Chapter 5
Ecosystems Ecology

1. The ecosystem

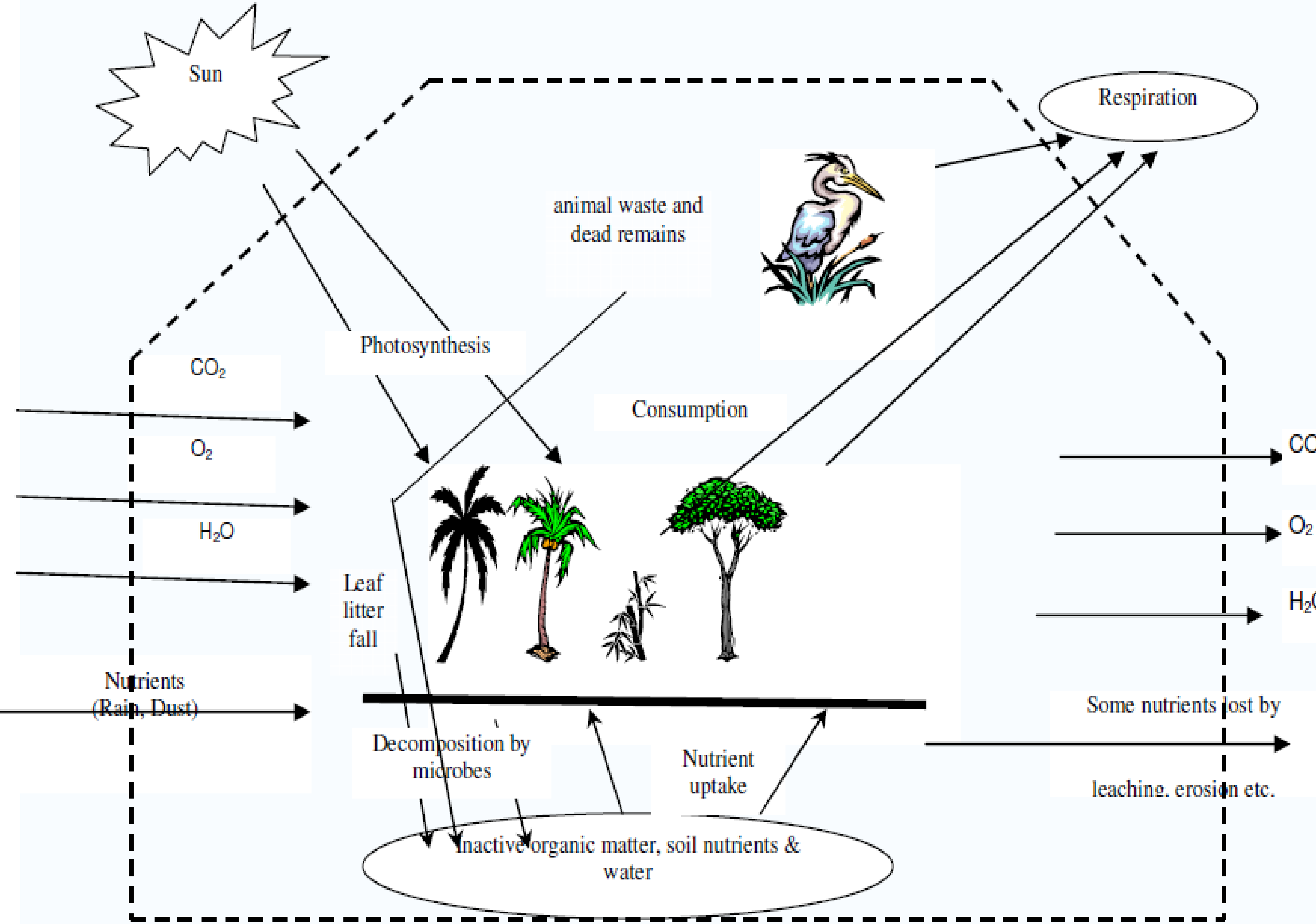
- In ecology, an ecosystem is a naturally occurring assemblage of organisms such as plant, animal and other living together in their physical environment, functioning as a unit.

→ecosystem consists of **the community of organisms plus the associated physical environment**.

- The prefix ‘eco’ indicates environment and ‘system’ refers to a complex of coordinated units.
- An ecosystem is a dynamic and complex whole, interacting as an ecological unit.
- *It is a structured functional unit in equilibrium characterized by energy* and material flows between its constituent elements.

Ecosystems

- The size of an ecosystem can vary widely. It may be as big as a whole forest, or as small as a little pond.
- Different ecosystems are often separated by **geographical barriers**, like deserts, mountains or oceans, or are isolated otherwise, like lakes or rivers.
- As these borders are never rigid, ecosystems tend to blend into each other. As a result, the **whole earth can be seen as a single ecosystem**, or a lake can be divided into several ecosystems depending on the scale used.



Sun
Respiration
animal waste and
dead remains
Photosynthesis
CO2
O2
H2O
Consumption
CC
O2
H2
Leaf
litter
fall
Nutrients
(Rain, Dust)
Some nutrients lost by
leaching, erosion etc.
Decomposition by
microbes
Nutrient
uptake
Inactive organic matter, soil nutrients &
water

Ecosystem ecology

- **Ecosystem ecology** is the study of the movement of energy and matter through ecosystems.
- The ecosystem is an **energy processing system** whose components have evolved together over long period of time.
- The structure of an ecosystem is related to **energy flow and material cycling through and within the system**.
- The organisms in an ecosystem are usually well balanced with each other and their environment through various types of symbiosis.
- Introduction of new elements into an ecosystem, whether it is living or non-living tend to have a disruptive effect.
- In some cases, this can lead to ecological collapse and the death of many native species.

Ecosystem structure

2. Ecosystem structure

- Although every ecosystem is different from one another, whether it is aquatic or terrestrial is made up of two major components: the *biotic and the abiotic.*
- ***The biotic*** *component refers to* all interacting groups of organisms living in an area.
- The ***abiotic part,*** *on the other* hand, embraces the non-living or the physical environment with which the organisms do interact with.
- If we take Lake Haik, as an example of a closed aquatic ecosystem, we find the following major components and units that interact to each other to make the whole integrated ecosystem.

