Principles of Ecology

BSc. Course 2024 – 2025

Lecture – 5

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Biogeochemical Cycles

What are biogeochemical cycles?

- **Describe the flow of essential elements from the environment through living organisms and back into the environment.**
- Earth system has four parts
  - **Atmosphere, Hydrosphere, Lithosphere, Biosphere**
- **Biogeochemical cycles:** The chemical interactions (**cycles**) that exist between the atmosphere, hydrosphere, lithosphere, and biosphere.
- **Abiotic** (physio-chemical) and **biotic** processes drive these cycles

Hydrological Cycle

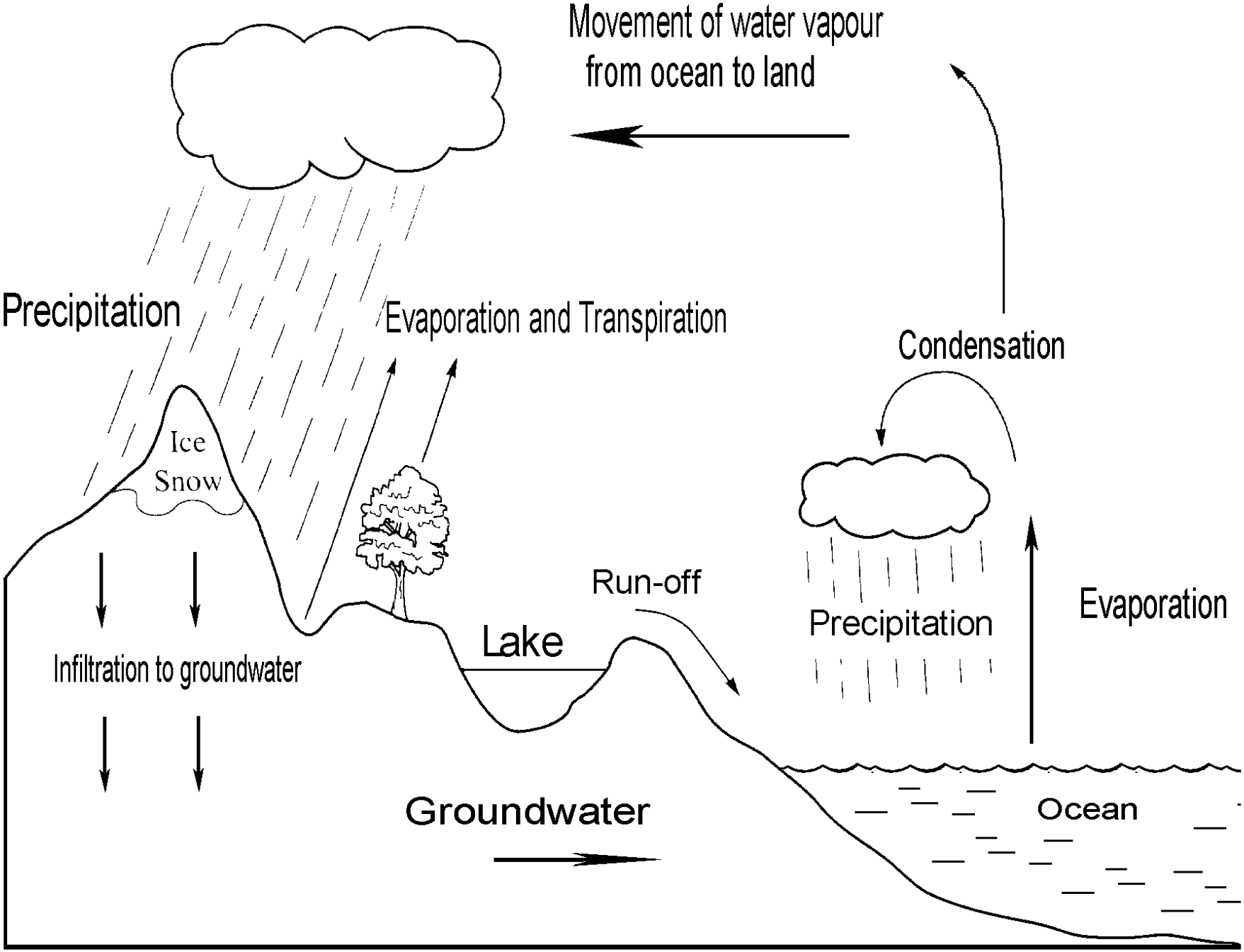
(water cycle)

