0.625 = 0.375$$

- Difference in fitness of 0.375 is quite large
- Natural selection in this case strongly favors the green phenotype.

#### Components of Fitness

- Survival
- Mating success
- Number of offspring per mating
- Predicting fitness from a single component can be tricky.
- As traits favored for one component of fitness may be at a disadvantage for others.

#### Example:

- In water strider (fish), larger females lay more eggs than smaller females.
- Larger females are supported by natural selection.
- But larger females die at younger age.
- Having fewer opportunities to reproduce than smaller females.

## Lecture 94

### • Interactions Among Evolutionary Forces

The amount of genetic variation in a population may be determined by the relative strength of different evolutionary processes. Sometimes these processes act together, and in other cases they work in opposition.

#### Mutation and genetic drift may counter selection

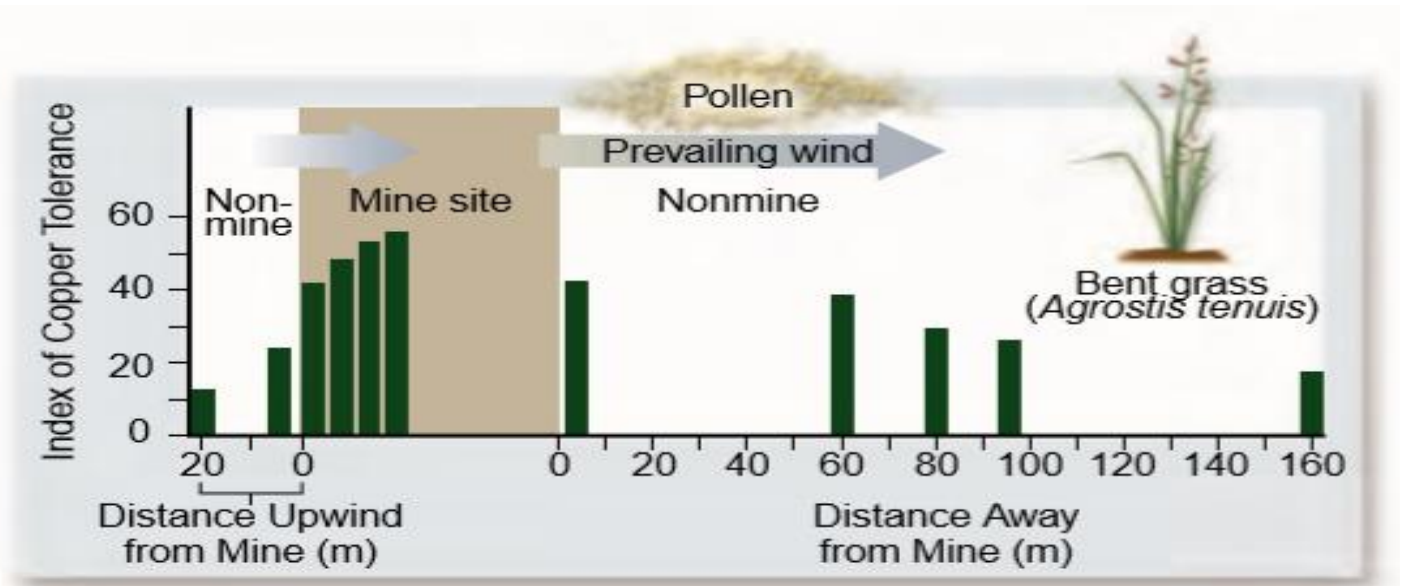
- Both genetic drift and natural selection remove alleles from population.
- Natural selection is non random
- It operates to increase the representation of alleles that enhance survival and reproductive success.
- Genetic drift is random.
- In which any allele may increase or depart the population.
- Sometimes, drift may lead to a decrease in the frequency of an allele that is favored by selection.
- Mutation may also counter natural selection.
- It may randomly decrease or increase the frequency of alleles.

#### Gene flow may promote or constrain evolutionary change

- Gene flow can be either a constructive or a constraining force.
- It can spread a beneficial mutation that arises in one population to other populations.
- Gene flow can impede adaptation within a population by the continual flow of inferior alleles from other populations.
- Natural selection is removing inferior alleles while gene flow can bring them back.

#### Example:

- **Heavy metals tolerance**



## Lecture 95

## • Maintenance of Variations - 1

Natural selection removes variation from a population by favoring one allele over others at a gene locus. However, in some circumstances, selection can do exactly the opposite.

It actually maintains population variation.

#### Frequency dependent selection

This type of selection favors certain phenotypes depending on how commonly or uncommonly they occur.

It has two types:

1. **Negative**
2. **Positive**

#### Negative frequency dependent selection

- Rare phenotypes are favored by selection
- Making them more common thus maintaining variation.

Reason:

- Commonly abundant animals are easy and recognized prey for predators.

- Animals having rare alleles for that trait will have higher chances to survive.

#### **Example:**

- Fish predation on an insect, the water boatman, which occurs in three different colors.
- Experiments indicate that each of the color types is preyed upon disproportionately.
- Fish eat more of the common-colored insects than uncommon colors.

#### **Positive frequency-dependent selection**

- Favours common forms
- It tends to eliminate variation from a population.

#### **Example:**

- Predators don't always select common individuals.
- Both positive and negative frequency dependent selections play their role in evolutionary processes.
- There cannot be a standard rule of selection around the globe for one trait.

## **Lecture 96**

## **• Maintenance of Variations-2**

### **Oscillating Selection**

- In some cases, selection favors one phenotype at one time and another phenotype at another time.

#### **Example:** Medium ground finches of the Galápagos Islands

- In times of drought, the supply of small, soft seeds is depleted.
- But there are still enough large seeds around.
- Consequently, birds with big bills are favored.
- However, when wet conditions return, the ensuing abundance of small seeds favors Oscillating Selection
- However, when wet conditions return, the ensuing abundance of small seeds favors birds with smaller bills.

### **Difference between oscillating and Frequency dependent selection**

- In oscillating selection, the fitness of a phenotype does not depend on its frequency.
- Rather, environmental changes lead to the oscillation in selection.
- In frequency dependent selection, it is the change in frequencies themselves.
- Fitness of the different phenotypes can vary according to their frequencies and environment.

### **Heterozygotes may exhibit greater fitness than homozygotes**

- Fitness favors individuals with copies of both alleles
- Works to maintain both alleles in the population

## **Lecture 97**

## **• Kinds of Selection**

- Traits are affected by more than one gene.
- Selection operates on all the genes.
- Influencing most strongly those that make the greatest contribution to the phenotype.

### **Three kinds of Selection**

1. Disruptive Selection

## 2. Directional Selection

## 3. Stabilizing Selection

### Disruptive Selection

- Selection acts to eliminate intermediate types

#### Example:

##### Different beak sizes of seed cracker finches

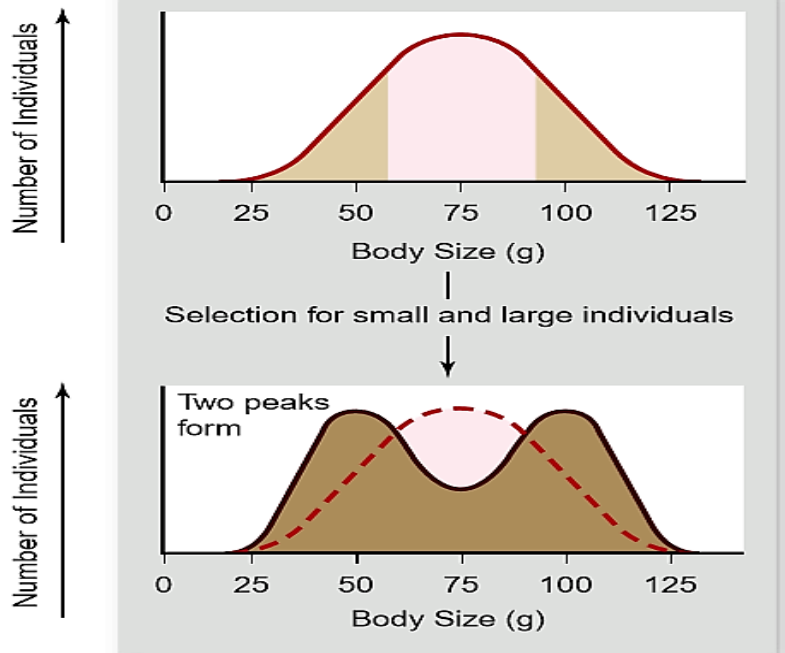
- Populations of these birds contain individuals with large and small beaks
- Very few individuals with intermediate-sized beaks
- Large beaked birds can open the tough shells of large seeds.
- Birds with the smaller beaks are more adept at handling small and soft seeds.
- Birds with intermediate-sized beaks are unable to open large and small seeds properly.
- Selection eliminates birds with intermediate-sized beaks.
- Disrupting the population into two phenotypically distinct groups; large and small.

### Directional Selection

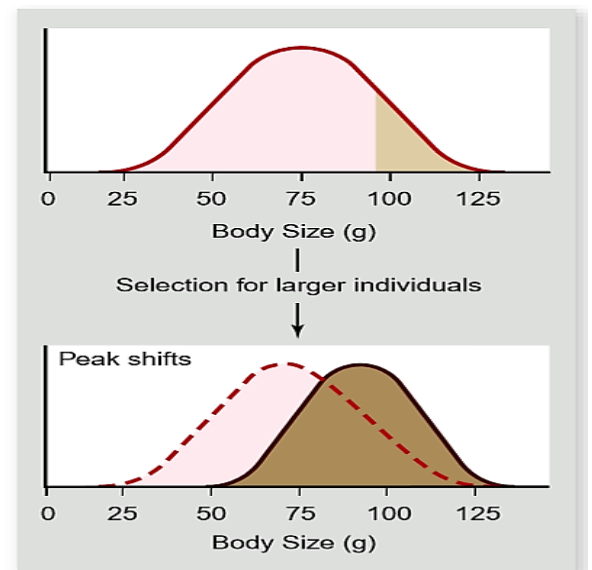
- Elimination of one extreme from an array of phenotypes
- Genes promoting this extreme become less frequent in the population
- Eventually disappear

### Stabilizing Selection

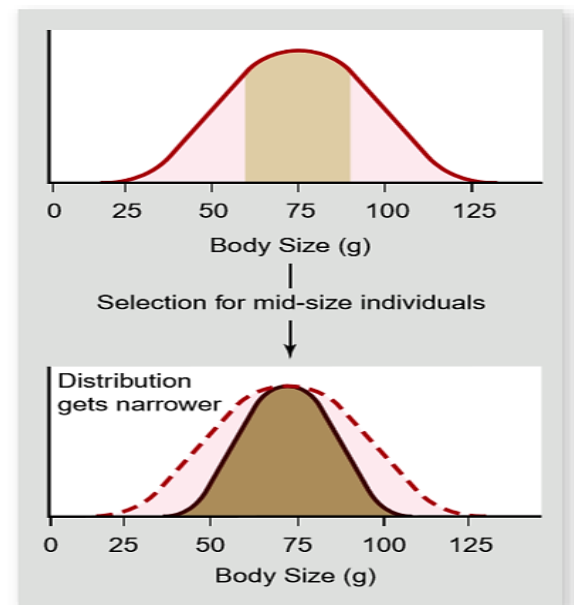
- Elimination of both extremes from an array of phenotypes
- Increase in frequency of the already common intermediate type
- No change in the most common phenotype of the population
- Making it even more common by eliminating extremes.



a. Disruptive selection



b. Directional selection



c. Stabilizing selection

## Lecture 98

### • Polymorphism

- Polymorphism occurs in a population when two or more distinct forms exist
- Without a range of phenotypes between them.

## Balanced Polymorphism

It occurs when different phenotypes are maintained at relatively stable frequencies in the population. Resemble a population in which disruptive selection operates.

### Example:

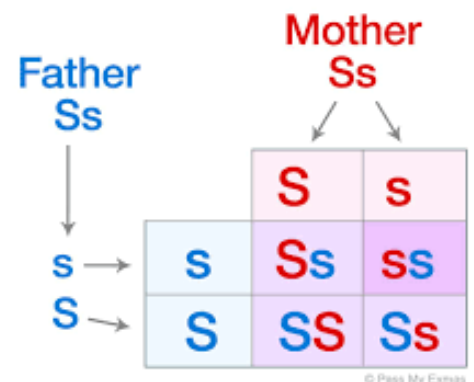
Sickle cell anemia is homozygous recessive trait.

Most common in Africa where malaria is common as well.

Heterozygous alleles carriers are less more susceptible to malaria.

Homozygous dominant alleles carriers are more susceptible to malaria.

Homozygous recessive alleles carriers have low survival due to anemia.



Therefore, heterozygous are more successful in survival and reproductive potential than two others.

- Heterozygote superiority
- It leads to balanced polymorphism
- Because perpetuation of the alleles in the heterozygous condition maintains both alleles at a higher frequency
- Frequency of homozygous phenotypes will be lower than heterozygous.
- This is Balanced polymorphism.

## Lecture 99

## • The Limits of Selection

Natural selection is the most powerful of the principal agents of genetic change. There are limits to what it can accomplish.

### 1. Evolution requires genetic variation

#### Example:

- Racing horses breeds by artificial breeding
- Performance has not much improved from 50 years.
- Artificial breeding might have removed variation from the population.
- Rate of mutation is slower to replenish it.
- Little genetic variation now remains
- Variations in phenotype
- No variation in genotype
- No variation means no evolutionary change

### 2. Gene interactions affect fitness of alleles

- Effect of one gene is dependent on the presence of one or more genes.
- Interaction between genes
- Gene encoding the enzyme that synthesizes penicillin cannot work alone.
- Gene encoding the enzymes that synthesize the necessary precursors in the metabolic pathway.
- One gene interacts with the other.
- Natural selection cannot favour one gene to over other

### 3. Genes have multiple effects

- Alleles often affect multiple aspects of a phenotype.
- Selecting for large clutch size in chickens eventually leads to eggs with thinner shells that break more easily.
- That's why we could never produce chickens that lay eggs twice as large as the best layers do now.

- Likewise, we cannot produce gigantic cattle that yield twice as much meat as our leading breeds.
- There are limits in selection (natural & artificial) due to genes interactions.

## Lecture 100

### • Speciation - 1

Species is a group of populations in which genes are actually, or potentially, exchanged through interbreeding.

**This definition has problems.**

**Taxonomists depend upon:**

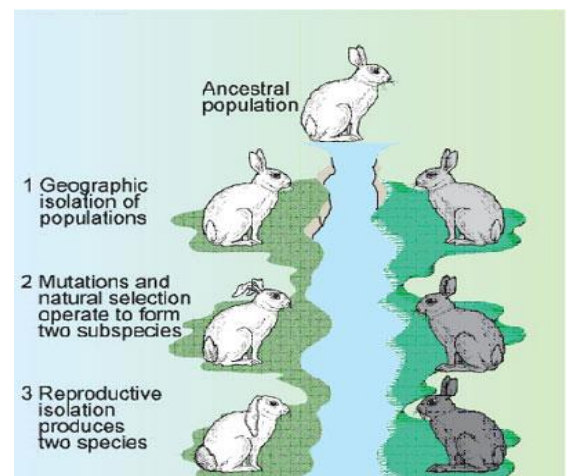
1. Morphological
2. Ecological information
  - Especially in case of fossils
  - Reproductive criteria are not fully examined.
  - Not all organisms reproduce sexually.
  - Different populations of same species are geographically isolated.
  - It is not easy to assess if they can interbreed.
  - Other criteria need to be applied in these cases.

**In describing species, taxonomists use following criteria:**

2. Morphological
  3. Physiological
  4. Embryological
  5. Behavioral
  6. Molecular
  7. Ecological
- Realizing that all of these have a genetic basis.

### Speciation

- Formation of new species.
- A requirement of speciation is that subpopulations are prevented from interbreeding.
- This is called reproductive isolation.
- No gene flow in case of reproductive isolation.
- Natural selection and genetic drift result in evolution in each sub population.



## Lecture 101

### • Speciation - 2

#### Ways of Reproductive Isolation

##### 1. Premating isolation

##### Geographical Isolation –

prevents mating from taking place

- Barriers, such as rivers or mountain ranges, may separate subpopulations.

##### Mechanical Isolation –

If courtship behavior patterns of two animals are not mutually appropriate for each other. Mating does not occur.

##### Temporal Isolation –

type of reproductive isolation due to reproducing at different times.

##### Behavioral Isolation –

- reproductive isolation due to differences in mating or courtship behavior.
- Even though they are able to physically interbreed.

**Example:** Different ways to decorate nests to attract females.

- **Satin bowerbird & MacGregor's Bowerbird**

### Ecological Isolation –

reproductive isolation due to living in different parts of the habitat (microhabitats)

- Rarely come in contact with each other
- Two closely-related birds of the *Turdus* genus
- Blackbird (*Turdus merula*)
- Ring ouzel (*Turdus torquatus*)
- Population of the blackbird is a woodland species.
- Ring ouzel is a moorland breeding species.
- Both are ecologically isolated and developed into two different species.

### 2. Postmating isolation

- Prevents successful fertilization and development
- Even though mating may have occurred.

**Example:**

- Conditions in the reproductive tract of a female may not support the sperm of male.
- Though successful fertilization

**Other kinds of postmating isolation:**

- Developmental failures of the fertilized egg or embryo
- Hybrids produced after rare mating of two different species

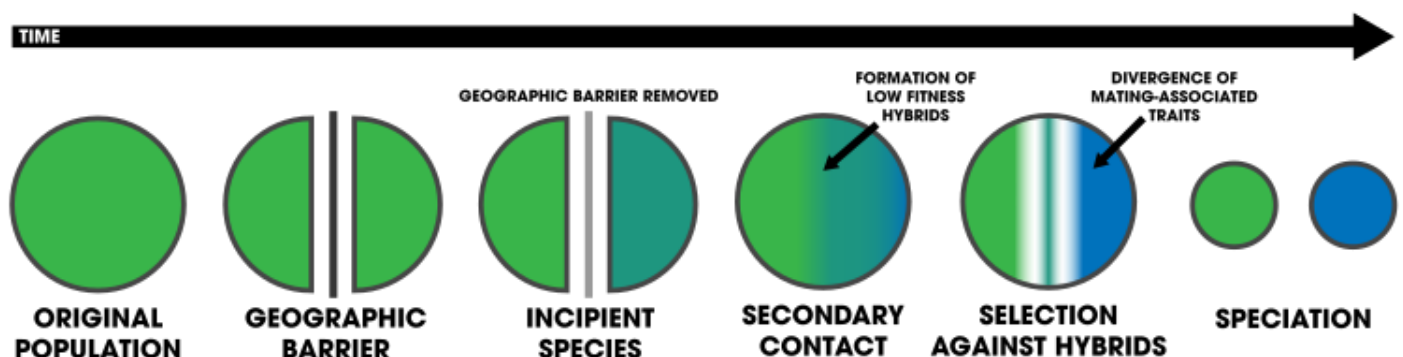
**Example:**

- Mule produced from a mating of a male donkey and a mare is a sterile hybrid.

## Lecture 102

### • Allopatric Speciation

- Geographical isolation of subpopulations from one another



In allopatric speciation, a species population becomes separated by a geographic barrier, whereby reproductive isolation evolves producing two separate species. From this, if a recently separated population comes in contact again, low fitness hybrids may form, but reinforcement acts to complete the speciation process.

- Classical example are Darwin's finches on the Galápagos Islands
- 14 species of finches evolved from the original seed eater finches from mainland.
- Populations became isolated on various islands over time
- Adapted to new habitats and available food resources
- Evolved into new species due to geographical isolation
- Mutations further increased variations.
- Natural selection favored the retention of the variations that promoted successful reproduction.

- Combined forces of isolation, mutation, and natural selection
- Allowed the finches to diverge into a number of species with specialized feeding habits.
- About 800 species of drosophilid flies in Hawaiian islands

## Lecture 103

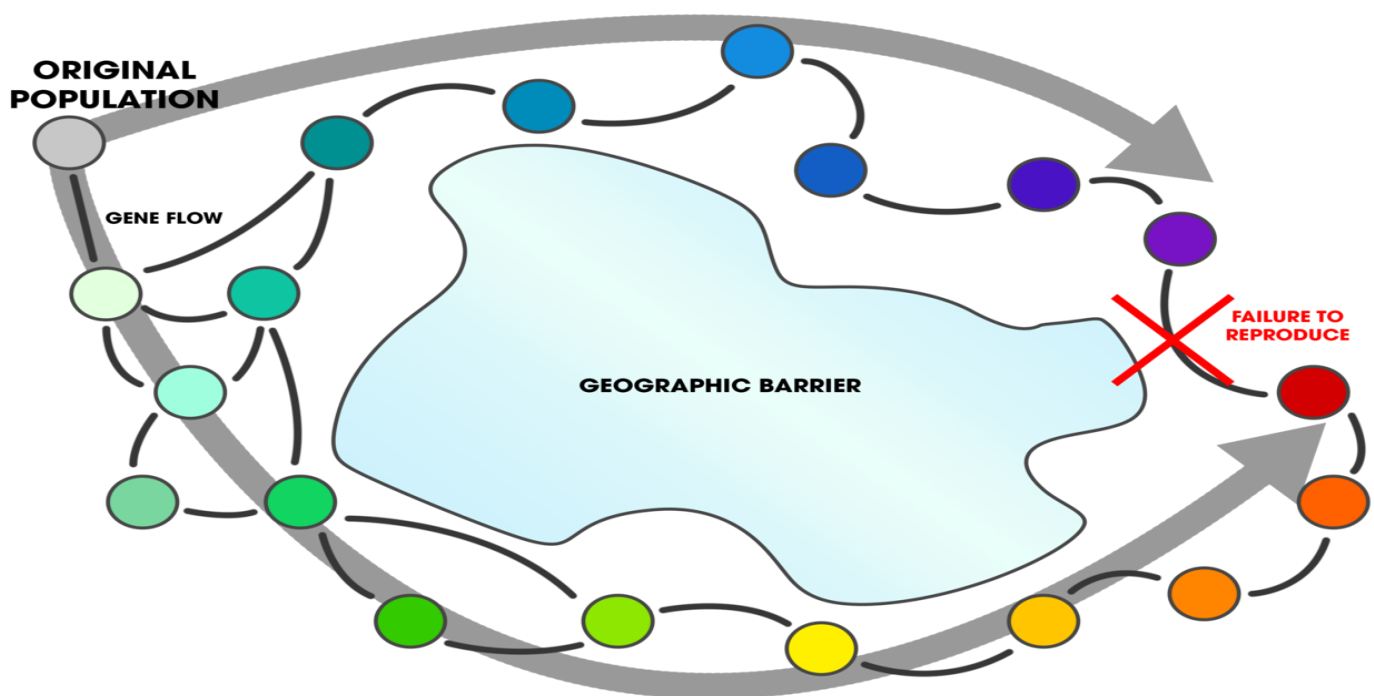
### • Parapatric Speciation

Occurs in small, local populations, called **demes**. All of the frogs in a particular pond or all of the sea urchins in a particular tidepool make up a deme. Individuals of a deme are more likely to breed with one another than with other individuals in the larger population.

They experience the same environment. They are subject to similar selection pressures. Demes are not completely isolated from each other. Individuals, gametes can move among demes of a population.

Exchange of genes continues. No certain cases of parapatric speciation are known.

Therefore considered of less importance in the evolution of animal groups than allopatric speciation.