Biotic Component (includes the different animal, plant and microbe communities)		**Abiotic component** (includes all the physical and chemical factors)
– Phytoplankton (floating photosynthetic organisms such as algae and bluegreens – Zooplankton (floating invertebrates and microbes) – Macrophytes (rooted aquatic plants) – Weed bed fauna (decomposer invertebrates) – Aquatic insects (e.g., dragonfly, beetles) – Microscopic organisms (like bacteria, blue-greens, and pathogens) – Fishes and amphibians – Reptiles such as alligators and lizards – Mammals such as hippos and otter – Aquatic birds (including fish predators, scavengers, insect eaters, herbivores, filter feeders and many others)	**Interaction**	– Suspended solid particles – Salinity and pH – Light intensity of the water – Dissolved nutrient – Dissolved gases – Water temperature – Water movement (wave motion) The mud and the rock

Ecosystem structure

- In an agricultural ecosystem, which is a managed ecosystem, we find also a number of plant and animal communities interacting to each other.
- For example, crops interact with different weeds, pollinators, parasites, pathogens, pests, earthworms, soil microbes, herbivores, shading trees, and many other organisms

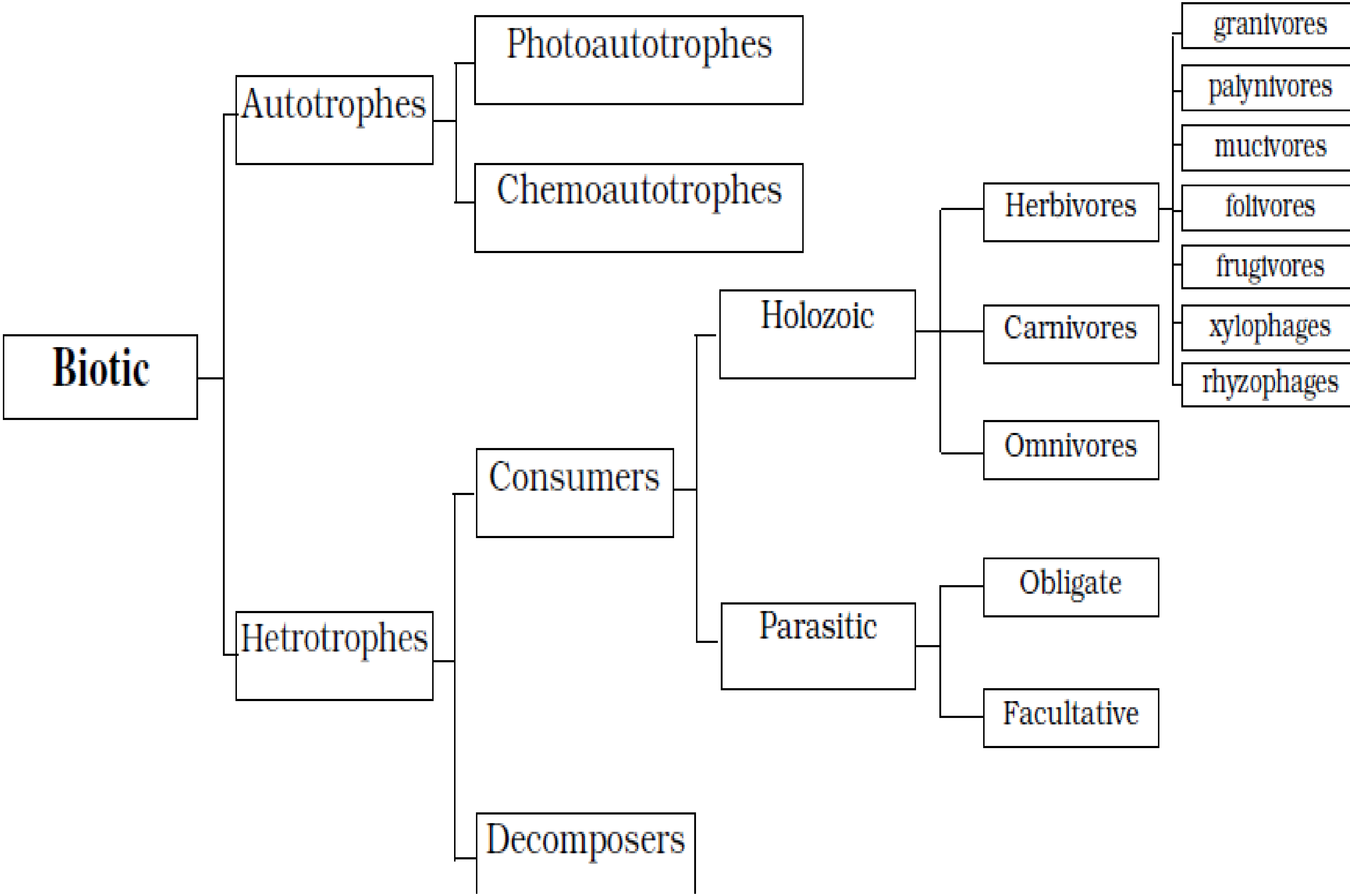
→A gram of soil may contain over a thousand fungal hyphae and up to a million or more individual bacterial colonies

- These communities are useful in nitrogen fixing and nutrient cycling.
- Those groups of organisms form the biotic component of the ecosystem.
- On the other hand, the physical and chemical characteristics of the soil such as its texture, color, pH, nutrient level, temperature, speed and direction of wind, moisture, light and a number of other factors form the abiotic component of the ecosystem

Ecosystem Structure

Structure of Biotic Components of an Ecosystem

- There are various ways of interactions between organisms in an ecosystem.
- The clearly observed form of interaction is revealed in their energy and food source in the ecosystem.
- Organisms in any kind of ecosystem could be generally classified or structured into two broad categories based on their ability to synthesize their organic molecules: ***autotrophs and heterotrophs***.
- *The following* diagram shows how the biotic component of an ecosystem is structured in terms of the trophy.
- Each organism has its own specific role in the ecosystem.


Biotic
Autotrophes
Photoautotrophes
Chemoautotrophes
Hetrotrophes
Consumers
Decomposers
Holozoic
Parasitic
Herbivores
Carnivores
Omnivores
Obligate
Facultative
granivores
palynivores
mucivores
folivores
frugivores
xylophages
rhyzophages

Structure of ecosystem

Structure of Abiotic Components of an ecosystem

- The abiotic component of an ecosystem is made up of all the substances, factors and forces in the habitat that affect the organism.
- The abiotic environment is the result of the interactions among the energy, inorganic minerals, gases, dead organic matter and a number of other factors and forces.
- The abiotic component of an ecosystem, hence, could be generally categorized in to the following components
  - **Lithosphere**: all the solid mineral matter including the soil and rocks;
  - **Hydrosphere:** all the water bodies (in the ocean, lakes, rivers) and its physico-chemical characteristics;
  - **Atmosphere**: all the gaseous mixture in the air;
  - **Radiant solar energy:** the electromagnetic radiation (including visible light) coming from the sun and stars; and
  - **Position and movement of the earth,** the moon and other extraterrestrial bodies, and their gravitational force

Energy Flow in an Ecosystem

3.1 Trophic Structure and the Food Chain

- Most important relationships between living organisms and their environment are ultimately controlled by the amount of energy reaching the earth from the sun, beside the water and nutrients they require for their metabolism and growth
- Only a very small proportion of energy that the earth receives from the sun is trapped by green plants and converted into a biochemical form.
- For example, a study indicates that maize can utilize only about **1.6%** of available solar energy that hits the surface of its leaf.
- It is estimated that the most efficient ecosystems are rarely able to trap more than 3% of this energy.
- The remaining energy is radiated back to the atmosphere or other objects in the form of heat.

