ENVIRONMENTAL SCIENCE

Course Code : 18 CE M01

UNIT-2
ECOSYSTEMS

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CONTENTS

- Concept, structure and function of an ecosystem
- Role of producers, consumers and decomposers
- Energy flow in an ecosystem
- Food chains, food webs, ecological pyramids
- Nutrient cycling, Bio-geo chemical cycles
- Terrestrial and Aquatic ecosystems.

Ecology and Ecosystem

- Scientific study of the distribution and the interactions between organisms and their natural environment.
- A natural unit consisting of all plants, animals and micro-organisms in an area functioning together with all of the non-living things.
- The smallest unit of biosphere that has all the characteristics to support life.

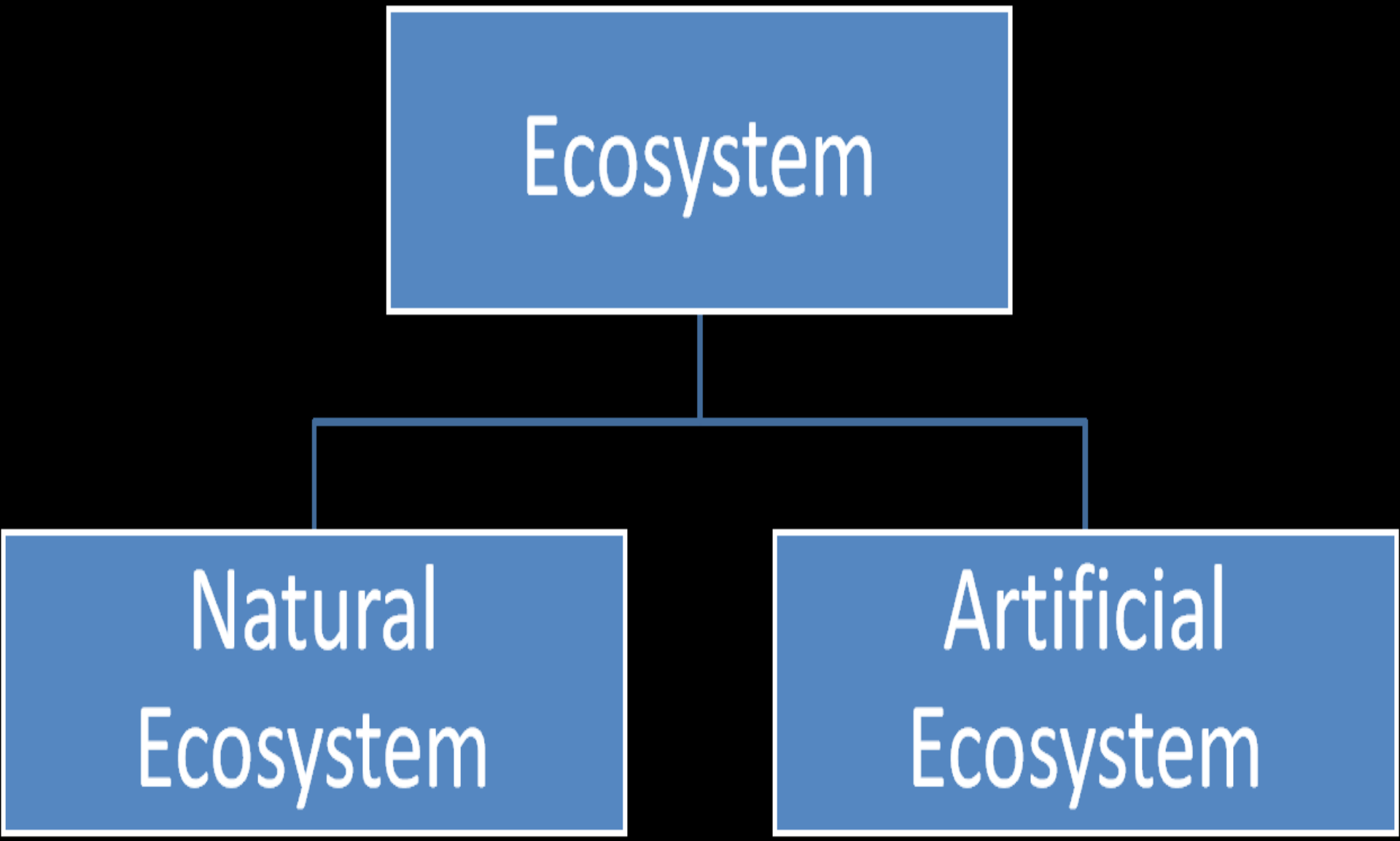
Scope of an ecosystem

An important role in

- agriculture crop rotation
- weed control
- management of grasslands, forestry
- biological surveys, fishery surveys
- conservation of soil, wild life
- surveys of water bodies like rivers, lakes; ponds etc...

Concept of an Ecosystem

- Interaction of life with its environment at many levels.
- A single bacteria in the soil interacts with water, air around it within a small space
- A fish in a river interacts with water and other animals, rivals in a large space.
- Both organisms and abiotic environment each influencing the properties with other for maintenance of life.


Ecosystem
Natural Ecosystem
Artificial Ecosystem

Artificial Ecosystem

- Maintained or created artificially by man.
- The man tries to control biotic community as well as physico chemical environment.
- Eg: Artificial pond, urban area development.

Natural Ecosystem

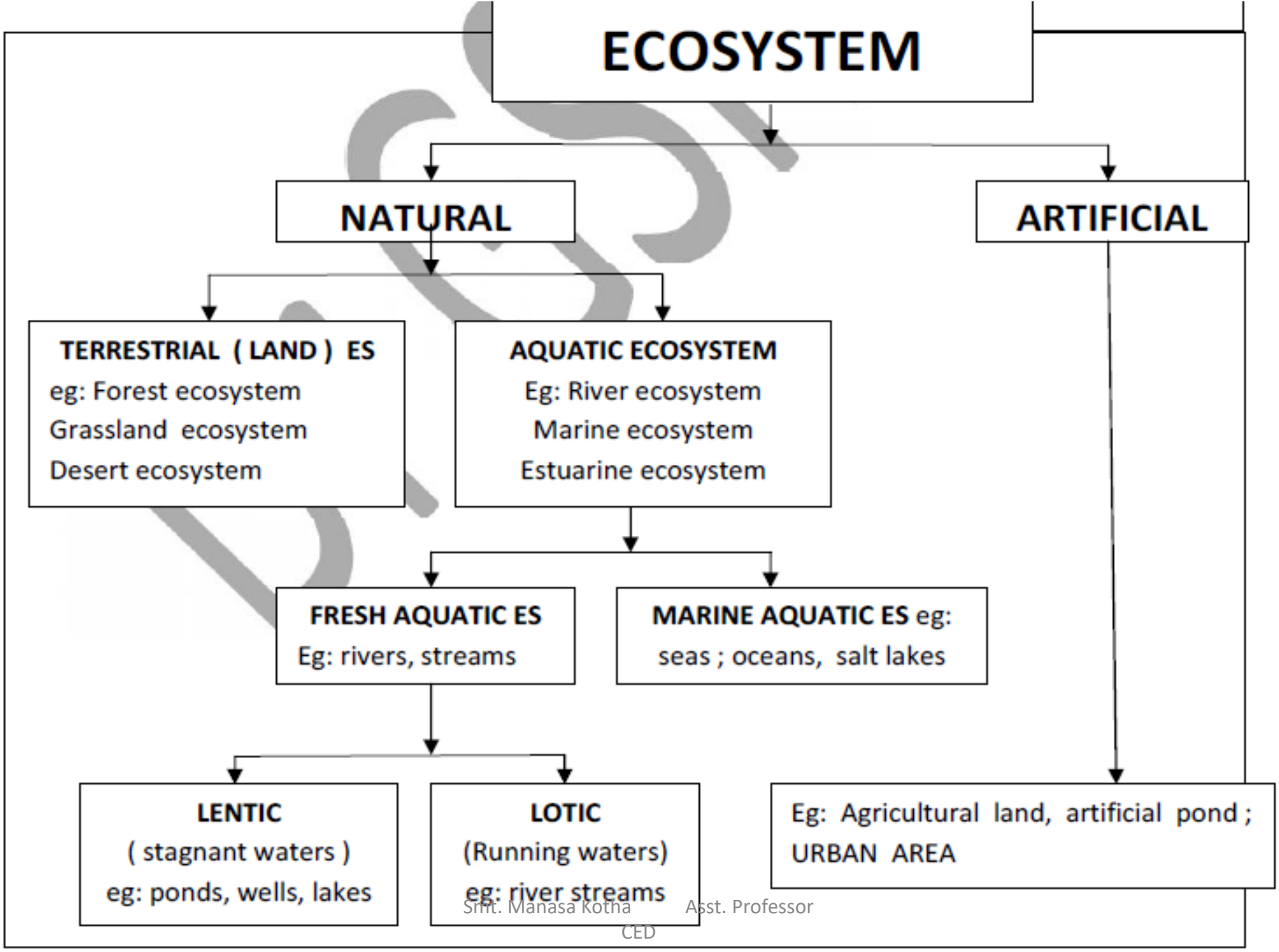
- Consists of Terrestrial and Aquatic Ecosystems which are maintained naturally.

Terrestrial Ecosystem:

- Relates to biotic components living on the land.
- Vegetation dominates the community and the types of vegetation affect the climate, soil structure & a rapid exchange of O_2, water & CO_2

Aquatic Ecosystem:

- Relates to biotic community living in water. The types of water (fresh water, saline water, polluted water) dominate and affect the pH of water, depth of water, temperature of water etc..
- Aquatic ecosystem has been sub-divided into fresh water and saline water based on the quality of water.


ECOSYSTEM
NATURAL
ARTIFICIAL
TERRESTRIAL (LAND) ES
eg: Forest ecosystem
Grassland ecosystem
Desert ecosystem
AQUATIC ECOSYSTEM
Eg: River ecosystem
Marine ecosystem
Estuarine ecosystem
FRESH AQUATIC ES
Eg: rivers, streams
MARINE AQUATIC ES eg:
seas ; oceans, salt lakes
LENTIC
(stagnant waters)
eg: ponds, wells, lakes
LOTIC
(Running waters)
eg: river streams
Eg: Agricultural land, artificial pond ;
URBAN AREA

STRUCTURE

The structure of an ecosystem comprises:

(a) The composition of biological community species (plants, animals, microorganisms), their population, life cycles, distribution in space etc.

(b) The quantity and distribution of non-living things such as soil ; water etc .

(c) The range or intensity of conditions like temperature, light, rainfall, humidity, wind & topography plays a major role in the structure of ecosystem

STRUCTURE (ctd..)

Abiotic structure

- Includes the non-living things of the ecosystem such as
- Physical factors (soil, temperature, light & water)
- Chemical factors consisting the inorganic compounds (N, C, H, K, P, S) & organic compounds (carbohydrates, proteins).

STRUCTURE (ctd..)

Biotic structure

- Includes plants, animals & microorganisms present in an ecosystem form the biotic component.
- These organisms have different nutritional behavior in the ecosystem and are known as Autotrophs (Producers)
- Heterotrophs (Consumers) & Micro-consumers (Decomposers) based on how they get their food.