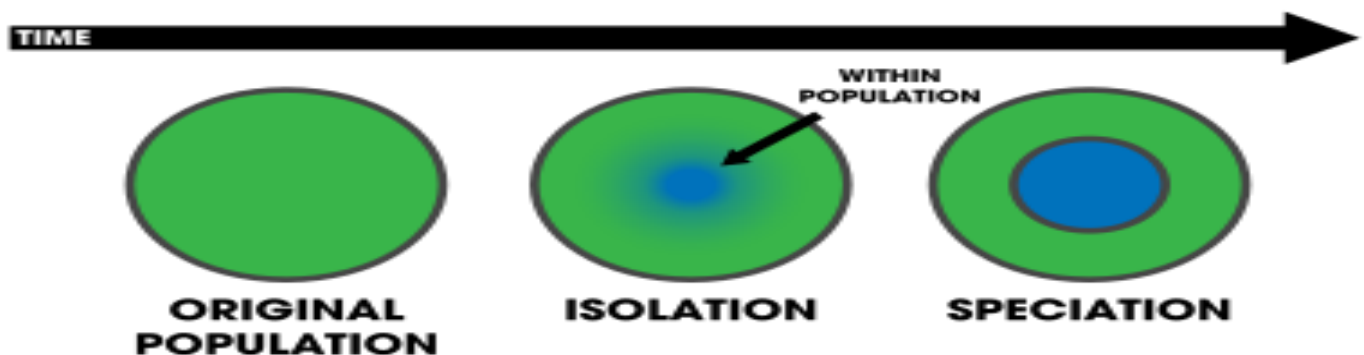


## Lecture 104

### • Sympatric Speciation

This speciation, occurs within a single population.

- Evolution of a new species from a surviving ancestral species
- While both continue to inhabit the same geographic region.
- Rarely occurs in plants.
- Uncommon in animals



Sometimes hybrids between two parental flowering plants are formed.

This can happen because plants can't choose their mate and way of pollination.

Hybrids may be sterile if paternal and maternal chromosomes are incompatible and cannot pair in meiosis.

But sometimes, chromosome sets “accidentally” double (polyploidy).

This doubling results in compatible partners.

Plants can self-pollinate, produce seeds, and so propagate: a new species has formed.

Between 30 and 50% of angiosperm plant species may have formed in this way.

**Examples:** wheat, tobacco, cotton, bananas, potatoes



*Mimulus lewisii*  
line LF10



*Mimulus cardinalis*  
line CE10

### Sympatric speciation in *Mimulus* flowers

- The two closely related flower species.
- One species is best adapted to bumblebee pollination
- Other to hummingbird pollination

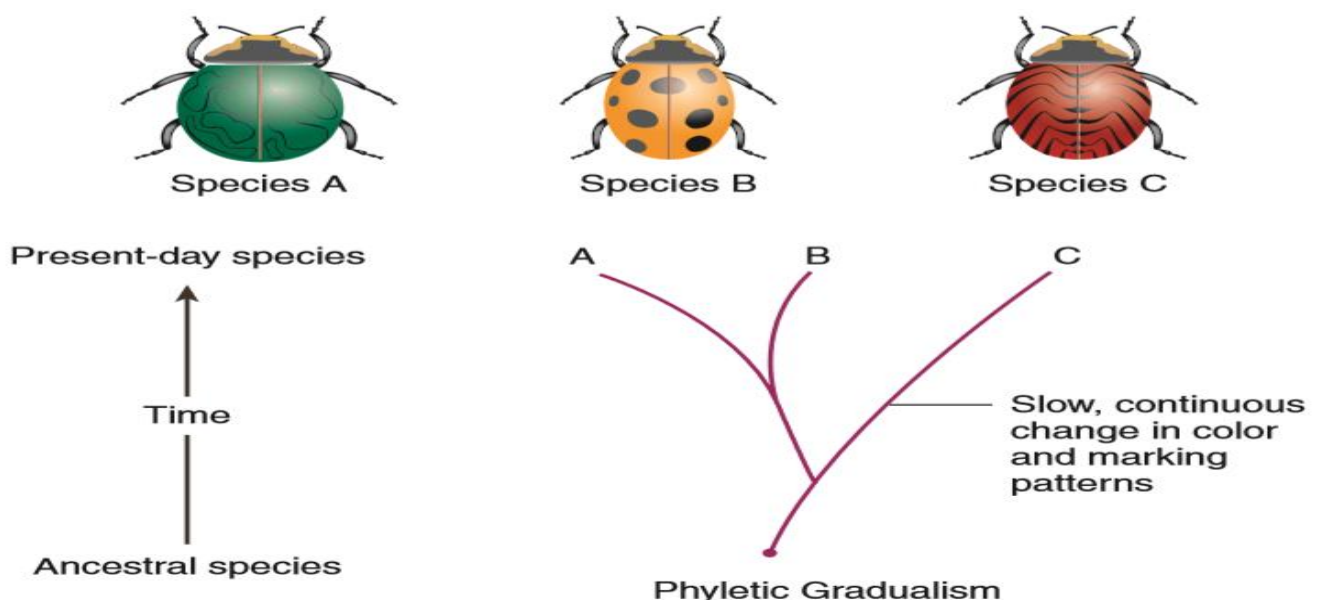
### Differences

- Morphology
- Placement of reproductive organs
- Colour
- Nectar content

## Lecture 105

## • Rates of Evolution

- Evolutionary changes are occurring gradually over millions of years.
- This concept, called phyletic gradualism.
- It has been the traditional interpretation of the tempo, or rate, of evolution.
- Species do not change significantly over millions of years.
- Periods of stasis or equilibrium



Stasis is interrupted by ecological crisis, such as a change in climate or a major geological event.

At this interruption, variation that previously was selectively neutral or disadvantageous might now be advantageous.

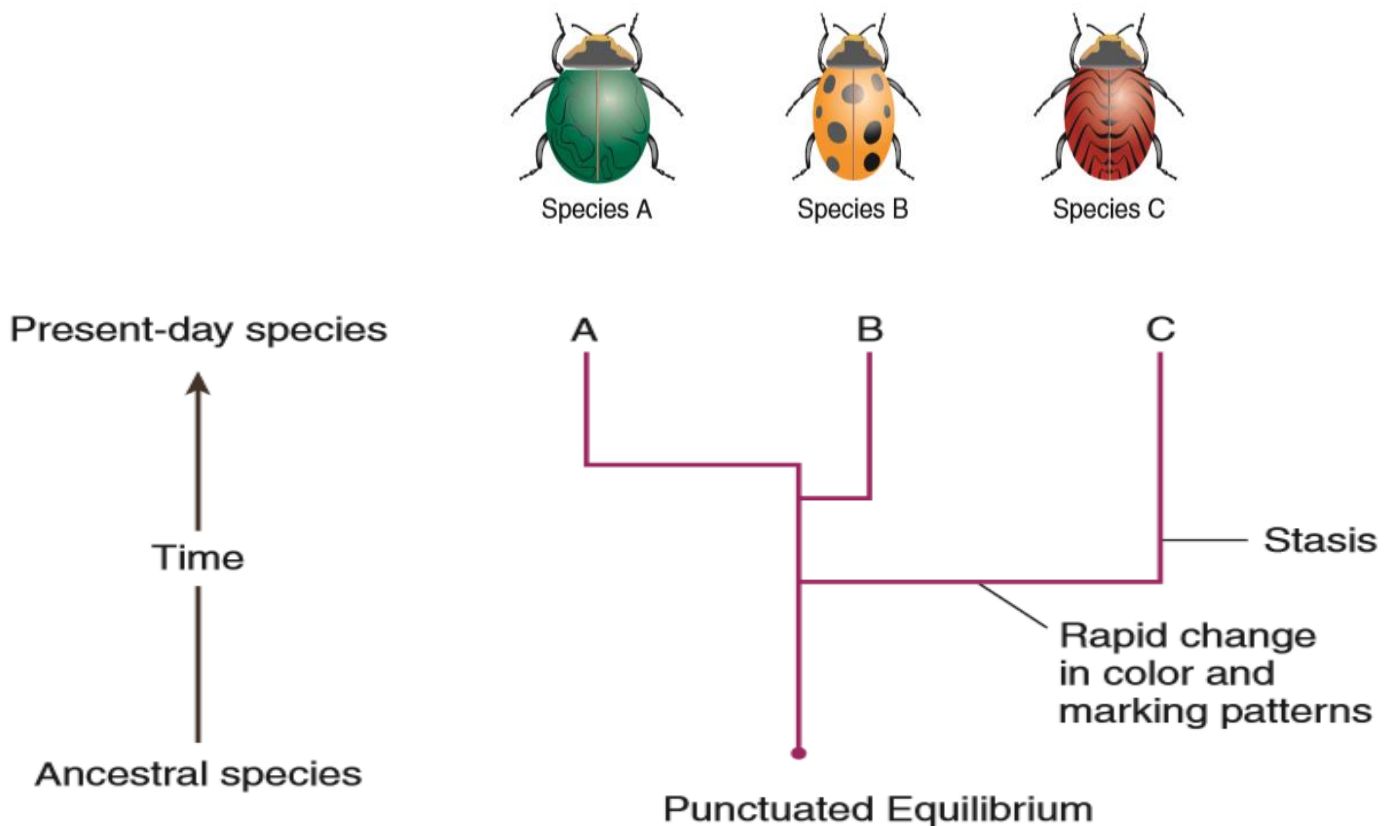
Geological events might result in new habitats becoming available.

Brief period of interruption punctuates long periods of stasis.

It is called as **punctuated equilibrium model of evolution**.

Stabilizing selection characterizes the periods of stasis.

Directional or disruptive selection characterizes the periods of change.



(b)

- Change is rapid over thousands of years.
- Transitional fossils are unlikely.

- Rapid evolutionary changes in small populations.

**Example:** rapid pesticide and antibiotic resistance

- Galapagos islands finches
- A long, dry period from the middle of 1976 to early January 1978 resulted in birds with larger, deeper bills.
- Over one year time period
- Initially, birds consumed smaller seeds.
- After depletion of small seeds, they had to eat large seeds.
- Small beaks developed into large beaks.
- This period of rapid change is followed by stasis again.
- It explains missing transitional stages in fossil record.

## Lecture 106

### • Molecular Evolution

- Evolutionary changes whether over long period or rapid are result of change in genetic make up.
- DNA

Changes in the base sequences in DNA and amino acids in proteins

*Cytochrome c* is a protein present in the cellular respiration pathways in all eukaryotic organisms.

Closely related organisms have similar *cytochrome c* molecules.

Structure of *cytochrome c* has changed so little during hundreds of millions of years.

It is said to have been conserved evolutionarily. Highly conserved proteins can help establish evolutionary relationships among distantly related organisms.

Not all proteins are conserved as rigorously as *cytochrome c*.

Less conserved proteins are useful for looking at relationships among more closely related animals.

## Lecture 107

### • Gene Duplication

Major mechanism through which new genetic material is generated during molecular evolution. Duplication of a region of DNA that contains a gene.

Products of several types of errors in DNA replication and repair machinery

Duplication of gene or whole genome

**Examples:**

#### 1. Aneuploidy

Nondisjunction at a single chromosome results in an abnormal number of chromosomes.

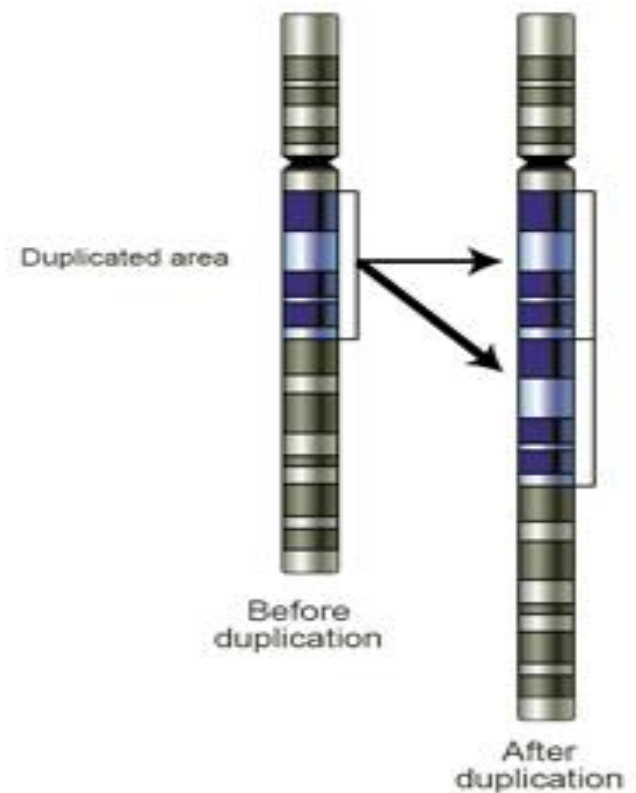
#### 2. Polyploidy

Product of nondisjunction during meiosis which results in additional copies of the entire genome.

#### 3. Replication Slippage

Error in DNA replication that can produce duplications of short genetic sequences.

There are other mutations as well.



## Lecture 108

### • Mosaic Evolution

A species is a mosaic of different molecules and structures that have evolved at different rates. Some molecules or structures are conserved in evolution.

Others change more rapidly. The basic design of a bird provides a simple example.

All birds are easily recognizable as they because of highly conserved structures

1. **Feathers**
2. **Bills**
3. **Body form**

Particular parts of birds, however, are less conservative and have a higher rate of change.

**Wings have been modified for:**

1. Hovering (humming bird)
2. Soaring (eagle, vulture)
3. Swimming (swans, ducks)

**Legs have been modified for:**

1. Wading (stork, heron)
2. Swimming (penguin, duck)
3. Perching (sparrow, parrot)

## Lecture 109

### • Systematics and Five Kingdom System

- Rich biodiversity
- Millions of animals, plants and microbes

- Need of a naming them
- Classification system

**In 1735, Carl Linnaeus, presented the criteria of classification:**

1. Similarities
2. Degree of evolutionary relatedness
3. In 1736, Linnaeus published a system of binomial nomenclature, still in use today.
4. Father of taxonomy

### Classification

Systematists develop classifications based on evolutionary relationships.

**They tend to look at:**

1. Anatomy - a traditional method.
2. Molecular data - to examine genetic similarities and differences.

### Old System of Classification

- **Three Kingdoms of nature:**

1. Plants
2. Animals
3. Minerals

### Two Kingdom System

- **Linnaeus divided all living things into two kingdoms:**

1. Plants
2. Animals

### Analogous structures:

### Solutions to a common challenge

### Homologous structures:

### Inherited similarities

- Up until the 1960's, textbooks used the 2 Kingdom System to describe the living world.
- Linnaeus developed his system at a time when the microbial world was a new discovery.
- Many one-celled organisms, such as Euglena, don't fit well in a 2 Kingdom system.

### Three Kingdom System

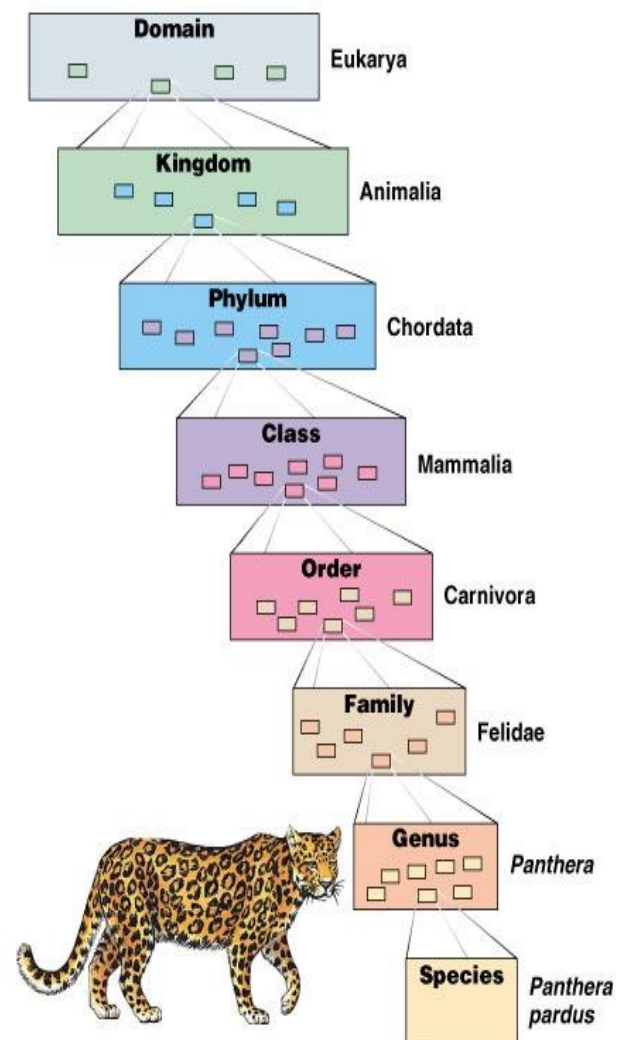
Robert Whittaker, working in the 1940s-70s, was dissatisfied with the old 2-kingdom systems.

- **Developed first a 3-kingdom system**

1. Fungi
2. Plants
3. Animals

### Later a 5-kingdom system

### Five Kingdom System



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1. Bacteria
2. Protists
3. Fungi
4. Plants
5. Animals

**This system is in use now.**

### Three Domain System

1. Archaea
2. Bacteria
3. Eukarya

### Binomial Nomenclature

The binomial system of nomenclature brings order to a chaotic world of common names.

Common names vary from country to country, and from region to region within a country.

There was need of globally recognized names.

In binomial system, no two kinds of animals have the same binomial name.

Every scientific name has two parts:

1. First from genus
2. Second from species

Names are written in italics

#### Example:

Common name: Indian frog

Genus name: Rana

Species name: tigrina

Scientific name: *Rana tigrina*

- This scientific name is universally accepted.

## Lecture 110

## • Cladistics

### Systematics

It is to arrange animals into groups that reflect evolutionary relationships.

### Three types of groups

#### 1. Monophyletic Groups

These groups should include a single ancestral species and all of its descendants.

#### 2. Polyphyletic groups

These have members that can be traced to separate ancestors. Since each group should have a single ancestor, a polyphyletic group reflects insufficient knowledge of the group.

#### 3. Paraphyletic Group

They include some, but not all, members of a lineage. Paraphyletic groups also result when knowledge of the group is insufficient.

## Phylogenetic systematics (cladistics)

- Cladists differentiate between homologies and analogies.
- Homologies of recent origin are most useful in phylogenetic studies.
- Characters that all members of a group share are referred to as symplesiomorphies.
- To decide what character is ancestral for a group of organisms, cladists look for a related group of organisms, called an outgroup.
- Characters that have arisen since common ancestry with the outgroup are called derived characters or synapomorphies.
- The hypothetical lineage shown in figure is called a **cladogram**.
- Cladograms depict a sequence in the origin of derived characters.

## Lecture 111

## • Domain Archaea

### “ancient” bacteria

Some of the first archaeobacteria were discovered in Yellowstone National Park’s hot springs and geysers. They live in extreme environments (like hot springs or salty lakes).

or normal environments (like soil and ocean water).

All are unicellular. No peptidoglycan in their cell wall. Some have a flagella that aids in their locomotion.

Most don’t need oxygen to survive

They can produce ATP from sunlight

They can survive enormous temperature and pressure extremes.

They can survive high doses of radiation

They can survive under rocks and in ocean floor vents deep below the ocean’s surface.

### Types

1. Methanogens
2. Thermoacidophiles
3. Halophiles

#### 1. Methanogens

- They release methane (CH<sub>4</sub>) as a waste product
- Many live in mud at the bottom of lakes and swamps because it lacks oxygen
- Some live in the intestinal tracts of animals to help break down food.
- They could play a role in garbage/sewage cleanup by eating garbage.

#### 2. Thermoacidophiles

- Live in the dark
- Live without oxygen
- Like to live in superheated water with temperatures reaching 750°F
- Prefer environments that are very acidic (between pH of 1-3)
- Live in a chemical soup of hydrogen sulfide (H<sub>2</sub>S) and other dissolved minerals.

#### 3. Halophiles

Halo = salt

phil = loving

- Can live in water with salt concentrations exceeding 15%.
- The ocean’s concentration is roughly 4%.
- One habitat of halophils is Great Salt Lake.
- actually three to five times saltier than the ocean.
- Great Salt Lake is actually three to five times saltier than the ocean.

2.5 million tons of sodium chloride is extracted from the lake.

Prokaryote

No membranous organelles

**Classified in three types:**

1. Cyanobacteria
2. Spirochaetes
3. Actinobacteria

**1. Cyanobacteria**

- Photosynthesizing bacteria that are related to the chloroplasts of eukaryotic plants and algae
- Also known as blue green algae
- Produce energy by photosynthesis
- They have flattened sacs called thylakoids where photosynthesis is performed.

**Symbiotic Relationships**

- Cyanobacteria can fix atmospheric nitrogen in anaerobic conditions.
- Symbiotic relationship with leguminous plants roots.
- Nitrogen gas is converted into ammonia ( $\text{NH}_3$ ), nitrites ( $\text{NO}_2$ ) or nitrates ( $\text{NO}_3$ ) to be available for plants.

**2. Spirochaetes**

- Gram-negative bacteria that include those causing syphilis and Lyme disease
- Double membrane bacteria, most of which have long, helically coiled.
- Chemoheterotrophic ; obtaining energy from oxidation

**3. Actinobacteria**

- Gram-positive bacteria
- Great economic importance
- Decompose the organic matter of dead organisms
- Cause diseases
- Streptomyces species, are recognized as the producers of many bioactive metabolites:
- Anti bacterial
- Antifungals
- Antivirals
- Anti thrombotics
- Immunomodifiers
- Antitumor drugs
- Enzyme inhibitors
- In agriculture, including insecticides, herbicides, fungicides

**Bacteria**

- Average bacteria 0.5 - 2.0  $\mu\text{m}$  in diameter.
- Surface Area  $\sim 12 \mu\text{m}^2$
- Volume is  $\sim 4 \mu\text{m}^3$
- Surface Area to Volume is 3:1



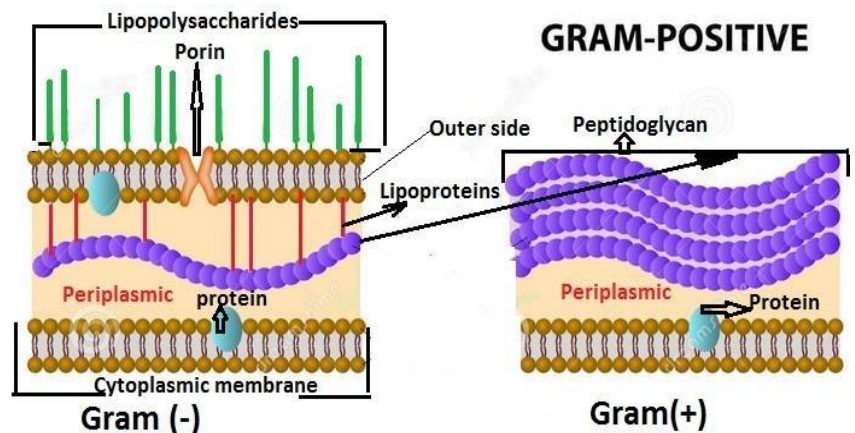
- Gel-like matrix of water, enzymes, nutrients, wastes and gases and contains cell structures like numerous ribosomes and polysomes.
- No endoplasmic reticulum and no membrane bound organelles.
- Location of growth, metabolism, and replication.

