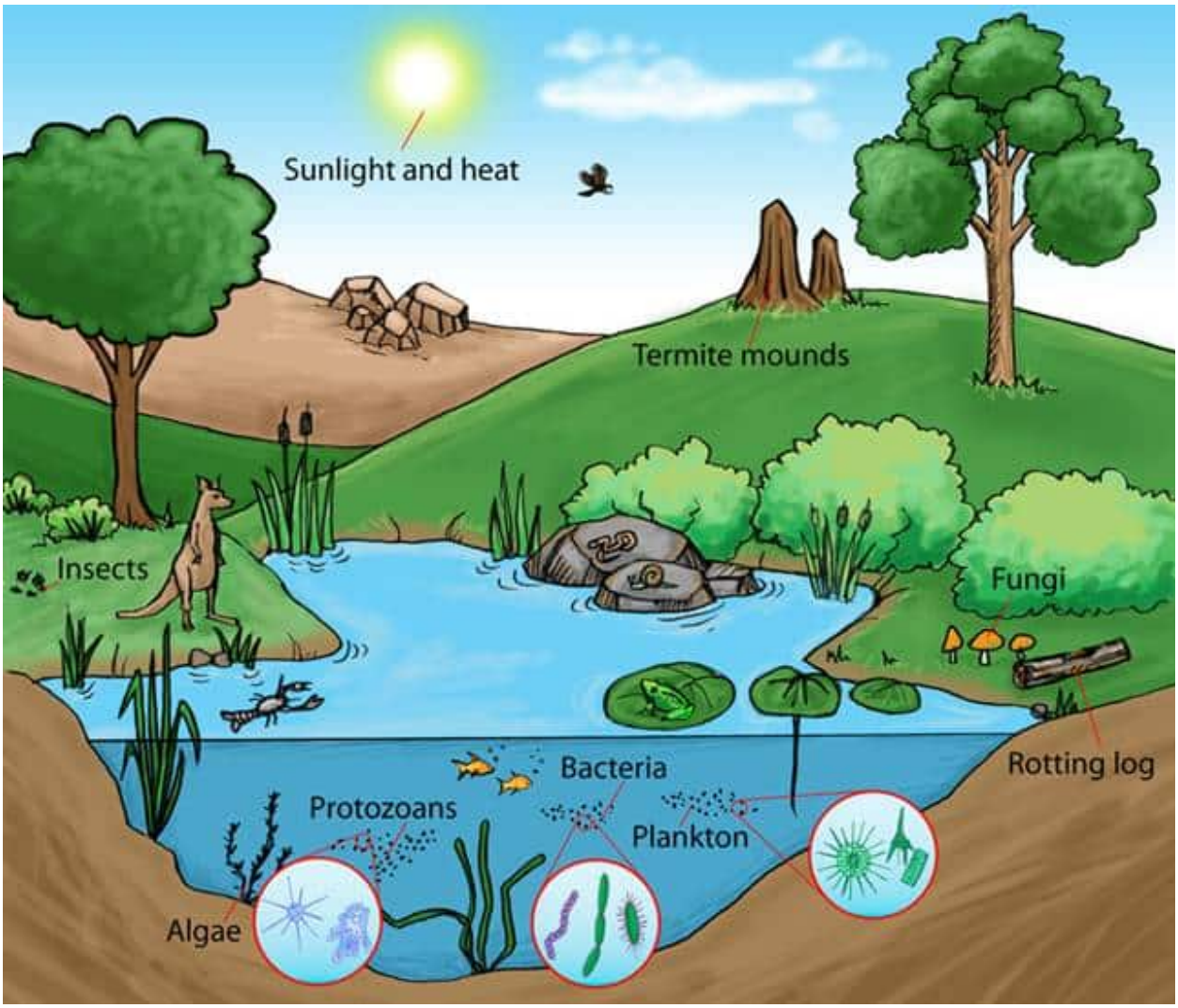
Unit 9 - How do Species Interact:

Ecosystems:

An ecosystem is a community of living organisms interacting with each other and their physical environment. It's like a small world where plants, animals, and other organisms live and depend on each other.

For example, a forest ecosystem includes trees, animals like squirrels and birds, insects, soil, water, and sunlight. Each part of the ecosystem has a role to play. Plants make food from sunlight, animals eat plants or other animals, and everything relies on water and nutrients from the soil.

Ecosystems can be big, like a forest, or small, like a pond. They're important because they help maintain balance in nature and provide us with things we need, like clean air and water.



Robert Paine:

Robert Paine's experiment, known as the "keystone species" experiment, was conducted in the rocky intertidal zone of the Pacific Northwest coast of the United States in the early 1960s. Here's an outline of the experiment:

1. **Background**: Paine observed that the intertidal ecosystem was dominated by various species, including mussels, sea stars (predators), barnacles, and algae.
2. **Hypothesis**: Paine proposed that certain species, particularly the predatory sea star Pisaster ochraceus, were critical in maintaining species diversity and ecosystem stability.