Forms of Energy in the Ecosystem/ Biological Production

- Living organisms may use energy in two basic forms; **either radiant or fixed energy.**
- ***Radiant energy*** *is electromagnetic radiation, such as solar light. For example, green plants use this energy* to synthesize glucose molecule.
- ***Fixed energy*** *is the chemical energy stored* within the carbon bonds of organic molecules, such as glucose.
- This energy is then released through either aerobic or anaerobic respiration to yield ATP that is stored in the tissue and utilized for different biochemical activities, when oxidized in to ADP and AMP.
- The process of storing or producing fixed energy by organisms is referred to as **biological production**.
- There are two kinds of biological productions: **Primary production and Secondary production.**

Primary Production

- This is the form of fixed energy accumulated by autotrophs by converting the radiant energy.
- The total amount of fixed energy incorporated into the bodies of photosynthetic organisms is known as the **gross primary production (GPP).**
- **Primary productivity**, on the other hand, is the rate at which energy is incorporated into the body of plants at a given time, usually for most ecosystems, it is measured per year
- The rate of GPP in an ecosystem could be estimated using different techniques such as **infrared gas analysis or radioisotope method**
- The analyzer measures the gas entering and leaving an airtight enclosure of a known area or volume that is constructed of a light-transmitting substance, in which a plant leaf or branch is placed.

- a comparable study is required using a light tight (non-transparent) container where, no photosynthesis will take place, but respiration will.
- Therefore, the amount of the gas measured from the two chambers, will be added to approximate the gross primary production of the system.
- In the process of photosynthesis, 6 moles of CO_2 and 6 moles of H_2O are used to make 1 mole of $C_6H_{12}O_6$ and 6 moles of O_2 (byproduct).
- Based on this net balance, for example, if 6 moles of CO_2 are absorbed by the plant, then 1 mole of glucose (molecular mass of 180 g) is produced.
- The same way, if 6 million moles of CO_2 are absorbed, approximately 1 million moles (i.e., 180 million gram) of glucose is synthesized.

- A percentage of this energy (GPP), however, is used by the plant to carryout different metabolic activities such as for growth, repairing dead tissues, gamete production, movement, transportation, defense and others.
- This energy is called **respiration energy (R).**
- The net energy stored by autotrophs, which is **GPP minus R**, is called the **Net Primary Production (NPP).**
- Therefore, this is the only energy available to herbivores (heterotrophs) which consumes it, providing the required fixed energy to survive.

Factors affecting the rate of primary production

- Primary production in terrestrial ecosystems is influenced by various factors such as temperature, precipitation, nutrient availability, length of growing season, animal utilization and fire.
- For example, tropical rain forests are the most productive ecosystems unlike deserts, tundra and open sea ecosystems.
- In equatorial regions, where the **temperature is high** throughout the year, and there is **good water supply**, it is suitable for the plant growth.
- Therefore, the primary productivity is very high as compared to other ecosystems.
- On the other hand, annual primary production is low in lower-latitude and middle-latitude deserts, where growth is limited due to the lack of moisture.

- Annual net production is a convenient basis for comparing various ecosystems
- More than 60% of the terrestrial primary production occurs in the tropics.
- However, on average, only about 30% of the GPP is available as NPP in Tropical Rain Forests when compared to 40% in temperate forests (Kormondy, 1996).
- This difference is in part due to the faster rate of respiration than photosynthesis in higher temperature

Secondary Production

- Once it has been fixed by autotrophs, energy may travel in an ecosystem through the consumption of dead or living organic material.
- On decomposition, complex organic molecules may be broken down again into inorganic forms, allowing them to be taken up once again by autotrophs.
- This inorganic energy may also move from one ecosystem to another through a variety of processes.
- These include animal migration or harvesting, plant harvesting or seed dispersal, leaching and erosion.
- The total amount of energy stored at consumer level is called ***secondary production***.

- *The total energy assimilated in the tissue of the consumer, which is equivalent to* GPP in Primary producers, is called ***Assimilation energy****.*
- *The net amount of energy, which is* equivalent to NPP in Primary producers, left from maintenance and respiration is called ***Production energy****.*
- *This energy is stored in the form of the production of new tissue, fat deposit,* growth and production of new individuals.
- This is available for the next trophic level, when consumed

Food chain and Food Web

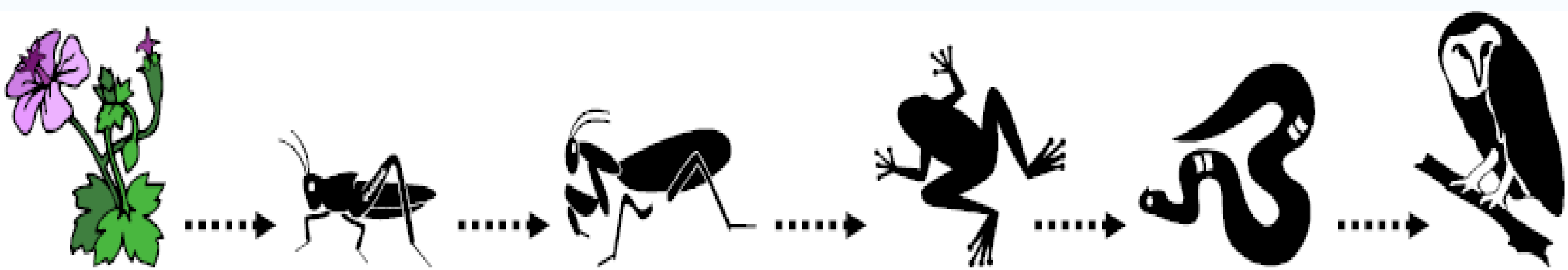
- A food chain is a simple food relationship between organisms.
- It is a link (chain) of organisms, one supplying food for the next.
- Like many simple models, the idea of a food chain only provides an abstract idea of the way energy flows through an ecological community.
- A food chain cannot really exist as a single series of connections, isolated from any others.
- A model describing the relationship between organisms in many different food chains is called a **food web.**
- The food web demonstrates the complex patterns of energy flow in an ecosystem.
- It is believed that the more complex a food web is, the more resistant it is to outside interference.

- There are two kinds of food chain:

a) Grazing Food Chain

- This is a model that describes the general flow of energy in communities.
- For most ecosystems, this model of food chain begins with the fixation of light, water and carbon dioxide by photosynthetic autotrophs.
- **Primary producers** include green plants, photosynthetic bacteria and protists.
- **Primary consumers** (such as ants, termites, sheep and other herbivores) form the second link in the grazing food chain, when they gain energy by consuming the primary producers.
- The third link in the grazing food chain are the **primary carnivores (or secondary consumers), s**uch as foxes, cats and spiders, which kill and consume the primary consumers.