1. **Reservoir** – oceans, air (as **water vapor**), groundwater, lakes and glaciers; evaporation, wind and precipitation (**rain**) move water from oceans to land

2. **Assimilation** – plants absorb water from the ground, animals drink water or eat other organisms which are composed mostly of water

3. **Release** – plants transpire, animals breathe and expel liquid wastes

Hydrological Cycle

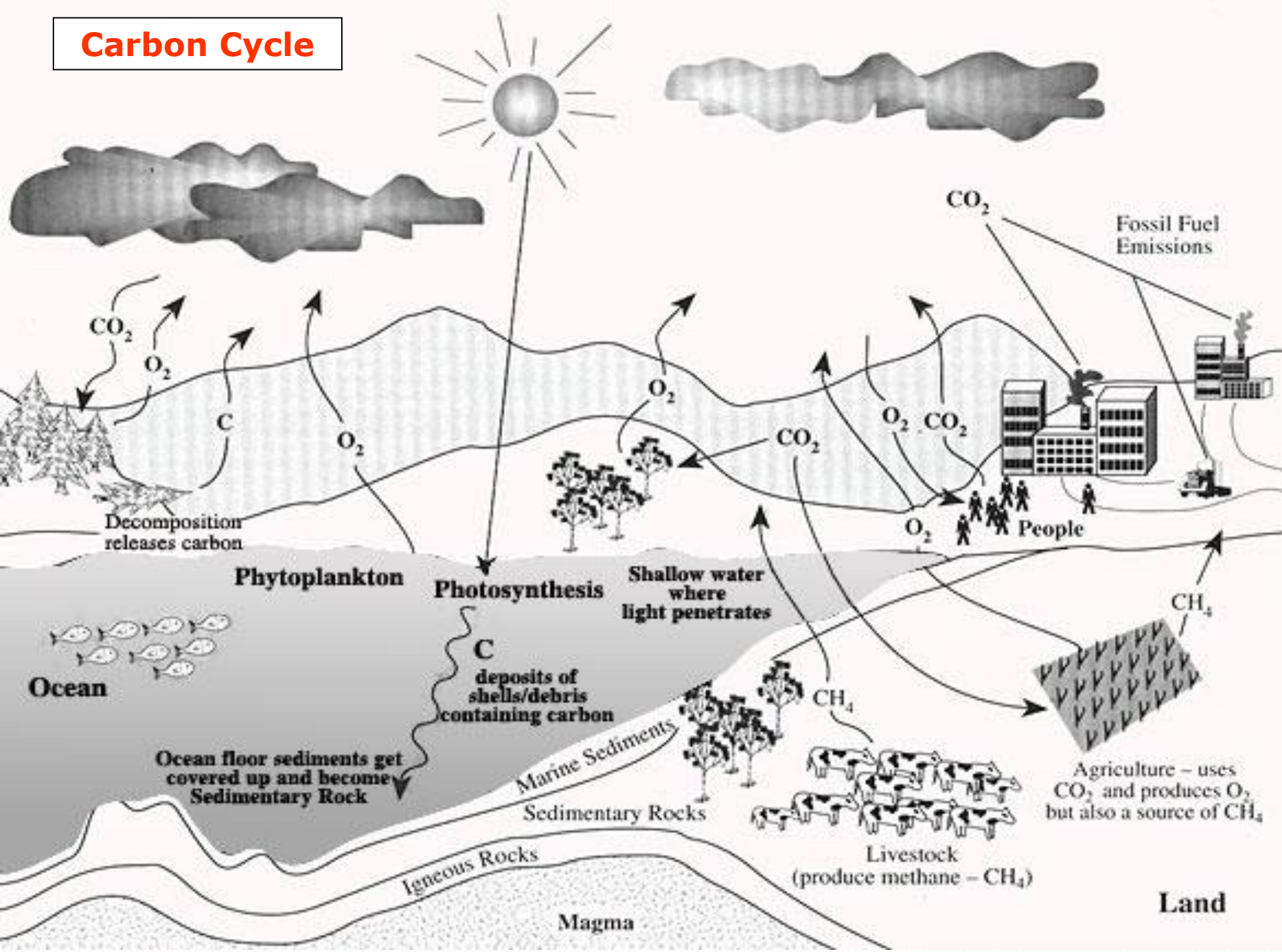


Carbon Cycle

(carbon is required for building organic compounds)

1. **Reservoir** – atmosphere (as CO_2), fossil fuels (**oil**, **coal**), durable organic materials (for example: **cellulose**).
2. **Assimilation** – plants use CO_2 in photosynthesis; animals consume plants.
3. **Release** – plants and animals release CO_2 through respiration and decomposition; CO_2 is released as wood and fossil fuels are burned.