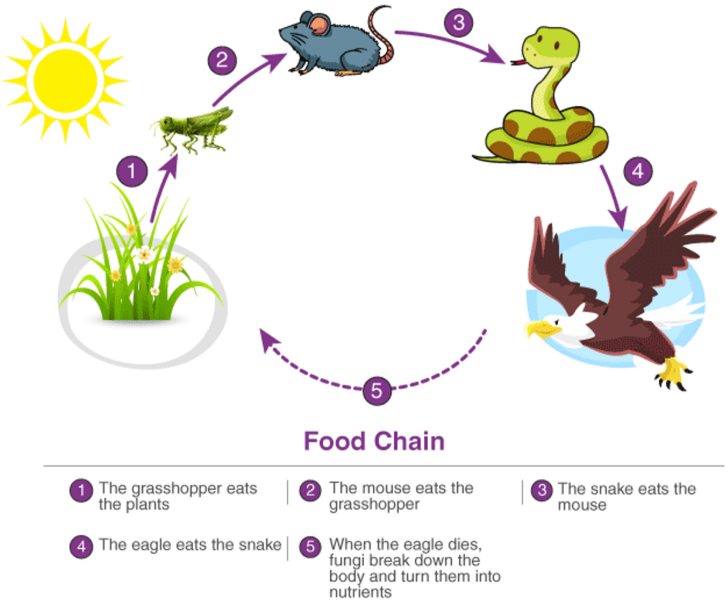
3. **Experimental Setup**:
    - Paine conducted manipulative experiments by removing sea stars (Pisaster ochraceus) from sections of the rocky shore.
    - He created control plots where sea stars were left undisturbed.
4. **Observations**:
    - In areas where sea stars were removed, the population of their prey, particularly mussels, increased dramatically.
    - The increased mussel population led to competitive exclusion, where other species, such as barnacles and algae, were outcompeted and displaced.
5. **Conclusion**:
    - Paine concluded that sea stars act as a "keystone species" in the intertidal ecosystem, meaning they have a disproportionately large impact on the structure and function of the ecosystem relative to their abundance.
    - By preying on mussels, sea stars prevent the dominance of mussels and create habitat heterogeneity, allowing other species to coexist and maintain biodiversity.
6. **Significance**:
    - Paine's experiment provided empirical evidence for the concept of keystone species and their importance in maintaining ecosystem stability.
    - The findings highlighted the interconnectedness of species within ecosystems and the cascading effects of removing or altering key species.
    - Paine's work had a profound influence on ecological theory and conservation biology, emphasizing the need to protect keystone species and their habitats for ecosystem health and resilience.

https://www.youtube.com/watch?v=rN5KzBVxNl4

Food Chain:

A food chain is a simplified model that illustrates the transfer of energy and nutrients through an ecosystem

It shows the flow of energy from one organism to another, typically starting with a producer organism (like plants) that creates energy through photosynthesis, followed by consumers that eat the producers, and then other consumers that eat those consumers, forming a linear chain. For example, a simple food chain in a terrestrial ecosystem could be: grass (producer) → rabbit (primary consumer) → fox (secondary consumer).



Importance of the Top Predator:

Removing the top predator, like the ochre sea star, from an ecosystem can cause several effects:

1. **Population Increase of Prey**: With no predator to keep them in check, the prey population, such as mussels, might grow rapidly.
2. **Changes in Species**: This population increase can disrupt the balance of species in the ecosystem, possibly leading to the dominance of certain species over others.
3. **Habitat Changes**: The absence of the top predator can alter the physical structure of habitats. For example, if mussels overgrow due to lack of

predation, they might change the landscape.

4. **Impact on Other Animals**: Changes in prey populations can affect other animals that depend on them for food, potentially causing a ripple effect throughout the ecosystem.
5. **Loss of Biodiversity**: Overall, removing the top predator can reduce the diversity of species in the ecosystem, which is important for its health and stability.

In simpler terms, taking out the top predator can mess up the balance of the ecosystem, leading to big changes in the population of other animals and even the environment itself.

Key Terms:

1. **Producer**: Organisms, usually plants, that create their own food through photosynthesis, using sunlight, water, and carbon dioxide.
2. **Trophic Level**: A position in the food chain or food web that indicates an organism's feeding relationship to other organisms. It typically includes producers, primary consumers (herbivores), secondary consumers (carnivores or omnivores), and so on.
3. **Niche**: The role or position of an organism within its environment, including its habitat, behavior, diet, and interactions with other species.
4. **Consumer**: Organisms that obtain energy and nutrients by feeding on other organisms. They include herbivores (eating plants), carnivores (eating other animals), and omnivores (eating both plants and animals).
5. **Omnivore**: A type of consumer that eats both plants and animals for energy and nutrients. Examples include humans, bears, and pigs.
6. **Decomposer**: Organisms, such as bacteria and fungi, that break down dead organic matter into simpler substances, recycling nutrients back into the environment.
7.

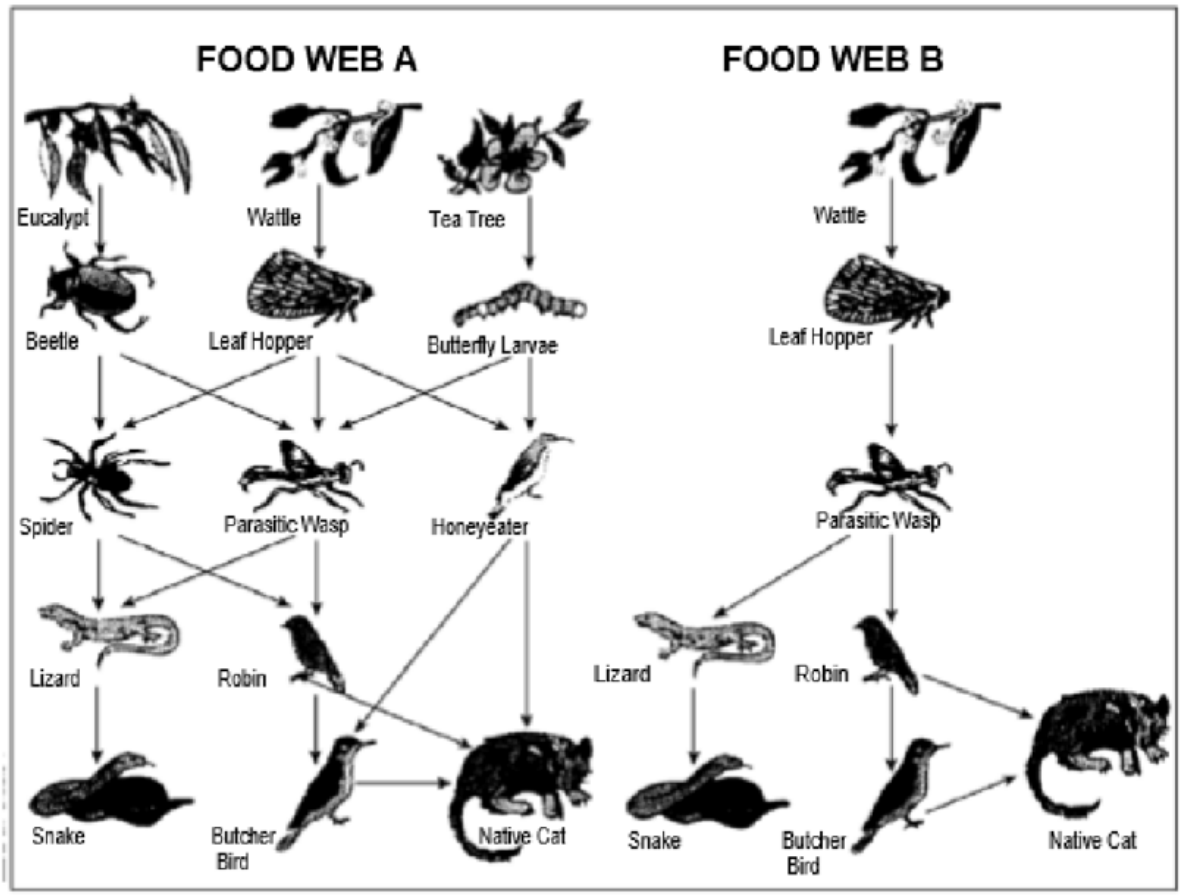
Saprotroph: Another term for decomposer, referring to organisms that obtain nutrients by consuming dead or decaying organic matter.
8.
Detritivore: Organisms that feed on detritus, which is dead organic matter or organic waste. They help break down detritus into smaller particles, aiding in the decomposition process. Examples include earthworms and some insects.