FUNCTIONS

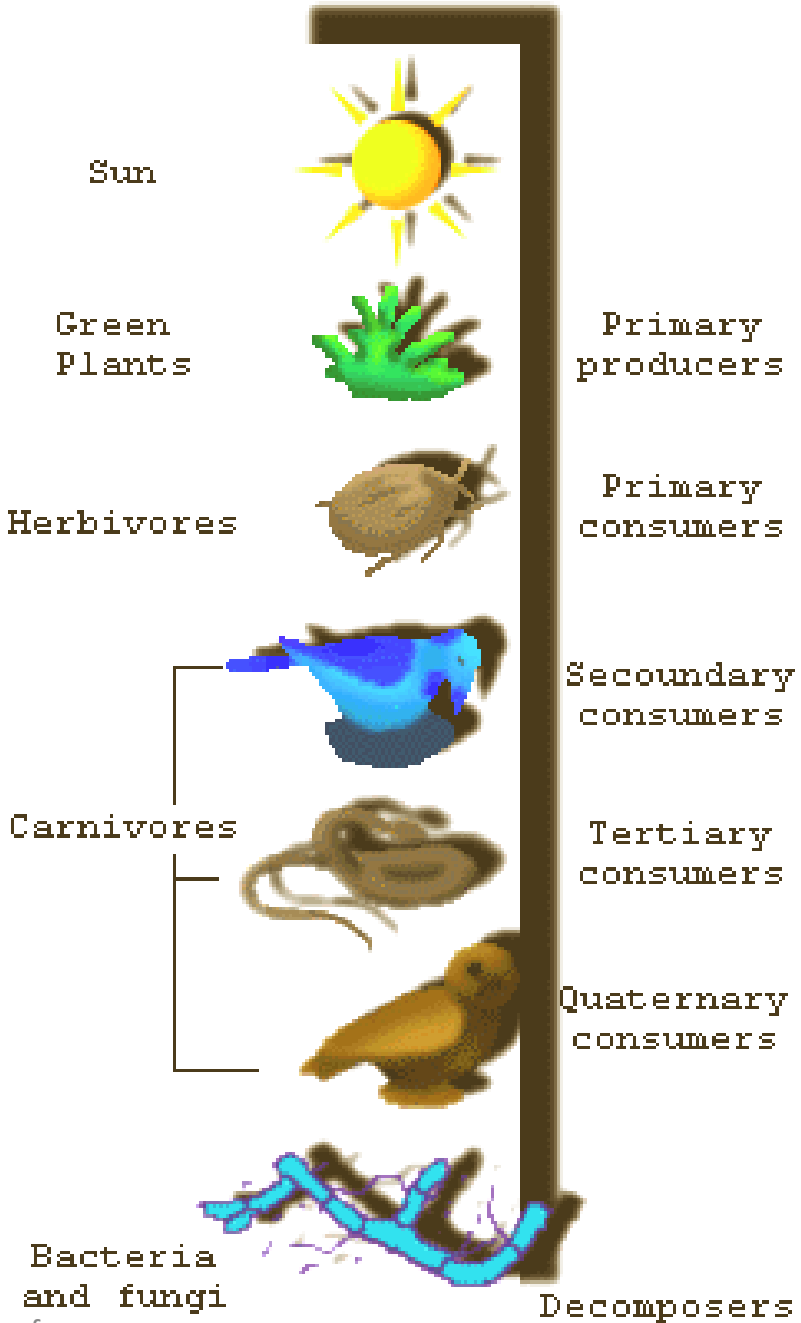
- Air pollution are tapped by leaves of tree and convert into harmless compounds.
- Waste water gets filtrated through the natural soil and make drinkable.
- Function means how an ecosystem works/ operates under natural conditions.

- The rate of biological energy flow ; the rate of nutrient cycles → Bio-Geo-Chemical cycles and Ecological regulation (regulation of organisms by Environment & regulation of Environment by organisms) plays a major role in the function of an ecosystem

Energy Flow in an Ecosystem

- A trophic level is the position occupied by an organism in a food chain.
- Trophic levels can be analyzed on an energy pyramid.
- Producers are found at the base of the pyramid and compromise the first trophic level.

- Primary consumers make up the second trophic level.
- Secondary consumers make up the third trophic level.
- Tertiary consumers make up the top trophic level.



1. Autotrophic components (Producers)

- Autotrophic means self nourishing, also called producers. Eg: Algae, Green plants, Bacteria of photo synthetic.
- Green plants prepare their food themselves by making use of CO_2 present in the air & water in the presence of sunlight through the process of **photosynthesis.**

2.Hetero-trophic components(Consumers)

- Dependent on others for nourishment directly or indirectly upon the autotrophs for their food.

a. **Herbivores (Primary consumers) :** These animals feed directly on living plants or remains of plants. Eg: Rabbits, Deer's, Insects.

b. **Carnivores (Secondary consumers):** These carnivores (flesh eating) feed on the herbivores. Eg: Snakes, birds, Lizards, fox.

c. **Tertiary consumers (or) Tertiary carnivores**: These feed on the primary & secondary consumers. Eg: Lions, Tigers.

d. **Omnivores:** These consumers feed on both plants & animals. Eg Human beings, Birds (hawk) etc…

3. Decomposers or Micro consumers

- They feed on organic compounds of dead or living plants and animals for their food and energy.
- They absorb some of the products from decomposed material and release organic compounds (nutrients) making them available to producers.
- Eg: Bacteria, Fungi, Flagellates. The decomposers are also called as "**Saprotrophs".**

FOOD CHAIN

- The transfer of food energy from the producers (plants) through a series of organisms (Herbivores, Carnivores) successively with the repeated activities of eating and being eaten is known as food chain. In an ecosystem(s), one organism is eaten by the second which in turn is eaten by the third and so on... This kind of feeding relationship is called food chain.

Examples of food chain

1. Grass → Grasshopper → Frog → Snake → Hawk
2. Grass → Mouse → Snake → Hawk.
3. Grass → Rabbit → Man .
4. Grass → Mouse → Hawk.
5. Plant leaf → Caterpillar → Sparrow → Hawk.

Types of Food Chains

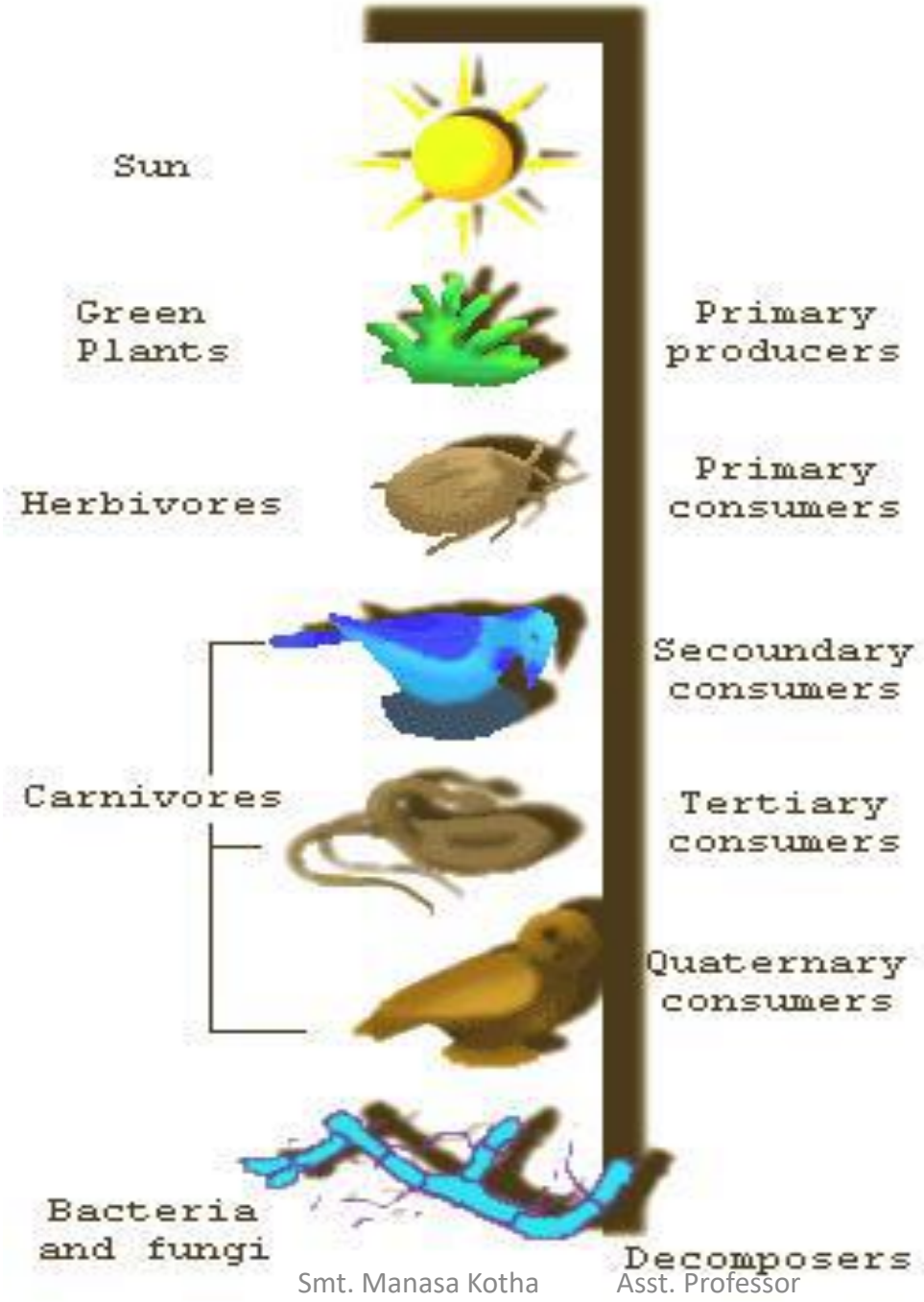
1. Grazing food chain
2. Detritus food chain

- **Grazing food chain:** This food chain starts with green plants (primary producers) and goes to herbivores and on to carnivores.

1. Phytoplanktons → Zooplanktons → Small fish → Tuna.
2. Phytoplanktons → Zooplanktons → Fish → Man.
3. Grass → Rabbit → Fox → Tiger.

- **Detritus food chain:** This food chain starts from dead organic matter (dead leaves / plants / animals) and goes to Herbivores and on to Carnivores and so on. .
- Leaves or dead plants → Soil mites → Insects → Birds .
- Dead organic matter → Bacteria → Insects .
- Dead leaves → Algae → Fish → Man

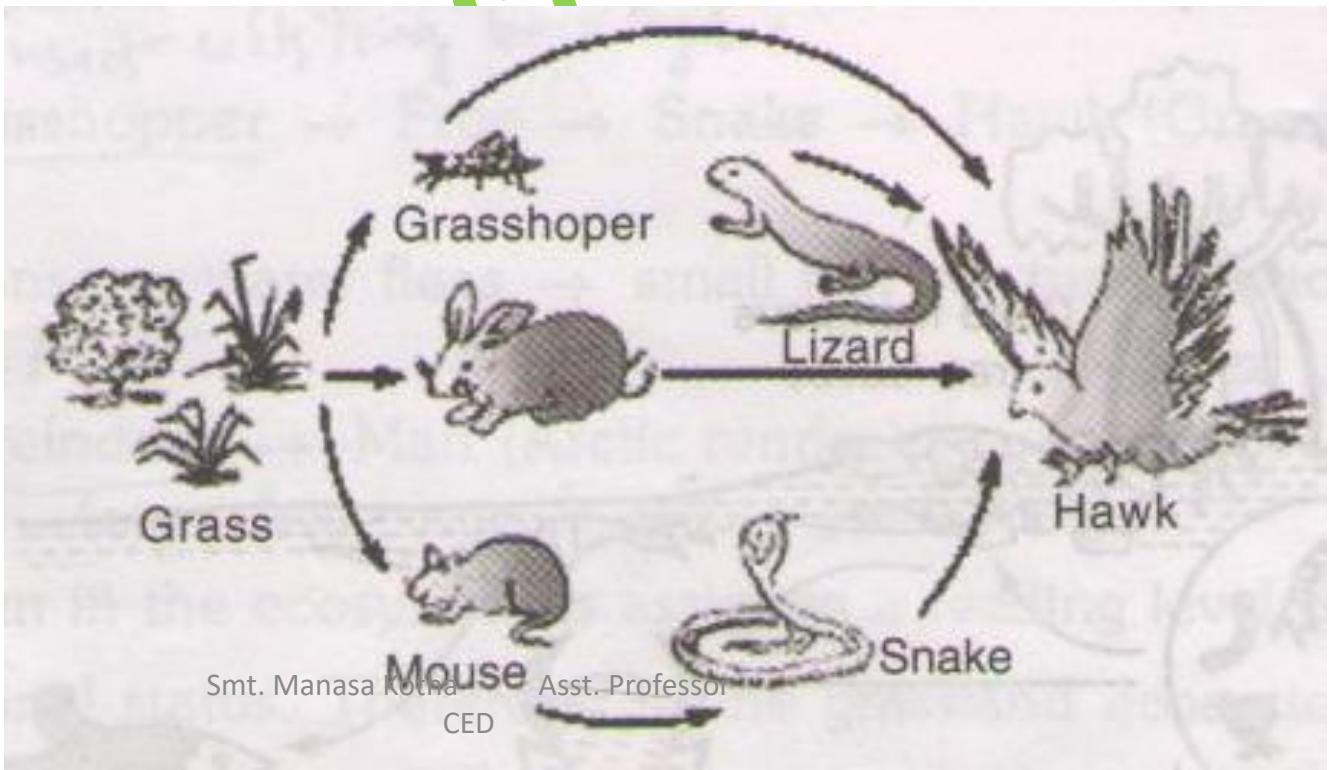
- The dead remains of plant and animals, dead leaves and flowers & fruits are degraded by decomposers (Fungi, Bacteria) and convert the organic matter into simple substances which are then taken up by the primary producers as nutrients.