### Plasma Membrane

- Protection of cell contents
- Thin and elastic semipermeable membrane
- Made up of proteins embedded in two layers of lipids (lipid bilayer model)
- Cell motility
- Exchange of materials

### Cell Wall

- Peptido-glycan Polymer (amino acids + sugars)
  - Unique to bacteria
  - Sugars; NAG & NAM
1. **N-acetyl glucosamine**
  2. **N-acetyl muramic acid**
- Hard to break down
  - Amino acids cross link NAG & NAM



### Ribosomes

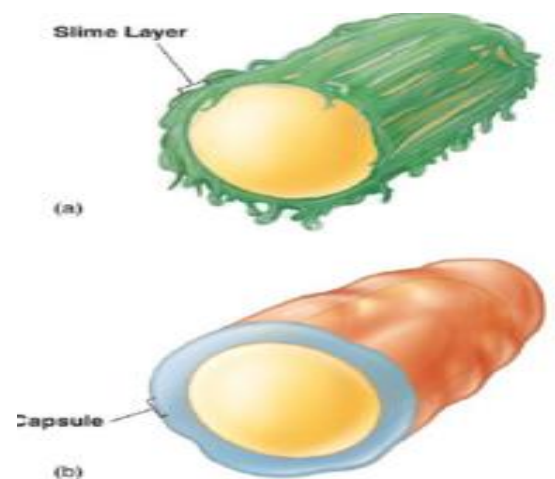
- Involved in protein synthesis
- Different from host cell ribosomes in SR.

### 3 types of RNAs:

- Ribosomal, transfer, mRNA
- Found within cytoplasm or attached to plasma membrane

### Glycocalyx

- Polysaccharides firmly attached to the cell wall.
- It exists either as capsule or slime layer.
- Capsules adhere to solid surfaces and to nutrients in the environment.
- Capsule also protect bacteria from being phagocitized by cells of the hosts immune system.



## Lecture 114

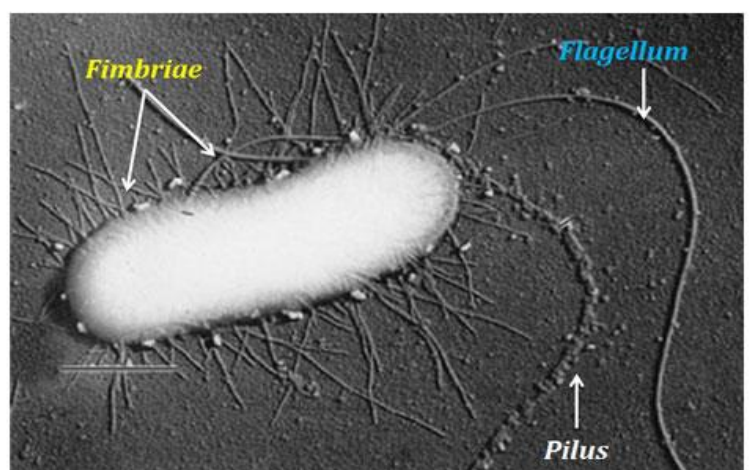
## • Structure and Function of Prokaryotic Cell-2

### Flagella

- Motility - movement

### Arrangement basis for classification

1. **Monotrichous**; one flagella
2. **Lophotrichous**; tuft at one end
3. **Amphitrichous**; both ends
4. **Peritrichous**; all around bacteria.



## Pili

- Short protein appendages smaller than flagella
- Made up of protein pilin
- Length is 0.5 – 2  $\mu\text{m}$ .
- Number is 1 – 10 per cell.
- Used in conjugation for exchange of genetic material.

## Endospores

- Dormant, tough, and non-reproductive structure produced by some bacteria
- Do not need nutrients to survive, may survive millions of years
- Resistant to heat, irradiation and cold
- Boiling > 1 hour still viable
- Takes time and energy to destroy spores

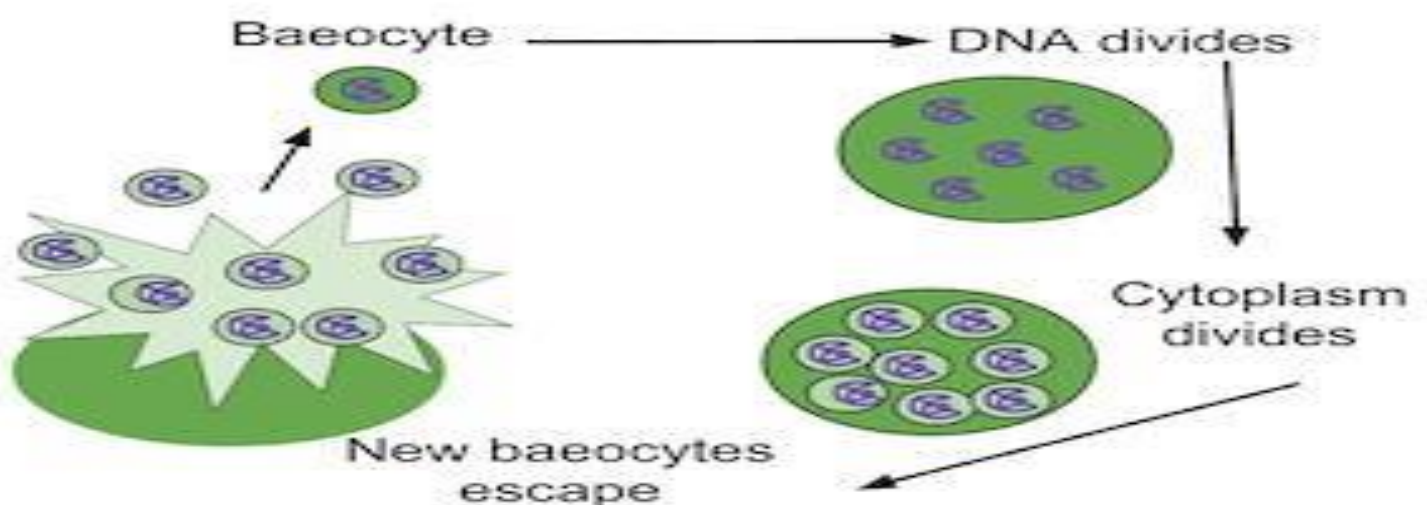
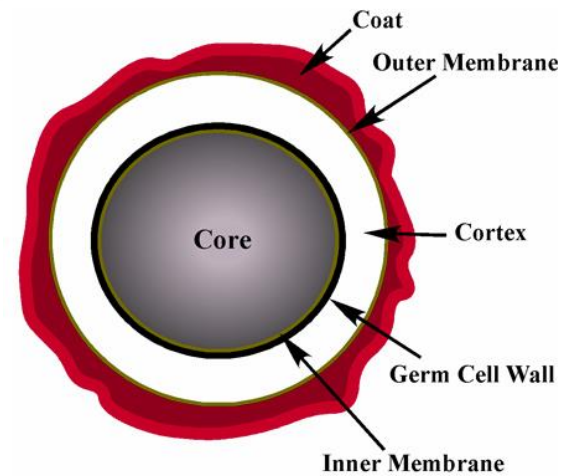
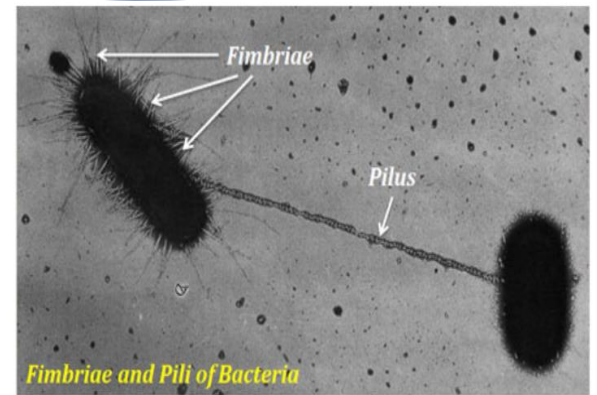
## Reproduction

### Asexual reproduction

1. Binary fission
2. Multiple fission

### Sexual reproduction

1. Conjugation



## Lecture 115

## • Domain Eukaryota

- Organisms whose cells have a nucleus enclosed within membranes.
- Contain other membrane-bound organelles such as mitochondria and the Golgi apparatus.
- Can be multicellular unlike to other domains.
- Cells make different types of tissues and systems
- Animals and plants are common examples.
- Evolved 2.7 billion years ago

## Classification

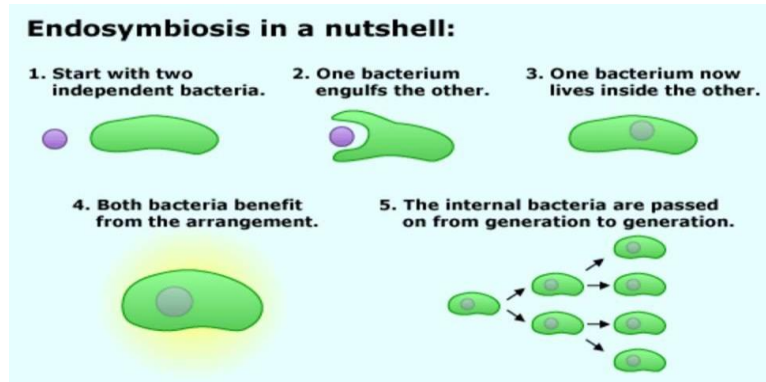
1. Kingdom Protista (unicellular eukaryotes)
2. Kingdom Plantae
3. Kingdom Fungi

#### 4. Kingdom Animalia

### Origin of Eukaryotic Cells

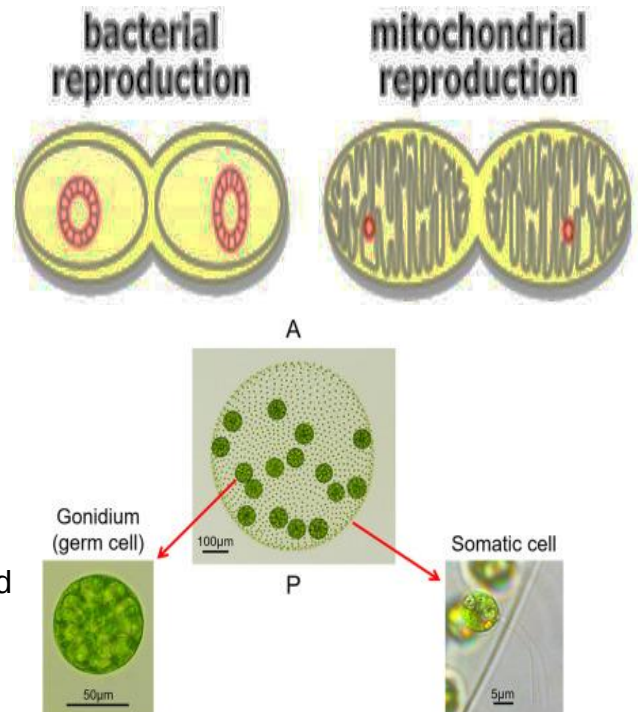
#### Endosymbiotic Theory

- Chloroplasts and Mitochondria evolved from symbiotic bacteria that lived inside of a larger prokaryote.
- Also known as Symbiogenesis
- Chloroplasts evolved from endocytosis of cyanobacteria
- Mitochondria evolved from endocytosis of aerobic bacteria.



#### Evidence of evolution of mitochondria

- Membranes- Have double cell membranes
- DNA- Have circular DNA, like bacterial genome
- Reproduction- via budding, just like bacteria
- Size- similar size to bacteria (1-10 microns)
- Multicellularity
- Cell specialization, larger size, more complexity
- Volvox algae with division of labor



#### Two types of cell functions

1. Swimming (somatic cells)
2. Reproduction (gonidium)

Multicellularity became more complex in kingdom animalia and plantae.

## Lecture 116

# • Nucleus

### Nucleus

The nucleus is an organelle found in eukaryotic cells. Inside its fully enclosed nuclear membrane, it contains the majority of the cell's genetic material. This material is organized as DNA molecules, along with a variety of proteins, to form chromosomes.

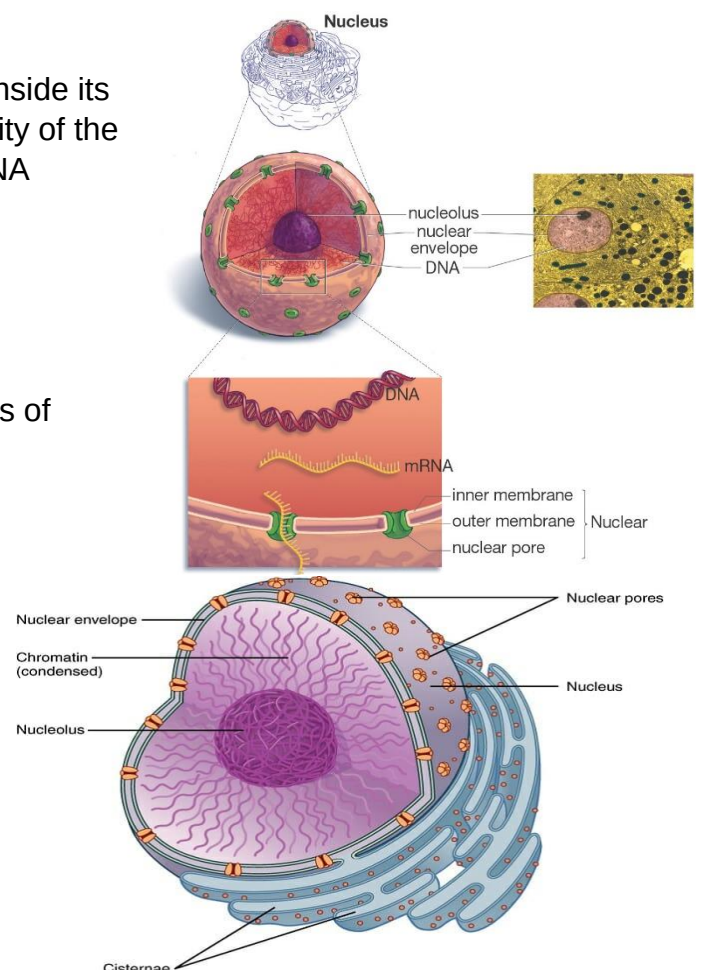
#### What is nucleus made up of?

1. The nuclear envelope
2. Nucleoplasm and Chromatin (two major types of material)
3. The nucleolus
4. DNA

Two meters of human DNA fits into a nucleus that's 0.000005 meters across.

#### Nuclear Envelope or Membrane

- The nuclear envelope is a double-layered membrane
- Perforated with pores, which control the flow of material going in and out of the nucleus.



- The outer layer is connected to the endoplasmic reticulum, communicating with the cytoplasm of the cell.
- The exchange of the large molecules (protein and RNA) between the nucleus and cytoplasm happens here.

### Nucleoplasm

- A jelly-like (made mostly of water) matrix within the nucleus
- All the other materials “float” inside
- Helps the nucleus keep its shape and serves as the median for the transportation of important molecules within the nucleus

### Nucleolus

- Site of ribosome synthesis
- Compartment in the nucleus where ribosomes are assembled.
- Ribosomes are then moved out into cytoplasm through nuclear pores.
- Ribosomes and RNA work together outside the nucleus, to build all the proteins in the cell.

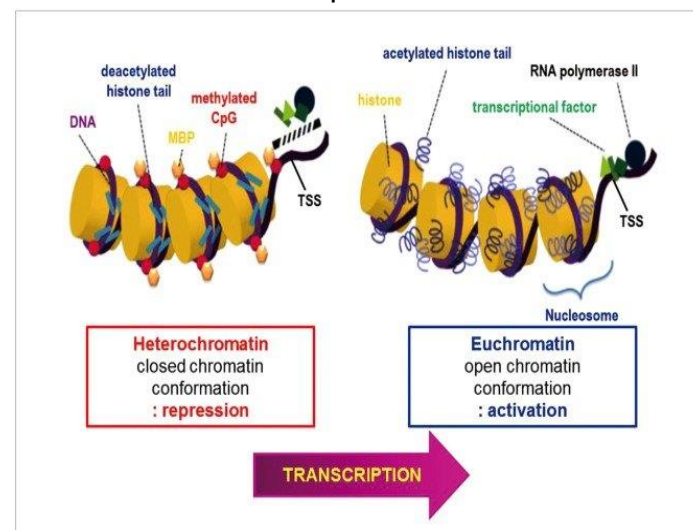
### Chromatin & Chromosomes

- Chromosomes contain double stranded DNA molecules in a condensed form attached to a histone protein.
- Chromatin is comprised of DNA.

There are two types based on function.

**Heterochromatin:** highly condensed, transcriptionally inactive mostly located adjacent to the nuclear membrane

**Euchromatin:** delicate, less condensed organization of chromatin, located in a transcribing cell



### DNA or Deoxyribonucleic acid

- Contains the information needed for the creation of proteins
- In the form of chromatin or chromosomes
- The nucleus is the site of DNA duplication, which is needed for cell division (mitosis) and organism reproduction and growth.

### The Nucleus and Cell Control

- The nucleus is the leader of the eukaryotic cell
- It contains the direction to make proteins.
- Every part of the cell depends on proteins, so by containing blueprint to make proteins, the nucleus controls the activity of the organelles.

### Major Functions of the nucleus

- It stores the cell's hereditary material, or DNA
- Coordinates the cell's activities, which include growth, intermediary metabolism, protein synthesis, and reproduction (cell division).
- Keep the DNA from getting tangled with cytoplasmic machinery
- Isolates DNA from potentially damaging interactions
- Cells control the movement of substances to and from the cytoplasm

## Lecture 117

# • Ribosome

- First isolated from cell cytoplasm by Claude (1943)
- Term ribosomes was coined by Palade (1955).
- Also called ‘palade particles’
- Ribosomes are the protein builders or the protein synthesizers of the cell.

- They connect one amino acid at a time and build long chains.
- Ribosomes are special because they are found in both prokaryotes and eukaryotes.

### Type of Ribosome

#### Classified according to their location

##### 1. Membrane-Bound Ribosomes

- Synthesize proteins for membranes and exocytosis (used outside the cell).
- Attached to endoplasmic reticulum

#### Classified according to their location

##### 2. Free Ribosomes

- Found freely in fluid cytoplasm
- Synthesize proteins that function inside the cytosol

On the basis of sedimentation coefficient, ribosomes are of 2 types:

##### (A) 70S Ribosomes:

- Found in prokaryotes.

##### (B) 80S Ribosomes:

- Found in cytoplasm of eukaryotes.

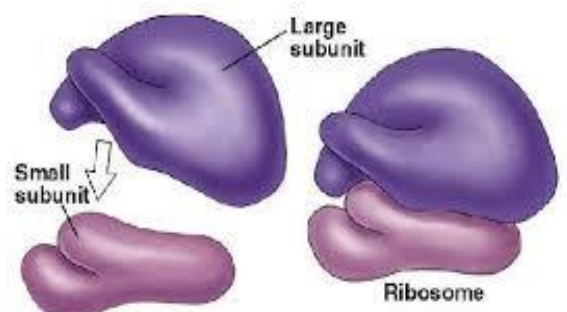
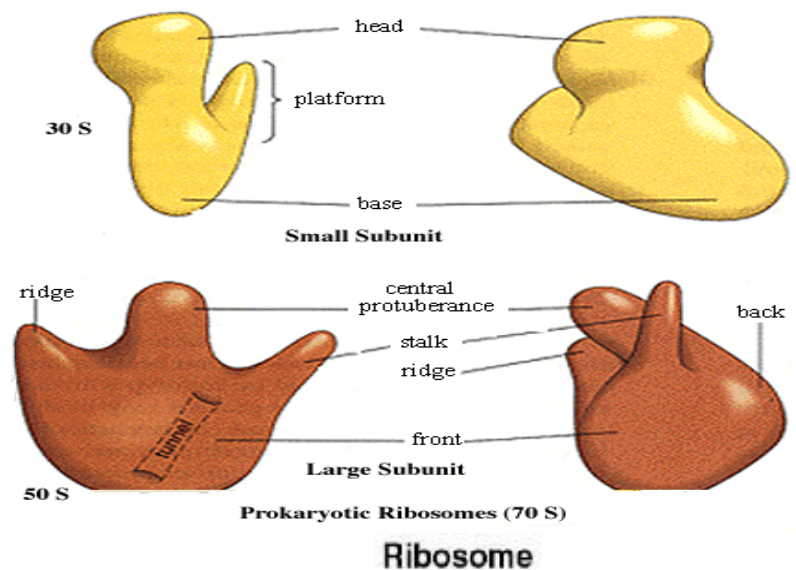
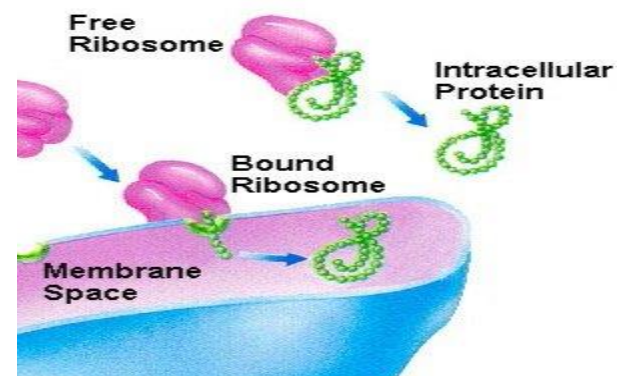
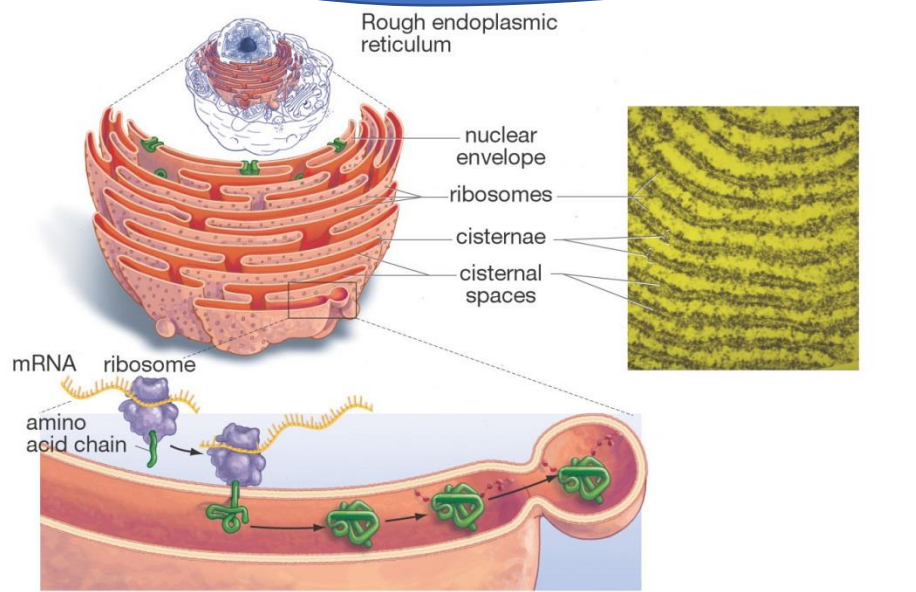
#### Chemical Composition

- 60-65% r-RNA
- Proteins
- 70S ribosome: 35-40%
- 80S ribosome: 55%

#### Function of the Ribosome

**Ribosomes** = site of protein synthesis

- Assembles peptides in the nucleolus
- Exported into cytoplasm
- Wrapped inside vesicles



## Lecture 118

## • Endoplasmic Reticulum

### Endoplasmic Reticulum (ER)

- Discovered in 1945 by Albert Claude
- It was first noticed in the cytoplasm of chick embryo cells.
- ER is a system of membranous channels and saccules.
- ER is an organelle found in the cells of eukaryotic organisms.

- These membranes are continuous, joining with the outer membrane of the nuclear membrane.