Chemosynthesis vs. Photosynthesis:

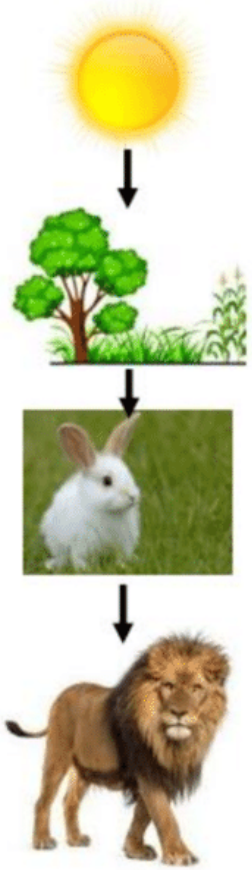
Chemosynthesis is a process used by certain bacteria and other organisms to produce energy and nutrients from inorganic molecules, typically in the absence of sunlight. Unlike photosynthesis, which uses sunlight to convert carbon dioxide and water into glucose and oxygen, chemosynthesis relies on chemical reactions to produce energy.

Photosynthesis	**Chemosynthesis**
It is a process of converting water and carbon dioxide to glucose and oxygen in the presence of sunlight and chlorophyll.	It is a process by which bacteria produce carbohydrates, sulfur, and water.
The presence of sunlight is necessary. Hence, this process occurs only during the day.	Sunlight is not required for chemosynthesis. Hence, it can occur both day and night.
Chlorophyll is required for this process.	Chlorophyll is not necessary for this process.
Oxygen is formed as a by-product.	Sulfur and water are formed as a by-product.
Photoautotrophs – Green plants, cyanobacteria, and green algae.	Chemoautotrophs – Sulfur bacteria. Iron-oxidizing bacteria and nitrogen-fixing bacteria.

Examples of Food Chains/Webs:



Source: Adapted from Steve Malcolm: 'Biodiversity is the key to managing environment', *The Age*, 16 August 1994.



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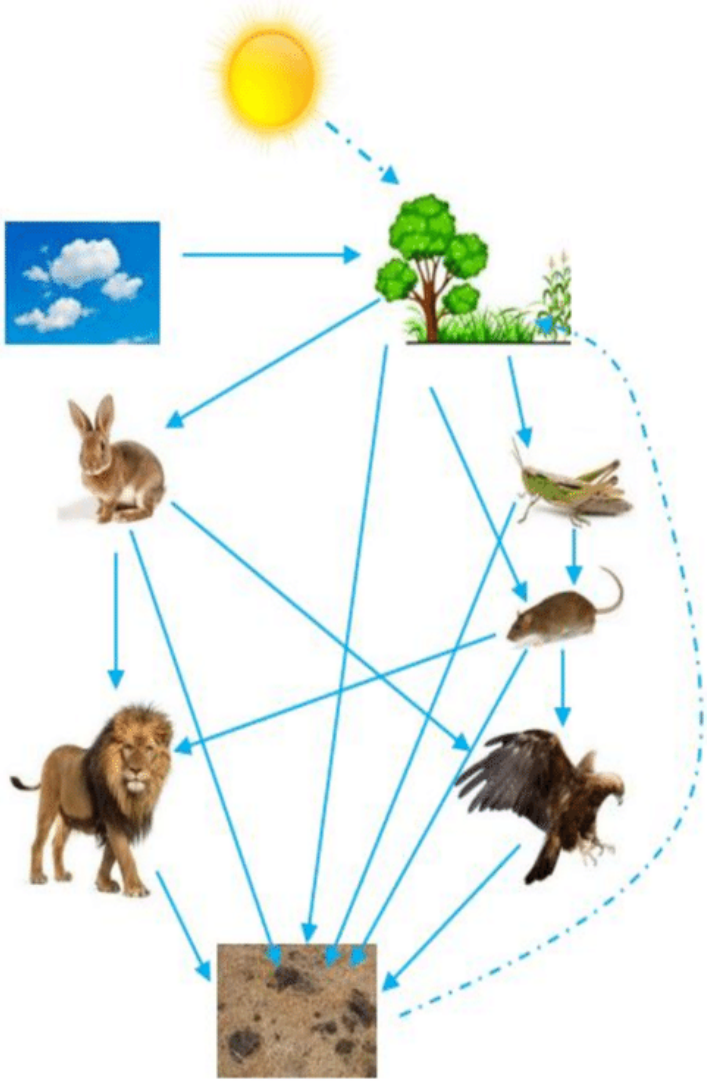