Sun
Green Plants
Primary producers
Herbivores
Primary consumers
Secoundary consumers
Carnivores
Tertiary consumers
Quaternary consumers
Bacteria and fungi
Decomposers

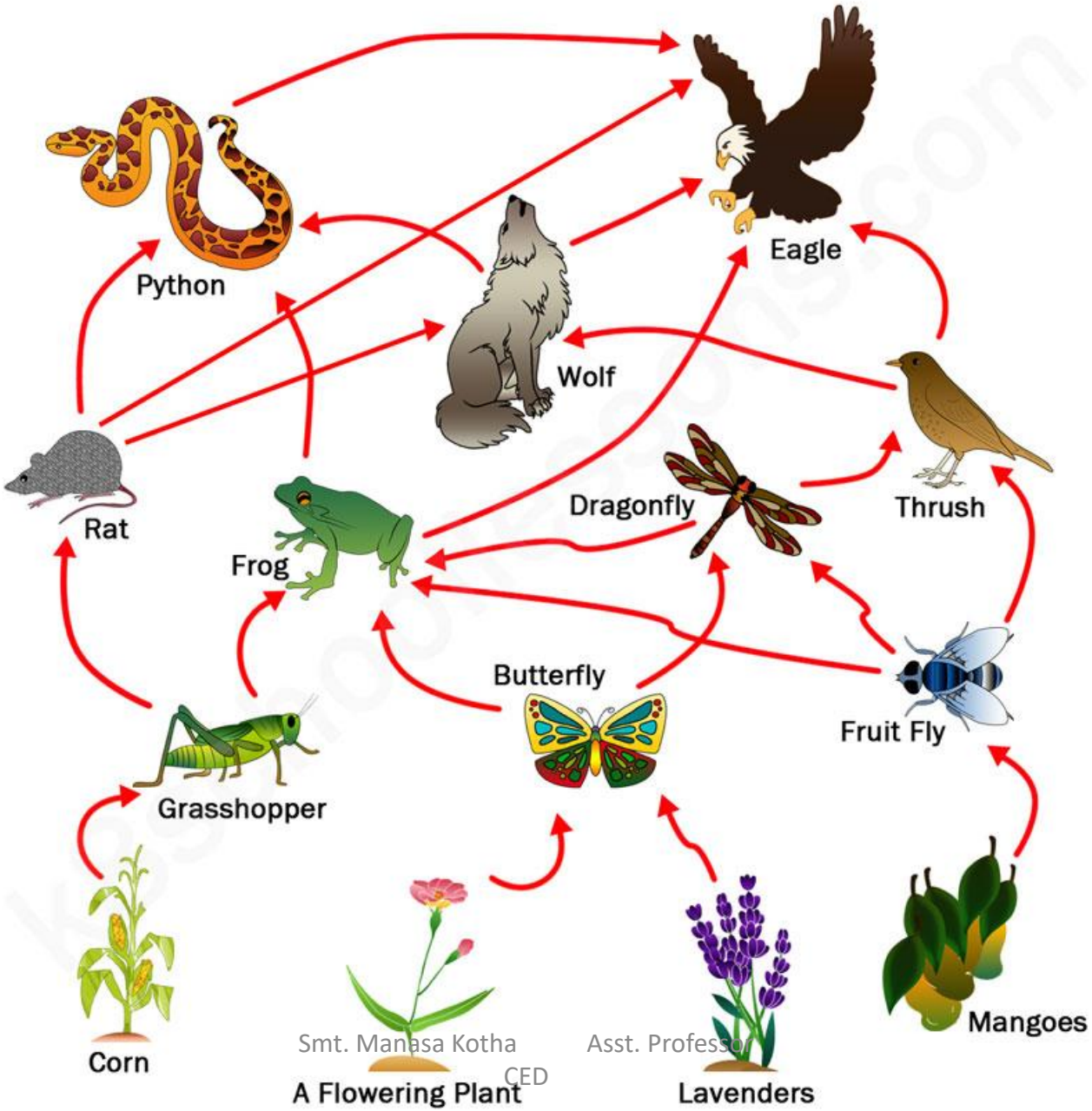
FOOD WEB

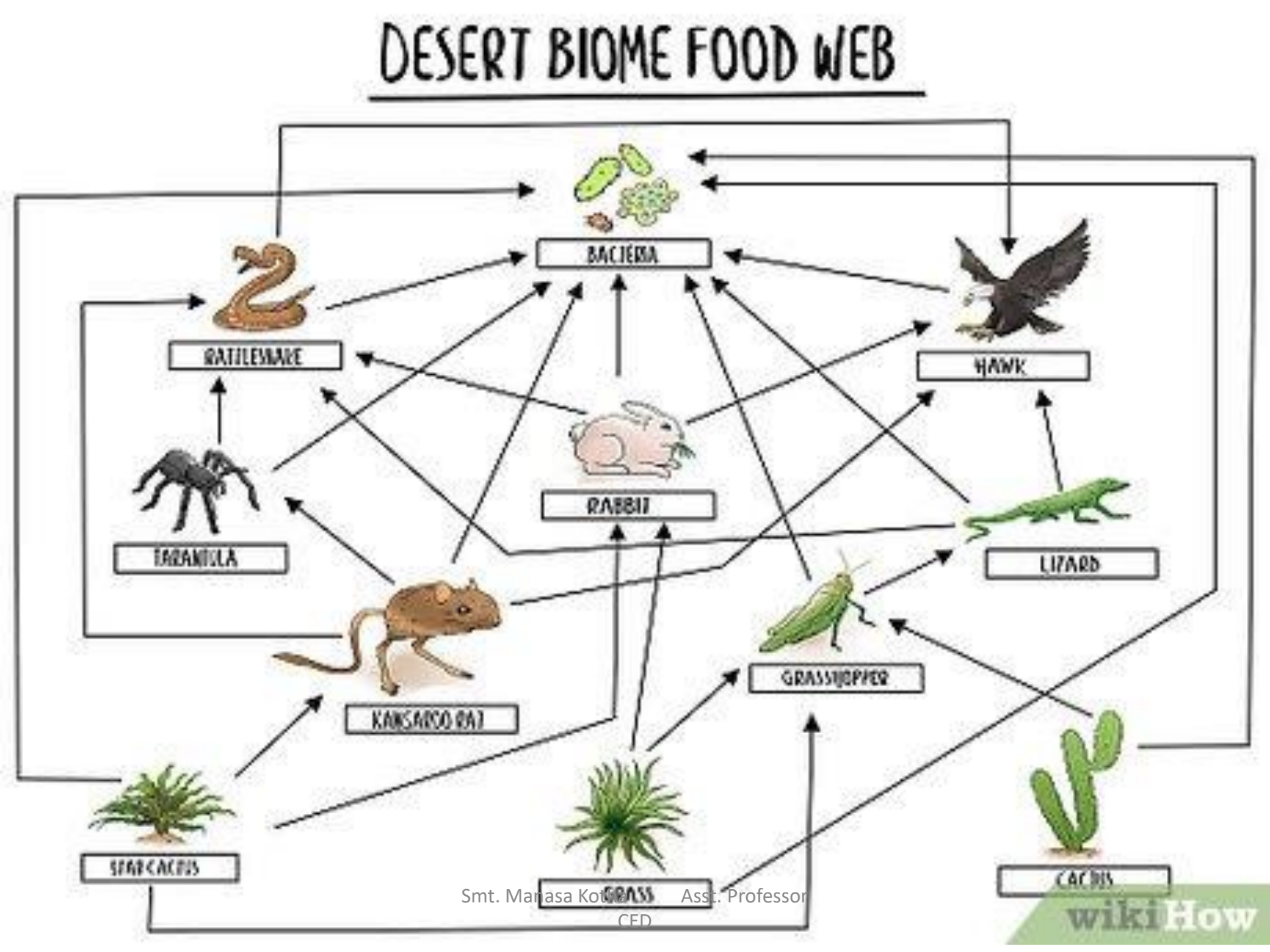
- A net work of food chains where different types of organisms are connected at different trophic levels so that there are a number of options of eating and being eaten at each trophic level. (A trophic level refers to an organism's position in the food chain)

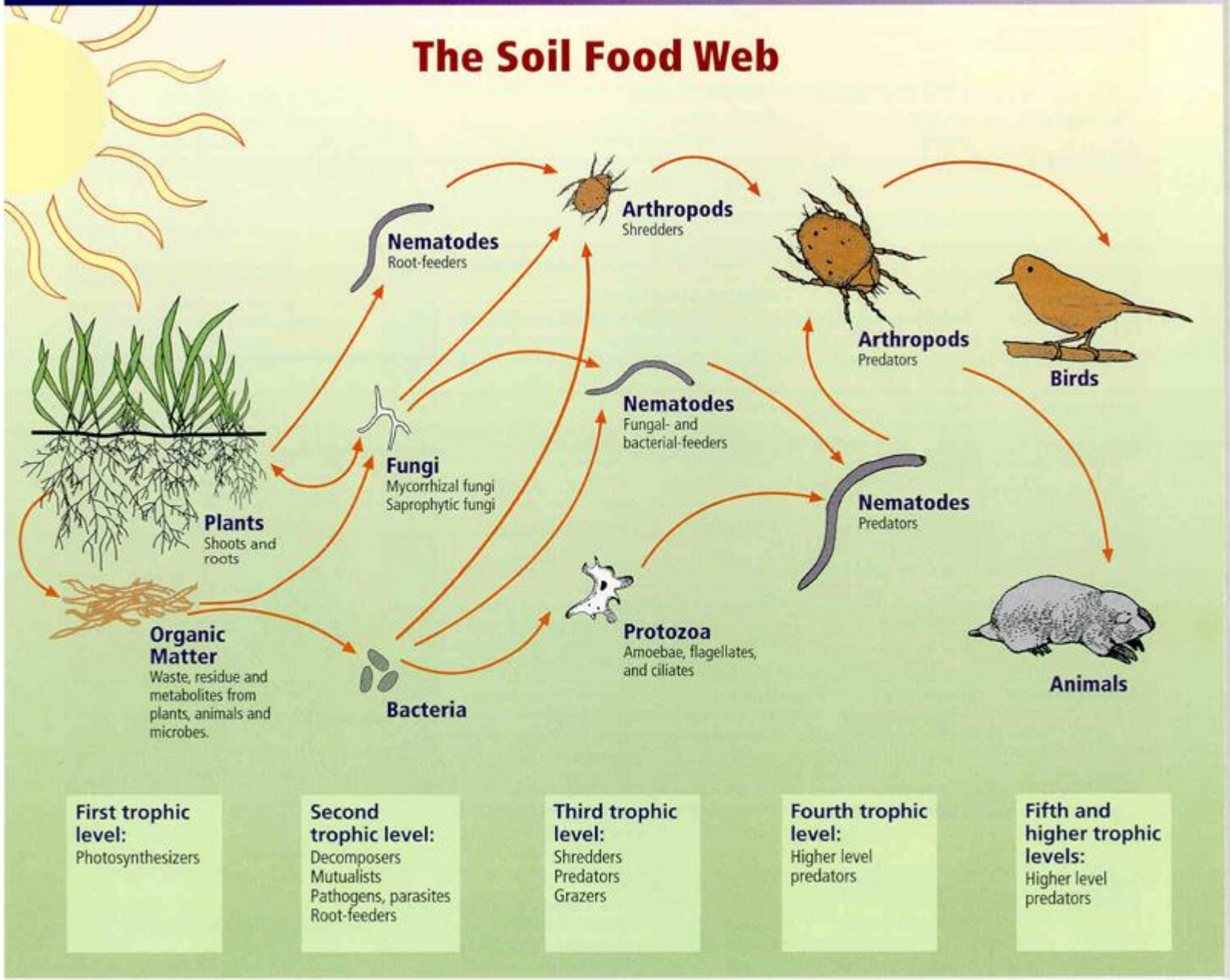
1. Grass → Grasshopper → Hawk
2. Grass → Grasshopper → Lizard → Hawk
3. Grass → Rabbit → Hawk
4. Grass → Mouse → Hawk
5. Grass → Mouse → Snake → Hawk



A Food Web


Python
Eagle
Wolf
Rat
Frog
Dragonfly
Thrush
Butterfly
Fruit Fly
Grasshopper
Corn
A Flowering Plant
Lavenders
Mangoes