Carbon Cycle



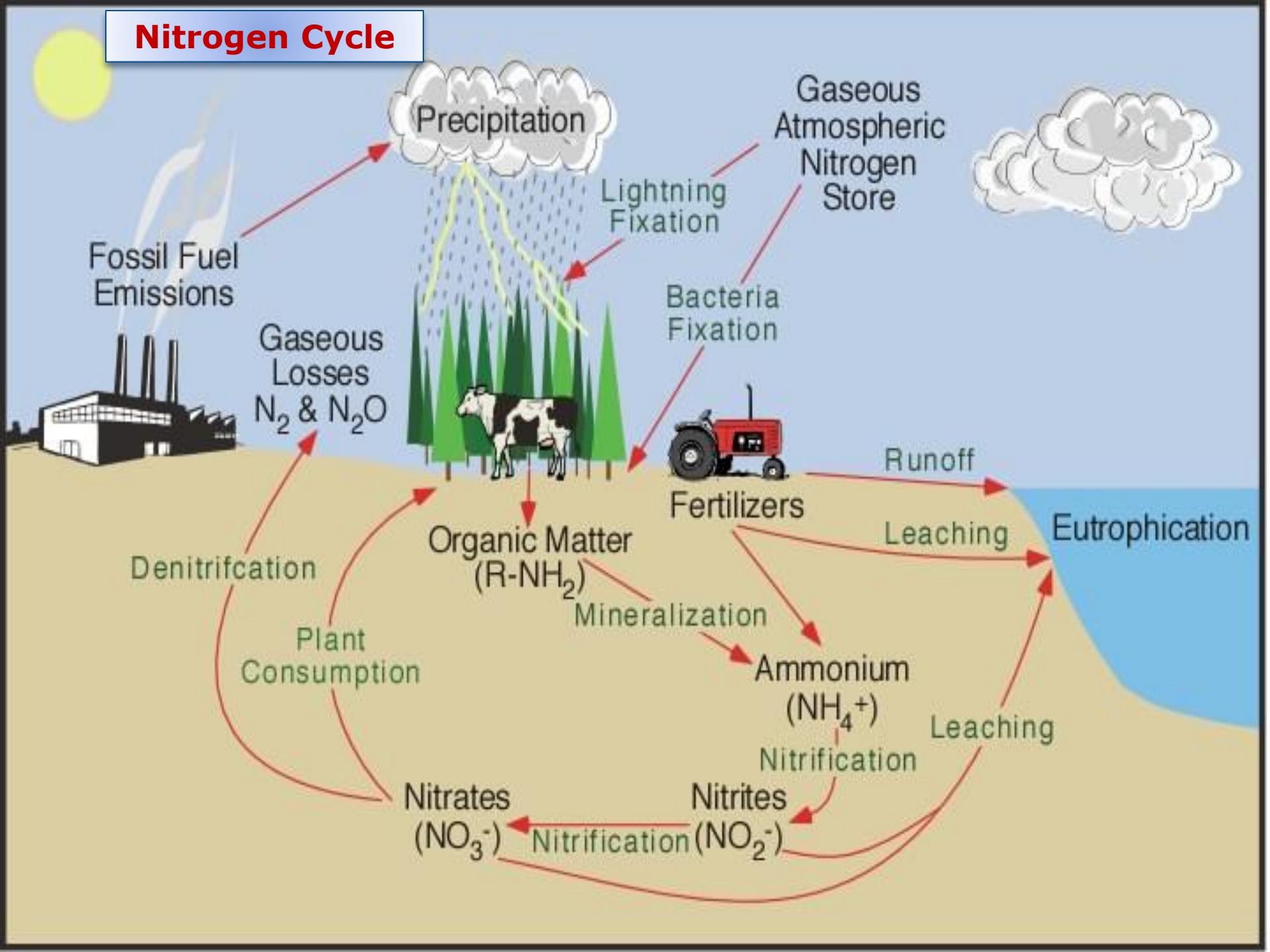
Nitrogen Cycle

(Nitrogen is required for the manufacture of amino acids and nucleic acids)

1. **Reservoir** – atmosphere (as N_2); soil (as NH_4^+ or ammonium, NH_3 or ammonia, $N0_2^-$ or nitrite, $N0_3^-$ or nitrate.
2. **Assimilation** – plants absorb nitrogen as either NH_4^+ or as $N0_3^-$, animals obtain nitrogen by eating plants and other animals. The stages in the assimilation of nitrogen are as follows:

   Nitrogen Fixation: N_2 to NH_4^+ by nitrogen-fixing bacteria (prokaryotes in the soil and root nodules), N_2 to $N0_3^-$ by lightning and **UV** radiation.