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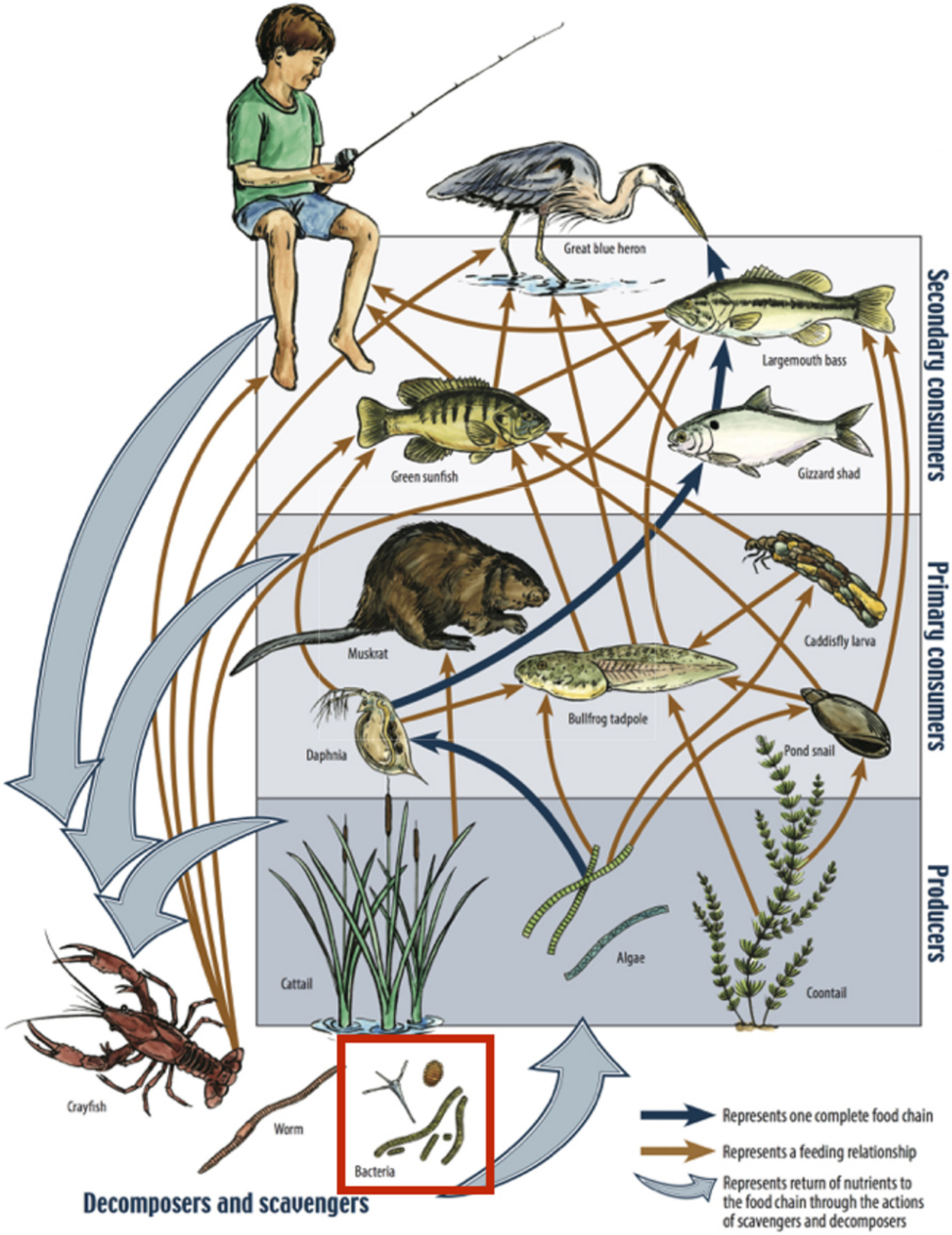

Great blue heron
Largemouth bass
Green sunfish
Gizzard shad
Muskrat
Caddisfly larva
Bullfrog tadpole
Daphnia
Pond snail
Cattail
Algae
Coontail
Crayfish
Worm
Bacteria
Decomposers and scavengers
Secondary consumers
Primary consumers
Producers
Represents one complete food chain
Represents a feeding relationship
Represents return of nutrients to the food chain through the actions of scavengers and decomposers

Flow of Energy in a Chain:

1. **Energy Flow through a Food Chain**:
    - **Producers**: Organisms like plants use sunlight to produce energy through photosynthesis, converting it into chemical energy in the form of glucose.
    - **Primary Consumers**: Herbivores consume producers, obtaining energy by eating plants.
    - **Secondary Consumers**: Carnivores or omnivores consume primary consumers, transferring energy further up the food chain.
    - **Tertiary Consumers**: Predators that feed on secondary consumers, continuing the energy transfer.
    - **Quaternary Consumers**: In some cases, some even higher-level consumers feed on tertiary consumers.
2. **The 10% Rule**:
    - The 10% rule states that only about 10% of the energy from one trophic level is transferred to the next trophic level.
    - This means that each trophic level has significantly less energy available to it compared to the previous trophic level.
    - The rest of the energy is lost as heat during metabolism, used for growth and reproduction, or passes out of the ecosystem through waste products.
    - As a result, energy diminishes with each step up the food chain.
3. **Illustration of the 10% Rule**:
    - If 10,000 units of energy are available to producers (plants) through photosynthesis, only about 1,000 units of energy will be transferred to the primary consumers (herbivores) that eat them.
    - Similarly, only about 100 units of energy will be transferred to the secondary consumers (carnivores or omnivores) that eat the primary consumers, and so on.
    - This pattern of energy transfer helps to explain why ecosystems typically have fewer top predators compared to the number of primary producers or

herbivores at the base of the food chain.