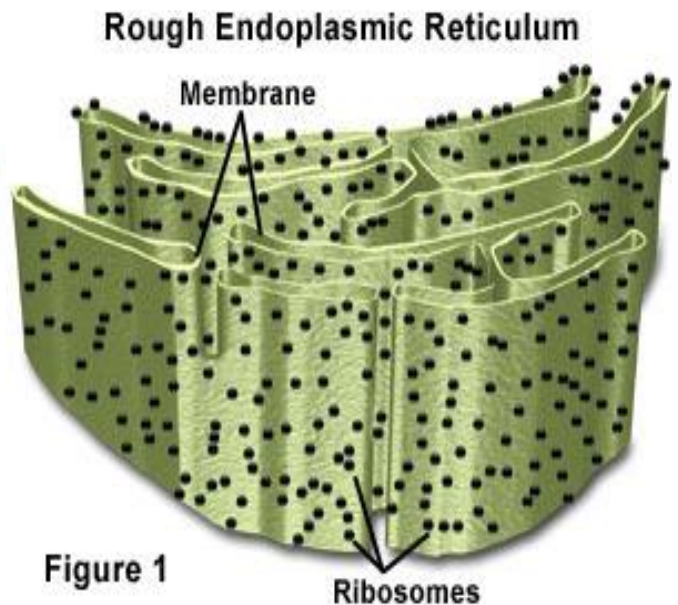
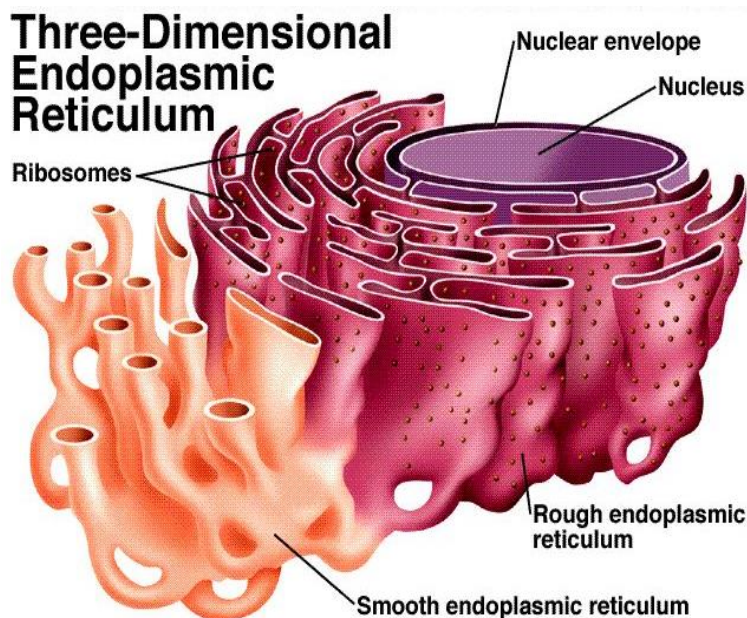


Figure 1

### Types of Endoplasmic reticulum

1. Rough ER (RER)
2. Smooth ER (SER)

#### RER

- RER has ribosomes attached.
- Involved with protein production, protein folding, quality control and dispatch.
- Synthesis of proteins.
- They produce and process specific proteins at ribosomal sites like glycosylation.
- Often interact with Golgi complex.
- Consists of network-like tunnels with tubules and vesicles
- which is held together by the cytoskeleton of the cell.

#### SER

- SER is more tubular than RER
- Forms a separate interconnecting network. (Is found evenly distributed among the Cytoplasm.)
- SER has no ribosomes on it.
- SER manufactures lipids and in some cases the metabolism of them and associated products.
- Storage of carbohydrates
- Detoxification reactions in liver
- Synthesizes much of the new membrane material
- Modification of existing molecules

## Lecture 119

## • Golgi Apparatus

### Golgi Body

- Named after Camillo Golgi
- An Italian biologist who discovered the organelle with a light microscope in 1897.

### Structure

- Located near the end of the ER close to the nucleus
- Composed of several layers of cisternae (fluid-filled sacs)

### Has three different parts:

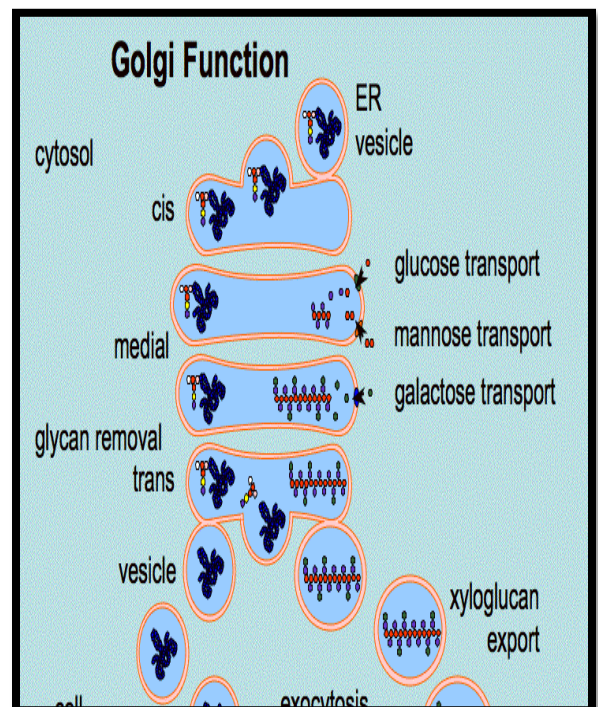
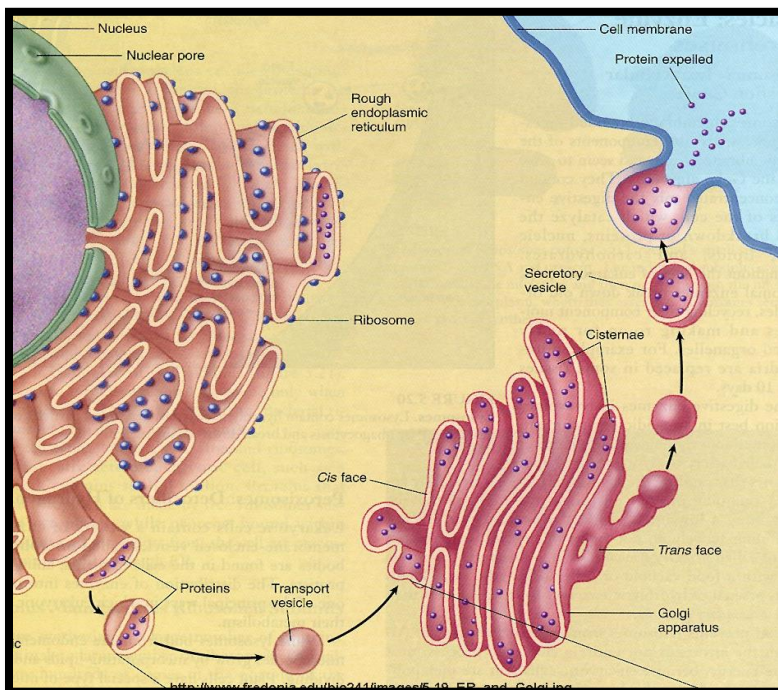
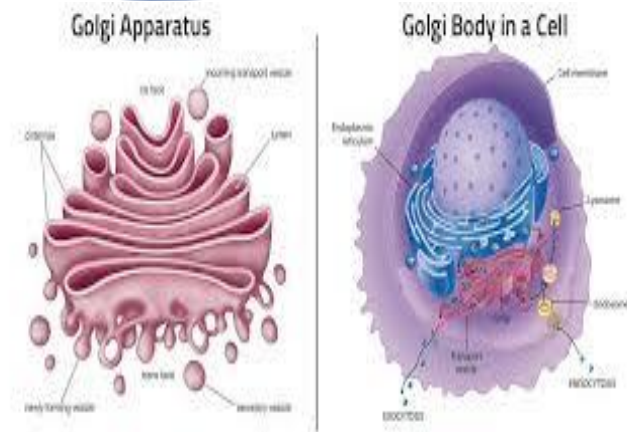
1. cis-Golgi

2. medial-Golgi

3. trans-Golgi

### Functions

- *cis* is first cisternae.
- *trans* is final cisternae.
- From trans, proteins are packaged into vesicles destined to lysosomes, secretory vesicles, or the cell surface.
- Transport vesicles are used to move back and forth between the ER and Golgi bodies
- One side of the Golgi body receives transport vesicles produced by the ER.
- This side is called cis face.
- Opposite side releasing vesicle is trans face.
- The Golgi body marks and sorts the molecules into different groups.
- These groups are sent in secretory vesicles inside or outside of the cell.
- Proteins are modified before sending by adding specific sugar molecules are added to a core oligosaccharide that is attached to a protein.



## Lecture 120

## • Lysosome

Lysosomes were discovered by the Belgian cytologist de Duve in the 1950s. Lysosomes are vesicles produced by the Golgi apparatus. Present in cytoplasm of eukaryotic cells. It contains degradative enzymes enclosed in a membrane.

Internal environment is acidic (**pH: 7**)

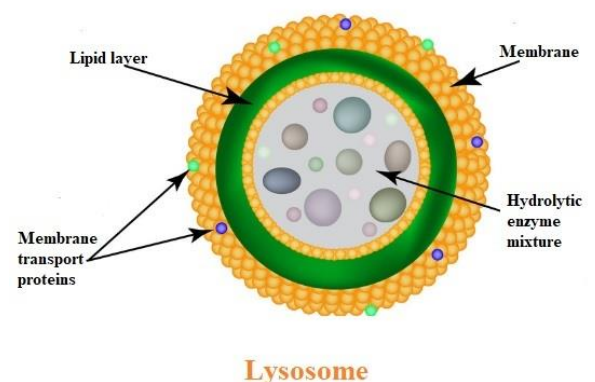
### Functions

**Lysosomes are known to contain:**

1. More than 60 different enzymes
2. More than 50 membrane proteins

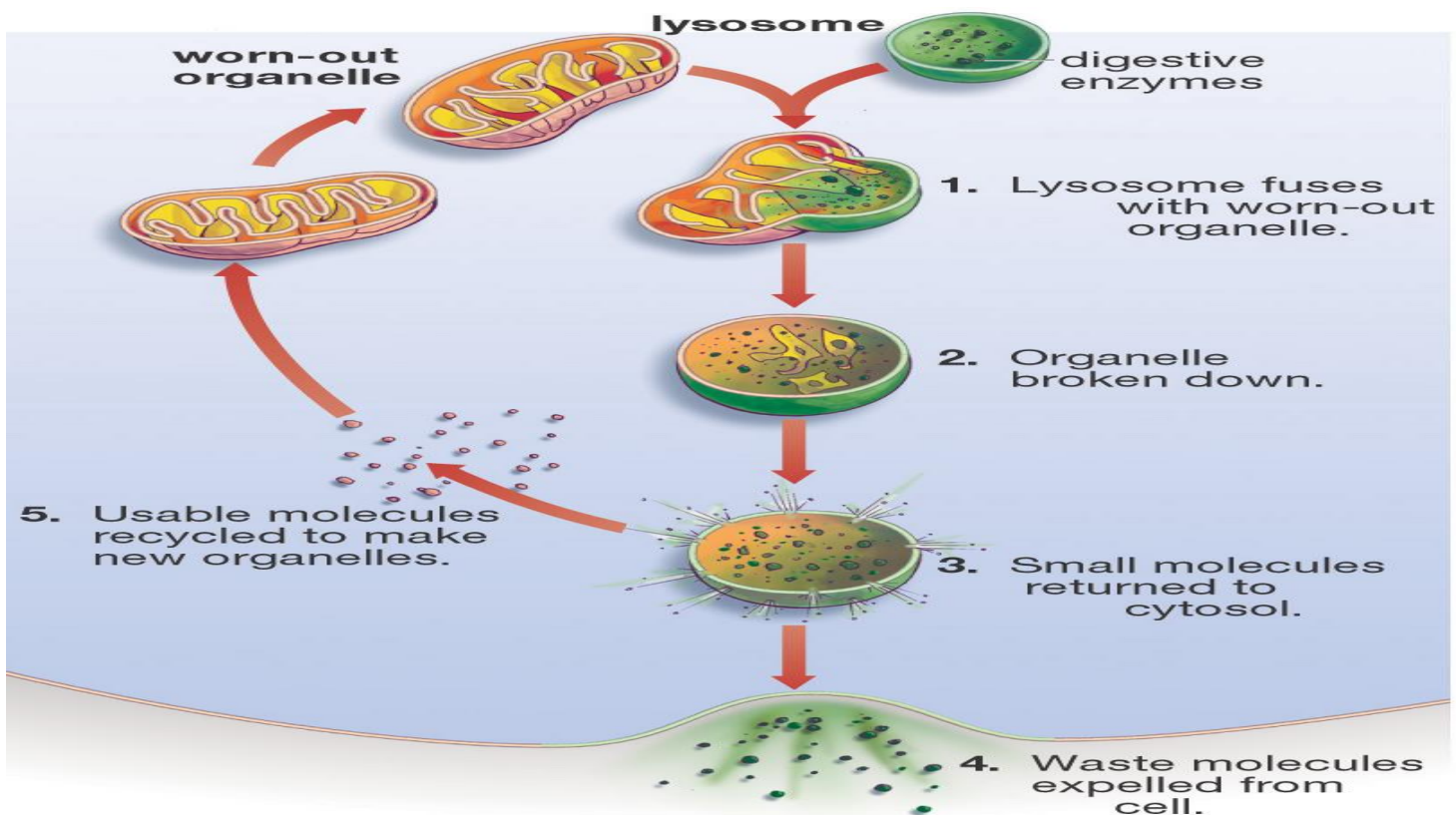
**Wide variety of hydrolytic enzymes (acid hydrolases) that break down macromolecules such as**

1. Nucleic acids
  2. Proteins
  3. Polysaccharides
- Carrying out digestion



**Lysosome**

- Recycling of cellular organelles
- The breakdown of viruses and other cellular invaders
- Single-celled organisms, such as amoebas, use lysosomes to digest their food since they have no process for extracellular digestion.



## Lecture 121

### • Mitochondria -1

- Mito – thread
- Chondrion – granule like
- First observed by Richard Altman (1894)
- Term mitochondria was coined by Carl Benda (1898).

**Size:** 0.05 – 1.0  $\mu\text{m}$

**Length:** 1 – 10  $\mu\text{m}$  long

**Shape:** Bean shaped, in fibroblast it is elongated and thread like.

**Number:** Depends on type, size and functional state of cell.

**Example:** average liver cell contain around 1500 mitochondria.

#### Structure

- Outer Membrane
- Intermembrane Spac (Perimitochondrial space)
- Inner Membrane
- Cristae
- Matrix

#### Outer Membrane

- Simple phospholipid bilayer.
- Contain large number of integral protein structures called porins.
- Porins allow molecules to freely diffuse from one side of the membrane to the other.
- Easy transport of ions, nutrient molecules, ATP, ADP.

#### Inner Membrane

- Permeable only to oxygen,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ .
- Contains proteins that perform redox reactions in :

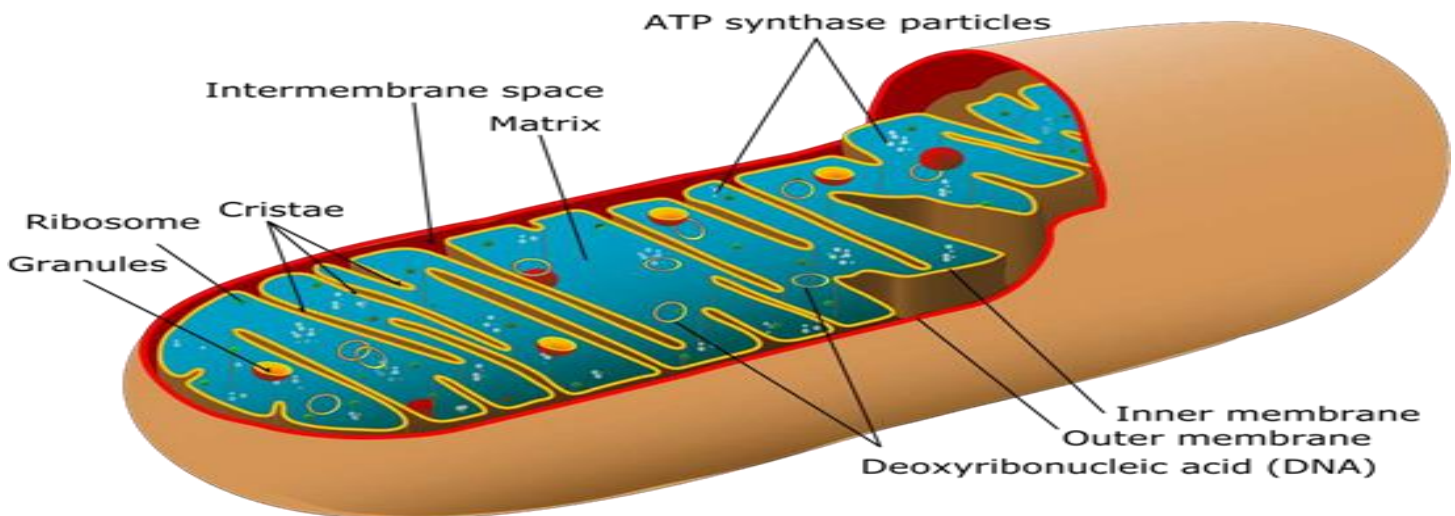
- Cellular respiration
- Transport of proteins
- Exchange of anions between the cytosol and the mitochondria

### Intermembrane Space

- It has high proton concentration.
- Because the outer membrane is freely permeable to small molecules, the concentration of small molecules such as ions and sugars in the intermembrane space is same as that of the cytosol.

### Cristae

- Folds of inner mitochondrial membrane
- Expand its surface area, enhancing its ability to produce ATP
- Contains stalked particles on inner side called as  $F_1$  particles.



## Lecture 122

### • Mitochondria -2

#### Matrix

- Enclosed in inner membrane
- Gel like consistency, Dense, homogenous.
- Contains 2/3<sup>rd</sup> of total protein of mitochondria.
- Contains enzymes, DNA genome, ribosomes, tRNA, granules, fibrils and tubules.

#### Mitochondrial DNA

- Own circular DNA, mostly attached to inner membrane
- Own ribosomes
- The DNA in the cell nucleus does not code for the construction of mitochondria.
- Stores biological info required for growth and multiplication of mitochondria.
- Encode RNAs and proteins that are essential for mitochondrial function.
- It codes 2 rRNAs, 22 tRNAs and 13 mitochondrial membrane proteins.
- It can undergo replication and duplication.

#### Functions

- Aerobic respiration
- Mitochondria uses complex molecules and oxygen to produce a higher energy molecule known as ATP.
- Synthesis of mtDNA, RNA, protein.
- Storage of calcium ions

#### OUTER MEMBRANE:

Oxidation of epinephrine

Degradation of tryptophan

Elongation of fatty acid

- **INNER MEMBRANE:** Oxidative phosphorylation
- **MATRIX:**
  - Kreb' s Cycle
  - Beta oxidation
  - Detoxification of ammonia

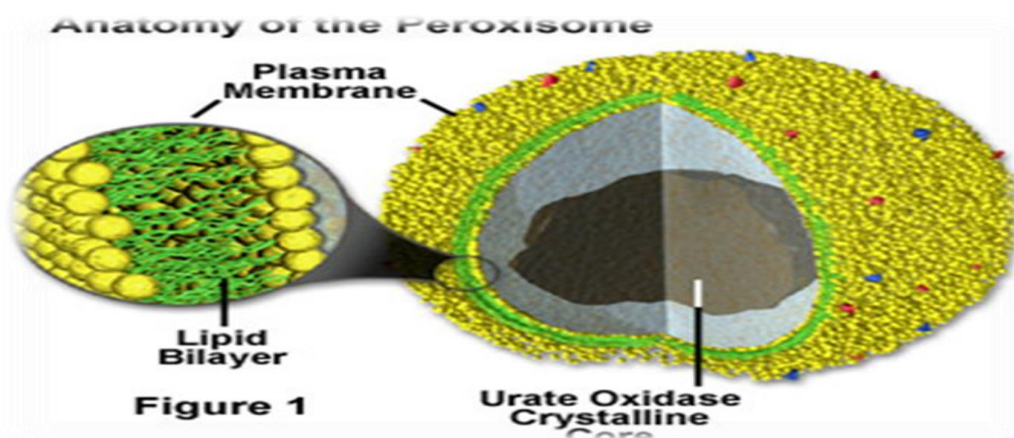
## Lecture 123

### • Peroxisomes

- First observed by electron microscopy in animal cells (195s), then in plant cells (1960)
- Christian deDuve (1967)
  - Isolated from liver cells by centrifugation
  - Called them peroxisomes because they generate and destroy  $H_2O_2$
- Peroxisome, membrane-bound organelle occurring in the cytoplasm of eukaryotic cells.

#### Functions

- Contains oxidative enzymes
- Break down fatty acids and amino acids by oxidation.
- Long fatty acids are converted to medium chain fatty acids
- Which are subsequently shuttled to mitochondria to be broken down to carbon dioxide and water.
- In yeast and plant cells, this process is carried out exclusively in peroxisomes.
- B-Oxidation of fatty acid
- Glyoxylate cycle
- Photorespiration (Glycolate pathway)
- Degradation of purines
- Decomposition of hydrogen peroxide



## Lecture 124

### • Chloroplast

Chloroplast was first isolated and named in 1817. Only photosynthetic organisms have chloroplasts.

#### Structure

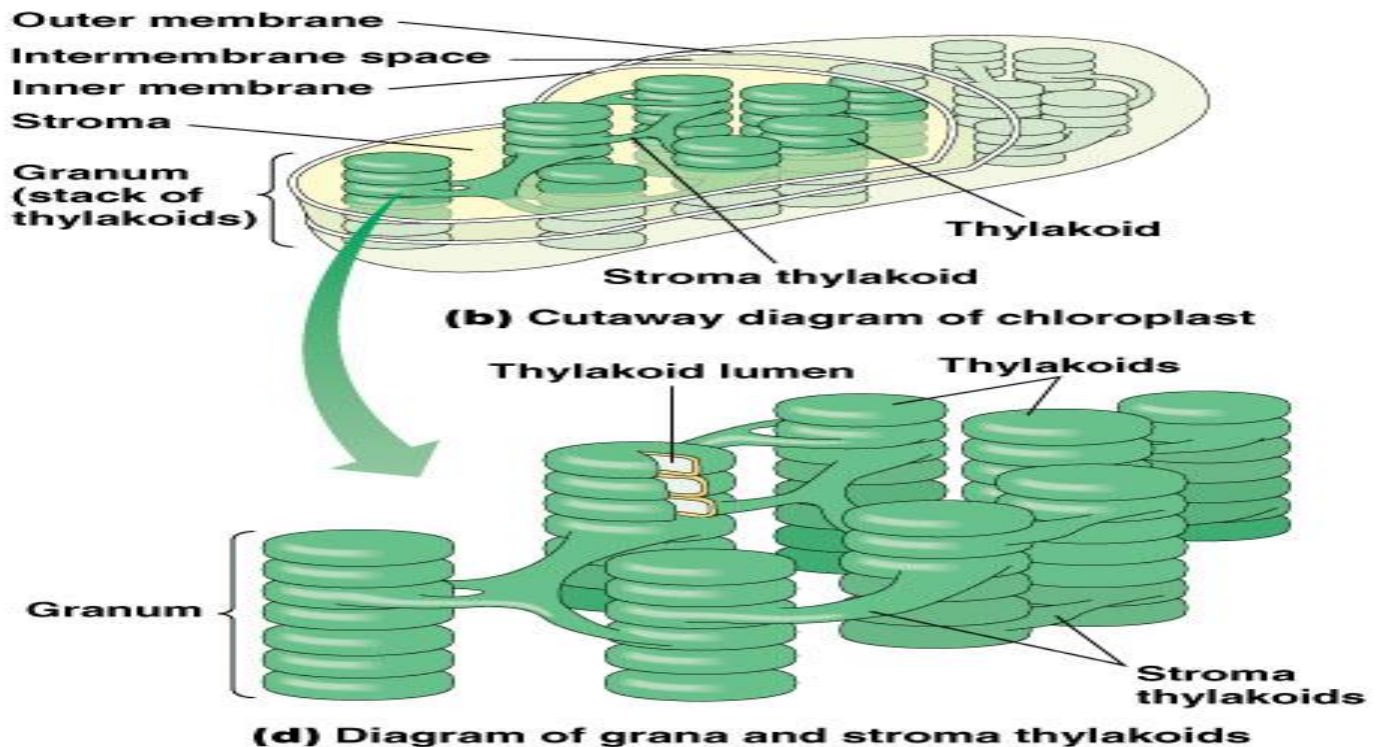
Chloroplasts are a type of plastids. They are round, oval, green, disk-shaped body that is involved in the synthesis and storage of foodstuffs. Presence of two pigments, chlorophyll a and chlorophyll b.