   Nitrification: NH_4^+ to $N0_2^-$ and $N0_2^-$ to $N0_3^-$ by various nitrifying bacteria.
3. **Release** – Denitrifying bacteria convert $N0_3^-$ back to N_2 (**denitrification**); detrivorous bacteria convert organic compounds back to NH_4^+ (ammonification); animals excrete NH_4^+ (or NH_3) **urea**, or **uric acid**.

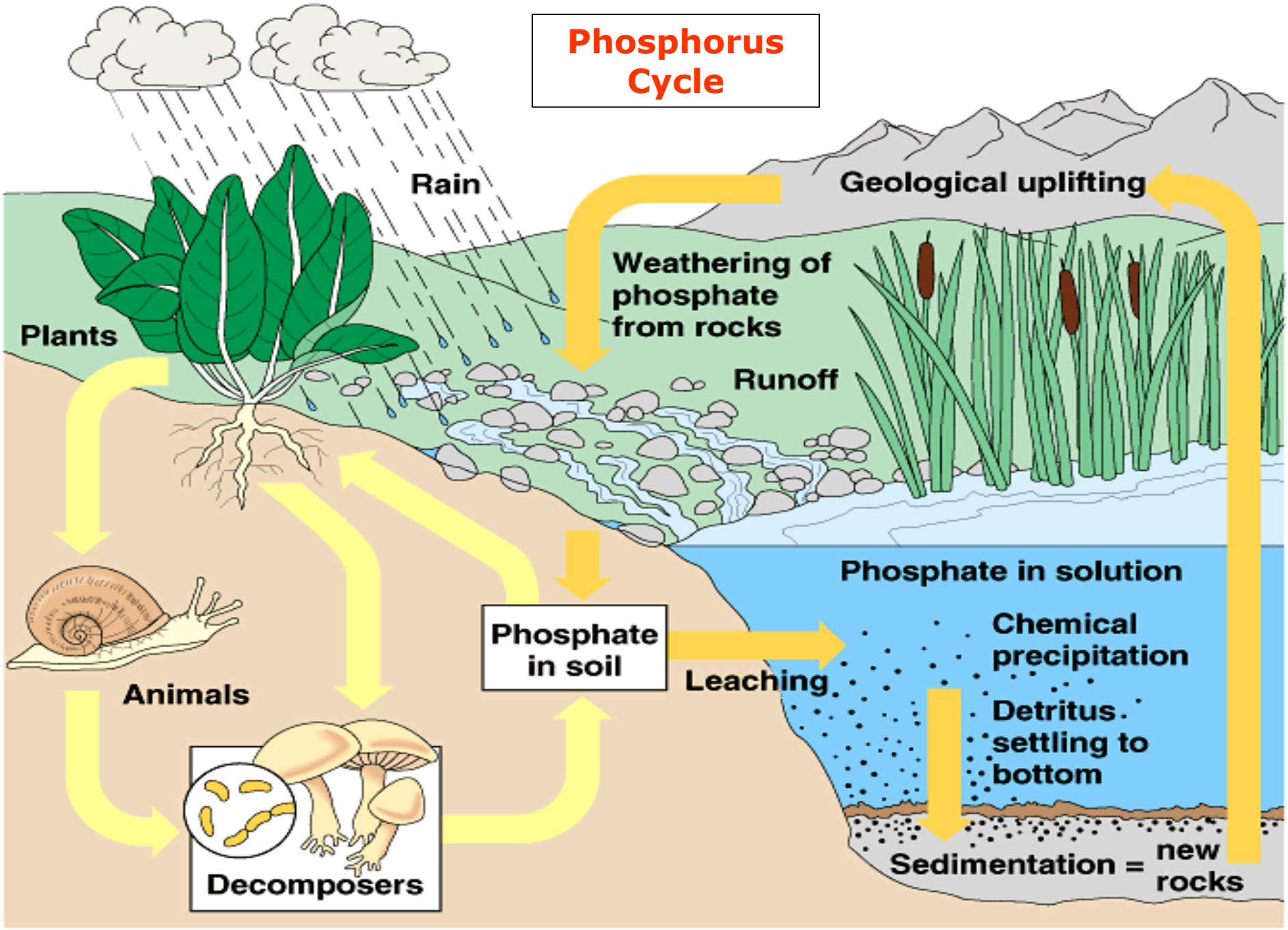

Nitrogen Cycle
Precipitation
Gaseous Atmospheric Nitrogen Store
Lightning Fixation
Fossil Fuel Emissions
Bacteria Fixation
Gaseous Losses N_2 & N_2O
Runoff
Fertilizers
Eutrophication
Leaching
Organic Matter ($R\text{-}NH_2$)
Denitrifcation
Mineralization
Plant Consumption
Ammonium (NH_4^+)
Leaching
Nitrification
Nitrates (NO_3^-)
Nitrites (NO_2^-)
Nitrification

Phosphorus Cycle

(Phosphorus is required for the manufacture of ATP and all nucleic acids)

1. **Reservoir** – erosion transfers phosphorus to water and soil; sediments and rocks that accumulate on ocean floors return to the surface as a result of uplifting by geological processes