https://www.youtube.com/watch?v=BRUd6HCGnOo

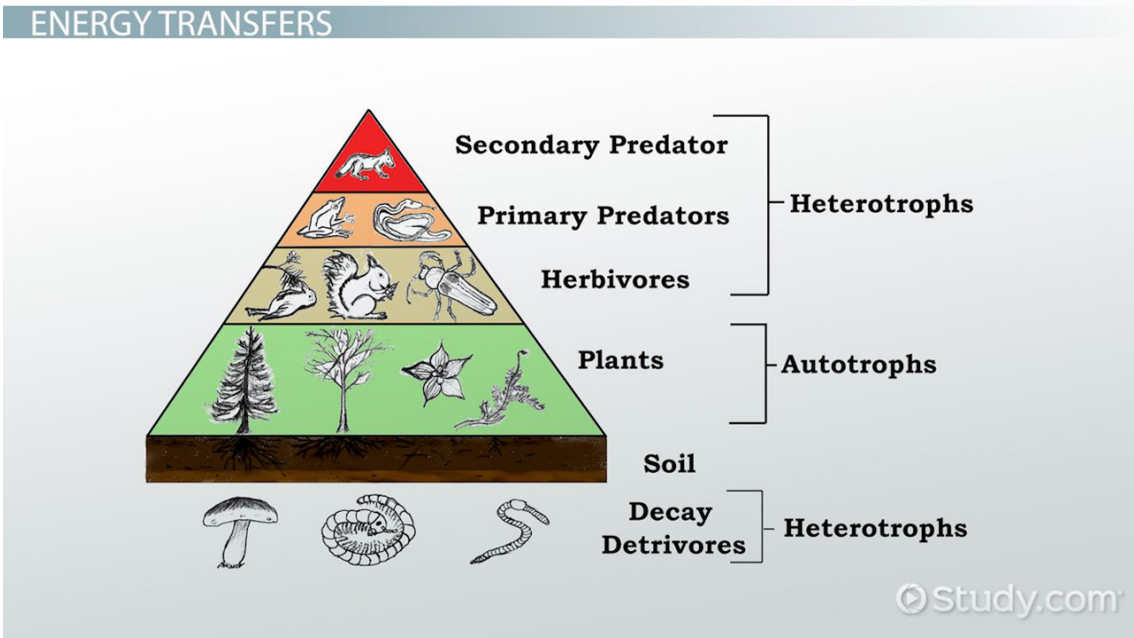
Multicellular and Unicellular Organisms:

1. **Multicellular Organisms**:
    - Multicellular organisms are made up of multiple cells that are organized into specialized structures, tissues, and organs.
    - These organisms exhibit a division of labor among different cell types, with each type performing specific functions necessary for the organism's survival.
    - Examples include humans, animals, plants, fungi, and many types of algae.

2. **Unicellular Organisms**:

- Unicellular organisms consist of only one cell that performs all necessary functions for life, including metabolism, reproduction, and responding to stimuli.
- Despite being composed of a single cell, unicellular organisms can exhibit complex behaviors and adaptations.
- Examples include bacteria, protists (such as amoebas and paramecia), some types of algae, and yeasts.

Energy Pyramid:



An energy pyramid is a graphical representation of energy flow in a food chain or food web within an ecosystem. It illustrates the transfer of energy from one trophic level to another and the distribution of energy among different organisms within the ecosystem. Here's how it works:

1. **Base of the Pyramid (Producers)**:
    - The bottom of the energy pyramid represents the producers, which are usually plants or other photosynthetic organisms.
    - Producers convert sunlight into chemical energy through photosynthesis, making them the primary source of energy in the ecosystem.
    - They have the highest energy content in the pyramid because they capture energy directly from the sun.
2. **First Trophic Level (Primary Consumers)**:
    - The next level of the pyramid represents the primary consumers, also known as herbivores, which feed directly on producers.
    - Primary consumers obtain energy by consuming plant material (or other producers) and converting it into their own biomass.
3. **Second Trophic Level (Secondary Consumers)**:

- The level above primary consumers consists of secondary consumers, which are typically carnivores or omnivores that feed on primary consumers.
- Secondary consumers obtain energy by consuming primary consumers, transferring energy further up the food chain.

4. **Higher Trophic Levels**:
    - Subsequent levels of the pyramid represent higher-order consumers, such as tertiary consumers (feeding on secondary consumers) and so on.
    - Each higher trophic level represents organisms that consume those from the level below, with energy diminishing as it moves up the pyramid.
5. **Energy Transfer and Loss**:
    - As energy moves up the energy pyramid, there is a decrease in the amount of energy available at each trophic level.
    - This decrease in energy is due to inefficiencies in energy transfer, with only a fraction of the energy being passed on from one trophic level to the next.
    - The 10% rule applies here, meaning that only about 10% of the energy from one trophic level is transferred to the next, with the rest being lost as heat or used for metabolic processes.

In summary, an energy pyramid visually represents the flow of energy through a food chain or food web, with producers at the base and successive trophic levels representing consumers.

Species Interactions:

Herbivory:

Herbivory is a feeding strategy where animals, called herbivores, primarily consume plant material as their main source of nutrients. These animals

have specialized adaptations, such as teeth for grinding plant matter or digestive systems capable of breaking down cellulose.

Key Points:

- **Diet**: Herbivores mainly eat plants, including leaves, stems, fruits, seeds, and roots.
- **Adaptations**: Herbivores have specialized digestive systems adapted to break down plant material, and some have specialized mouthparts or digestive enzymes to aid in plant consumption.
- **Impact**: Herbivores play a crucial role in shaping plant communities by consuming plant matter, and influencing plant distribution, abundance, and diversity.

Examples:

1. **Giraffes Eating Leaves**: Giraffes are herbivores that primarily feed on leaves from trees and shrubs. They use their long necks to reach high branches, consuming vegetation as their primary source of food.
2. **Caterpillars Feeding on Leaves**: Caterpillars, the larval stage of butterflies and moths, often feed on the leaves of plants. They have specialized mouthparts for chewing plant material and can cause significant damage to crops and garden plants.
3. **Deer Grazing in a Meadow**: Deer are herbivores that feed on grasses, leaves, and other vegetation found in meadows and forests. They play a crucial role in shaping plant communities through their feeding behavior.

Predation:

Predation is the act of one organism, called the predator, hunting, killing, and consuming another organism, called the prey, for food. Predators have adaptations for capturing, subduing, and consuming prey, such as sharp teeth, claws, or venomous stingers.

Key Points:

- **Feeding Strategy**: Predators rely on consuming other organisms (prey) as their primary food source.
- **Adaptations**: Predators have physical adaptations such as sharp teeth, claws, speed, camouflage, or venom to capture, kill, and consume prey.
- **Impact**: Predation influences population dynamics and shapes ecosystems by controlling prey populations, affecting prey behavior, distribution, and evolution.