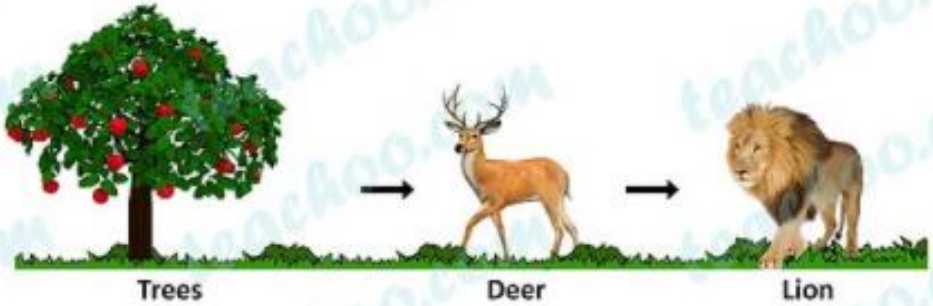

DESERT BIOME FOOD WEB
BACTERIA
RATTLESNAKE
HAWK
RABBIT
TARANTULA
LIZARD
KANGAROO RAT
GRASSHOPPER
SPAR CACTUS
GRASS
CACTUS

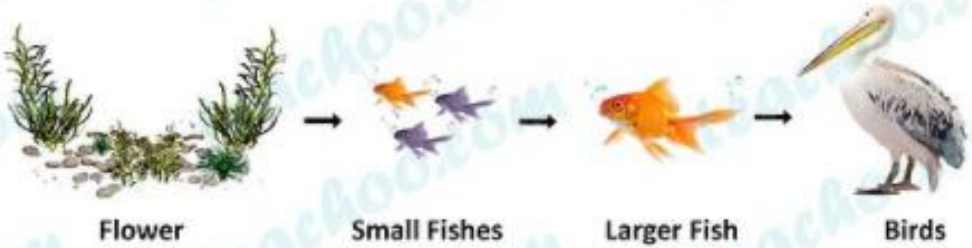


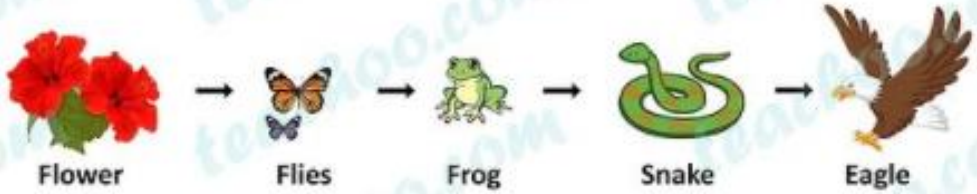
Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Food Chain	Food Web
In a food chain, there is a straight line from producers to first consumers to second consumers to third consumers	In a food web, each organism eats and is eaten by 2 or more organisms. So, everything is connected by a web.
An organism at higher level of food chain eats a specific organism at the lower level	An organism at higher level of food web can eat more than one organism from the lower level
Food chain is a simplified version of food web	Food web is what happens in reality. A food web contains many food chains.
Single food chains is unstable in an ecosystem	Food webs are stable in an ecosystem

Food Chain

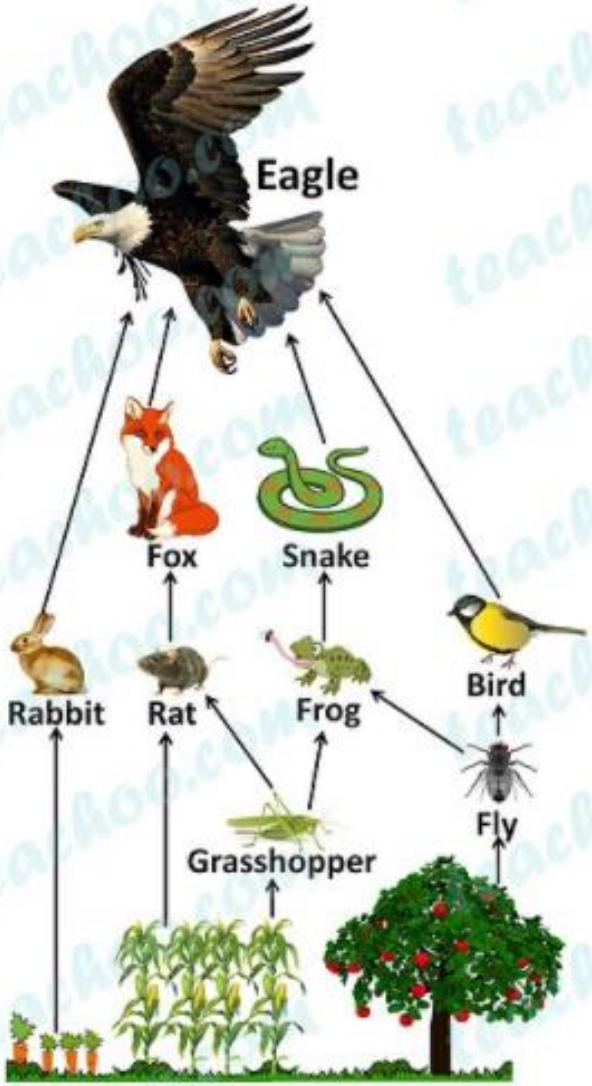






VS

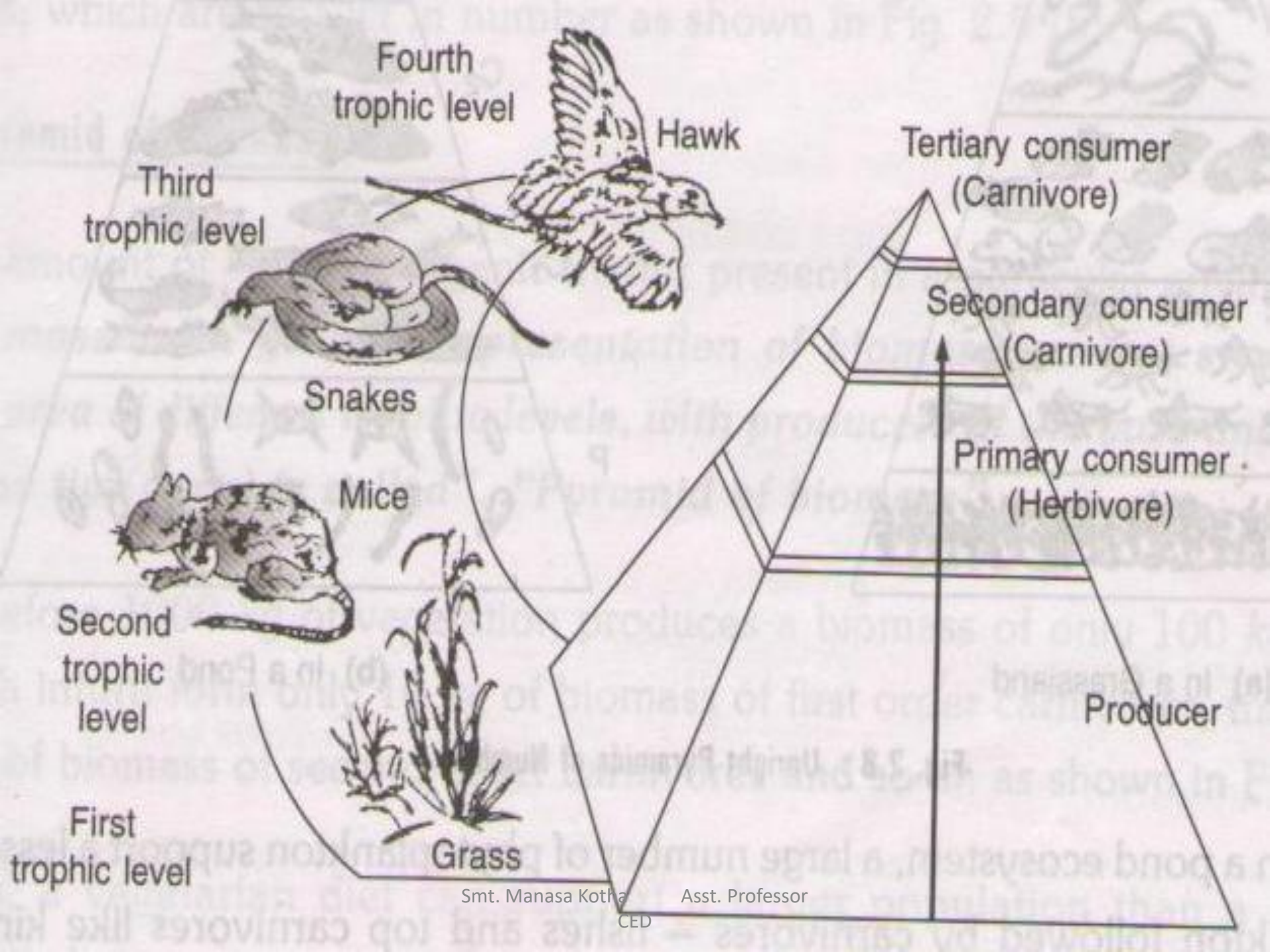
Food Web



ECOLOGICAL PYRAMID

- Ecological pyramids were first studied by a British ecologist CHARLES ELTAN (1927). An Ecological Pyramid is a graphical representation consisting various trophic levels with producers forming the base and top occupy the carnivores.
- In an ecological pyramid the huge number of tiny individuals form at the base and a few large individuals occupy the top / apex . This formation is known as ecological pyramid.

- Hence, all producers (micro & macro plants) belong to the *I trophic level; all primary* consumers belong to *II trophic level and organisms feeding on these consumers* belong to the *III trophic level and so on.*


Fourth
trophic level
Hawk
Third
trophic level
Snakes
Mice
Second
trophic
level
First
trophic level
Grass
Tertiary consumer
(Carnivore)
Secondary consumer
(Carnivore)
Primary consumer
(Herbivore)
Producer

The ecological pyramids are of three types. They are:

1. The pyramid of Numbers (showing population).
2. The pyramid of Biomass (showing total mass of organisms).
3. The pyramid of energy (showing energy flow).

1. The pyramid of Numbers:

- It shows the relationships among the producers, herbivores and carnivores at successive trophic levels in terms of their number.
- Mostly the pyramid of number is straight (or) upright with number of individuals in successive higher trophic levels goes on decreasing from base to apex.

The maximum number of individuals occur at the producers level. They support a small number of herbivores. The herbivores, in turn, support a fewer number of primary carnivores and so on..... Top carnivores are very few in number.

For eg:

(1) In a grass land ecosystem.

Grass → Grasshoppers → Frogs → Snakes → Peacock / Hawk.

(2) In a pond ecosystem:

Phytoplankton → Zooplankton → Fish → Crane

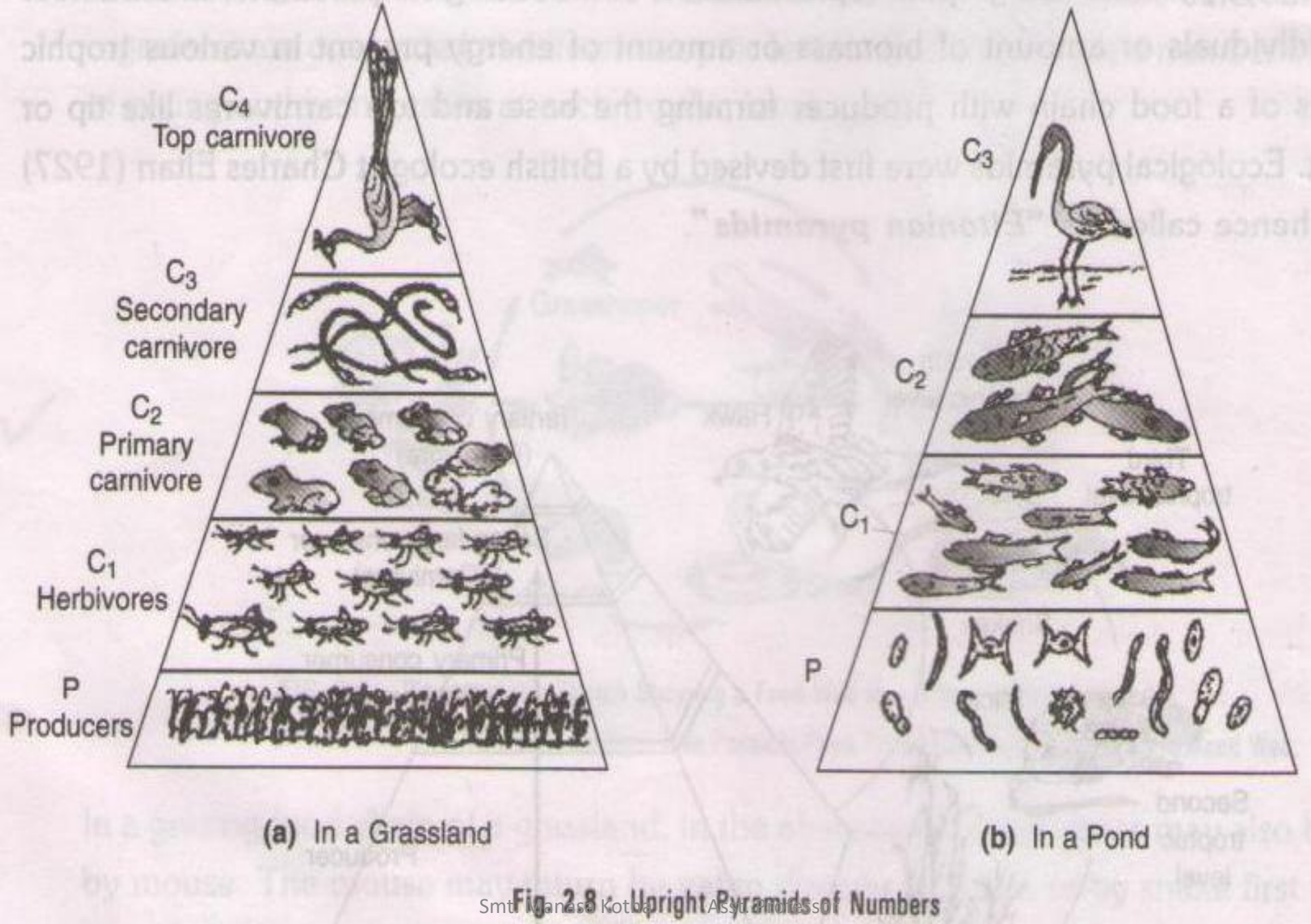


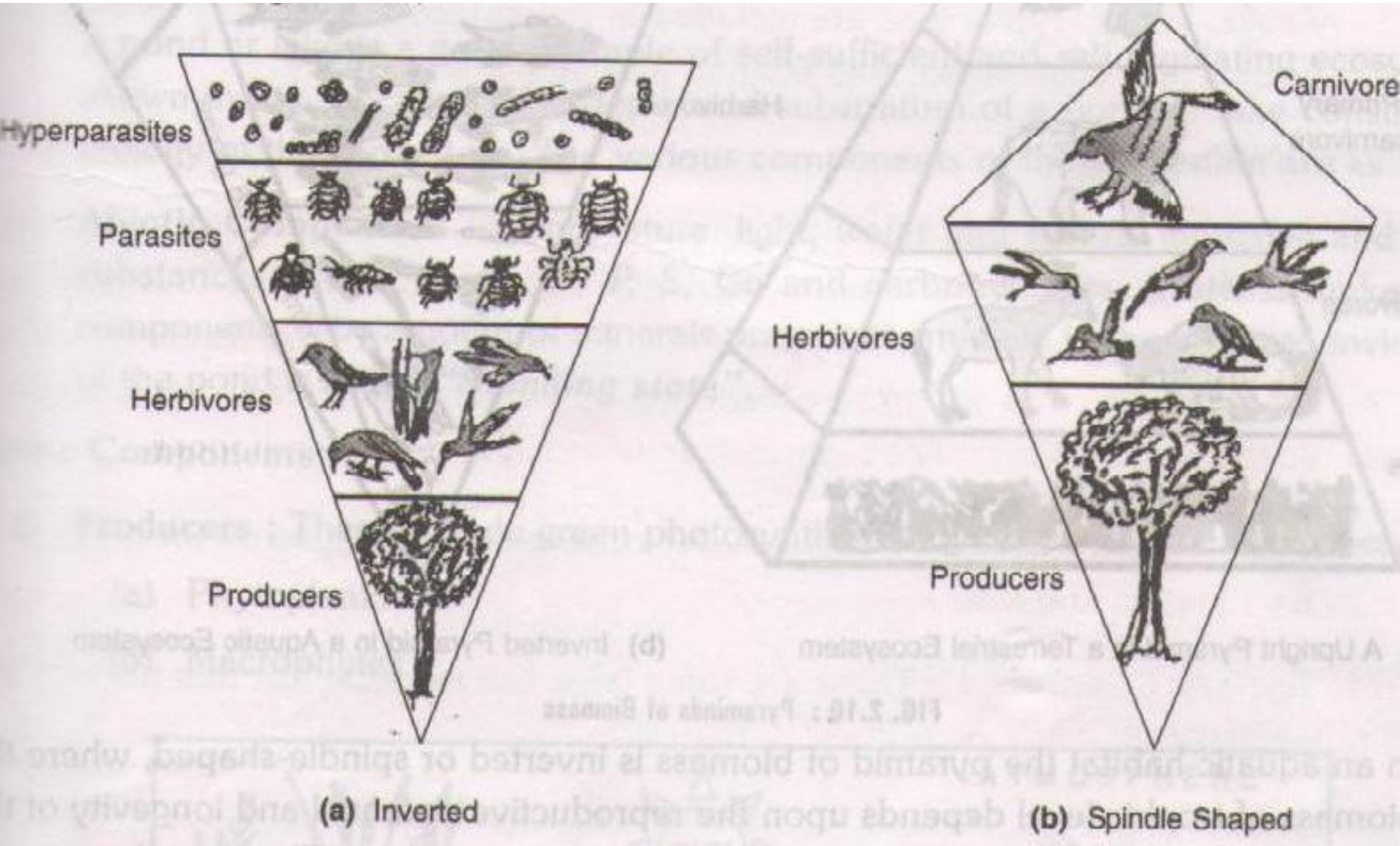
Fig. 2.8 : Upright Pyramids of Numbers

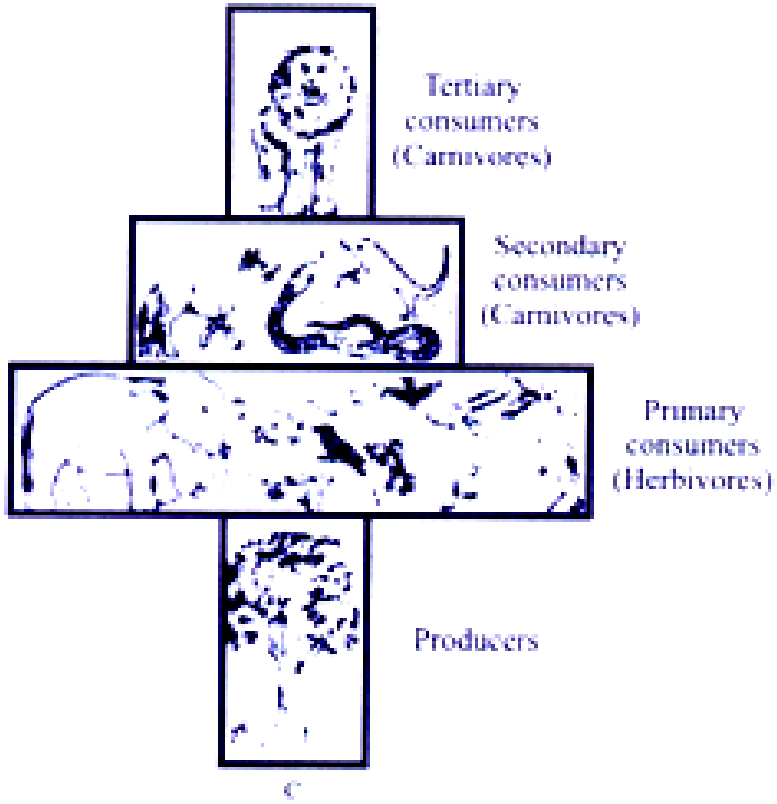
- A single plant may support the growth of many herbivores and each herbivore in turn provide nutrition to several parasites which support many hyper-parasites.
- From the producer towards consumers, there is a reverse position i.e., the number of organisms gradually shows an increase making the pyramid inverted in shape.

For eg: (3) in a Forest ecosystem

Tree → Birds / deer → Parasites → Hyper parasites

Tree → Birds → eagle


Hyperparasites
Parasites
Herbivores
Producers
(a) Inverted
Carnivore
Herbivores
Producers
(b) Spindle Shaped



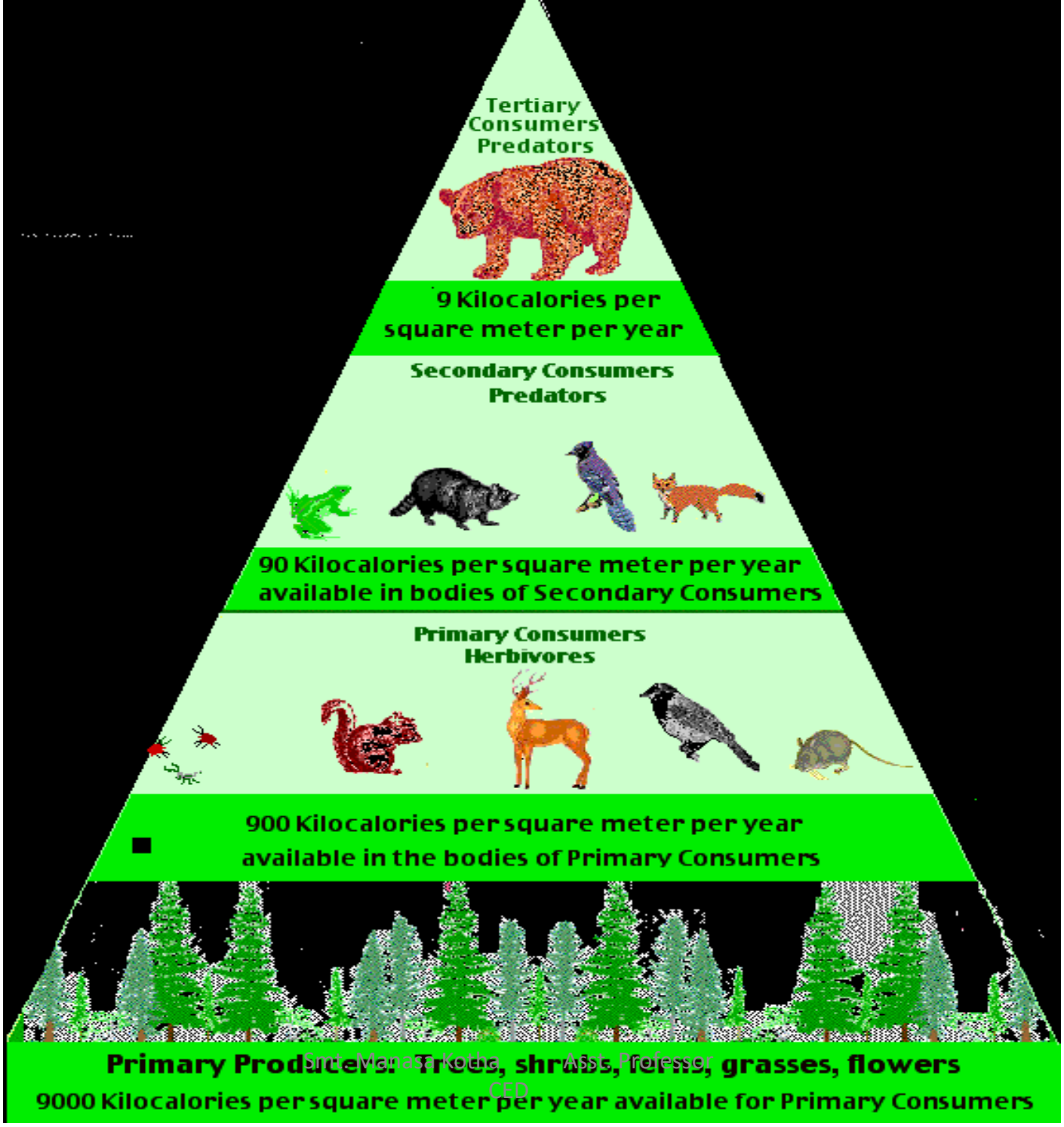
Spindle Shaped

2. The Pyramid of Biomass

- The amount of organic matter present in environment is called **biomass**. In pyramids of biomass, the relationship between different trophic levels is mentioned in terms of **weight** of organisms. The pyramid may be **upright** for grassland ecosystem and **inverted** for pond ecosystem.
- Eg: A vegetation produces a biomass of 1000 kg. Out of this 100 kgs of biomass for herbivores, which in turn only 10 kg of biomass for primary carnivores that gives rise 1 kg of biomass for second order carnivores and so on…

1000 kgs	100 kgs	10 kgs	1 kg
vegetation	herbivores	Primary carnivores	Secondary carnivores

- Hence, a vegetarian diet can support a larger population than a non – vegetation diet.