2. **Assimilation** – plants absorb inorganic $\mathbf{PO_4^{3-}}$ (**phosphate**) from soils; animals obtain organic phosphorus when they eat plants and other animals
3. **Release** – plants and animals release phosphorus when they decompose; animals excrete phosphorus in their waste products.

Phosphorus Cycle

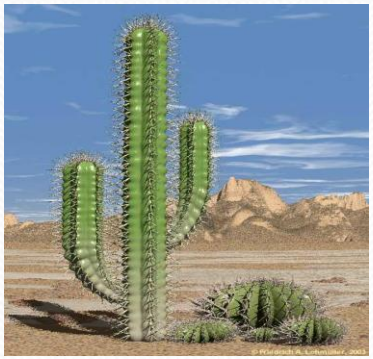


Types of Interspecific Interactions

	Effect on Species 1	Effect on Species 2
• Neutralism	0	0
• Competition	-	-
• Commensalism	+	0
• Amensalism	-	0
• Mutualism	+	+
• Predation	-	+
• Parasitism, Herbivory	+	-

Neutralism

- **Neutralism** the most common type of interspecific interaction.
- Neither population affects the other.
- If any interactions do occur they are indirect or incidental.
- **Example:** the **tarantulas** living in a desert and the **cacti** living in a desert



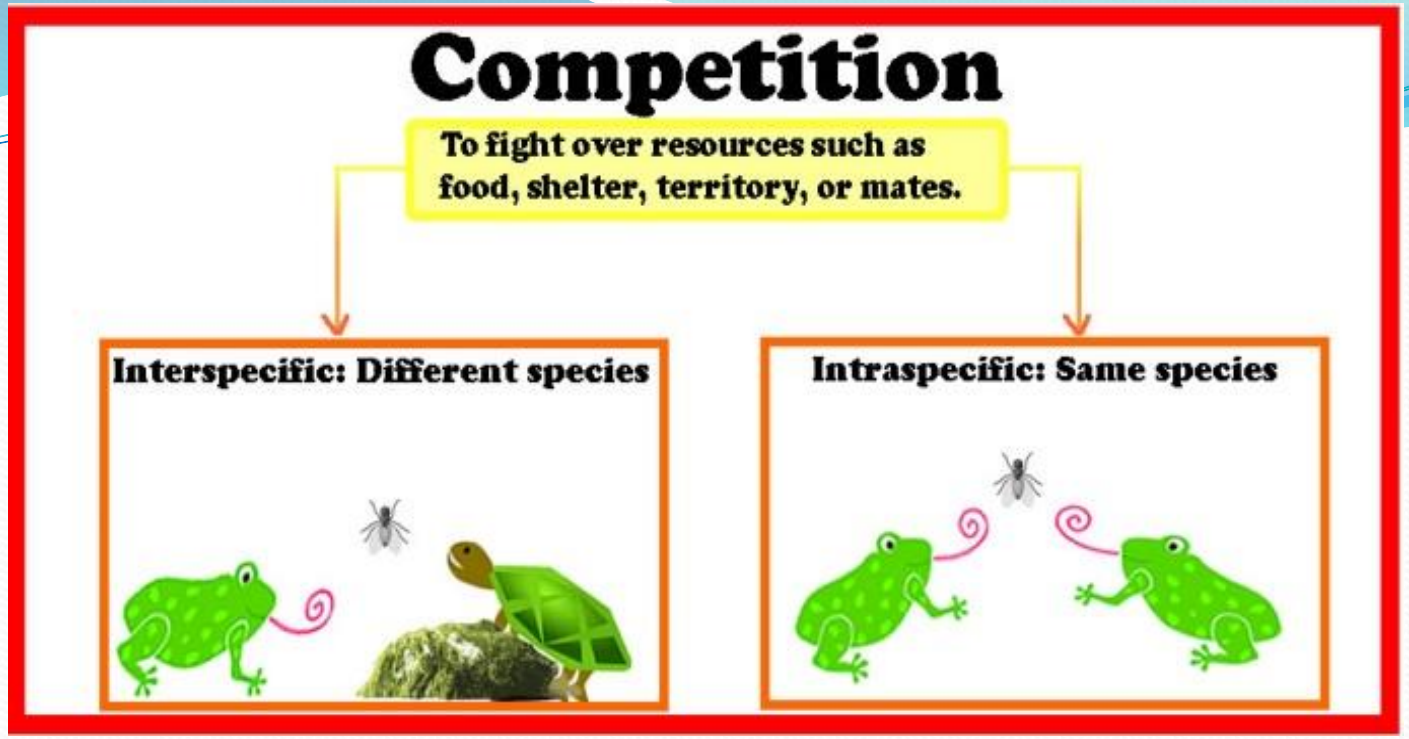
Competition: occurs when organisms in the same community seek the same limiting resource.