#### Structure

- Outer membrane
- Inner membrane
- Stroma
- Thylakoids

## Function

- Chlorophyll absorbs energy from light in form of photons.
- Transfer this energy to Photosystems present in thylakoid membrane.
- Photosystems convert light energy into chemical energy i.e. ATP and NADPH.
- ATP and NADPH are released into stroma.
- They are used to provide energy to run Calvin cycle in stroma to produce glucose.
- CO<sub>2</sub> and water are used as raw material for glucose synthesis.
- Synthesis of glucose and other oligosaccharides.
- Synthesis of structural carbohydrates like cellulose and starch.



## Lecture 125

## • Cytoskeleton-1

- Cytoskeleton provides support and shape to cell
- Present in both eukaryotic and prokaryotic cell.
- It is a network of protein fibers
- Supporting cell shape
- Anchoring organelles within the cell

## Structure

- Cytoskeleton is made up of three kinds of protein filaments:

1. Microtubules (formed by tubulins)

2. Microfilaments (formed by actins)

3. Intermediate Filaments

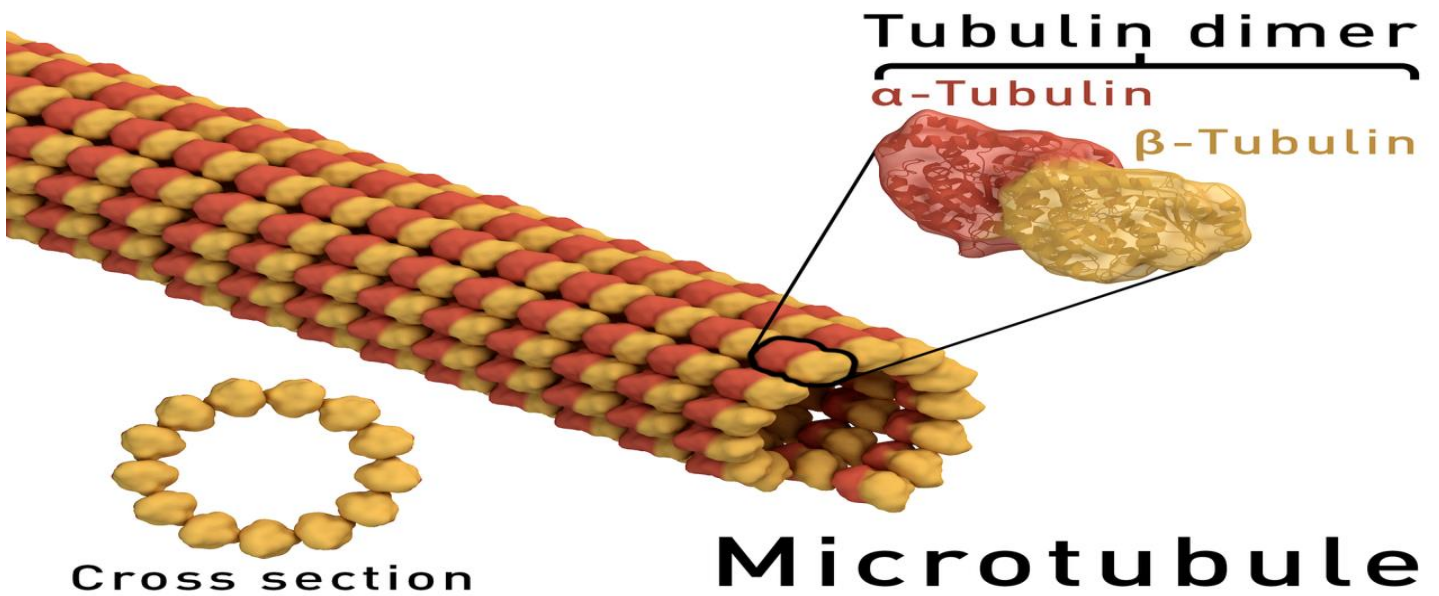
1. Microtubules

- Thickest fiber
- Hollow rods 25 nm in diameter
- Constructed of protein, tubulin
- Dimer of alpha and beta tubulin
- Grow or shrink as more tubulin molecules are added or removed.

## Functions

- Structural support and cell movement
- Centriole
- Spindle formation in cell division
- Transport of materials

- Motility of cell by flagella and cilia



## Lecture 126

## • Cytoskeleton-2

### 2. Microfilaments :(actin filaments)

#### Structure

- Thinnest class of fibers
- Solid rods of protein, actin
- Twisted double chain of actin subunits
- About 7 nm in diameter

#### Functions

- 3-D network inside cell membrane
- In muscle cells, actin filaments interact with myosin filaments to create muscle contraction.
- Cell movement
- Intracellular transport/trafficking
- Maintenance of eukaryotic cell shape
- Cytokinesis
- Cytoplasmic streaming

### 3. Intermediate Filaments

#### Structure

- Specialized for bearing tension
- Built from keratin proteins
  - Same protein as hair
- Intermediate in size 8-12 nm

#### Functions

- Hold “things” in place inside cell
- More permanent fixtures of cytoskeleton
- Reinforce cell shape and fix organelle location
- Movement of cell and movement of organelles
- Phagocytosis and Endocytosis

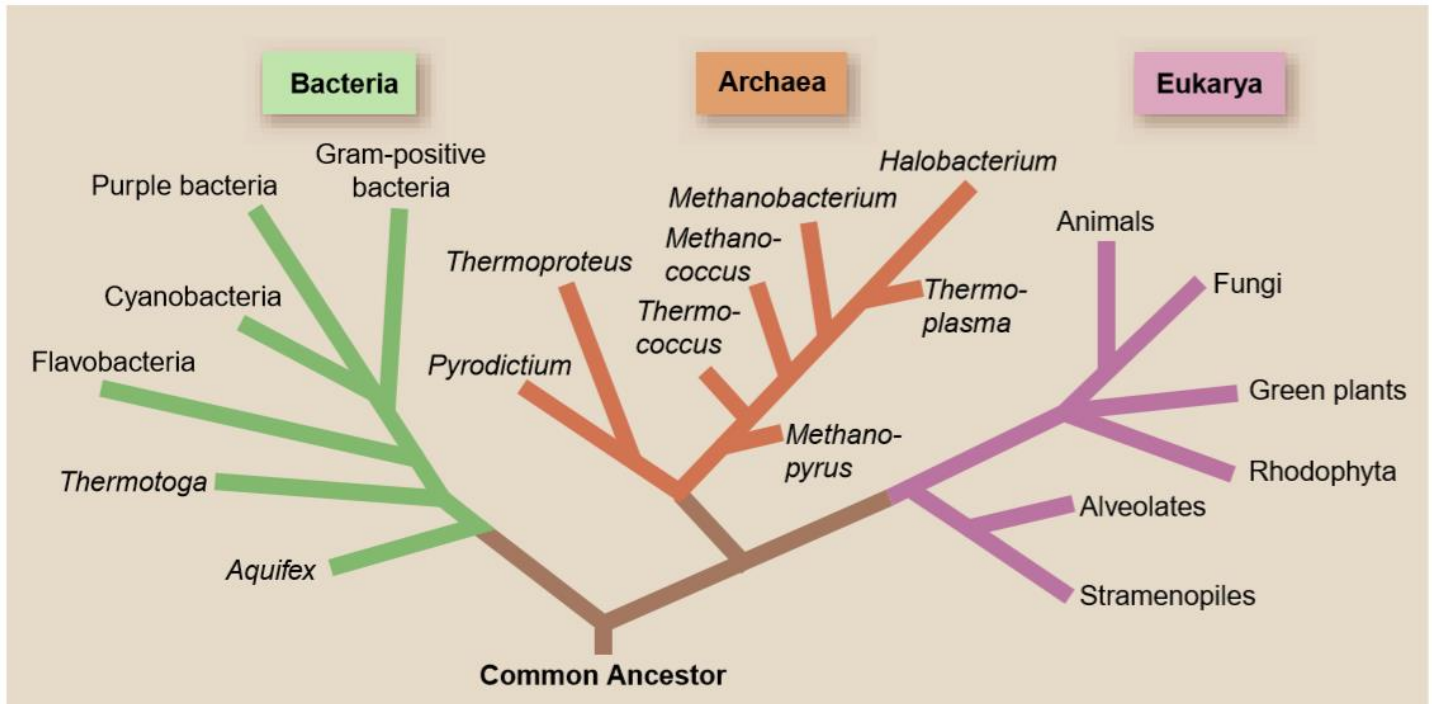
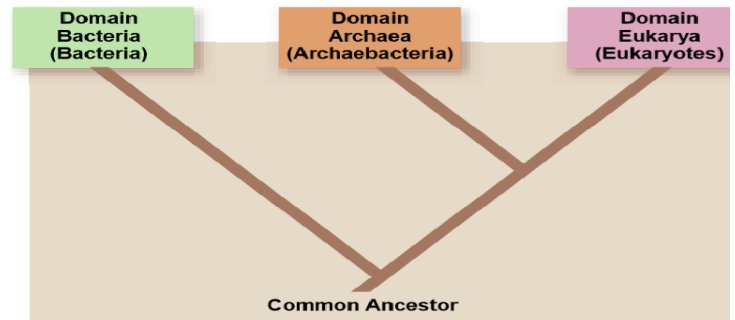
## Lecture 127

### • Protists

Genomic DNA sequences of an archaean and a bacterium were first compared in 1996.

- Archaea are very different from bacteria.
- Both are different from eukaryotes.

Three domain classification is authentic.



- Protists are unicellular.
- It cannot be implied that they are simple.
- Often they are more complex than any particular cell in multicellular organism.
- Organelles that are similar to the organelles of other eukaryotic cells carry out specific functions in protists.
- Some protozoan organelles, however, reflect specializations for unicellular lifestyles.

Too complex to be classified into seven phyla.

1. Sarcomastigophora
2. Labyrinthomorpha
3. Apicomplexa
4. Microspora
5. Acetospora
6. Myxozoa
7. Ciliophora

## Lecture 128

### • Phylum Mastigophora - 1

- Unicellular or colonial
- Locomotion by flagella, pseudopodia, or both
- Autotrophic (self-nourishing), saprozoic (living in decaying organic matter), or heterotrophic (obtains energy from organic compounds)
- Single type of nucleus
- Sexual reproduction (usually)

Phylum Mastigophora has two classes.

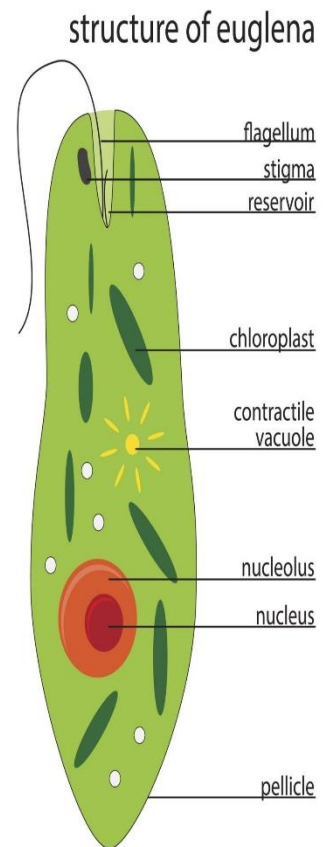
1. Phytomastigophora
2. Zoomastigophora

## 1. Phytomastigophora

- Have flagella for locomotion
- Posses chlorophyll
- Mainly autotrophs
- Some heterotrophs
- Produce a large portion of the food in marine food webs
- Much of the oxygen used in aquatic habitats comes from photosynthesis by these marine organisms.
- Common marine phytomastigophore are dinoflagellates.
- They contain two flagella.
- Contain chlorophyll, xanthophyll pigments, which gives golden brown color
- Chloroplasts change coloration of water
- Gymnodinium produce toxins – “red tides”
- Algal blooms, consume most of O<sub>2</sub> in water.

### Euglena

- Freshwater
- Chloroplast has a pyrenoid
- Involved in carbon fixation and starch formation and its storage
- Orients towards light
- Stigma covers photoreceptors at base of flagellum
- Stigma permits light in one direction
- Euglena flagella are haploid
- Flagella reproduce by binary fission- longitudinal
- Sexual reproduction is still unknown



### Volvox

- Colonial flagellate
- Embedded in a spherical, gelatinous matrix
- Individual cells posses two flagella
- Asexual reproduction occurs in spring and summer.
- Sexual reproduction occurs in autumn.

Some species of Volvox which reproduce in summer has:

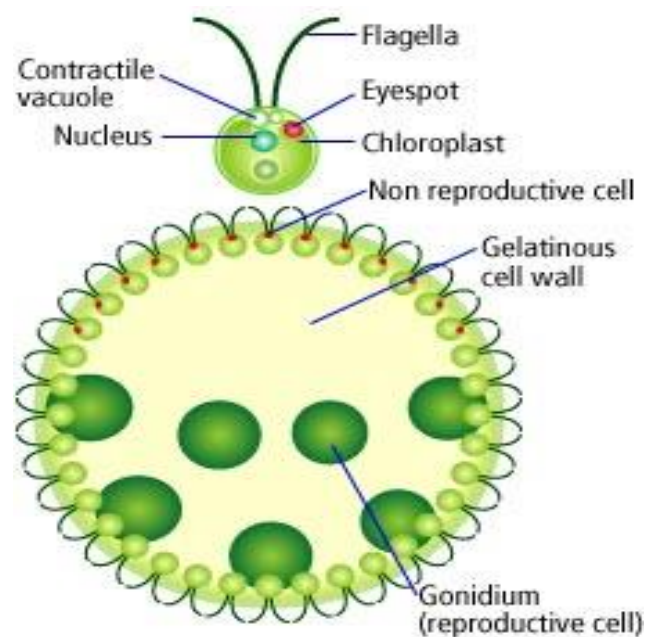
#### 1. Dioecious

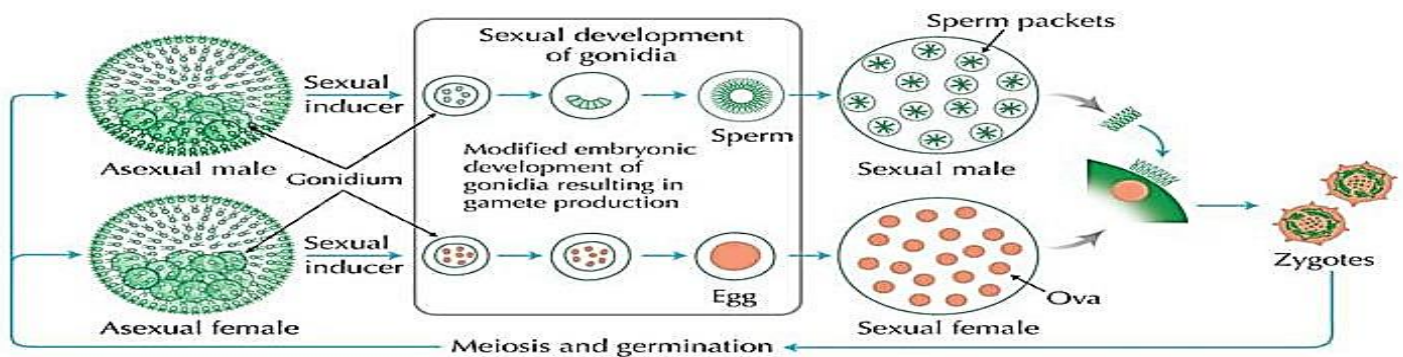
#### 2. Monoecious

- Specialized cells differentiate into macrogametes or microgametes.
- Macrogametes are large, filled with nutrient reserves, and nonmotile.
- Microgametes form a packet of flagellated cells (sperms).
- That leaves the parental colony and swims to a colony containing macrogametes.

**Syngamy occurs.**

- Zygote undergoes meiosis to retain haploidy.
- Product of meiosis undergoes mitotic division.
- Daughter colonies are released from zygotic capsule.





## Lecture 129

## • Phylum Mastigophora - 2

### 2. Zoomastigophora

- Lack chloroplast
- Heterotrophic or saprozoic
- Parasites of humans

#### Examples:

#### 1. *Trypanosoma brucei*

- It has three sub species.
- 1. *T. b. brucei*
  - Parasite of non human
  - Common host are mammals of Africa

**Trypanosoma  
brucei**

***T. b. brucei***

***T. b. gambiense***

***T. b. rhodesiense***

#### 2. *T. b. gambiense*

- Causes sleeping sickness in humans

#### 3. *T. b. rhodesiense*

- Causes sleeping sickness in humans.

**Tsetse flies is the intermediate host for all three sub species.**

- Trypanosoma reproduce asexually.
- In gut of fly for 10 days
- Migrate to salivary glands
- Transform into fly after 15 to 35 days.
- Infected Tsetse fly bites another host
- Parasite travel with salivary secretion
- Enter into blood of human
- Multiply asexually
- Inside host, they live in the blood, Lymph, spleen, central nervous system and cerebrospinal fluid
- When parasite enters into central nervous system
- Symptoms includes apathy, mental dullness, and lack of coordination.
- May be fatal

## Lecture 130

## • Subphylum Sarcodinia

- Members of the subphylum Sarcodinia are the amoebae.
- Cells are naked or with shell.
- Mostly free living
- When feeding and moving, they form temporary cell extensions called **pseudopodia**.

## Types of pseudopodia

Majorly amoeba has four types

1. Lobopodia
2. Filopodia
3. Reticulopodia
4. Axopodia

### 1. Lobopodia

- Contain ectoplasm and endoplasm
- Used for locomotion
- Used for engulfing feed

### 2. Filopodia

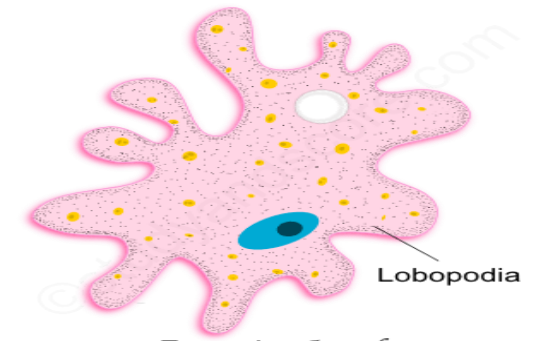
- Only ectoplasm in pseudopodia
- Two-way streaming
- Provides food in conveyor belt fashion

### 3. Reticulopodia

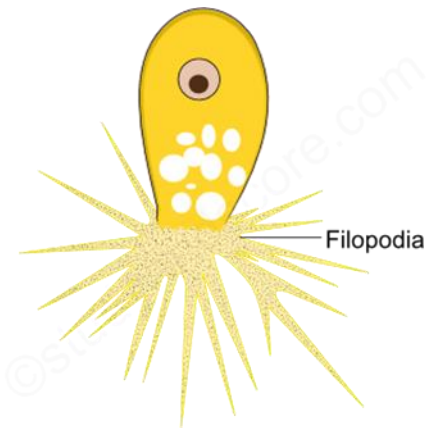
- Similar to filopodia
- Branch and rejoin to form net like series of cell extensions

### 4. Axopodia

- These are thin filamentous supported by central axis of microtubules.
- Food caught on axopodia delivered to the central cytoplasm of amoeba.



Example: *Amoeba*  
©studyandscore.com



## Lecture 131

### • SUPERCLASS RHIZOPODA, CLASS LOBOSEA

- Belong to Subphylum Sarcodinia
- Most familiar amoeba belong to these classes
- About 4000 species
- Mostly amoeba are naked without shell.
- Found in shallow water substrates of freshwater ponds, lakes, and slow-moving streams
- Feed on other protists and bacteria
- They engulf food by phagocytosis using pseudopodia.
- Reproduction by binary fission
- Superclass rhizopoda possess a test or shell
- Protective structures which cytoplasm secrete
- Pseudopodia extruded from opening in test

### Shell Composition

- Calcareous
- Proteinaceous
- Siliceous
- Chitins
- Sand
- Other debris

### Modes of Life

#### 1. Free Living Amoeba

- Diffflugia
- Arcella

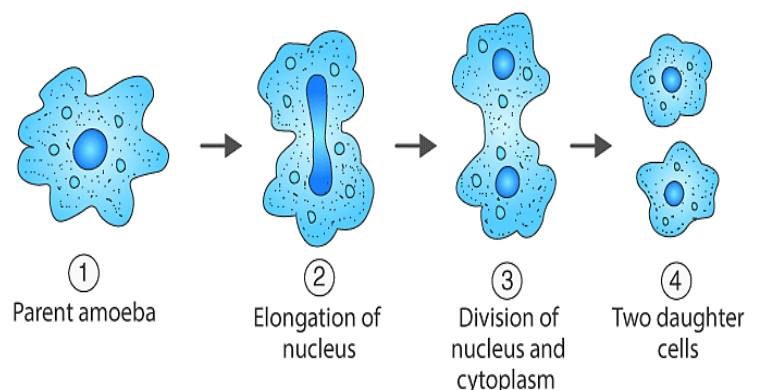
#### 2. Parasites

- Entamoeba

### Entamoeba

### BINARY FISSION IN AMOEBAS

BYJU'S  
The Learning App



- Causes dysentery in humans
- Inflammation and ulceration of the lower intestinal tract
- Debilitating diarrhea
- Lives in intestinal wall
- Pass to other host in the form of cyst

## Lecture 132

## • Subphylum Actinopoda

- Mostly marine
- Spherical, planktonic
- Axopodia supported by microtubules
- Includes marine radiolarians with siliceous tests
- About 3,000 species.

**Classified into further three super classes.**

1. Foraminiferans
2. Heliozoans
3. Radiolarians

### 1. Foraminiferans

- Primarily a marine group of amoebae
- Possess reticulopodia and secrete a test that is primarily calcium carbonate
- As they grow, they secrete new, larger chambers that remain attached to the older chambers.
- Foram tests are abundant in the fossil record since the Cambrian period.
- Make up a large component of marine sediments
- Resulted in limestone and chalk deposits at sea bottom.

### 2. Heliozoans

Aquatic amoebae that are either planktonic or live attached by a stalk to some substrate. Either naked or enclosed within a test that contains openings for axopodia.

### 3. Radiolarians

- Planktonic marine and freshwater amoebae
- They are relatively large; some colonial forms may reach several centimeters in diameter.
- They possess a test (usually siliceous) of long, movable spines and needles or of a highly sculptured and ornamented lattice.
- After death, tests drift to the ocean floor.
- Some of the oldest known fossils of eukaryotic organisms are radiolarians.