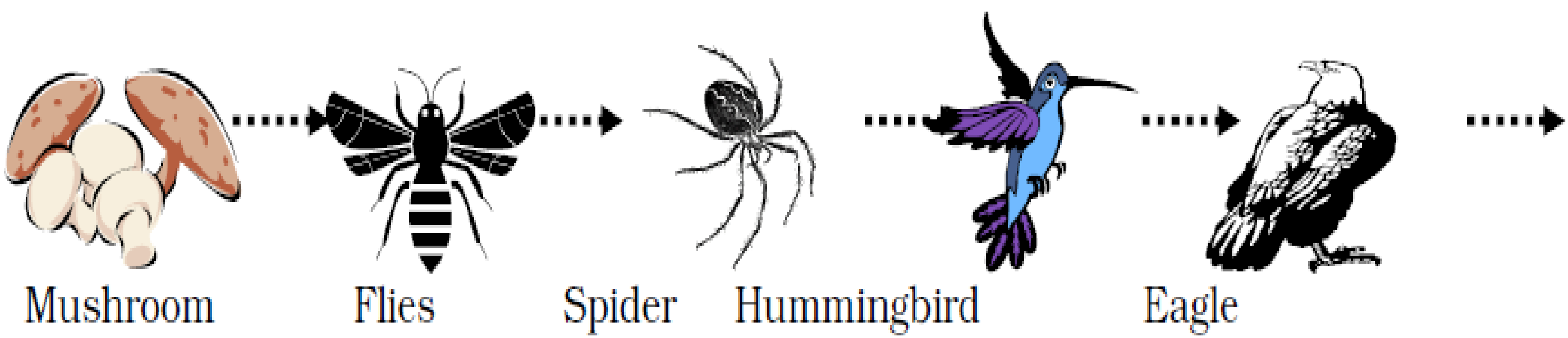
- A further step is the **secondary carnivores (or tertiary consumers),** which feed on primary carnivores; and the chain goes the same way
- **Decomposers (detritivores)** usually retain the last level in the food chain decomposing all dead organic matter, but are sometimes themselves consumed by some of the organisms they digest.



b) Detritus Food Chain

- This type of food chain begins with decomposing organisms (detrivors).
- The food chain differs from the grazing food chain in several fundamental ways.
  - Organisms in such a food chain are physically smaller.
  - The functional roles of the different organisms do not fall neatly into **various categories** as in the grazing food chain.
  - Detritivores live in habitats rich in scattered food particles → detritivores are generally less motile than herbivores or carnivores.

- → Include a large number species from different kingdoms or classes, such as algae, bacteria, slime moulds, fungi, protozoa, animals and plants.
- → Consume organic waste; shed tissues and dead bodies
- → Decompose large amounts of organic waste into inorganic nutrients.
- → The rate of decomposition in the detritus food chain is controlled by temperature, soil, oxygen and moisture content



Trophic Level

- Trophic Level is the level of each of the different organism in the food chain.
- Each trophic level is defined by the number of steps through which energy passes in order to reach the organisms in the food chain.
- Despite enormous differences between different communities, most have only 3 to 5 trophic levels.
- The reason is the fact that energy is lost between each level and the amount is gradually diminished.
- However, highly stable ecosystems, for example in tropical rain forests, may have up to 9 trophic levels.
- In a grazing food chain:
  - **producers retain** the 1st TL,
  - **herbivores** the 2nd,
  - **primary carnivores the 3rd**,
  - **secondary carnivore** the 4th TL, and the like

Ecological Pyramids

- Food chains are morphological systems of energy flow in an ecosystem.
- The energy flow within a system may be described in more quantitative terms using **ecological pyramids.**
- When energy flows and accumulates in the body of organisms at any trophic level in a certain food chain, it is revealed either in terms of increase in:
    - **Biomass (weight),**
    - **Calories (energy) or**
    - **Numbers** (new individuals born).
- If we measure in quantities and draw the relative number, biomass or calories of each organism at each trophic level in the specific food chain, we get a **pyramid-shaped diagram,** broader at the base and narrower at its apex.

- This implies that the amount of energy stored at each trophic level **gradually decline** in the process of transfer from the lower trophic level, at the base (e.g. Primary producers) to the highest trophic lever, at the apex
- In certain circumstances, the shape of the ecological pyramid might be distorted some where, and might not have exactly a pyramid shape, hence, we call this kind of pyramid, **an inverted pyramid**.

- There are three different kinds of ecological pyramids

a) **Pyramid of Numbers:**

- This is a diagrammatical representation showing the relative number of individuals at each trophic level.
- The unit of measurement is number of individuals per a given area.
- The diagram could be drawn just by counting the number of individuals in each of the trophic level in that specific food chain.

Pyramid of numbers, however, could be inverted in one of the following two occasions:

1. if there are **few and large producers** such as big trees that could support many smaller herbivores (e.g., insects) in the ecosystem;
2. if there **is parasite infestation** in the ecosystem that a host at the lower trophic level can support a large number of parasites situated at the upper trophic level in the food chain.

- For example if the snakes in Figure above are infected with tick, an ectoparasite**, the pyramid of number** will have inverted shape as indicated in Figure below