This resource may be prey, water, light, nutrients, nest sites, etc.

Competition among members of the same species is **intraspecific**.

Competition among individuals of different species is **interspecific**.

Individuals experience both types of competition, but the relative importance of the two types of competition varies from population to population and species to species.



Some specific types of competition

Consumptive competition

Preemptive competition

Overgrowth competition

Chemical composition

Territorial competition

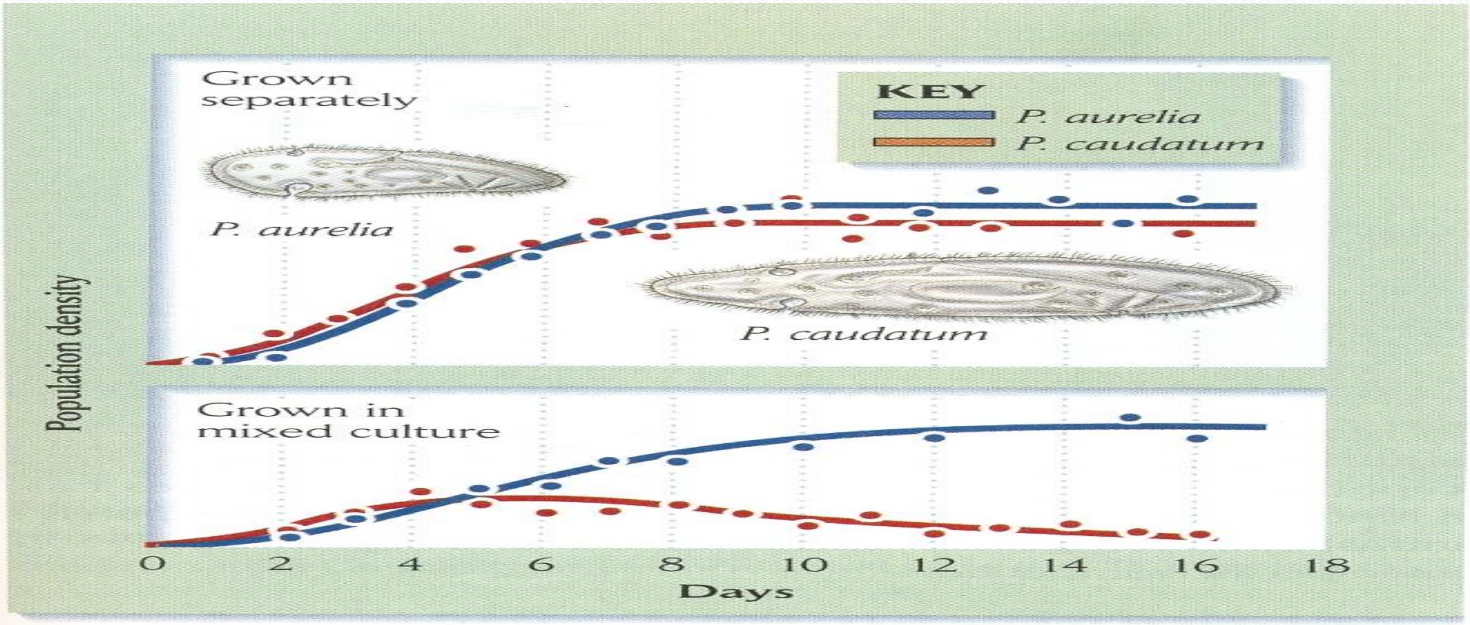
Encounter competition

Example of Interference Competition

- The confused flour beetle, *Triboleum confusum*, and the red flour beetle, *Triboleum castaneum* cannibalize the eggs of their own species as well as the other, thus interfering with the survival of potential competitors.
- In mixed species cultures, one species always excludes the other
- Which species prevails depends upon environmental conditions, chance, and the relative numbers of each species at the start of the experiment.

The Competitive Exclusion Principle

- Early in the twentieth century, two mathematical biologists, **A.J. Lotka and V. Volterra** developed a model of population growth to predict the outcome of competition.
- Their models suggest that two species cannot compete for the same limiting resource for long. Even a minute reproductive advantage leads to the replacement of one species by the other. This is called the **competitive exclusion principal**.
- A famous experiment by the Russian ecologist, **G.F. Gausse** demonstrated that ***Paramecium aurellia*** outcompetes and displaces ***Paramecium caudatum*** in mixed laboratory cultures, apparently confirming the principle.
- (Interestingly, this is not always the case. Later studies suggest that the particular strains involved affect the outcome of this interaction).



Amensalism

- **Amensalism** is when one species suffers and the other interacting species experiences no effect.
- Example: Redwood trees falling into the ocean become floating battering-rams during storms, killing large numbers of mussels and other inter-tidal organisms.