Examples:

1. **Lions Hunting Zebras**: Lions are apex predators that hunt a variety of prey species, including zebras. They use their speed, strength, and coordinated hunting tactics to chase down and capture their prey.
2. **Wolves Hunting Deer**: Wolves are carnivores that hunt large herbivores such as deer and elk. They hunt in packs, working together to bring down their prey through coordinated attacks and strategic maneuvers.
3. **Spiders Catching Insects**: Spiders are predators that use silk webs or traps to catch prey, typically insects. Once caught, they immobilize their prey with venom and then consume it for nourishment.

Examples of Commensalism, Mutualism, Parasitism:

Commensalism:

1. **Remora and Shark**: Remoras are small fish that attach themselves to larger marine animals such as sharks. While the remora benefits by getting free transportation and access to potential food scraps, the shark is neither helped nor harmed by the relationship.
2. **Epiphytes on Trees**: Epiphytic plants like orchids or mosses grow on the branches of trees in tropical rainforests. These plants obtain sunlight and moisture from the air and rain, while the host tree is not significantly affected by their presence.

3. **Birds and Trees**: Birds often build nests in trees, utilizing the branches for support and protection. While the birds benefit from a safe place to raise their young, the trees are not affected by the presence of the nests.

Parasitism:

1. **Ticks on Mammals**: Ticks are parasitic arachnids that attach themselves to mammals such as deer or dogs to feed on their blood. While ticks benefit by obtaining nourishment, their hosts may suffer from irritation, disease transmission, or other negative effects.
2. **Tapeworms in Intestines**: Tapeworms are parasitic flatworms that live in the intestines of vertebrates, including humans. They absorb nutrients from the host's digested food, potentially causing malnutrition or other health issues in severe infestations.
3. **Mistletoe on Trees**: Mistletoe is a parasitic plant that attaches itself to the branches of trees and shrubs, obtaining water and nutrients from the host plant. While mistletoe benefits from this relationship, the host tree may suffer reduced growth or structural damage.

Mutualism:

1. **Bees and Flowers**: Bees pollinate flowers while collecting nectar for food. The flowers benefit from the transfer of pollen, which allows them to reproduce, while the bees obtain nectar as a food source.
2. **Legumes and Nitrogen-Fixing Bacteria**: Leguminous plants like peas and beans form mutualistic relationships with nitrogen-fixing bacteria in their root nodules. The bacteria convert atmospheric nitrogen into a form that the plant can use as a nutrient, while the plant provides the bacteria with carbohydrates.
3. **Oxpeckers and Large Mammals**: Oxpecker birds feed on parasites such as ticks and fleas found on the skin of large mammals like rhinos or buffalo. While the oxpeckers obtain food, the mammals benefit from parasite removal and grooming.

Intraspecies vs. Interspecies:

Interspecies Competition:

- **Definition**: Interspecies competition occurs when individuals of different species compete for the same limited resources, such as food, water, shelter, or territory, within an ecosystem.
- **Key Points**:
  - It involves interactions between individuals of different species.
  - Competition can occur between species occupying similar ecological niches or utilizing similar resources.
  - Interspecies competition can influence species distributions, population dynamics, and community structure within ecosystems.
- **Example**: Lions and hyenas competing for the same prey species (interspecific competition for food).

Intraspecies Competition:

- **Definition**: Intraspecies competition occurs when individuals of the same species compete with each other for resources within a population.
- **Key Points**:
  - It involves interactions between individuals of the same species.
  - Competition can occur for resources such as food, mates, nesting sites, or territory.
  - Intraspecific competition can regulate population size, influence mating behavior, and shape social structures within populations.
- **Example**: Male deer competing for access to mates during the breeding season (intraspecific competition for reproductive opportunities).

Distinguishing Factors:

1. **Species Involved**: Interspecies competition involves individuals of different species, while intraspecies competition involves individuals of the same species.

2. **Resource Utilization**: Interspecies competition involves competition for resources between different species, while intraspecies competition involves competition for resources within a population of the same species.
3. **Ecological Implications**: Interspecies competition can affect species coexistence, community structure, and ecosystem dynamics, while intraspecies competition can regulate population size, influence reproductive success, and shape social behavior within populations.

Keystone Species:

A keystone species is a species that has a disproportionately large impact on its ecosystem relative to its abundance or biomass. This species plays a critical role in maintaining the structure, function, and diversity of the ecosystem. The concept of a keystone species was first introduced by ecologist Robert T. Paine in 1969.

Key characteristics of keystone species include:

1. **Indispensability**: Keystone species have a unique ecological role that is not easily replaced by other species within the ecosystem.
2. **Influence on Community Structure**: The presence or absence of a keystone species can significantly affect the abundance and distribution of other species in the ecosystem.
3. **Diverse Effects**: Keystone species can have diverse effects on ecosystem processes, such as nutrient cycling, habitat creation, and regulation of population dynamics.
4. **Nonlinear Relationships**: Changes in the abundance or behavior of keystone species can lead to nonlinear changes in ecosystem structure and function, often referred to as "trophic cascades."

Examples:

1. **Sea Otters**: Sea otters in kelp forests eat sea urchins. Without them, sea urchins would overeat kelp, harming the ecosystem.

2. **Wolves**: In Yellowstone, wolves eat elk. This keeps elk from overgrazing plants, which helps other animals and plants thrive.
3. **Elephants**: Elephants in African savannas eat trees and bushes. This creates open spaces for other animals to live and helps spread seeds.
4. **Beavers**: Beavers build dams in streams, creating ponds. These ponds provide homes for many animals and help clean water.
5. **Corals**: Corals in reefs provide homes for lots of fish and other sea creatures. Without corals, many animals wouldn't have places to live.