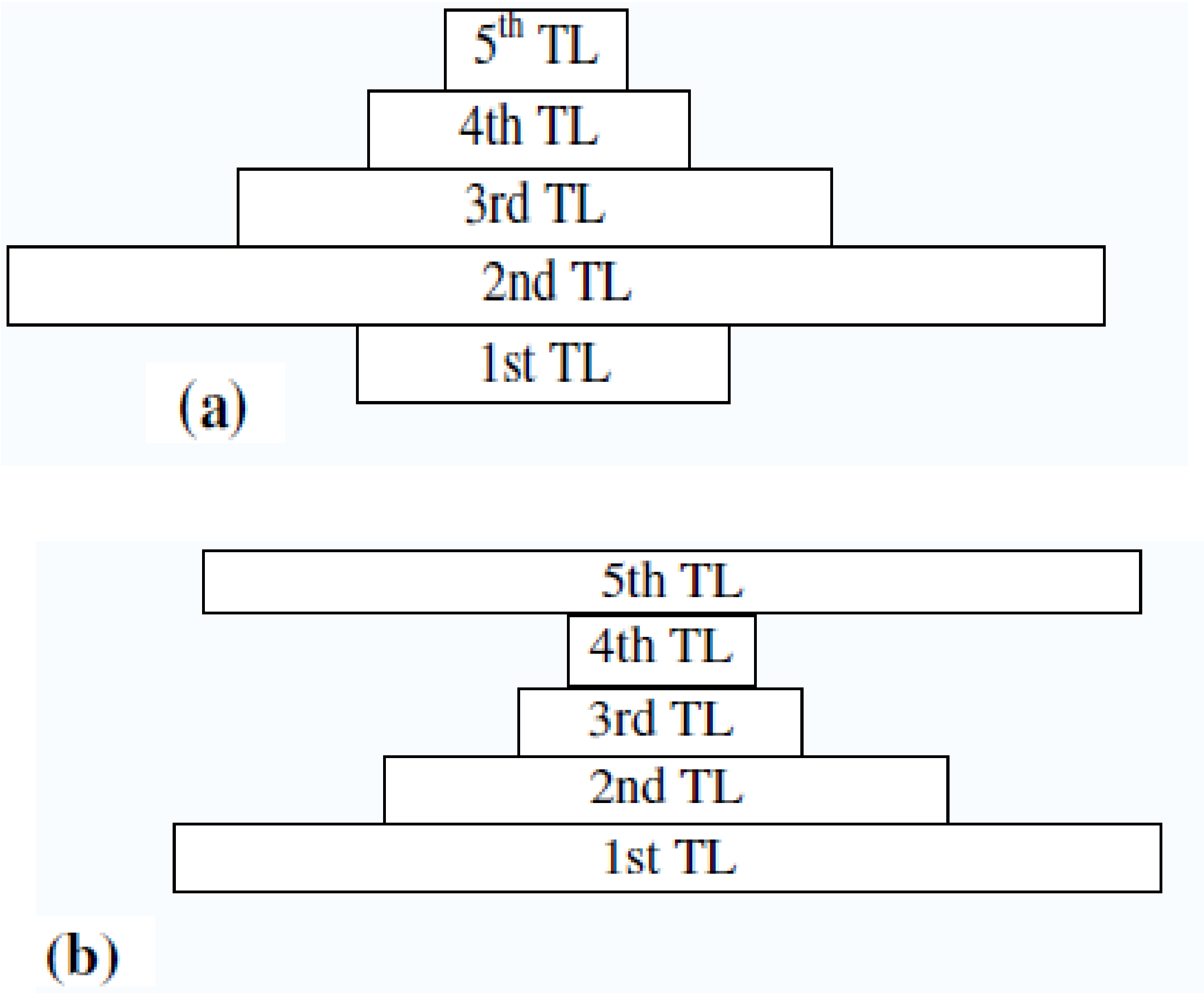


Illustration of inverted pyramid of numbers: (a) if the ecosystem is dominated by few and big primary producers; (b) if there is parasite infestation

b) Pyramid of Biomass:

- This is a diagram that quantifies all of the living biomass accumulated at each trophic level.
- In most systems, the amount of biomass decreases as one move from the lower end to the upper end of the food chain. The unit of measurement here is Kg/ha/year.
- In terrestrial ecosystems, it may require weighing the above ground and below ground biomass production of the organisms in each trophic level, which makes it very expensive and tiresome.
- However, it is possible to take representative samples in the community.

- The pyramid of biomass could be **inverted** if the food chain is in aquatic systems in one of the following cases:

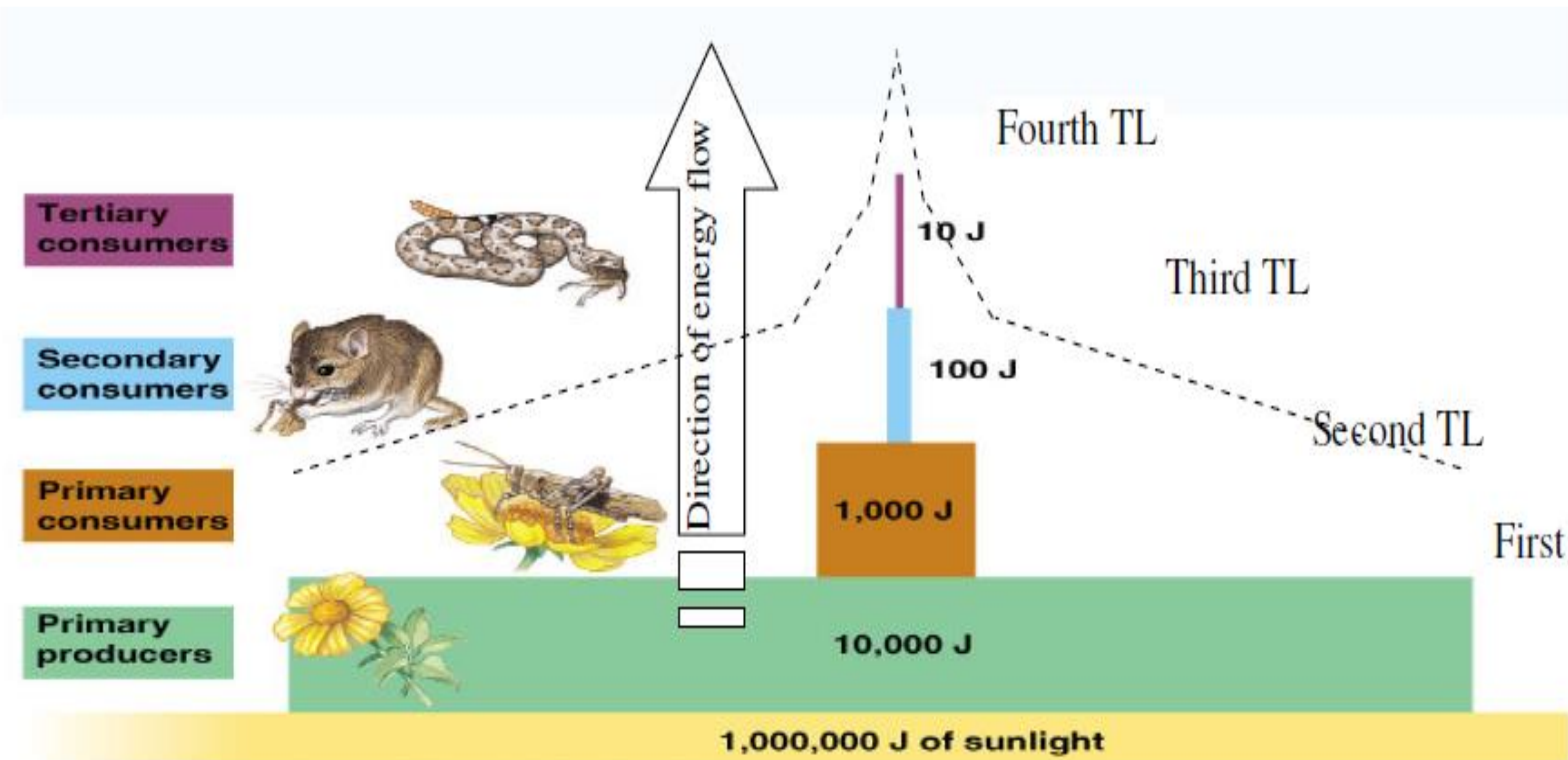
1. if the ecosystem is heterotrophic, such as rivers or lakes that are characterized by large imports of biomass in the form of dead organic matter. This may cause consumer production to be higher than the autotrophs present in the system;
2. if the ecosystem is dominated by high density of planktons (floating plants and animals).

- Planktons store their excess food in the form of oil to help them float on the surface of the water, unlike other plants that store in the form of starch. Oil has less density as compared to starch and water.
- In this occasion, the biomass of the first trophic level might be much smaller than the next higher trophic level in the food chain.

c) Pyramids of Energy:

- This is a diagram that shows the relative amount of calories flowing from one trophic level to the next in an ecosystem. The unit is Kilo Joule or Kilocalories per hectare per year.
- The above diagram clearly describes how energy is diminishing in the process of transfer
- The pyramid of energy, unlike the other two**, can never be inverted** because of the law of thermodynamics which states that energy cannot be 100 percent efficient when it is transferred from one form to another.
- When energy is transferred from one trophic level to the next, a certain amount is lost in the form of heat or other forms, as the result the amount of energy transferred to next trophic level **gradually diminishes**.