## Lecture 133

## • Phylum Apicomplexa - 1

- Parasitic
- Having apical complex used for penetrating host cells
- Cilia and flagella are lacking, except in certain reproductive stages.
- About 5, 500 species
- Single type of nucleus
- Sexual and asexual phases in life cycle

### Class Sporozoea

- Name derived from most sporozoeans producing a resistant spore or oocyst following sexual reproduction

- Some species cause a variety of diseases in domestic animals and humans.
- **Example:** plasmodium, coccidians

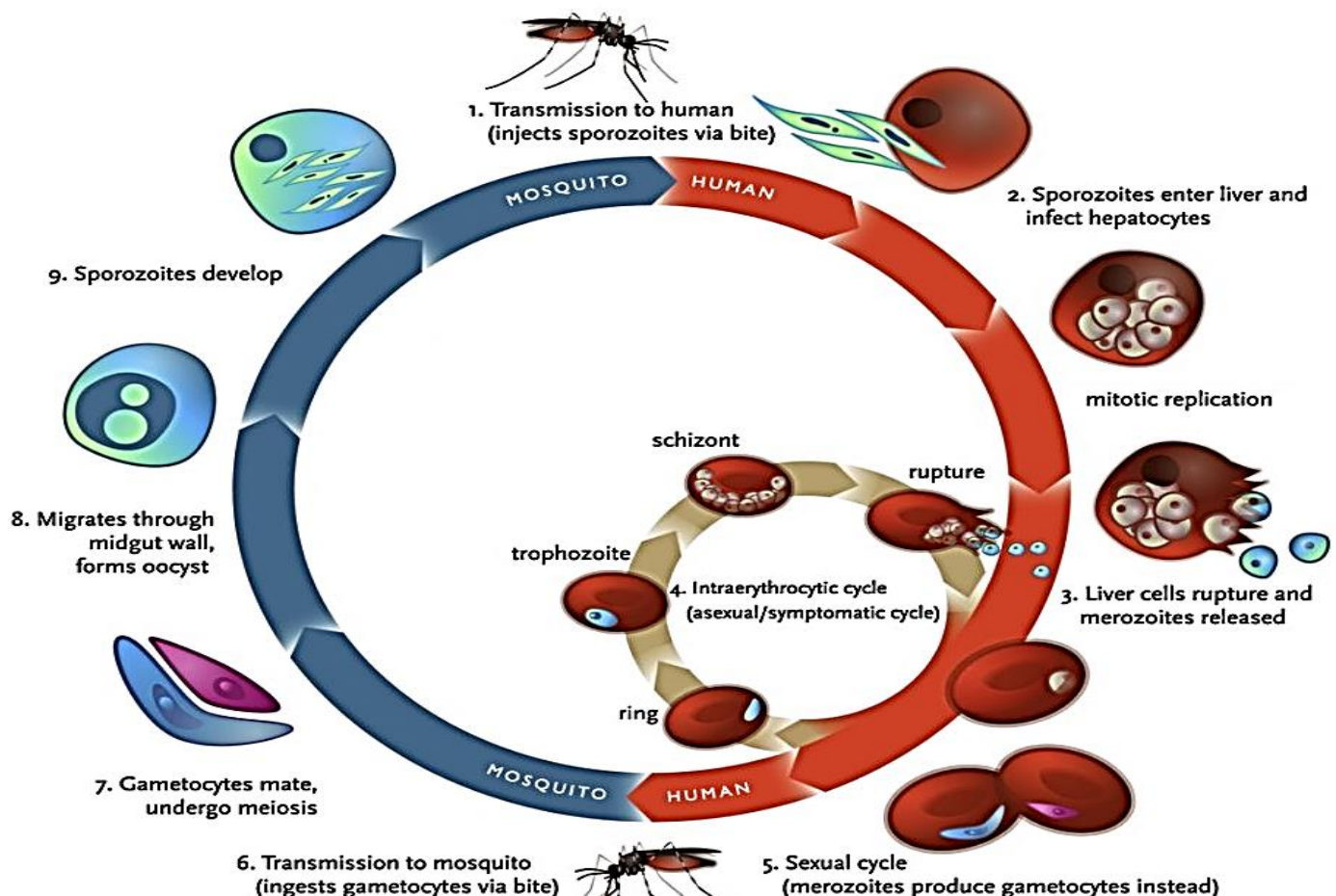
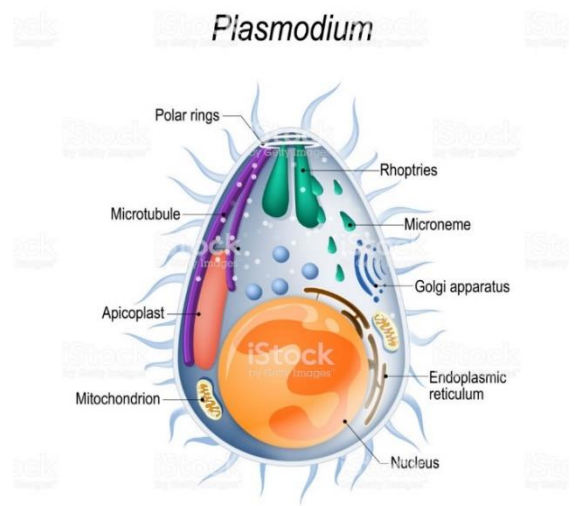
### Life cycle of sporozoeans

#### • Three stages of life:

1. Schizogony
2. Merogony
3. Gametogony

### Schizogony and Merogony

- Multiple fission of an asexual stage in host cells to form many more (usually asexual) individuals
- Which are called **merozoites**.
- They leave the host cell and infect many other cells.
- Merozoites undergo gametogony
- Begins the sexual phase of the life cycle
- The parasite forms either microgametocytes or macrogametocytes.
- Microgametocytes undergo multiple fission to produce biflagellate microgametes
- That emerge from the infected host cell.
- The macrogametocyte develops directly into a single macrogamete.
- A microgamete fertilizes a macrogamete to produce a zygote
- That becomes enclosed and is **called an oocyst**.



- Zygote undergoes meiosis.
- The resulting cells divide repeatedly by mitosis.
- This process, called sporogony, produces many rod-like sporozoites in the oocyst.

## Lecture 134

## • Phylum Apicomplexa - 2

### Plasmodium

- Causes malaria in humans
- Very common apicomplexan.

- Globally, an estimated 3.4 billion people in 92 countries are at risk of being infected with malaria.

### Coccidiosis

- Disease of poultry, sheep, cattle, and rabbits
- Two genera, *Isospora* and *Eimeria* have important parasites.

### Cryptosporidium (coccidian)

- Chronic diarrhea in AIDS patients
- Only known protozoan to resist chlorination
- Virulent in immunosuppressed individuals

### Toxoplasmosis

- Caused by *Toxoplasma*
- Virulent in immunosuppressed individuals as in AIDS
- major cause of stillbirths and spontaneous abortions.
- Fetuses that survive frequently show signs of mental retardation and epileptic seizures

## Lecture 135

## • Phylum Labyrinthomorpha

- Very small phylum
- Consists of protozoa with spindle-shaped, nonamoeboid, vegetative cells.
- In some genera, amoeboid cells use a typical gliding motion to move within a network of mucous tracks.
- Most members are marine
- Either saprozoic or parasitic on algae or seagrass
- Or as decomposers on dead plant material
- Organisms are uninucleated
- Typically ovoid in shape
- Move back and forth with help of ectoplasmic projections

This class has usually two orders.

1. Labyrinthulales
2. Thraustochytriales

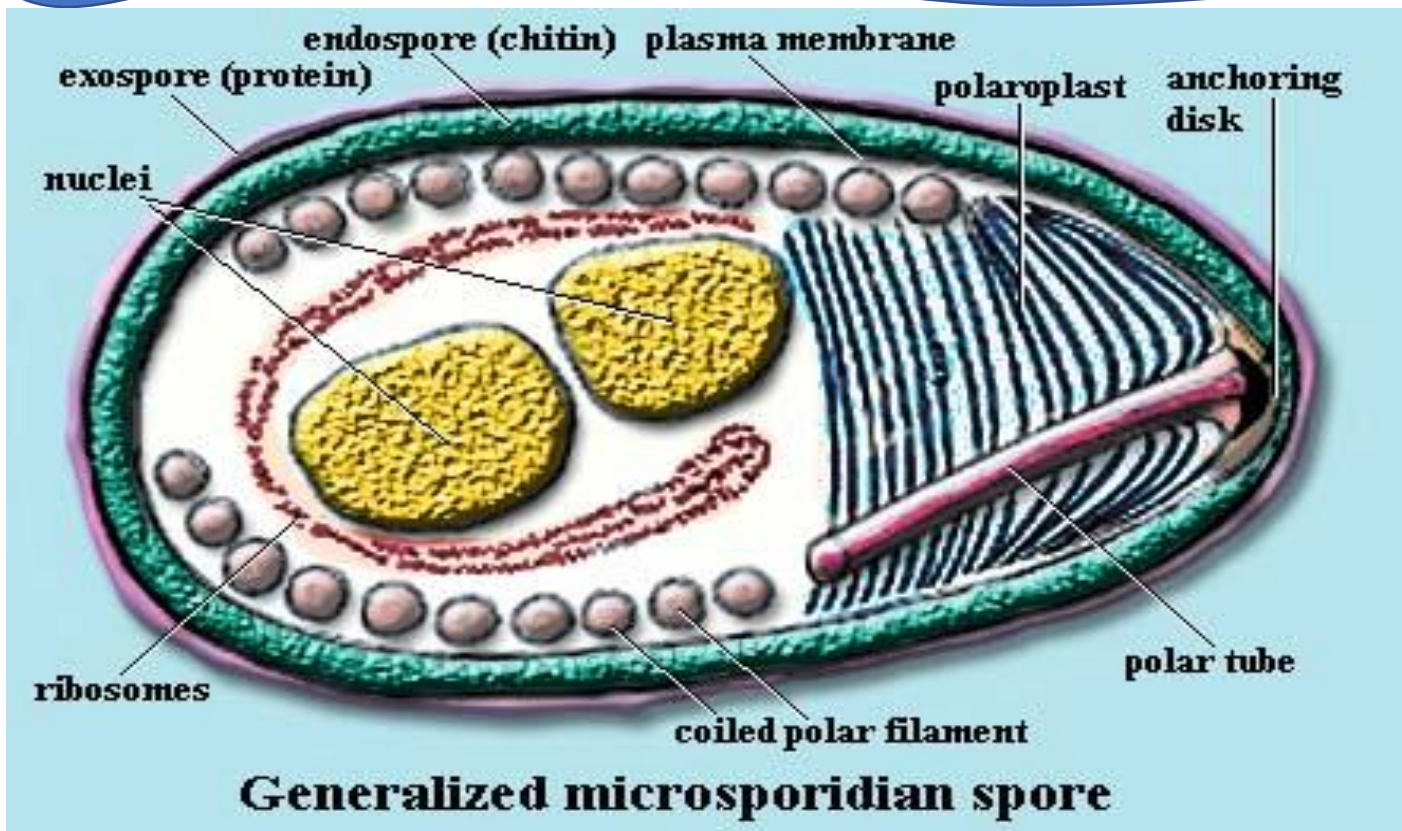
## Lecture 136

## • Phylum Microspora

- Members of the phylum are commonly called microsporidia
- Small, obligatory intracellular parasites
- Several species that parasitize beneficial insects.
- *Nosema bombicus* parasitizes silkworms
- Causing the disease pebrine or pepper disease
- Worms hatching from the infected eggs will die in their larva stage
- *N. apis* causes serious dysentery in honeybees.
- These parasites have a possible role as biological control agents for insect pests.

### Example:

U.S. Environmental Protection Agency has approved and registered *N. locustae* for use in residual control of rangeland grasshoppers.



Recently, four microsporidian genera have been implicated in secondary infections of immunosuppressed and AIDS patients.

## Lecture 137

## • Phylum Acetospora

### Phylum Acetospora

- Acetospora is a relatively small phylum.
- That consists exclusively of obligatory extracellular parasites
- Characterized by spores lacking polar caps or polar filaments
- They primarily are parasitic in the cells, tissues, and body cavities of molluscs.

### Phylum Myxozoa

- Commonly called myxosporeans
- All obligatory extracellular parasites in freshwater and marine fish.
- They have a resistant spore with one to six coiled polar filaments.
- The most economically important myxosporean is *Myxosoma cerebralis*.
- Which infects the nervous system and auditory organs of trout and salmon.
- Causing whirling or tumbling disease

## Lecture 138

## • Phylum Ciliphora - 1

- About 9,000 species
- Some of the most complex protozoa
- Ciliates are widely distributed in freshwater and marine environments.
- A few ciliates are symbiotic.
- Cilia for locomotion and for the generation of feeding currents in water
- Relatively rigid pellicle and more or less fixed shape
- Distinct cytostome (mouth) structure
- Dimorphic nuclei, macronucleus and micronuclei

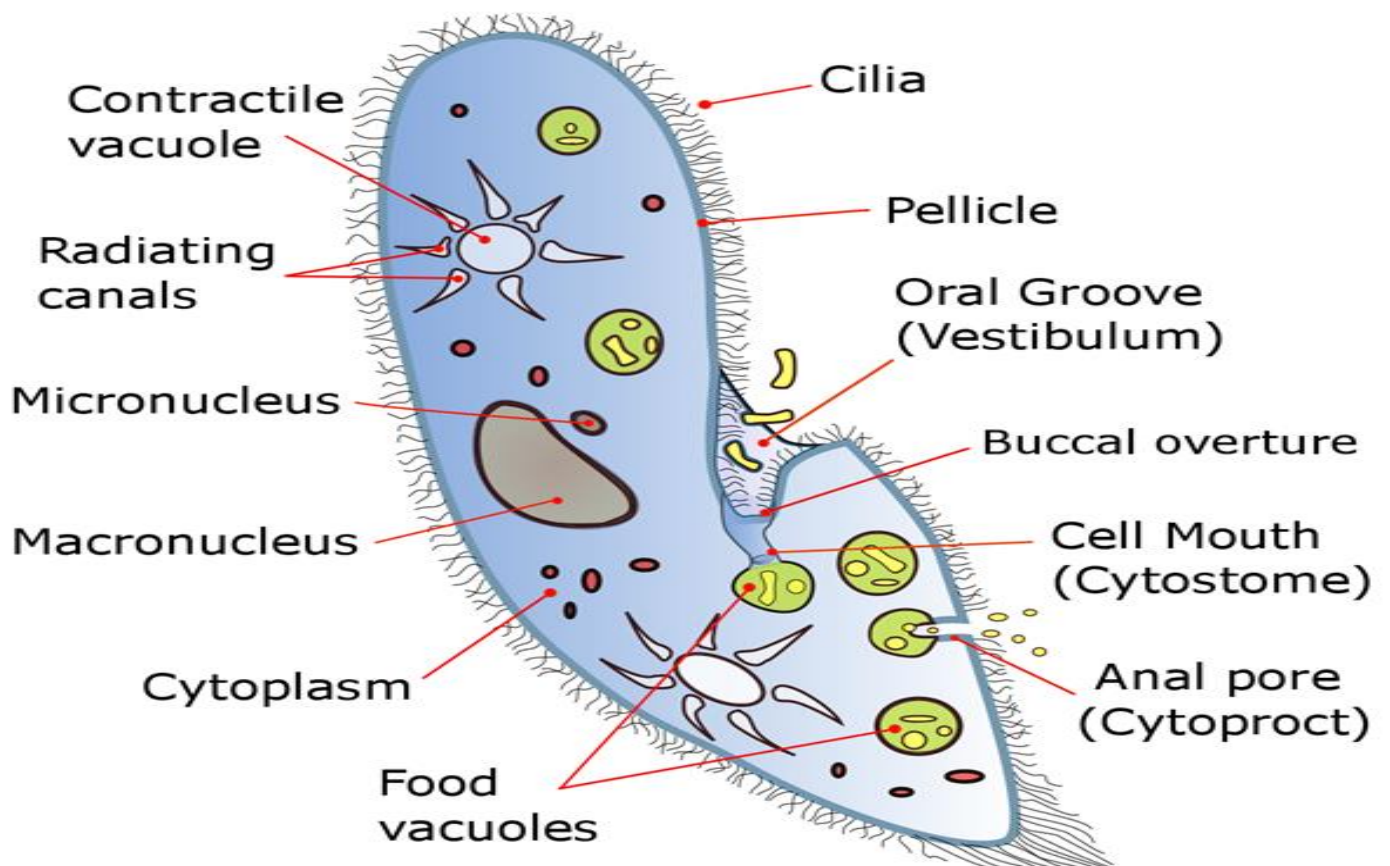
### Cilia and Other Pellicular Structures

- Shorter
- Widely distributed
- Similar like flagella
- Coordinated movement
- Connected basal bodies

- Give shape to organism
- Trichocysts are pellicular structures primarily used for protection.
- They are rodlike or oval organelles
- Oriented perpendicular to the plasma membrane
- Pellicle can discharge trichocysts, which then remain connected to the body by a sticky thread

### Nutrition

- Ciliates like paramecium have oral groove on one side
- Cilia sweep small food particles toward the cytopharynx
- Food vacuole forms
- Break and circulate in endoplasm
- Free living ciliates prey upon protists and small animals
- Prey capture by fortuitous contact
- Ciliate *Didinium* feeds principally on *Paramecium*



## Lecture 139

### • Phylum Ciliphora - 2

#### Excretion

- Excretion of waste material by contractile vacuole.
- Exchange of gases through plasma membrane

#### Genetic Material

- A large, polyploid macronucleus regulates daily metabolic activities.
- One or more smaller micronuclei are the genetic reserve of the cell.

#### Reproduction

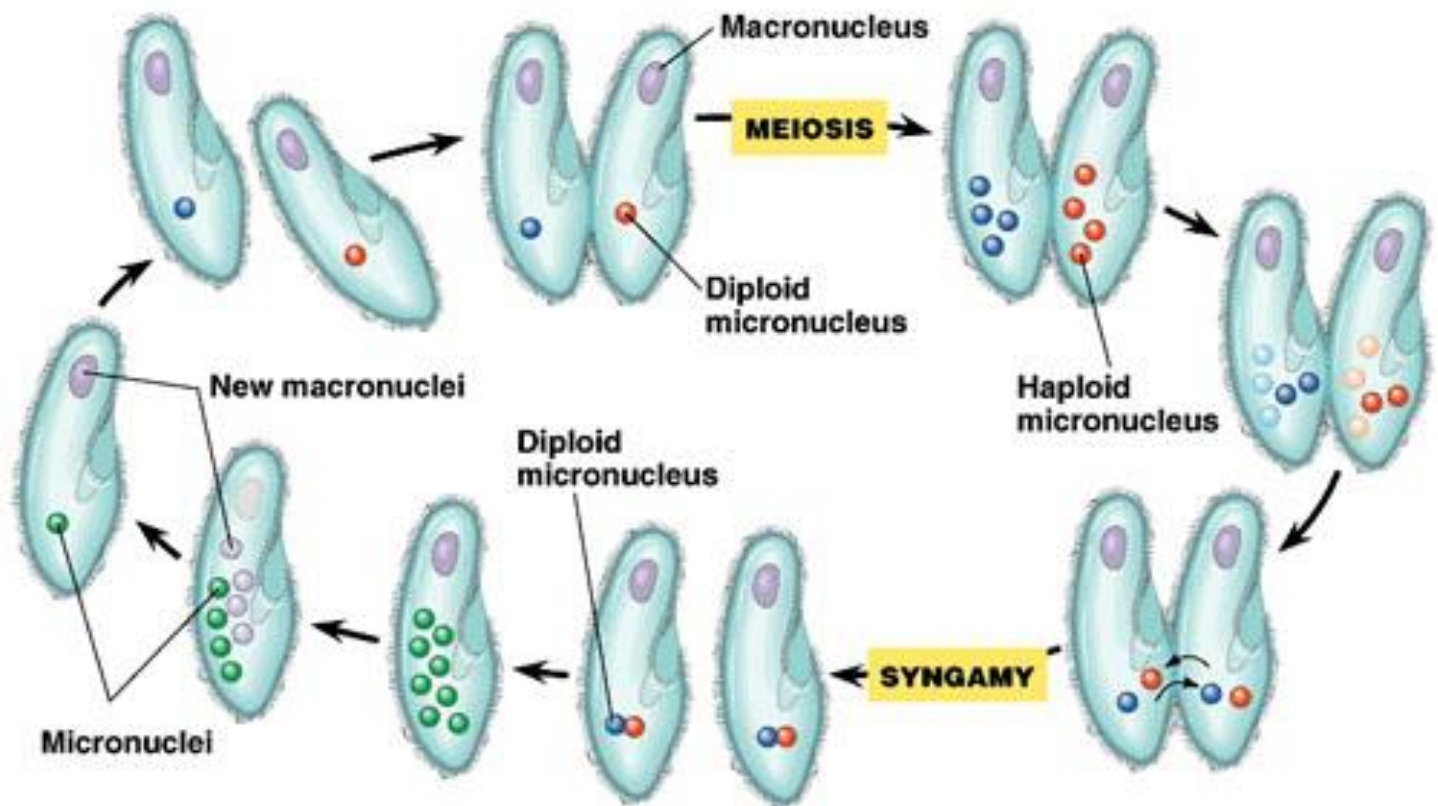
- Asexually reproduction is common.

#### Cell divided into two by mitosis through:

- Binary fission
- Budding

#### Reproduction

- Sexual reproduction
- Occurs when placed under stress
- Paramecia may engage in a process known as conjugation
- Exchange genetic material with other individuals
- Process may take many hours



### Symbiotic Ciliates

- Most ciliates are free living.
- Some are commensalistic or mutualistic
- A few are parasitic.
- Large numbers of different species of ciliates also inhabit the rumen of many ungulates.
- These ciliates contribute to the digestive processes of their hosts.

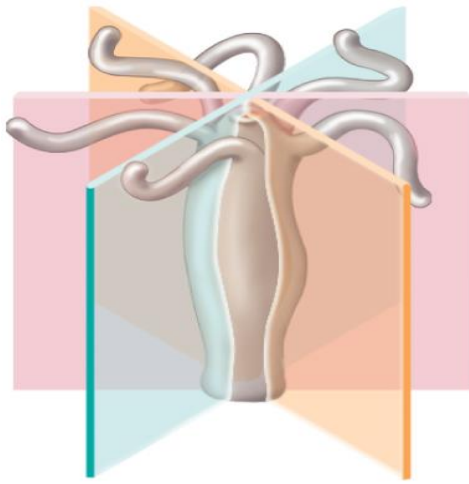
## Lecture 140

## • Kingdom Animalia - 1

- Multicellular with extensive specialization
- Eukaryotic Animal Cells (no cell wall)
- Heterotrophic
- Sexual reproduction
- Advanced nervous systems
- **Cells → Tissues → Organs → Organ Systems → Organism**

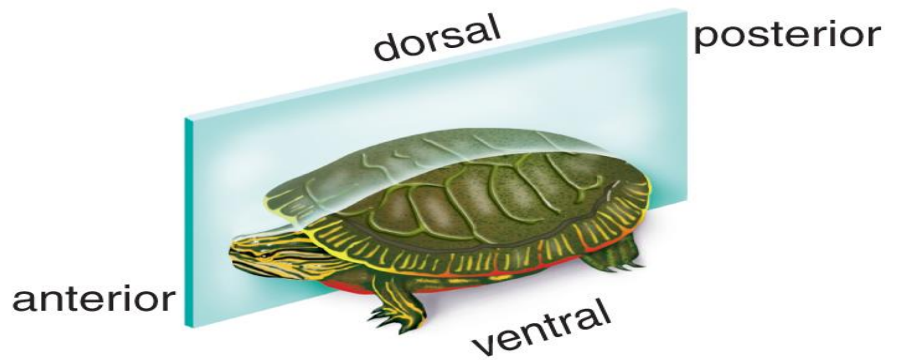
### Symmetry of body plan

1. Asymmetry
2. Radial
3. Bilateral



radial symmetry

a.



bilateral symmetry

b.

### Classification

1. **Phylum Invertebrata**
2. **Phylum Chordata**
  - Notochord
  - Invertebrates are without notochord.
  - Chordates have notochord.