Impact of Keystone Species from the Ecosystem:

1. **Biodiversity**: Keystone species help support many different types of plants and animals in an area. Without them, some species might disappear, leading to less diversity.
2. **Ecosystem Stability**: These species keep ecosystems balanced. For example, if there are too many elk in an area, wolves can help control their numbers, which prevents plants from being overeaten and keeps the ecosystem healthy.
3. **Resource Distribution**: Keystone species can change how resources like food and space are spread out in an area. For example, beavers create ponds, which provide homes for lots of other animals.
4. **Effects on Many Animals**: Changes in keystone species can affect lots of other animals and plants. For instance, if there are too many sea urchins because there aren't enough sea otters to eat them, the kelp forests they eat might disappear, leaving many marine animals without homes.
5. **Habitat Changes**: Keystone species can change the environment around them. Elephants, for example, knock down trees as they move, which can create open spaces for other animals to live in.

Factors that remove Keystone Species from Ecosystem:

1. **Habitat Destruction**: Loss or degradation of habitat due to human activities such as deforestation, urbanization, or agriculture can directly impact keystone species by reducing available resources and suitable habitat.

2. **Overexploitation**: Unsustainable harvesting or hunting of keystone species for commercial purposes can lead to their decline or extinction. This can occur if the population is harvested faster than it can reproduce, leading to population collapse.
3. **Invasive Species**: The introduction of invasive species into an ecosystem can disrupt native species interactions and outcompete or prey upon keystone species, leading to their decline or displacement.
4. **Pollution**: Pollution from various sources, such as industrial runoff, agricultural runoff, or oil spills, can directly harm keystone species by contaminating their habitats or food sources, leading to decreased survival and reproductive success.
5. **Climate Change**: Changes in climate patterns, such as temperature, precipitation, and sea level rise, can directly impact keystone species by altering their habitats, food availability, and reproductive cycles, leading to population declines or shifts in distribution.
6. **Disease Outbreaks**: Disease outbreaks, whether natural or introduced, can have devastating effects on keystone species populations, especially if they lack immunity or are already facing other stressors.
7. **Human Conflict**: Conflicts between humans and wildlife, such as poaching, habitat destruction, or retaliatory killings, can directly impact keystone species populations and their ability to function within ecosystems.
8. **Natural Disasters**: Events such as wildfires, hurricanes, floods, or droughts can have immediate and severe impacts on keystone species populations and their habitats, leading to population declines or local extinctions.

Carbon & Nitrogen Cycles:

Key terms:

1. **Combustion**:
    - Combustion is when something burns, releasing heat and light. For example, when you light a match or when a car burns gasoline,

combustion is happening.

2. **Decomposition**:
    - Decomposition is when dead things break down into simpler substances. Bacteria and fungi help with this process, turning dead plants and animals into soil.
3. **Consumption**:
    - Consumption is when animals eat plants or other animals for food. For example, when a deer eats grass or when a lion eats a gazelle, they are consuming food.
4. **Denitrifying Bacteria**:
    - Denitrifying bacteria are tiny organisms in soil that change nitrates (a type of nitrogen) into nitrogen gas. This helps send nitrogen back into the air.
5. **Ammonia**:
    - Ammonia is a type of nitrogen that plants use to grow. It's made by bacteria in the soil and is an important part of the cycle that helps plants get the nutrients they need.
6. **Nitrogen-Fixing Bacteria**:
    - These are bacteria in the soil that change nitrogen from the air into a form that plants can use. This helps plants grow better and is important for the health of ecosystems.

Nitrite:

- Nitrite is a type of nitrogen that's important for plants. It's like a middle step in a process that helps plants get the nutrients they need to grow.

Nitrate:

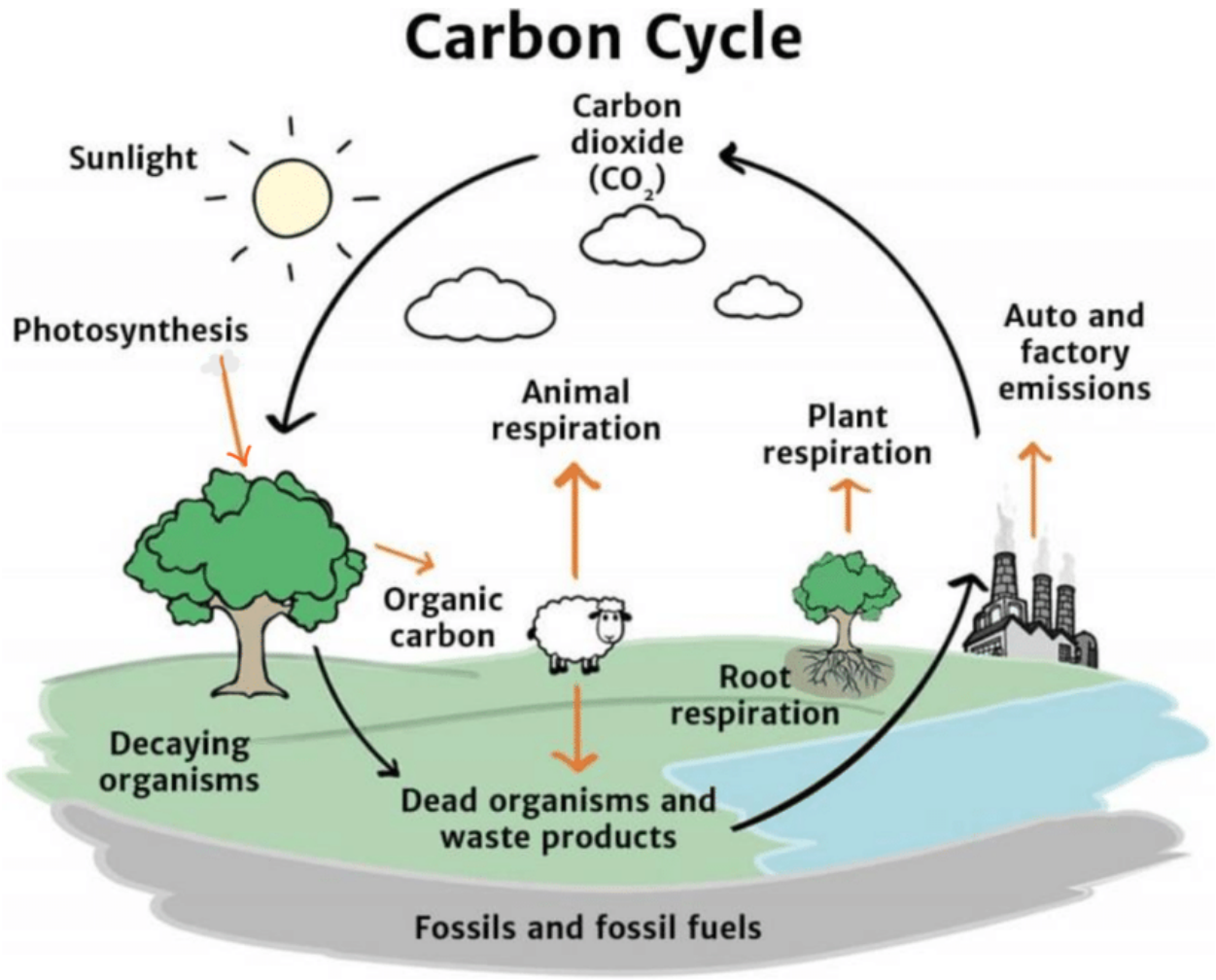
- Nitrate is another type of nitrogen that plants use to grow. It's made from nitrite and is also important for plants to be healthy.