- We can measure the amount of energy in the tissue of an organism at any trophic level in the food chain by measuring the **amount of calories generated when burned**.
- In average, a gram of dry plant material provides 4.0 to 4.5 calories of heat when burnt (algae gives about 4.9 calories per gram). A gram of animal tissue yields an average of 5.0 to 5.5 calories of heat.



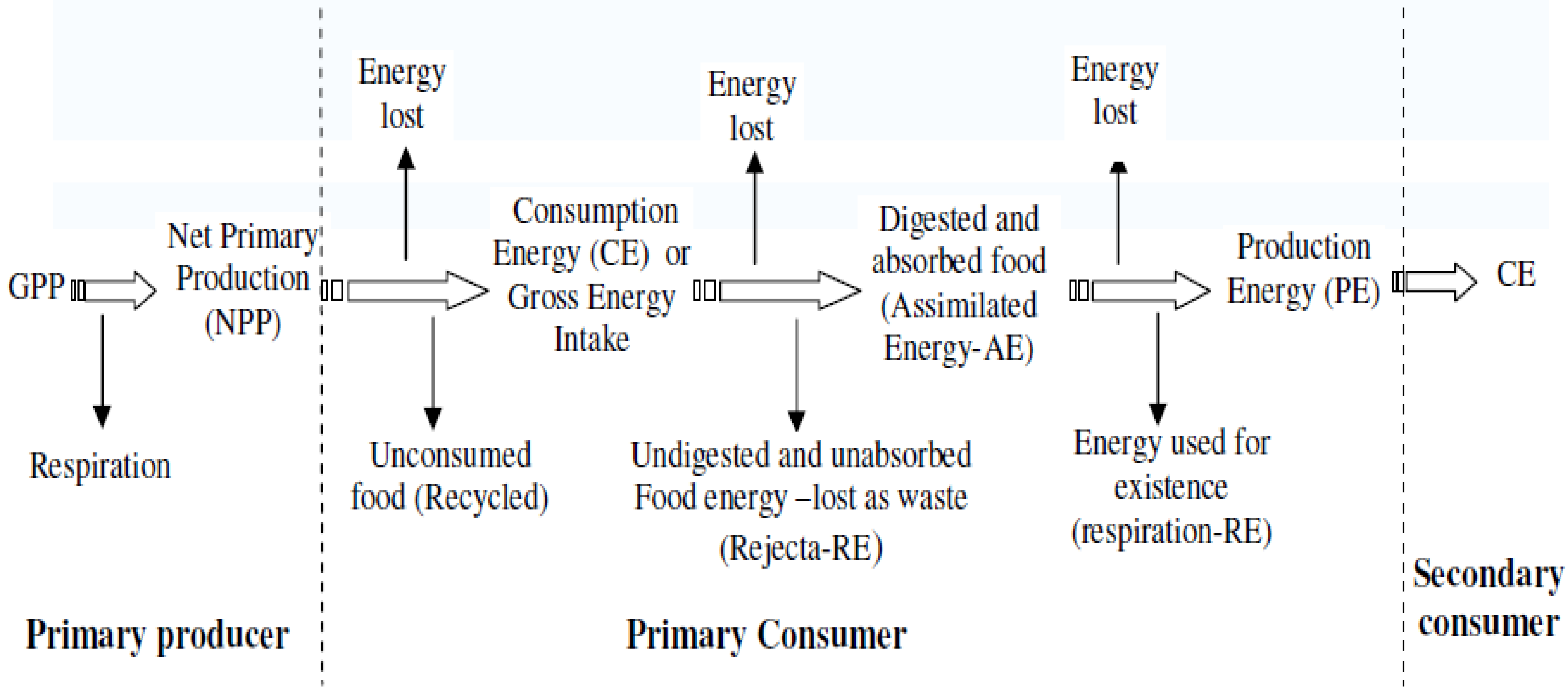
Ecological Efficiency

- The fate of the fixed energy assimilated by organisms ultimately ends up through four different routes:
  - ***Respiration for different activities,***
  - ***Accumulation in the form of biomass,***
  - ***Consumption by other organism***
  - ***Decaying of organic materials****.*
- *The real amount of energy* which is incorporated into the tissues of consumers at each level is not determined by the gross volumes consumed, but it is the amount of energy converted into **actual biomass**.
- A significant amount **of energy is lost** by consumers due to:
  - **Inefficiencies during assimilation**
  - **Respiration for morphological and physiological maintenance, reproduction, and**
  - **The process of finding or capturing food.**

- The energy that plants fix is used to support all the life forms in all other trophic levels.
- The amount of energy available in the biomass of **primary consumers** is much smaller than the amount present at **the primary producer level.**
- Herbivores do not consume all available plant material due to various mechanisms which plants have developed.
- That percentage which is consumed does not all become herbivore biomass, because of loss of biomass that occurs due to **inefficiencies and respiration.**

- Most terrestrial herbivores have an assimilation efficiency of between 20% and 60%.
- The primary carnivore, in their turn, consumes the greater portion of herbivore biomass for their survival, but again, all herbivores are not consumed due to defense mechanisms.
- In comparison to herbivores, carnivores have higher assimilation efficiency as some estimates between 50% and 90%.
- Generally, the gross ecological efficiency of terrestrial ecosystems ranges from 5% to 30%, averaging from 10%, from producers to herbivores, and 15% from herbivore to carnivore (Kormondy, 1996).

- only a small percentage of the assimilated energy is converted into primary carnivore biomass, as energy is expended for body maintenance, growth, reproduction and locomotion.
- Tertiary consumers feed on secondary consumers, and therefore the amount of biomass found on this trophic level is extremely small when compared relatively to the previous levels.
- This occurs due to the same reasons of **inefficiency during assimilation and the various processes the organism requires to live**.
- The following diagram shows the overall mechanism of energy transfer at consumer level in the food chain.



The complete energy budget of consumers

Efficiency of Consumers in an Ecosystem

- The energy efficiency of a consumer in an ecosystem is affected by the quality of the NPP, the amount of energy expenditure, and its conversion efficiency.
- If the produced energy by the consumer is not used, it accumulates in the form of fat hence, biomass increases.
- However, if the respiration is greater than assimilated energy, the organism is starved.
- There are three different measures of efficiency of a consumer in an ecosystem:

Consumption Efficiency *(also called trophic efficiency): It measures the efficiency of a consumer to* take the produced NPP.

- Depending on the palatability of the NPP, much of the energy is not consumed, hence decomposed to the soil. The Consumption Efficiency of the consumer is given by:

$$Cons.Eff. = \frac{Consumption\ Energy\ (CE)}{NPP} X\ 100\%$$

Assimilation efficiency*: It is the measure of percentage of assimilated energy that is absorbed* by the consumer as compared to the consumed food Energy.