### Invertebrates

- Fresh water, saltwater, on land and as parasites in other animals
- Lack of vertebral column
- Soft bodies
- Mostly exoskeleton
- Both sexual and asexual reproduction

### Classification of Invertebrata

- 1) Porifera
- 2) Cnidaria
- 3) Echinodermata
- 4) Platyhelminthes
- 5) Nematoda
- 6) Annelida
- 7) Arthropoda
- 8) Mollusca

## Lecture 141

## • Kingdom Animalia - 2

### Chordata

- Fresh water, saltwater, on land
- Bilaterally symmetrical,
- Four unique characteristics present at some stage in development:
  - Notochord, pharyngeal slits or pouches, dorsal tubular nerve cord, and postanal tail
- Presence of an endostyle or thyroid gland
- Complete digestive tract
- Ventral, contractile blood vessel (heart)

### Classification of Chordata

1. Subphylum Urochordata
2. Subphylum Cephalochordata
3. Subphylum Vertebrata

## Classes:

- 1) Pisces
- 2) Amphibia
- 3) Reptilia
- 4) Aves
- 5) Mammalia

## Lecture 142

## • Phylum Porifera

- Sponges
- Marine animals
- Loose organized cells
- Colonies of individual cells
- Asymmetrical or radially symmetrical

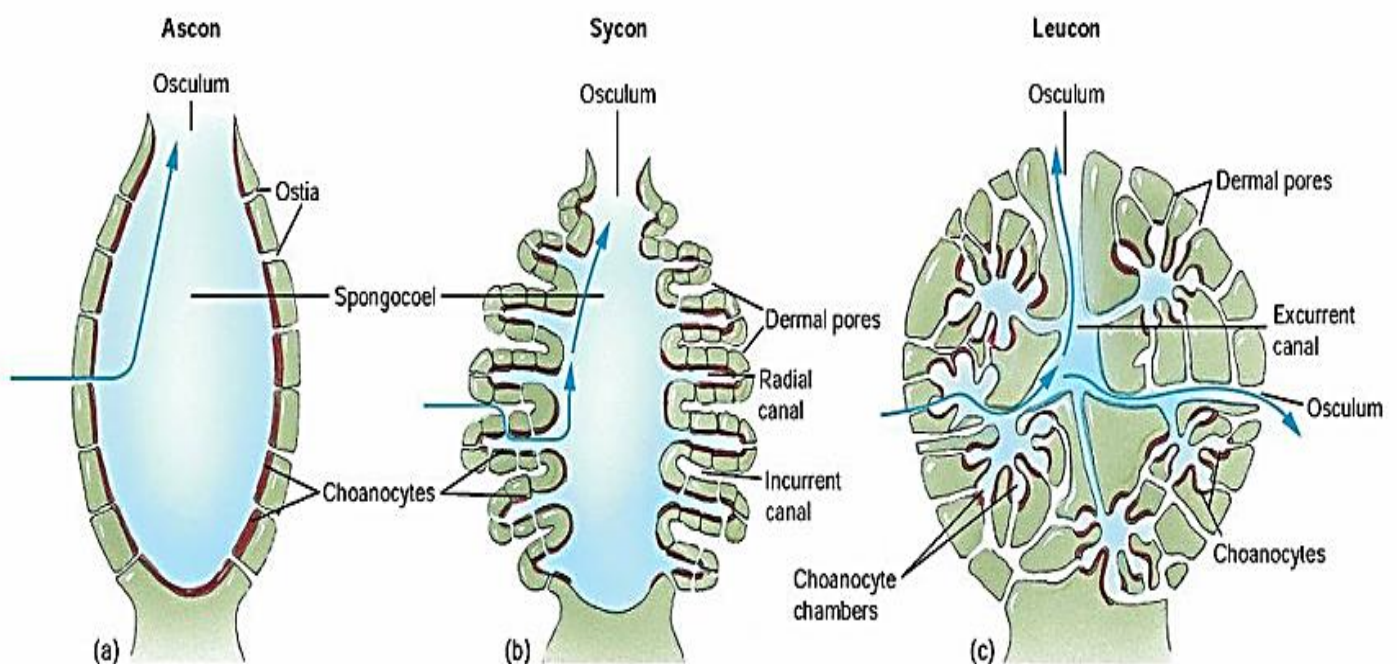
### Three cell types:

1. **Pinacocytes**
2. **Mesenchyme cells**
3. **Choanocytes**

- Central cavity, or a series of branching chambers
- No tissues or organs

### Skeleton

- Microscopic needlelike spikes called spicules.
- Formed by amoeboid cells
- Made of calcium carbonate or silica
- May be made of spongin



### Maintenance

- Feed on particles that range in size from 0.1 to 50  $\mu\text{m}$ .
- Nitrogenous waste removal and gas exchange occur by diffusion
- No nerve cells

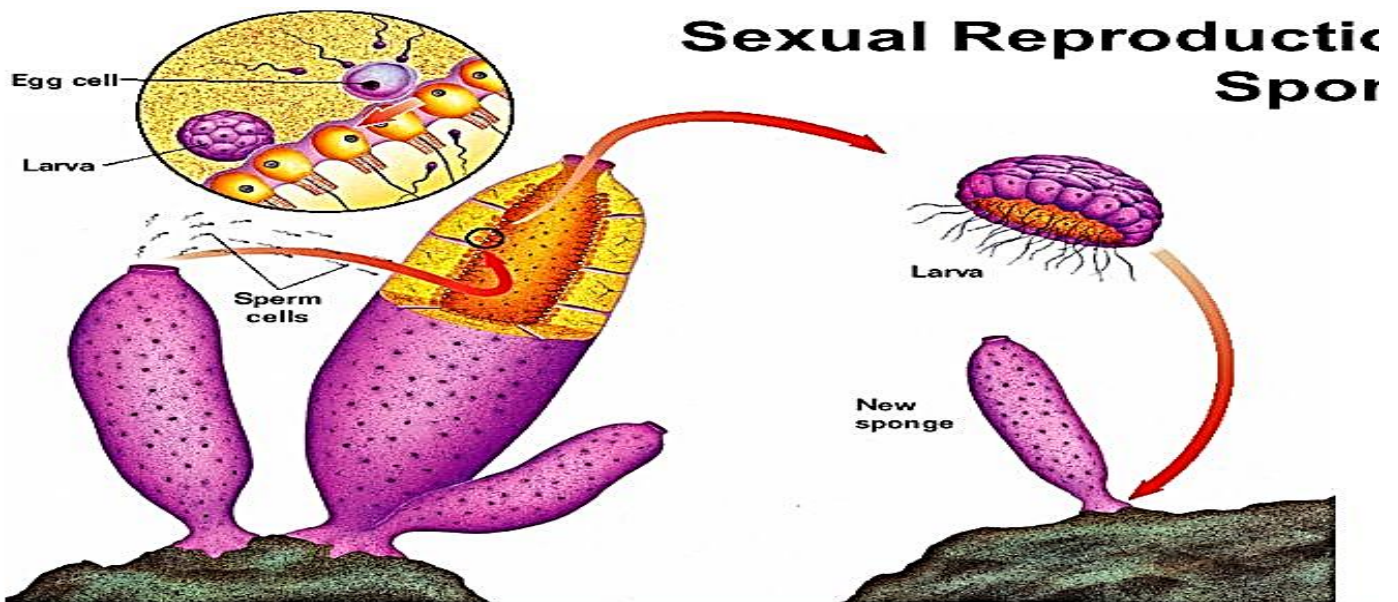
### Reproduction

#### 1. Asexual

- Budding
- Regeneration

## 2. Sexual

- Monoecious
- Choanocytes undergo meiosis to form flagellated sperm
- Other choanocytes form eggs by meiosis



## Reproduction

- Cleavage of a zygote results in the formation of flagellated larva
- Larva is released and develops into adult.

## Lecture 143

## • Phylum Coelenterata -1

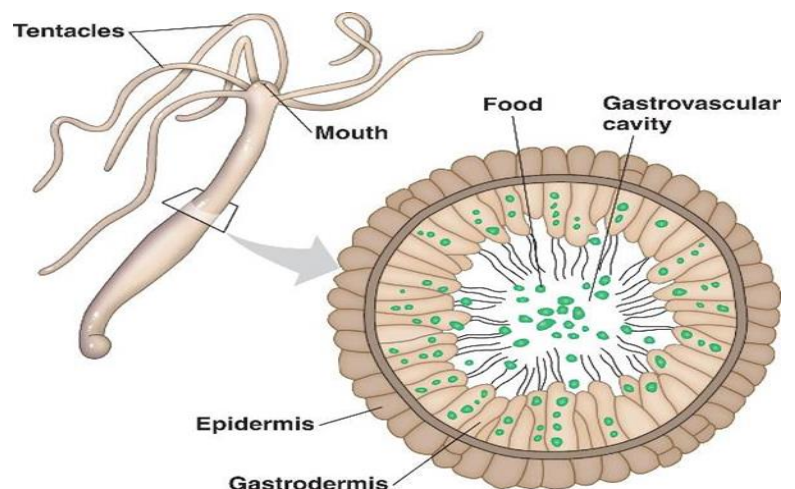
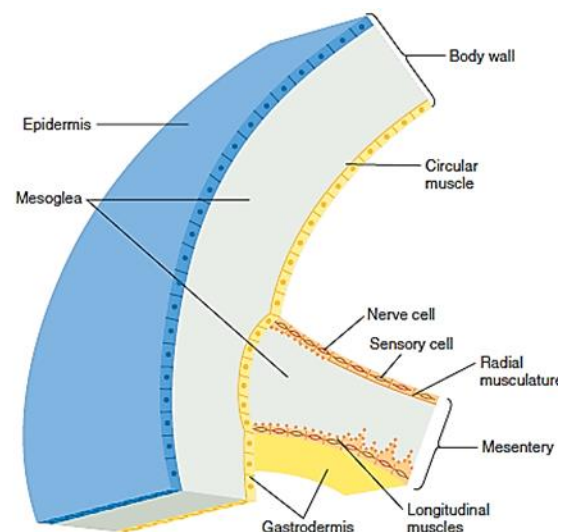
- Radial or biradial symmetry
- Diploblastic, tissue-level organization
- Gelatinous mesoglea between the epidermal and gastrodermal
- Gastrovascular cavity
- Specialized cells, called cnidocytes

## Classification

1. Class Hydrozoa
2. Class Scyphozoa
3. Class Cubozoa
4. Class Anthozoa

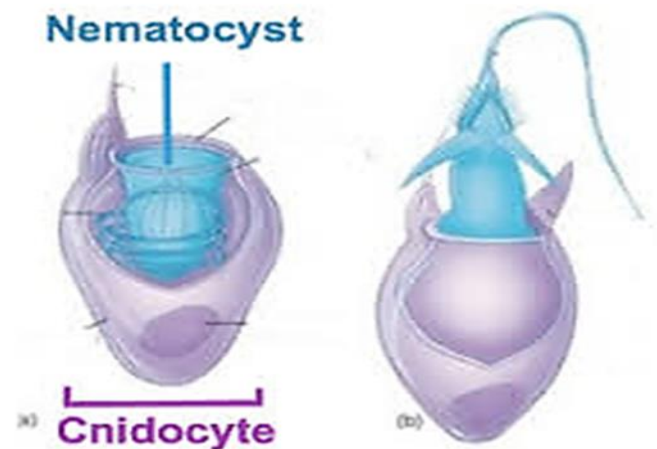
## Cells derived from embryological layers

- Epidermis
- Gastrodermis
- Mesoglea
  - Gastrovascular cavity
  - Cnidarians food consists of small crustaceans, small fish
  - Nutritive-muscular cells
  - Hydrostatic skeleton
  - Nervous system in the form of a nerve net



**Nematocysts**

- Fluid-filled, intracellular capsule enclosing a coiled, hollow tube
- A lid like operculum caps the capsule at one end
- The cnidocyte has a modified cilium called a **cnidocil**
- On stimulation, cnidocil discharge a coiled tube

**Alternation of Generation****1. Polyp**

- Asexual and sessile
- Attaches to a substrate at the aboral end
- Cylindrical body called **column**

**2. Medusa**

- Dioecious and free swimming
- Tentacles dangle from its margins

- Usually flattened dorsoventrally
- Triploblastic
- acoelomate
- Bilaterally symmetrical
- Unsegmented worms
- Beginning of cephalization with an anterior cerebral ganglion
- Longitudinal nerve cords
- Protonephridia as excretory structures
- Hermaphroditic
- Complex reproductive systems

**Classification**

- 1) Class Turbellaria (Free-Living Flatworms)
- 2) Class Monogenea
- 3) Class Trematoda (Flukes)
- 4) Class Cestoidea (Tapeworms)



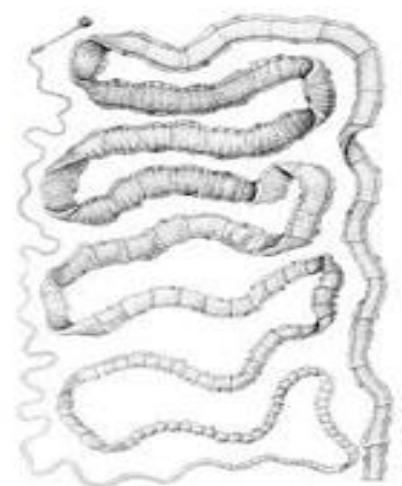
Planaria

Class - Turbellaria



Fasciola

Class - Trematoda



Taenia

Class - Cestoda

## Locomotion

- Bilaterally symmetrical animals
- Bottom dwellers
- Glide over the substrate
- Cilia and muscular undulations
- Sheet of mucus
- Aids in adhesion and helps the cilia gain traction

## Lecture 146

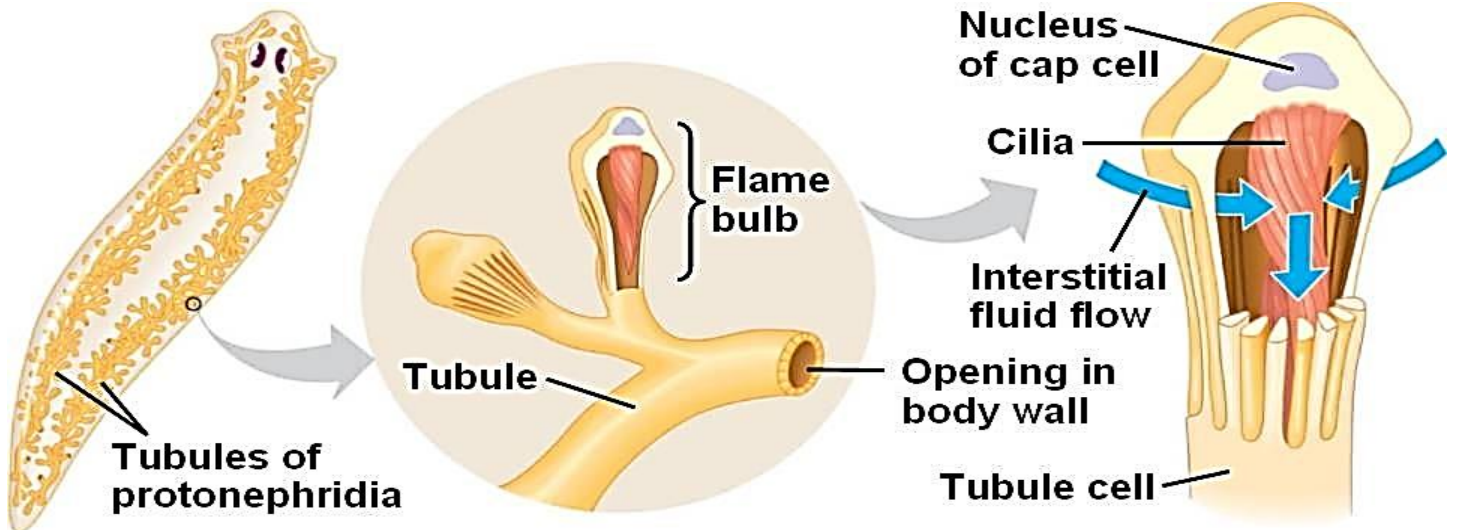
## • Phylum Platyhelminthes - 2

### Digestion and Nutrition

- Marine turbellarians lack the digestive cavity
- Other turbellarians have digestive tracts that are lobed
- Food digestion is partially extracellular
- Pharyngeal glands secrete enzymes that help break down food into smaller units
- Digestion is completed in intracellular vesicles

### Excretion

- Protonephridia or Flame cells



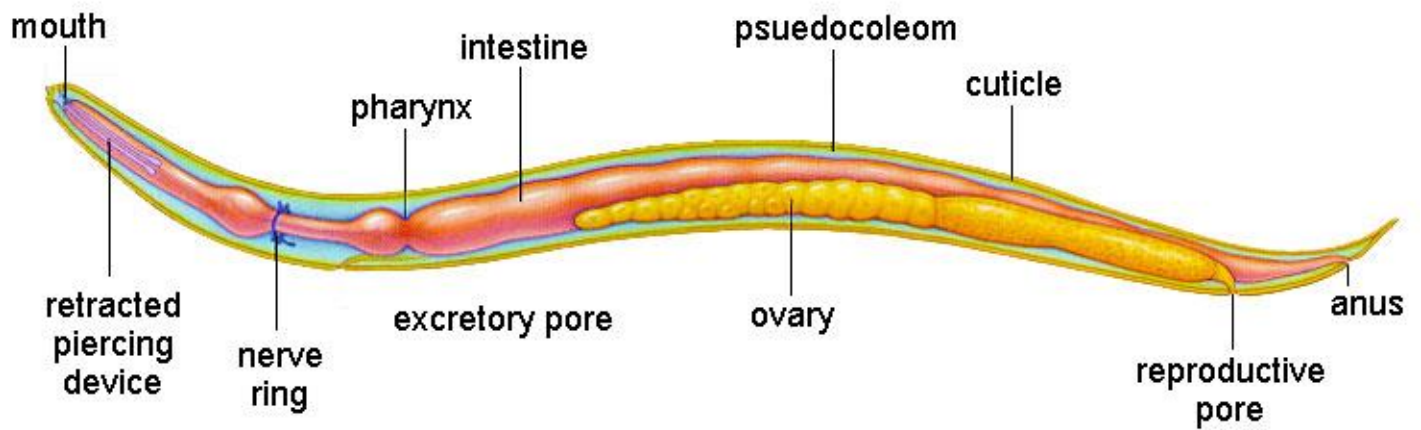
### Reproduction

- Reproduce asexually by transverse fission
- Monoecious
- Cross-fertilization
- reproductive systems arise from the mesodermal tissues in the parenchyma
- Female system has one to many pairs of ovaries
- Eggs are laid with or without a gel-like mass
- A hard capsule called a cocoon
- A few turbellarians have a free-swimming stage called a **Müller's larva**

## Lecture 147

## • Phylum Nematoda

- Triploblastic
- Bilateral
- Vermiform
- Unsegmented
- Pseudocoelomate
- Complete digestive tract
- Unique excretory system comprised of two or more renette cell



- Body wall has only longitudinal muscles
- Cuticle may contain spines, bristle papillae and ridges
- Pseudocoelom is a spacious fluid filled cavity
- Visceral organs
- Form hydrostatic skeleton
- May be herbivores, carnivores, omnivores and saprotrophs
- Feed on blood and tissue fluid of their hosts
- Complete digestive tract
- Excretion of nitrogenous waste
- Ventral gland cells, called **renette**
- Nervous system consist of anterior nerve ring

### Reproduction

- Dioecious and dimorphic
- Males are smaller than female

### Female System

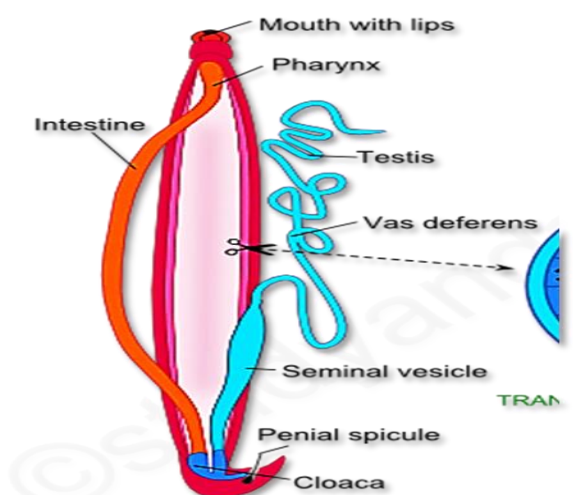
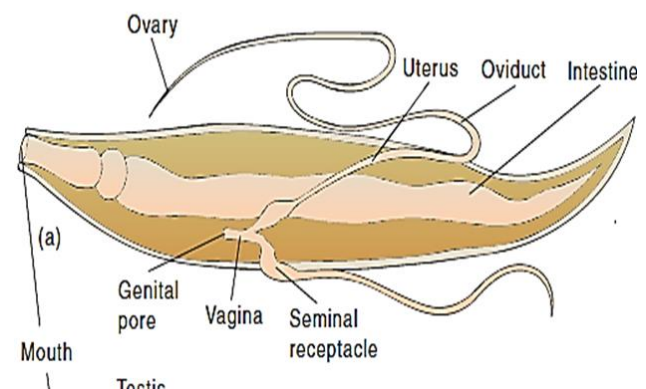
- Pair of convoluted ovaries
- Two uteri unite to form a vagina

### Male System

- Single testis
- Present vas deferens
- Seminal vesicles connect to the cloaca
- Posterior flap of tissue called **bursa**
- Help in copulation
- Parasites
- Parasitic adaptations

### Examples

- Ascaris
- Roundworms
- Hookworms
- Heartworms



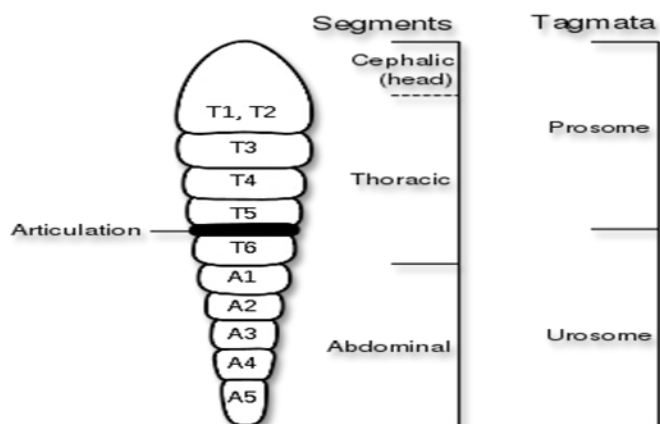
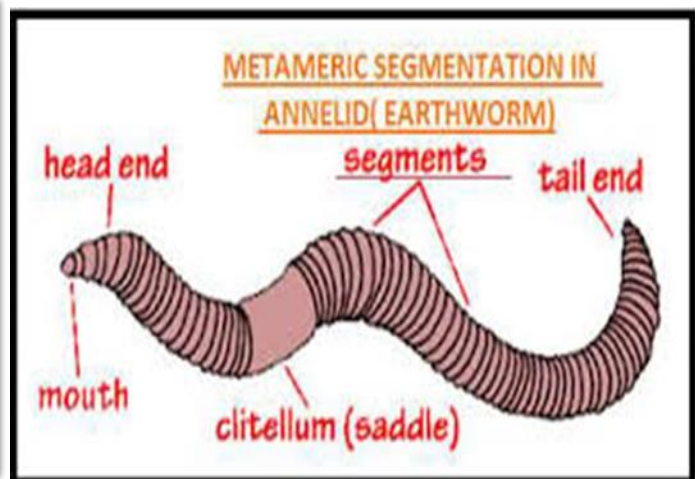
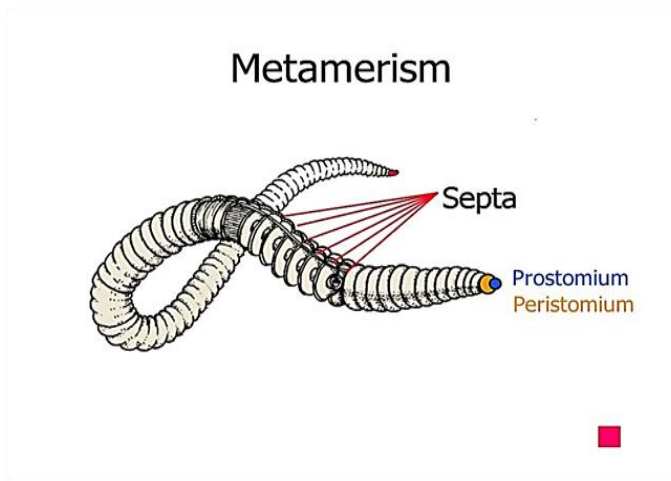
## Lecture 148

### • Phylum Annelida - 1

- Segmentation
- Metameric segmented
- Bilaterally symmetrical or wormlike
- Protostome characteristic
- Spiral cleavage, Trochophore larvae
- Paired epidermal setae
- Closed circulatory system
- Metanephridia or protonephridia

## Metamerism

- Segmented arrangement of body parts in an animal is called **Metamerism**.
- Each segment having its own excretory, nervous and circulatory system.