Decomposers:

- Decomposers are tiny living things like bacteria and fungi. They help break down dead stuff like leaves and animals into smaller parts. This

helps create healthy soil and gives plants the food they need to grow.

Carbon Cycle:



1. Carbon Fixation:

- Carbon dioxide (CO2) from the atmosphere is absorbed by plants during photosynthesis.
- Plants use sunlight energy to convert CO2 into organic carbon compounds like glucose, which they use for growth and energy.

2. Carbon Storage in Living Organisms:

- Carbon is stored in living organisms through the formation of carbohydrates, proteins, lipids, and other organic molecules.

- Carbon moves through food chains as organisms eat plants or other organisms, transferring carbon from one organism to another.

3. Respiration:

- Organisms release carbon dioxide (CO_2) back into the atmosphere through respiration.
- During cellular respiration, organisms break down organic compounds to release energy, producing CO_2 as a byproduct.

4. Decomposition:

- Dead organisms and organic matter are broken down by decomposers such as bacteria and fungi.
- Decomposition releases carbon dioxide (CO_2) back into the atmosphere as organic matter is broken down into simpler compounds.

5. Combustion:

- Human activities such as burning fossil fuels (coal, oil, and natural gas) and biomass release carbon stored in these sources into the atmosphere as carbon dioxide (CO_2).
- The combustion of fossil fuels for transportation, energy production, and industrial processes is a major contributor to increased atmospheric CO_2 levels.

6. Carbon Storage in the Oceans:

- Carbon dioxide (CO_2) dissolves in the surface waters of the oceans, where it can be stored for long periods.
- Marine organisms such as phytoplankton use CO_2 for photosynthesis, and their remains can sink to the ocean floor, storing carbon in sediments over geologic time scales.

7. Weathering and Erosion:

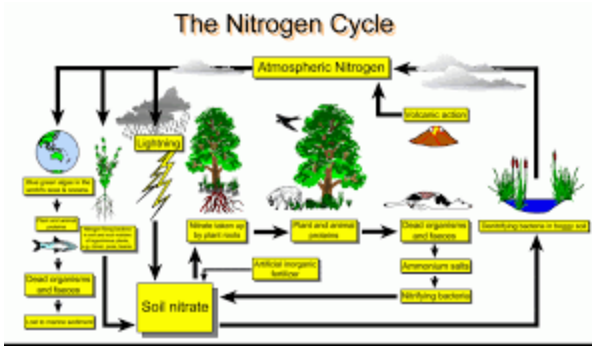
- Carbon stored in rocks and minerals is released through weathering and erosion processes.
- Over long time scales, carbon dioxide (CO_2) from the atmosphere reacts with minerals in rocks, forming carbonate compounds that can be stored in

sedimentary rocks.

8. Carbon Sequestration:

- Some carbon is stored in long-term reservoirs such as forests, soils, and deep ocean sediments, where it can remain for thousands to millions of years.
- Human activities such as afforestation, reforestation, and carbon capture and storage aim to enhance carbon sequestration to mitigate climate change.

Nitrogen Cycle:



1. **Nitrogen Fixation**:
    - Atmospheric nitrogen gas (N2) is converted into ammonia (NH3) or ammonium ions (NH4+) by nitrogen-fixing bacteria found in the soil or through abiotic processes like lightning.
    - Nitrogen-fixing bacteria such as Rhizobium in root nodules of leguminous plants or free-living bacteria like Azotobacter and Clostridium convert atmospheric nitrogen into ammonia through biological nitrogen fixation.
2. **Assimilation**:
    - Plants absorb ammonia (NH3) or nitrate (NO3-) ions from the soil through their roots.
    - Nitrogen is assimilated into organic molecules within the plant, primarily in the form of amino acids, which are the building blocks of proteins, nucleic acids, and chlorophyll.
3. **Ammonification**:

- Decomposers like bacteria and fungi break down organic nitrogen compounds found in dead plants, animals, and waste materials, releasing ammonia (NH_3) or ammonium ions (NH_4^+) as byproducts.
- This process occurs during the decomposition of organic matter, such as leaf litter, dead animals, and animal waste.

4. **Nitrification**:
    - Ammonia (NH_3) or ammonium ions (NH_4^+) in the soil are converted into nitrite (NO_2^-) by nitrifying bacteria like Nitrosomonas.
    - Nitrite (NO_2^-) is further oxidized into nitrate (NO_3^-) by other nitrifying bacteria such as Nitrobacter.
    - Both ammonia oxidation and nitrite oxidation are aerobic processes that occur in well-oxygenated soils.
5. **Denitrification**:
    - Denitrifying bacteria like Pseudomonas perform denitrification under anaerobic conditions, converting nitrate (NO_3^-) back into atmospheric nitrogen gas (N_2) or nitrous oxide (N_2O).
    - This process occurs in waterlogged or oxygen-depleted environments such as waterlogged soils, wetlands, and sediments.