- Assimilated Energy is the difference between Consumption energy (ingested) and egested energy (Rejecta).

$$Assim.Eff. = \frac{Assimilated\ Energy\ (AE)}{Consumption\ Energy\ (CE)}\ X\ 100\%$$

Production efficiency*: It is the percentage of the energy storage remaining in the tissue of the* consumer after a considerable amount is utilized for respiration (i.e. for growth or reproduction),etc.

- Production energy is the difference between assimilated energy and respiration energy

$$\mathrm{Pr}\,od.Eff. = \frac{\mathrm{Pr}\,oduction\ \ Energy\ (PE)}{Assimilated\ Energy\ (AE)}\ X\ 100\%$$

Activity

- The annual primary production of a certain woodland ecosystem in Southern part of Ethiopia is 20,000 tones per hectare. The plant utilizes nearly 30% of its production for respiration purpose. Calculate the production, assimilation and consumption efficiency of the herbivores if they consume 2000 tones of forage and assimilated 500 tones to produce 100 tones of biomass per year.

Biogeochemical cycling in Ecosystems

- The existence of the living world depends up on the flow of energy and the circulation of materials through the ecosystem.
- Nutrients required for life exist in mineral form in Earth's crust.
- All the essential nutrients flow from non-living to living and back to the non-living parts of the ecosystem in a more or less circular path.
- This is termed as the *biogeochemical cycle.*
- In ecology, a biogeochemical cycle is a circuit or pathway by which a chemical element or molecule moves through both biotic ("bio-") and abiotic ("geo-") compartments of an ecosystem.
- In effect, the element is recycled, although in some such cycles there may be places (called "sinks") where the element is accumulated or held for a long period of time.

Main Important Nutrients in an Ecosystem

- Plants have nutritional requirements in order to accumulate energy, grow, develop and complete their life cycle.
- The supply of nutrients to the plants should be balanced, ensuring not to over or under-fertilize.
- There are about **16 most important elements** in an ecosystem that are crucially important for the plant growth.
- These nutrients are classified into different categories based on the **amount of requirement to plants**

A. ***Non-Mineral elements***: *This category includes those elements that are not found in mineral* forms, rather are mainly found in molecular forms in the atmosphere or dissolved with water.

- These include: C, H_2 and O_2.

B. ***Mineral elements***: *This category includes those elements that are mainly found in mineral* forms associated with rocks and soils. They are further classify into three categories.

   i. ***Primary nutrients:*** *are those nutrients that are required in large quantity. This includes:* N, P and K

   ii. ***Secondary Nutrients:*** *are those nutrients that are required relatively in moderate* quantities. This includes: Ca, Mg and S.

   iii. ***Micronutrients:*** *are those nutrients that are required in a very small quantity, but are* crucially important and limiting factor for the plant growth.

   They includes: CU, Fe, Co, B, Zn, M) and Mo.

Types of Nutrient Cycling

- There are two basic types of biogeochemical cycles in an ecosystem:
- *Gaseous and sedimentary* cycles.

a) Gaseous (atmospheric) cycle: In this kind of cycling, the main reservoirs of elements are *the* atmosphere and oceans.

- Example of elements cycling in the gaseous or atmospheric cycle include the following:
  - **Hydrological cycle, Oxygen cycle, Carbon cycle and Nitrogen cycle**

b) ***Sedimentary (edaphic) cycle:*** In this kind of cycling, the main reservoirs of elements are the soil and rocks. Examples include:

  - Sulfur cycle , Phosphorus cycle and Nitrogen cycle

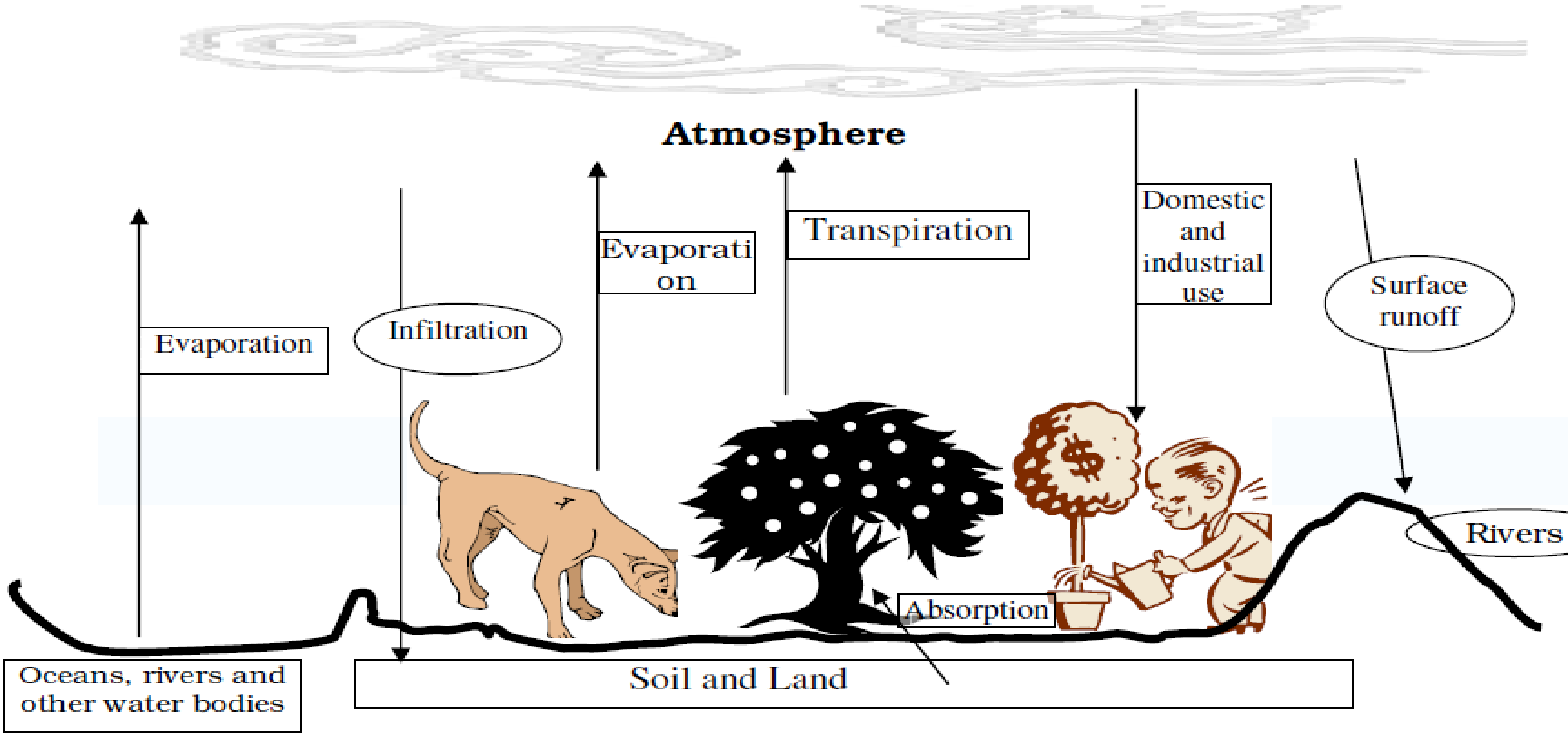
End of chapter 5

Hydrological/ Water Cycle

- Solar energy is the driving force behind the water cycle. The heating of the atmosphere and its role in evaporation provide the basic mechanism of the cycle.
- Water evaporates from the water bodies, soil, and the tissue of plants and animals and is held in the atmosphere.
- Water vapor in the atmosphere when condensed, it falls in the form of rain as droplets or in the form of ice crystals
- The precipitation that reaches the soil runs off to the surface water bodies (rivers, lakes and streams) or gets into the ground by infiltration.
- The rate of infiltration is influenced by the nature of the soil, the landform (slope) and the characteristic of the vegetation.