## Tagmatization

- Organization of segments into functional units (e.g. head, thorax and abdomen)

## Locomotion

Capable of walking, fast crawling or swimming

### 1. Parapodia

- Paired muscular bristle-bearing appendages used in locomotion, sensation and respiration.

### 2. Setae

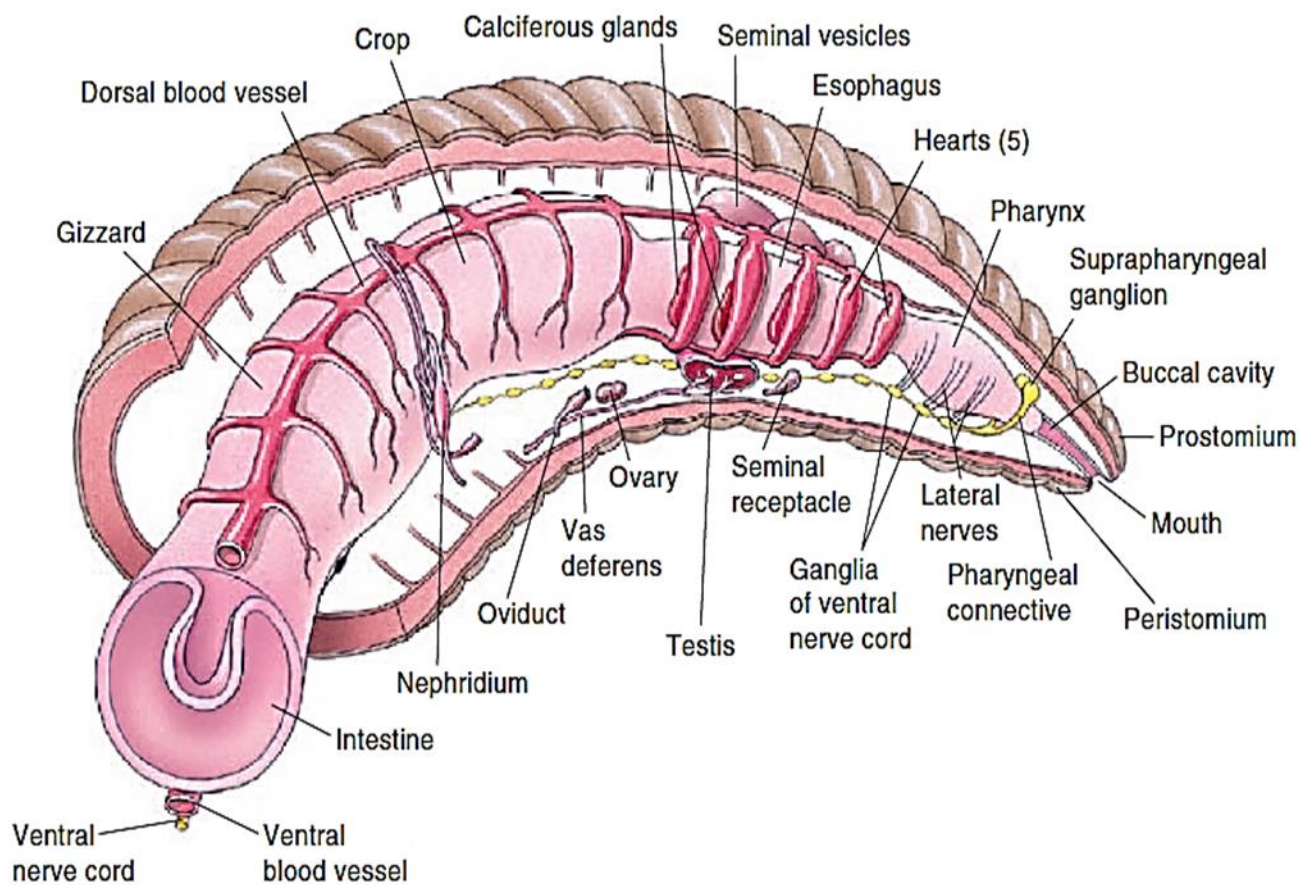
- Bristle secreted from invaginations of the distal ends of Parapodia.

## Feeding

- Oligochaetes are scavengers.
- Feed primarily on fallen and decaying vegetation
- Polychaetes are herbivores and scavengers
- Use jaws for tearing food
- Oligochaetes feed on body fluid of other vertebrates

## Classification

- Class Polychaeta (marine habitat)
- Class Oligochaeta (marine and terrestrial habitat)
- Class Hirudinea (marine, freshwater and terrestrial habitat)

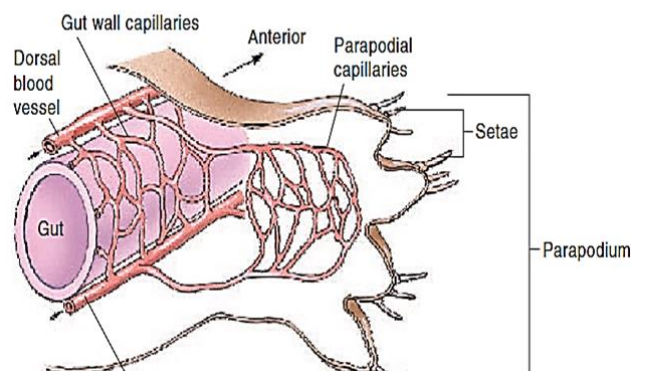


## Lecture 149

## • Phylum Annelida - 2

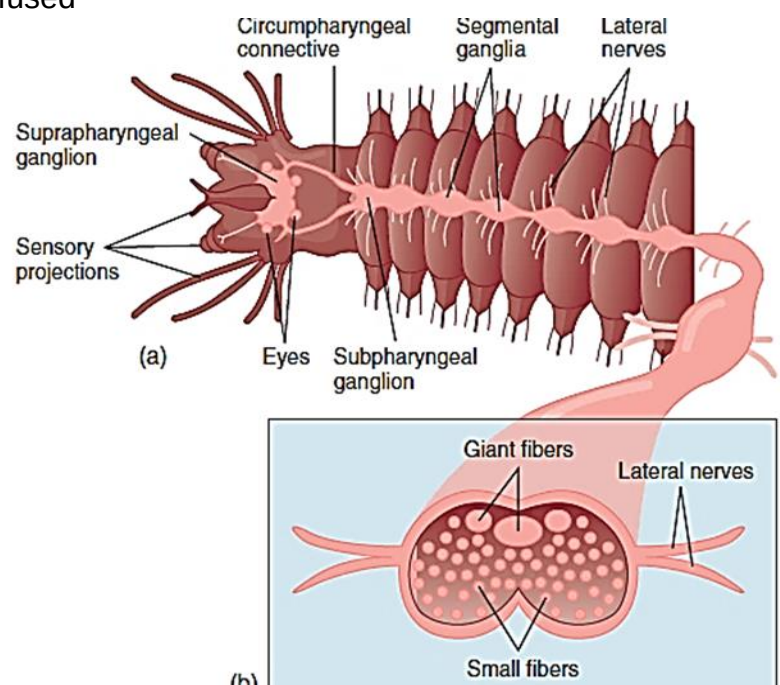
### Circulation

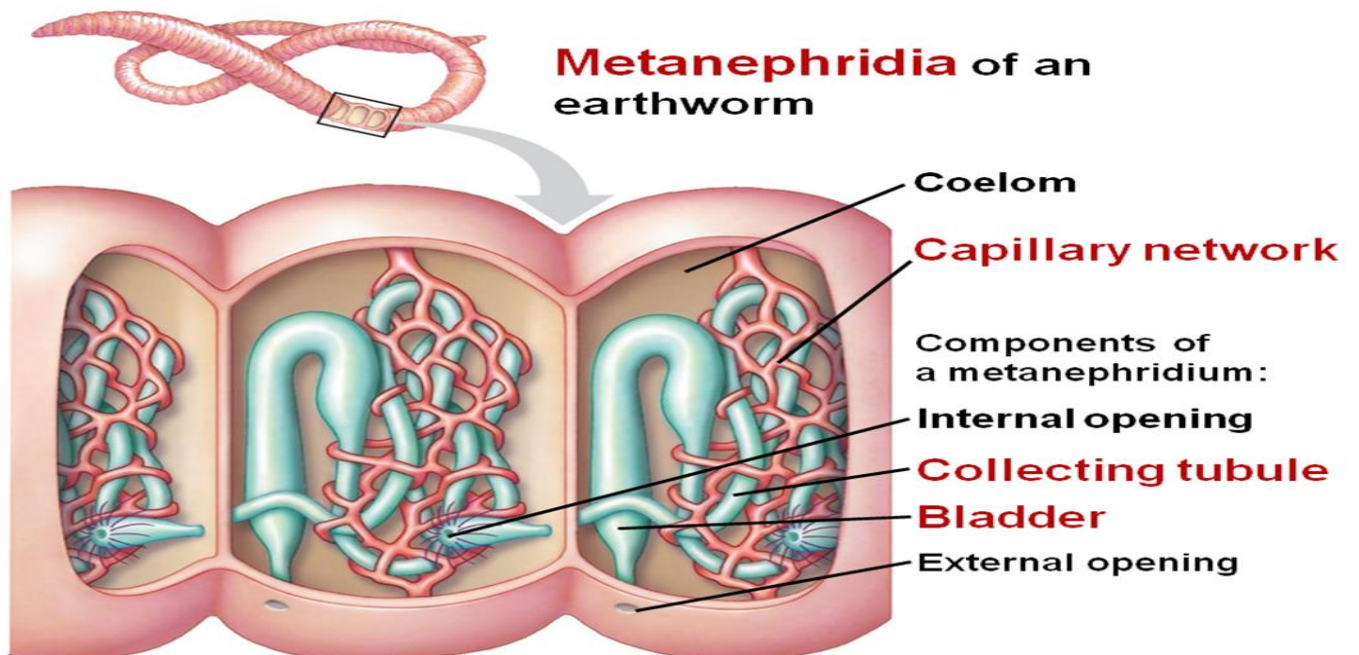
- Segmented vessels expand and may be contractile
- Expanded segmented vessels surround the esophagus
- Propel blood between dorsal and ventral blood vessels
- Branches from the ventral vessels supply the intestine and body wall.



### Nervous System

- Ventral nerve cord and all ganglia fused
- Giant fibers mediate escape response (Oligochaetes and Polychaetes)
- Ventral nerve cord are unfused, except at the ganglia (Leech)
- Sense organs are widely scattered over the body





### Reproductive System

- Power of regeneration
- Reproduce asexually by budding, transverse fission
- Dioecious and monoecious
- Three pairs of seminal vesicles
- Seminal receptacles receive sperm during copulation
- Cocoon is released.
- Contains many juveniles.

### Reproductive System

- Spiral cleavage
- No larva form
- Hatching occur in one to few weeks

## Lecture 150

## • Phylum Mollusca

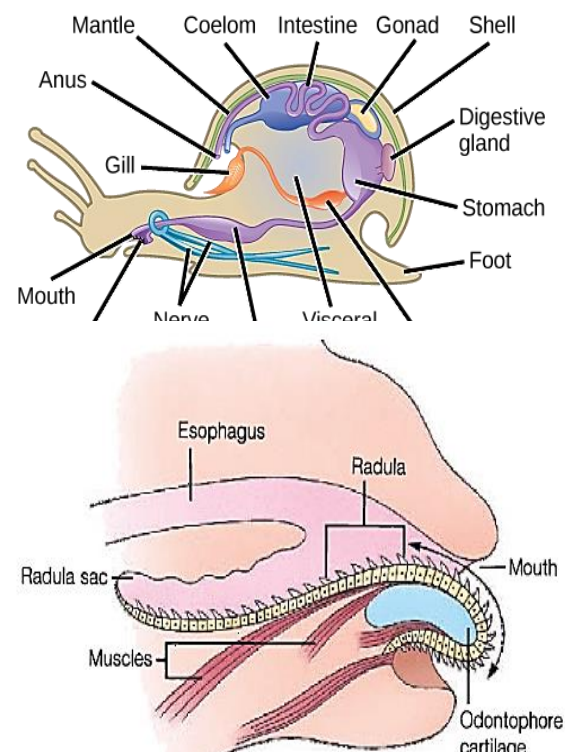
- Body divided into three parts
- Head-foot, visceral mass and mantle
- Mantle secretes a calcareous shell
- Bilateral symmetry
- Coelom reduced to cavities surrounding the heart, nephridia and gonads

### 1. Head-foot

- Elongate with an anterior head
- Containing mouth, nervous and sensory structure
- Elongate foot
- Used for attachment and locomotion

### 2. Visceral mass

- Contains the organ for:
- Digestion
- Circulation
- Reproduction
- Excretion

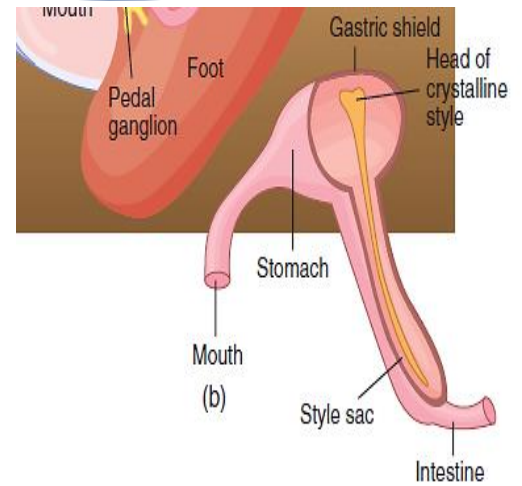


### 3. Mantle

- Attach to the visceral mass
- Secrete a shell
- Between the mantle and foot is a space **called mantle cavity**.
- Mantle cavity open to the outside

### 4. Radula

- Rasping structure called radula
- Consist of Chitinous belts
- Curved teeth
- Fleshy tongue like structure called odontophore
- Digestive tract is ciliated
- Food is trapped in mucous strings
- Mucoïd mass, called the protostyle
- Extend to the stomach and rotated by cilia
- Digestive gland releases enzymes and acids into stomach
- Food trap on the protostyle
- Wastes form fecal pellets move into intestine



### Reproduction

- Both dioecious and monoecious
- Gonads lie in spirals of the visceral mass
- External fertilization
- Internal, cross fertilization
- In gastropods, spiral cleavage results in Trochophore larva
- This develop into another larva called veliger larva

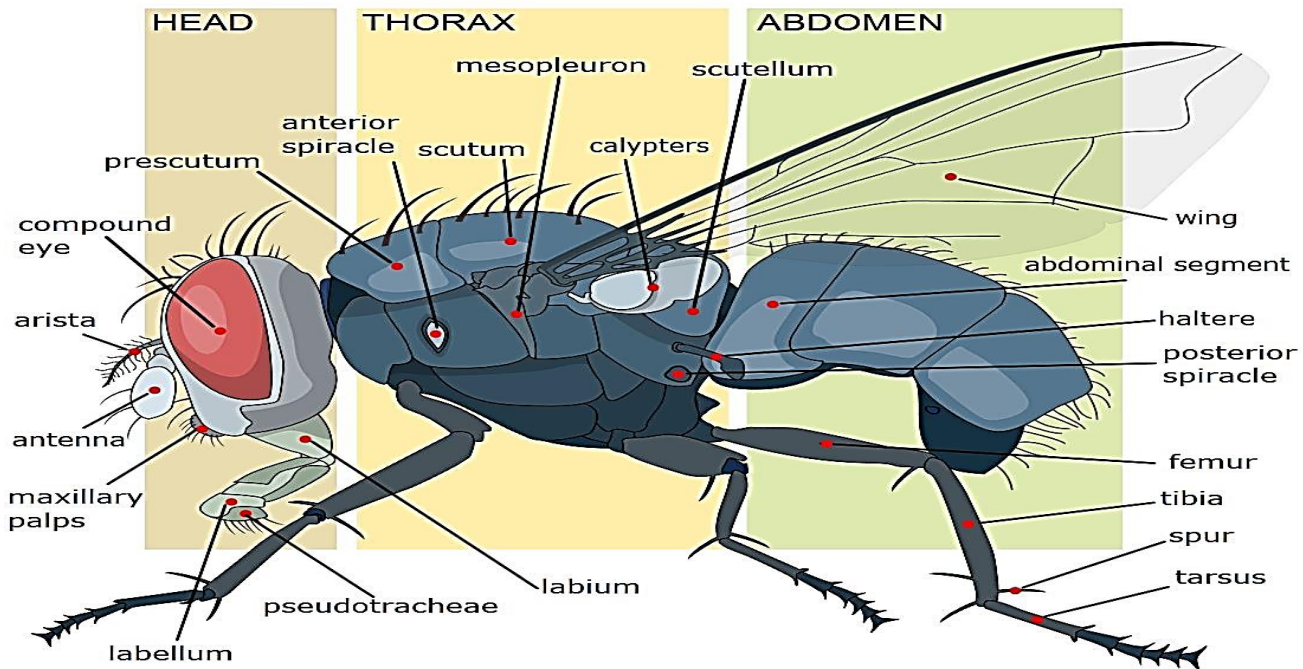
### Classification

1. Class Gastropoda (snails and slugs)
2. Class Bivalvia (oysters, mussels)
3. Class Cephalopoda (octopuses and cuttle fish)

## Lecture 151

## • Phylum Arthropoda - 1

- **Metamerism and Tagmatization**
- Chitinous exoskeleton that provides support and protection
- Paired, joined appendages
- Growth accompanied by Ecdysis and molting
- Ventral nervous system
- Open circulatory system in which blood is released into tissue spaces
- Complete digestive tract
- An external, jointed skeleton called exoskeleton or cuticle
- Non-living and secreted by single layer of epidermis

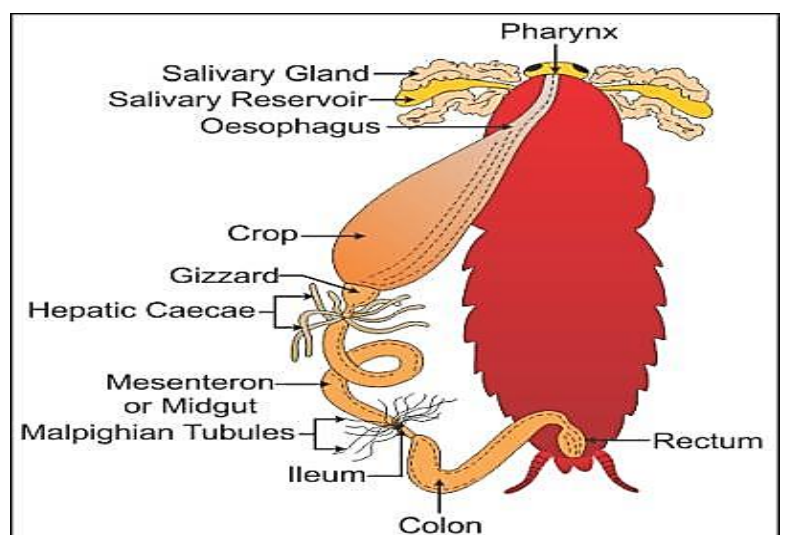


### Exoskeleton

- Provides structural support
- Protection
- Impermeable surfaces for the prevention of water loss
- Muscle attachment and movement
- It is shed off at the time of growth, called **ecdysis**.

### Digestion

- Herbivore, carnivore, parasites
- Complete gut
- Three parts of gut
- Gizzard may be present.
- Gut receives nitrogenous wastes for excretion



## Lecture 152

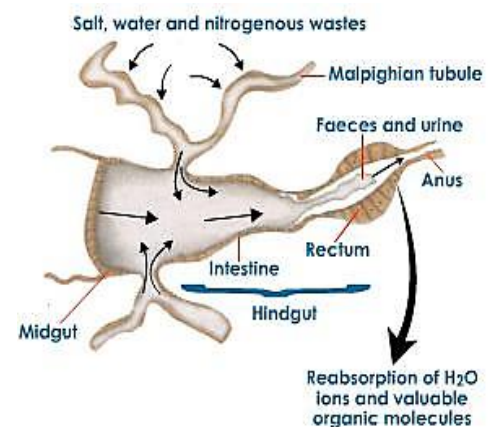
## • Phylum Arthropoda - 2

### Excretion

1. Coxal glands
2. Malpighian Tubules

#### 1. Coxal glands

- Paired
- Thin walled
- Absorb nitrogenous waste and excrete through excretory pore



## 2. Malpighian tubules

- Absorb waste material from the blood and empty them into the gut tract
- Major excretory product is uric acid
- Uric acid is excreted as a semisolid with little water loss

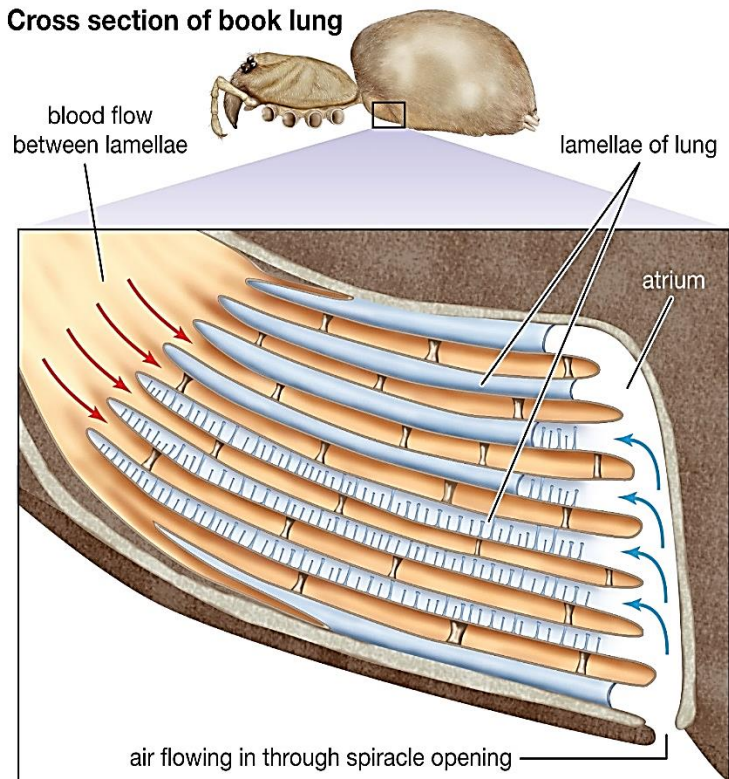
## Respiration

- Gas exchange occurs through minimal water loss
- Arachnids possess structures, **called book lungs**
- Insects have tracheal system

## Circulatory System

- Open circulatory system
- Blood pump into blood spaces
- Large tissue spaces are called hemocoel
- Blood bath the tissues and then return into the dorsal aorta, through an opening called ostia

Cross section of book lung



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