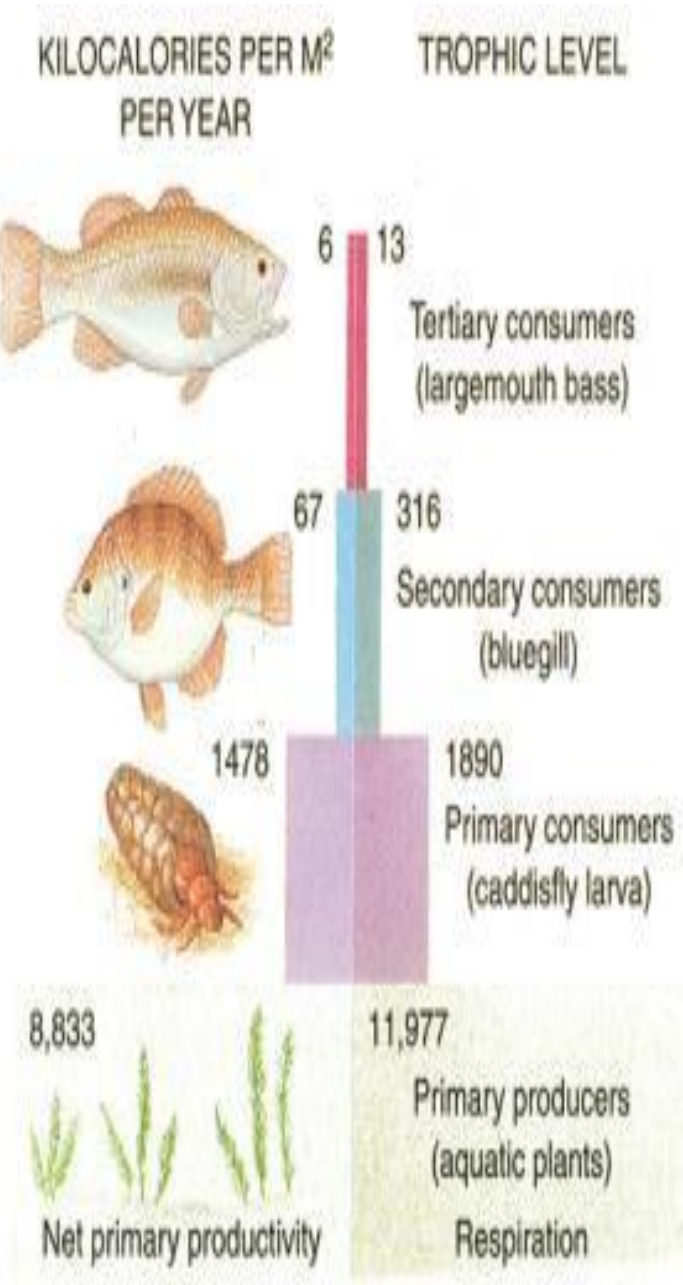

Tertiary
Consumers
Predators
9 Kilocalories per
square meter per year
Secondary Consumers
Predators
90 Kilocalories per square meter per year
available in bodies of Secondary Consumers
Primary Consumers
Herbivores
900 Kilocalories per square meter per year
available in the bodies of Primary Consumers
Primary Producers: Trees, shrubs, ferns, grasses, flowers
9000 Kilocalories per square meter per year available for Primary Consumers

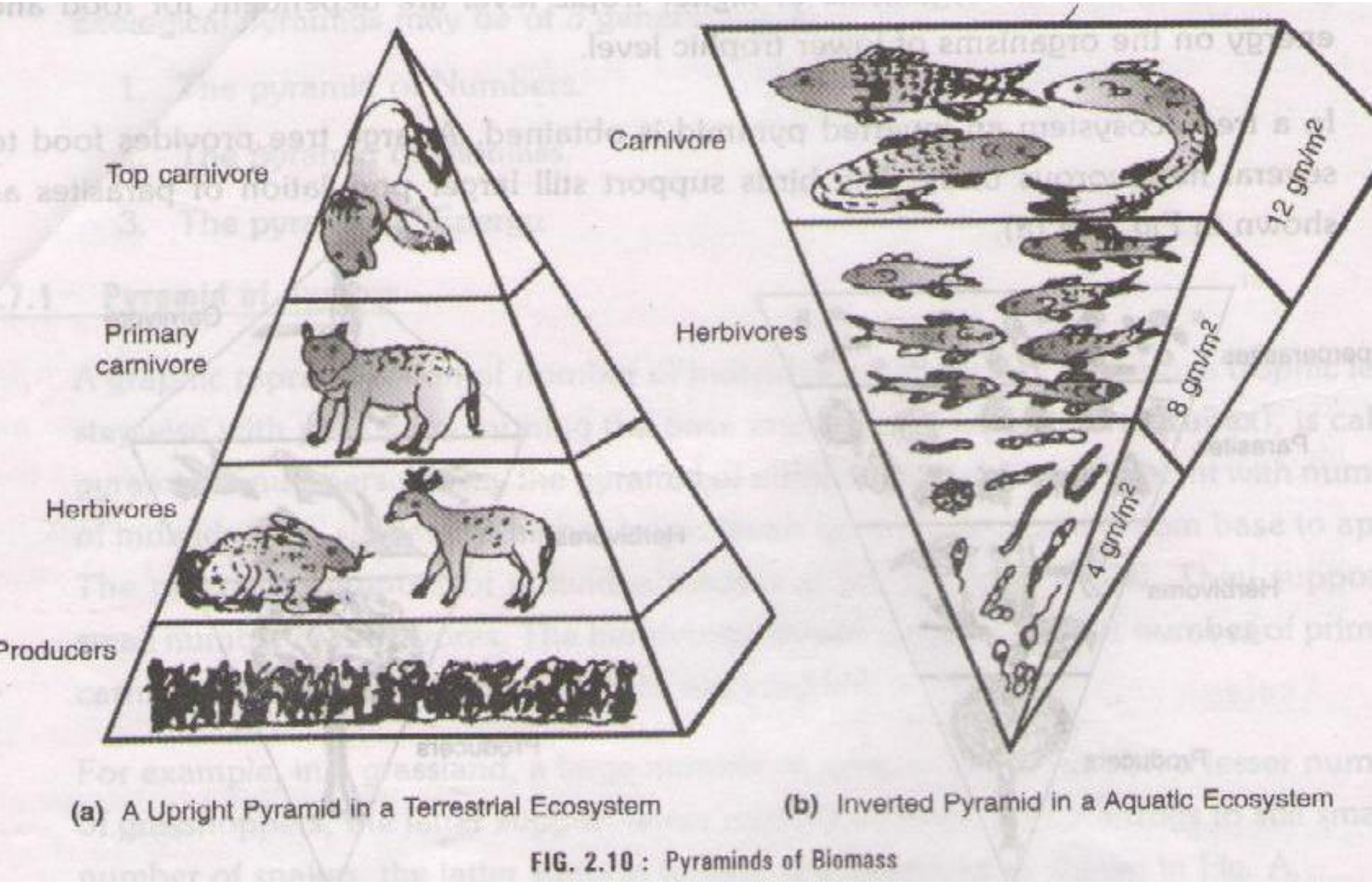
- *An upright pyramid is one where the combined weight of producers is larger than the combined weight of consumers.*

Ex : a forest ecosystem.

- *An inverted pyramid is one where the combined weight of producers is smaller than the combined weight of consumers.*

Ex : an aquatic ecosystem.





(a) A Upright Pyramid in a Terrestrial Ecosystem (b) Inverted Pyramid in a Aquatic Ecosystem

FIG. 2.10 : Pyraminds of Biomass

3. The pyramid of energy: The amount of energy trapped **per unit time and area** at different trophic levels of a food chain with producers forming the base and the top carnivores at the apex is called pyramid of energy.

- The energy content is generally expressed as K cal /m^2 / year **or** KJ /m^2 / year

Large Fish ---126 KJ / m^2 / year

Small Fish ----840 – 126 KJ / m^2 / year

Zooplankton ---- 7980 KJ / m^2 / year

Phytoplankton (producers) --- 31080 KJ / m^2 / year

- Number and weight of organisms at any level depends not on the amount of fixed energy present at any **one time** in the level just below but rather on the rate at which food is being produced.
- The other two pyramids are pictures of the standing situations like organisms present at any moment
- The pyramid of energy is a picture of the rates of passage of food, mass through the food chain.
- Always upright, as in most of the cases there is always a gradual decrease in the energy content at successive trophic levels from the producers to various consumers.

Energy flow /Transformation of energy in Ecosystem

- The movement of energy (or) transfer of energy through a series of organisms in an ecosystem from the external environment and back to the external environment again is known as **energy flow.**

BIO – GEO-CHEMICAL CYCLES:

- In every ecosystem sunlight or solar radiant energy is accepted by producers (green plants) and the energy doesn't recycle through an ecosystem.
- But nutrients like Carbon; Nitrogen; Oxygen, Hydrogen; Water, Sulphur; Phosphorous etc move in circular paths through biotic and abiotic components and they are known as Bio-geochemical cycles.

- They describe the flow of essential elements from the environment through living organisms and back into the environment.
- The biogeochemical cycle is the continuous flow of elements and compounds between organisms and the earth.

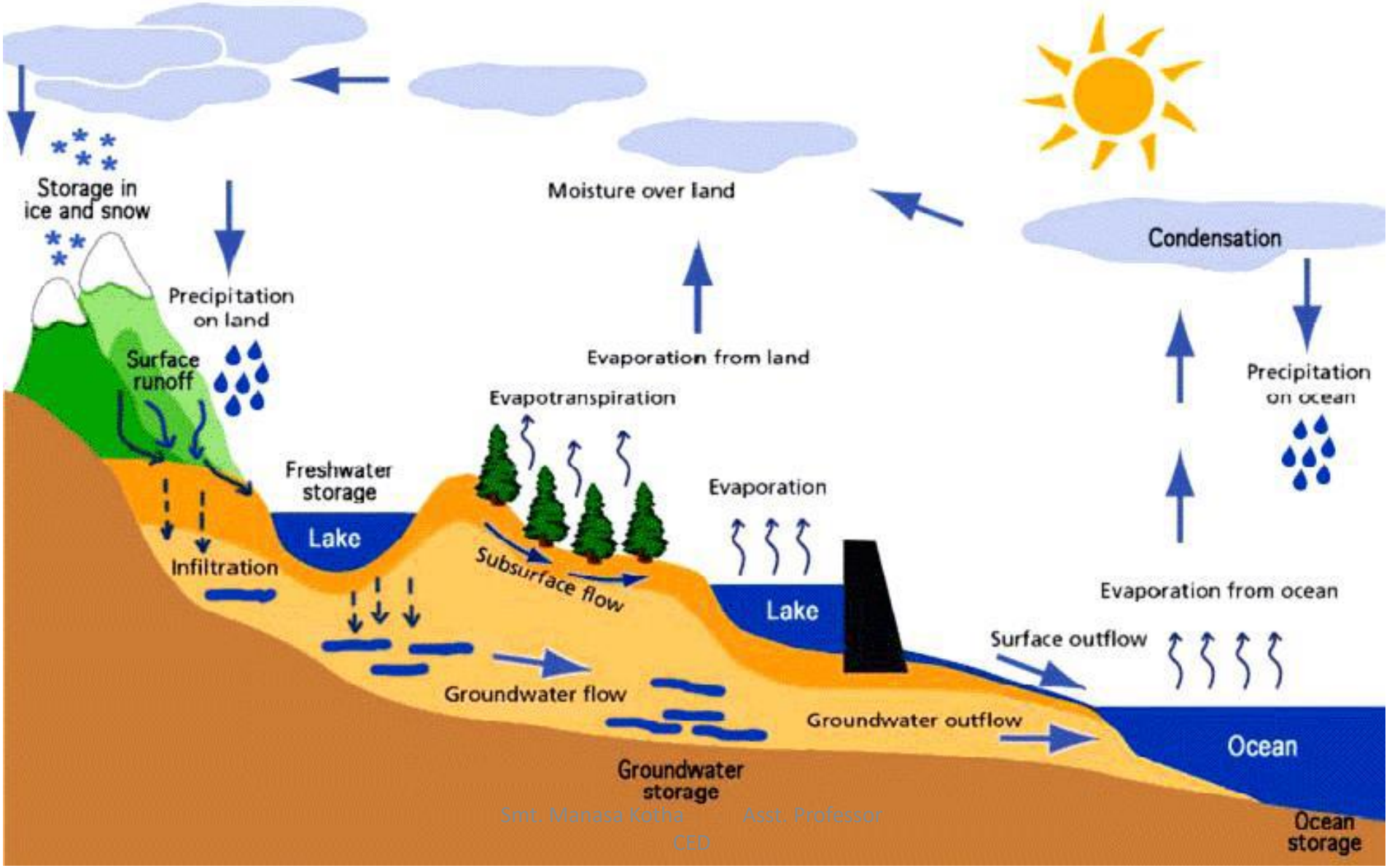
TYPES OF CYCLES:

- **Hydrological cycle:** deal with the interchange of water with organisms and environment
- **Gaseous cycle:** Deal with inter change with gases
- **Sedimentary cycle:** Deals with SO4 and PO4 cycle and concern with the interchange of nutrition and minerals

Elemental Cycles

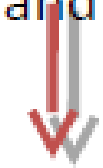
- H, O, and C make up > 99 % of the Earth's biomass
- N, Ca, K, Mg, S, and P are significant nutrients
- Cycling of C, O, N, P, and S are discussed in this chapter

1. THE WATER CYCLE / HYDROLOGIC CYCLE



Steps in Water Cycle

Evaporation and transpiration



Condensation and formation of cloud: Rising air current all the vapour up into the atmosphere → cool → formation of cloud → cloud is made up of droplet of water

Precipitation: Snow or rain fall

Run off and collection of under ground water

Infiltration and percolation

Human Impacts

- Pollution of water
- Reduces the vegetation cover increases the surface ran off decreases the percolation
- Global warming
- Heavy deforestation reduces the transpiration loss of water through plants and trees

2. THE CARBON CYCLE

- All life is based on the element carbon and hence carbon is the main constituent of living organisms.
- Carbon may be present in most organic matter from fossil fuels to the complex molecules (DNA & RNA).
- In fact, the lithosphere is only 0.032% carbon by weight. In comparision, oxygen and silicon make up 45.2% and 29.4% respectively of the earth's surface rocks.
- It is found in caves ands mines and also evolves from volcanoes

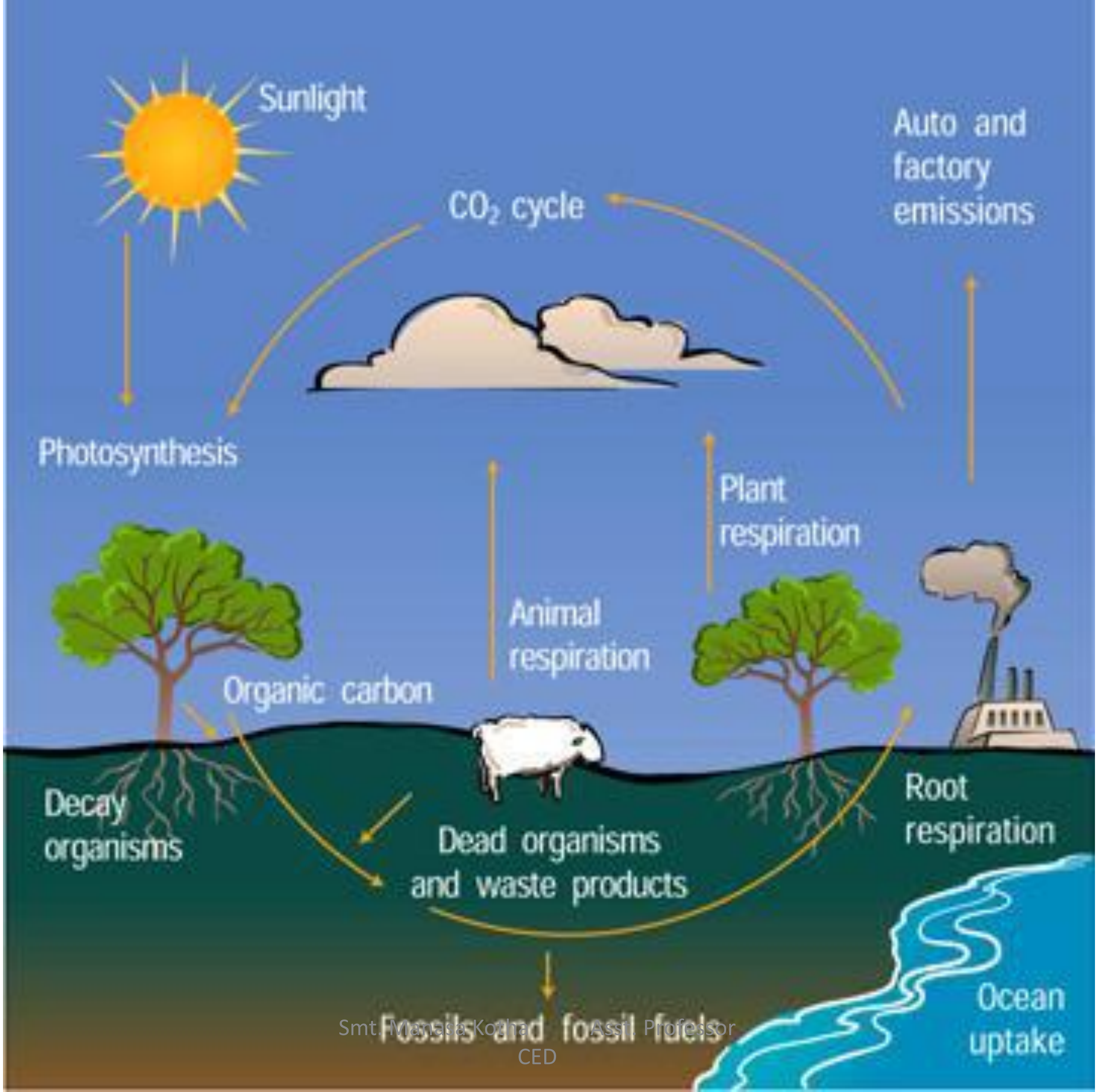
Reservoirs of Carbon

- Carbon is found in all four spheres
- Biosphere - organic matter
- Atmosphere - CO_2, CH_4
- Hydrosphere - H_2CO_3 , HCO_3^- , CO_3^{-2}
- Lithosphere - $CaCO_3$, coal, oil, and gas
- Processes: photosynthesis, formation of sediments, weathering, combustion, plate tectonics
- Decay of organic material

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.

Human Interference

- Human-induced processes
- Extraction and combustion of fossil fuels (speeds up the medium-term cycling)
- Cement manufacturing
- Deforestation (biomass burning)
- All of these processes release CO_2 into the atmosphere and affect the natural cycling of carbon


Sunlight
Auto and factory emissions
CO_2 cycle
Photosynthesis
Plant respiration
Animal respiration
Organic carbon
Decay organisms
Dead organisms and waste products
Root respiration
Fossils and fossil fuels
Ocean uptake