- **Allelopathy** involves the production and release of chemical substances by one species that inhibit the growth of another.
- These **secondary substances** are chemicals produced by plants that seen to have no direct use in metabolism.
- This same interaction can be seen as both **amensalism**, and extremely one-sided interference competition-in fact it is both.

Commensalism

- **Commensalism** is an interspecific interaction where one species benefits and the other is unaffected.
- Commensalisms are ubiquitous in nature: birds nesting in trees are commensal.
- Commensal organisms frequently live in the nests, or on the bodies, of the other species.
- **Examples of Commensalism:**
- Ant colonies harbor rove beetles as commensals.
- These beetles mimic the ants behavior, and pass as ants.
- They eat detritus and dead ants.
- Anemonefish live within the tentacles of anemones.
- They have specialized mucus membranes that render them immune to the anemone's stings.
- They gain protection by living in this way.

Mutualism

- **Mutualism** in an interspecific interaction between two species that benefits both members.
- Populations of each species grow, survive and/or reproduce at a higher rate in the presence of the other species.
- Mutualisms are widespread in nature, and occur among many different types of organisms.
- **Facultative vs. Obligate Mutualisms**
- **Facultative** Mutualisms are not essential for the survival of either species. Individuals of each species engage in mutualism when the other species is present.
- **Obligate** mutualisms are essential for the survival of one or both species.

Mutualism

- **Examples of Mutualism:**

- Most rooting plants have mutualistic associations with fungal mychorrhizae. Mychorrhizae increase the capability of plant roots to absorb nutrients. In return, the host provides support and a supply of carbohydrates.
- Many corals have endosymbiotic organisms called zooxanthellae (usually a dinoflagellate).
- These mutualists provide the corals with carbohydrates via photosynthesis. In return, they receive a relatively protected habitat from the body of the coral.