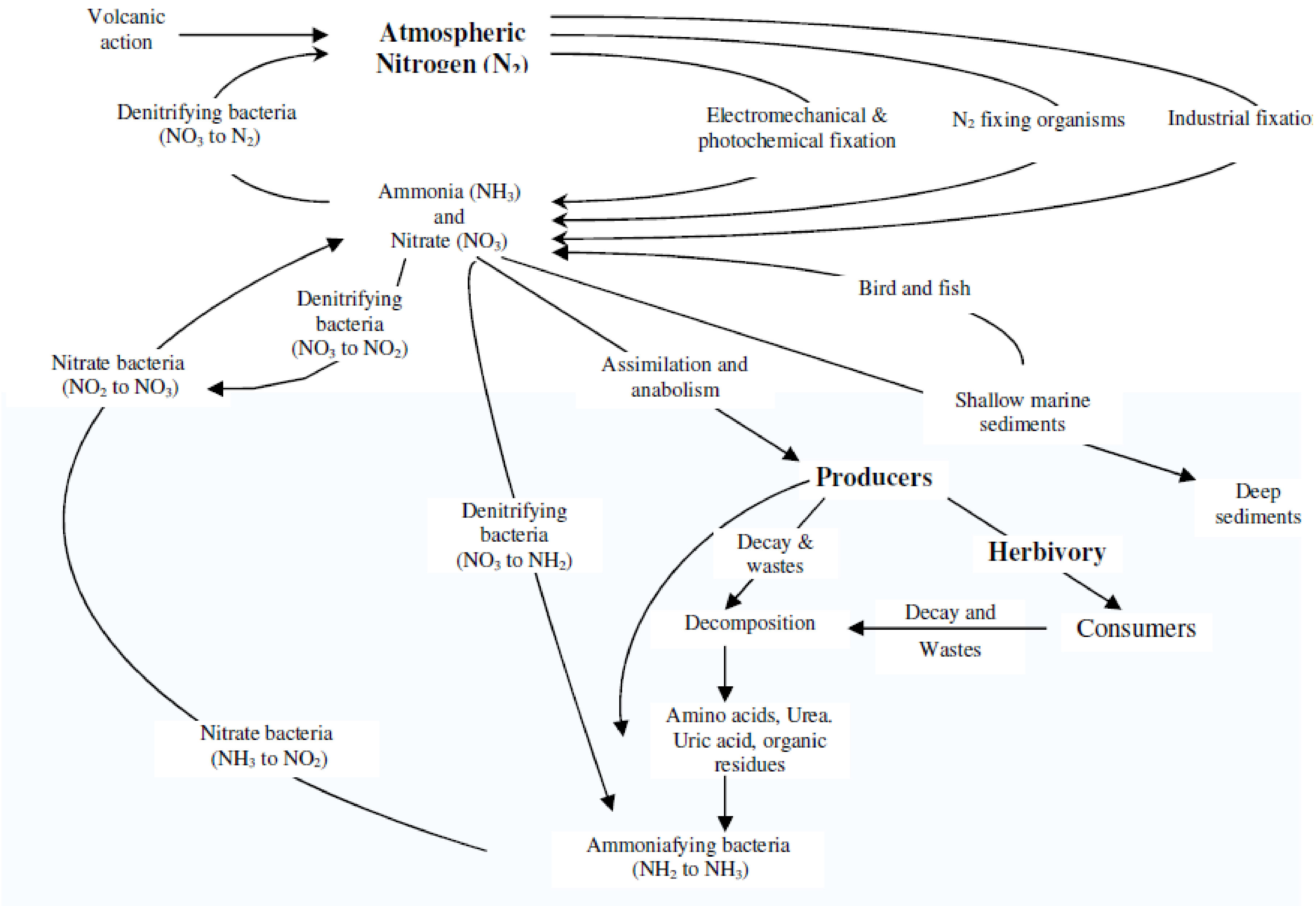
The water that is retained by the soil is absorbed by the plants and used for different physiological activities such as cooling, photosynthesis, and transportation of elements.

The water in the tissue of organisms and the soil, again, evaporates and returns back to the atmosphere or oceans, the reservoirs. The cycle continues the same way



The Nitrogen cycle

- About 78 percent of the air is composed of nitrogen. Nitrogen is essential for many biological processes.
- All nitrogen obtained by animals can be traced to the consumption of plants at some stage of the food chain. However, the molecular form of nitrogen is not usable by plants.
- They get the usable nitrogen from the soil by absorption by their roots in the form of either ***nitrate ions or ammonia.***
- There are different mechanisms to fix atmospheric nitrogen and convert into a more chemically reactive form:
- ***Biological fixation:*** *some bacteria (associated with certain leguminous plants) and certain bluegreen* algae (also known as *cyanobacteria) are symbiotic microbes able to fix nitrogen and* assimilate it as organic nitrogen
- ***Lightening:*** *the formation of NO from N2 and O2 due to photons and lightning are important in* the process of nitrogen fixation. However, it contributes little for terrestrial or aquatic nitrogen turnover.
- ***Combustion of gasoline and fossil fuel:*** *A fossil fuel has different impurities of nitrogen gas. The* combustion of fuel by automobile engines and thermal power plants transfers elemental nitrogen gas into oxides of nitrogen (NOx).



Nitrogen Cycle in terrestrial and aquatic ecosystem

- In the process of biological fixation, ammonia is produced in the soil by nitrogen fixation organisms which can produce the **enzyme *nitrogenase***
- Another source of ammonia is the decomposition of dead organic matter by saprophytic bacteria called *decomposers, which produce ammonium ions (NH4*+).
- In well-oxygenated soil, these are then oxygenated first by a group of bacteria such as *Nitrosomonas europea into nitrites (NO2*-); and then by *Nitrobacter into nitrates (NO3* -). This conversion of ammonia into nitrates is called ***nitrification***
- In the presence of anaerobic (low oxygen) conditions in soils, *denitrification by bacteria such as Thiobacillus denitrificans can happen. This is the reverse of **nitrification** and results in nitrates being converted* to **nitrogen gas and lost to the atmosphere**.