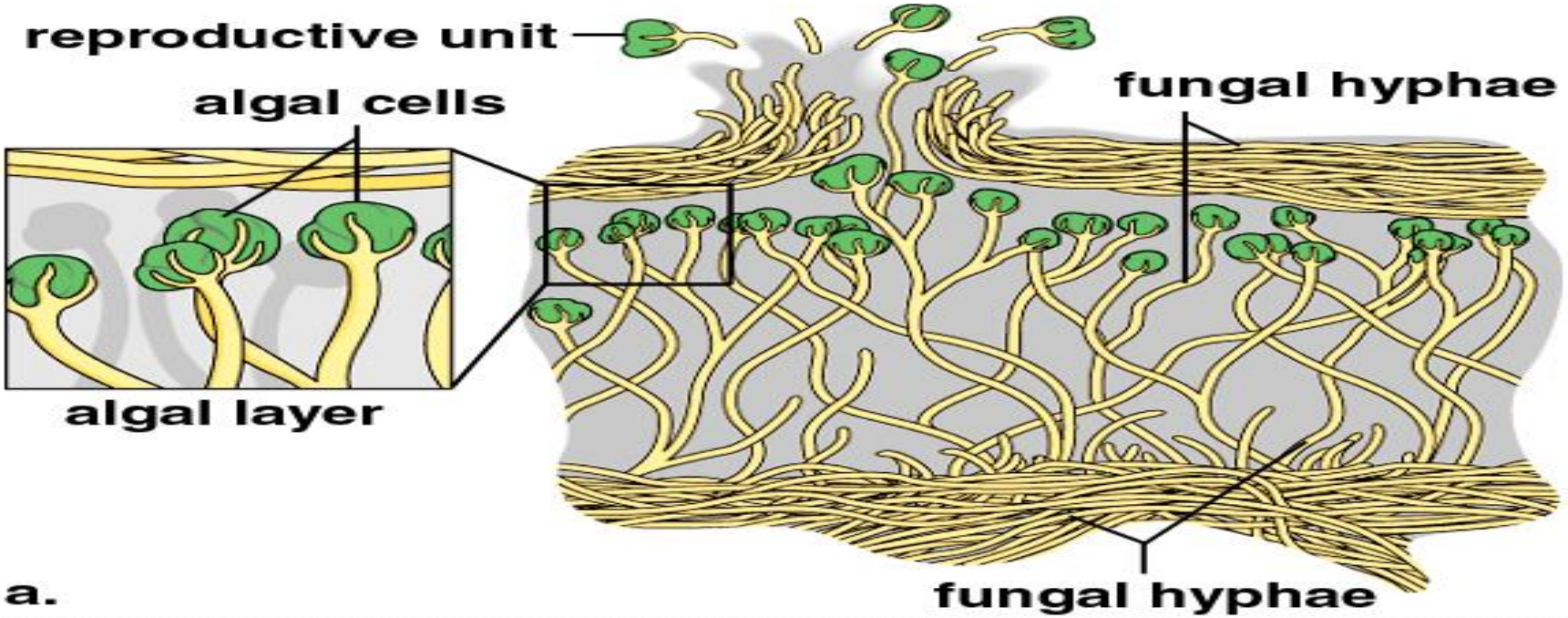
Mutualism

- **Examples of Mutualism:**
  - Flowering plants and pollinators.(both facultative and obligate)
  - Parasitoid wasps and polydnaviruses. (obligate)
  - Ants and aphids. (facultative)
  - Termites and endosymbiotic protozoa. (obligate)
  - Humans and domestic animals. (mostly facultative, some obligate)

Mutualistic Symbiosis

- **Mutualistic Symbiosis** is a type of mutualism in which individuals interact physically, or even live within the body of the other mutualist.
- Frequently, the relationship is essential for the survival of at least one member.
- Example: **Lichens** are a fungal-algal symbiosis (that frequently includes a third member, a cyanobacterium).
- The mass of fungal hyphae provides a protected habitat for the algae, and takes up water and nutrients for the algae.
- In return, the algae (and cyanobacteria) provide carbohydrates as a source of energy for the fungus.

Lichen morphology



Predation, Parasitism, Herbivory

- **Predators, parasites, parasitoids, and herbivores** obtain food at the expense of their hosts or prey.
- **Predators** tend to be larger than their prey, and consume many prey during their lifetimes.
- **Parasites** and **pathogens** are smaller than their host. Parasites may have one or many hosts during their lifetime.
- **Pathogens** are parasitic microbes-many generations may live within the same host.
- Parasites consume their host either from the inside **(endoparasites**) or from the outside **(ectoparasites).**
- **Parasitoids** hunt their prey like predators, but lay their eggs within the body of a host, where they develop like parasites.
- **Herbivores** are animals that eat plants. This interaction may resemble **predation**, or **parasitism**.
- The relationships between **predator** and **prey**, and **parasites** and **hosts**, have coevolved over long periods of time.
- Evolutionary biologist named Haldane suggested that the interaction between parasite and host (or **predator** and **prey**) resembles an **evolutionary arms race** in that parasite (or **predator**) evolves a trait that allows it to attack its host (or **prey**).