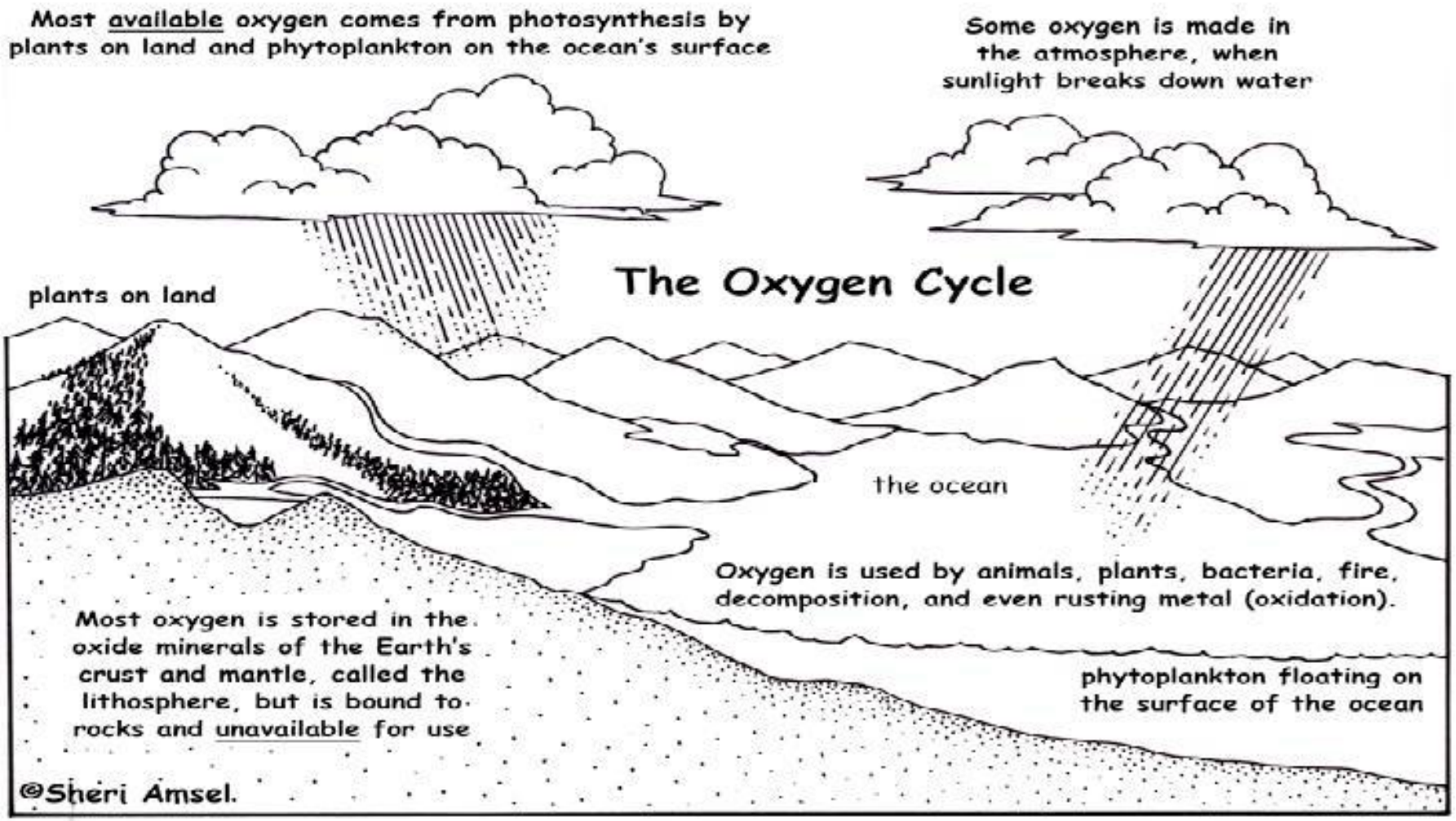
3. THE OXYGEN CYCLE

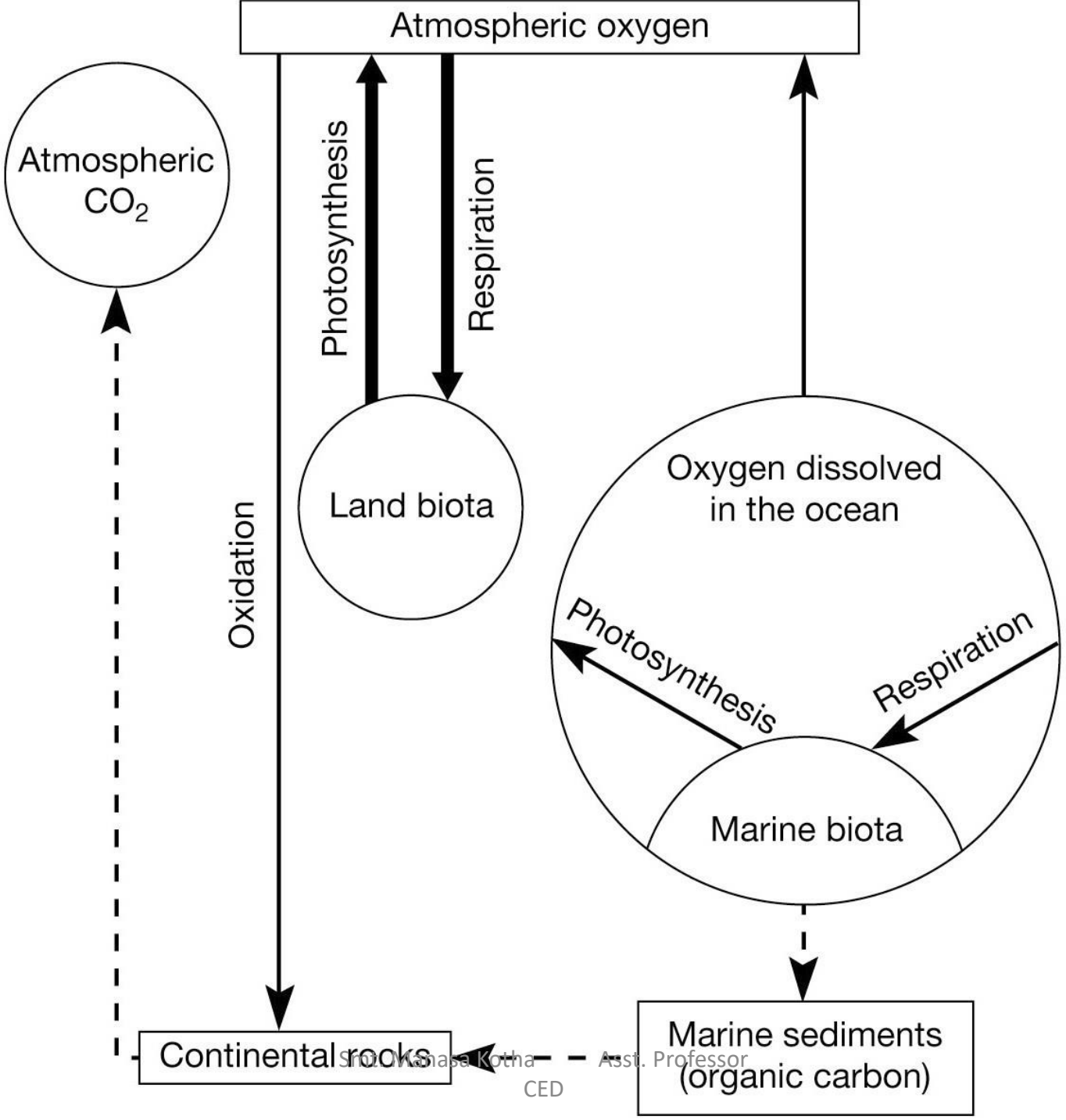
- Oxygen is present in CO_2 and H_2O. Oxygen is released into the atmosphere by plants during photosynthesis and taken up both autotrophs and Heterotrophs during respiration.
- All the oxygen in the atmosphere is biogenic ie., it was released from water through the process of photosynthesis.
- Because of the vast amounts of oxygen in the atmosphere, even if all photosynthesis cease it would take 5000 million years to strip out more or less all oxygen.

- Essential for aerobic life
- Closely linked to carbon cycle
- Very large reservoir (21% of gas in atm.), not susceptible to human interference
- Also, not a greenhouse gas
- Reservoirs: atmosphere, surface organic material (biosphere), and buried organic matter (lithosphere)

Processes

- Photosynthesis/ respiration: short-term cycle; balanced on land; excess O_2 in ocean - phytoplanktons
- Mineral oxidation, weathering, burial - removes O_2 from atmosphere
- Combustion or weathering of organic matter - removes O_2 from atmosphere
- Atmosphere => marine biota => sediments => rocks => atmosphere


Most available oxygen comes from photosynthesis by plants on land and phytoplankton on the ocean's surface
Some oxygen is made in the atmosphere, when sunlight breaks down water
The Oxygen Cycle
plants on land
the ocean
Oxygen is used by animals, plants, bacteria, fire, decomposition, and even rusting metal (oxidation).
Most oxygen is stored in the oxide minerals of the Earth's crust and mantle, called the lithosphere, but is bound to rocks and unavailable for use
phytoplankton floating on the surface of the ocean
©Sheri Amsel.


Atmospheric oxygen
Atmospheric CO_2
Photosynthesis
Respiration
Oxidation
Land biota
Oxygen dissolved in the ocean
Photosynthesis
Respiration
Marine biota
Continental rocks
Marine sediments (organic carbon)

4. THE NITROGEN CYCLE

- Nitrogen is used by living organisms to produce a number of complex organic molecules like Amino acids; Proteins ; Nucleic acids ; Enzymes; Chlorophyll etc..
- The largest reservoir of nitrogen is the atmosphere where it exists as a gas mainly N_2. But atmospheric nitrogen is not utilized directly.

- Nitrogen is an essential constituent of animals and plants.
- Green plant combined with Nitrogen and carbohydrates to make proteins and Nucleic acid.
- Not directly used most form of life .
- Taken by Process called nitrogen fixation.
- 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**
- **Ammonification**
- **Nitrification and Denitrification**

Nitrogen Fixation

- Conversion of free nitrogen into biologically acceptable form is referred to as Nitrogen Fixation.
- **N_2 to NH_4** by nitrogen-fixing bacteria (prokaryotes in the soil and root nodules), N_2 to NO_3 by lightning and UV radiation.

1. Biological : Nitrogen fixing bacteria
2. Industrial fixation: fertilizer
3. Electrification ($N_2 + O_2 \rightarrow$ Nitrogen Oxide)

Amonification: Amino acid and urea → Ammonia

Nitrification

1. Nitrogen fixation :

Combination of Nitrogen with other element

2. Ammonification

Organic Nitrogen → NH_3

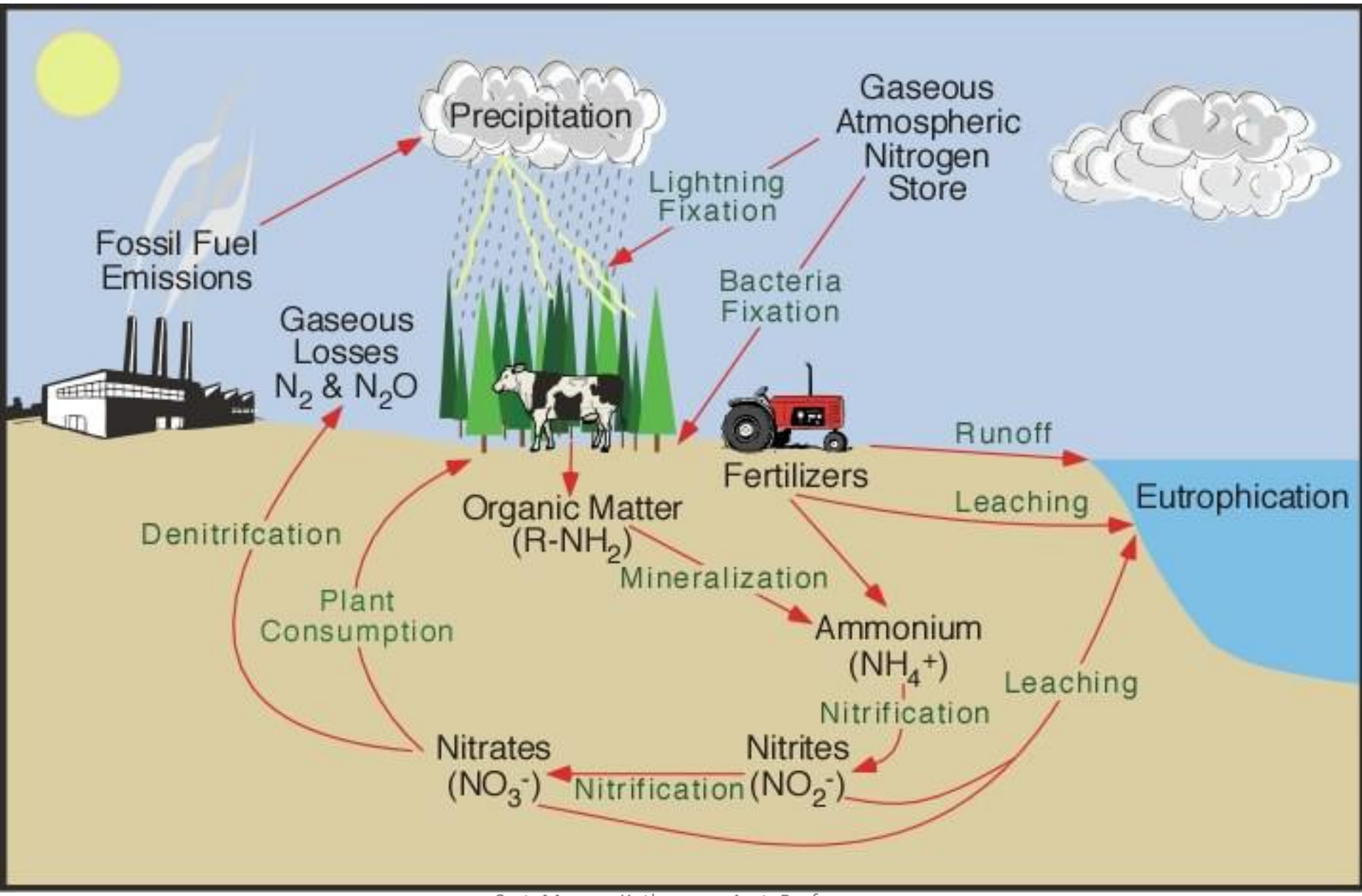
3. Nitrification and denitrification

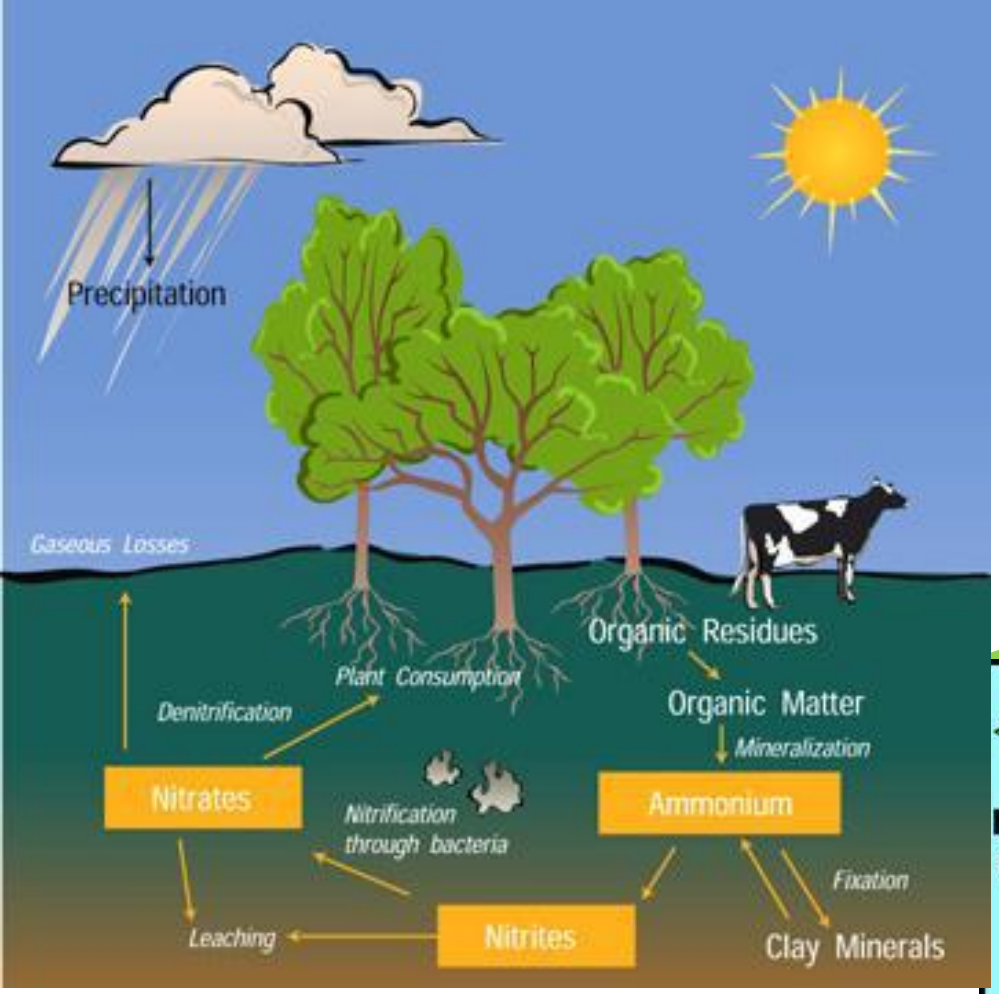
Ammonia(NH_3)- Nitrite forming bacteria (Nitromonas) → Nitrite(NO_2)

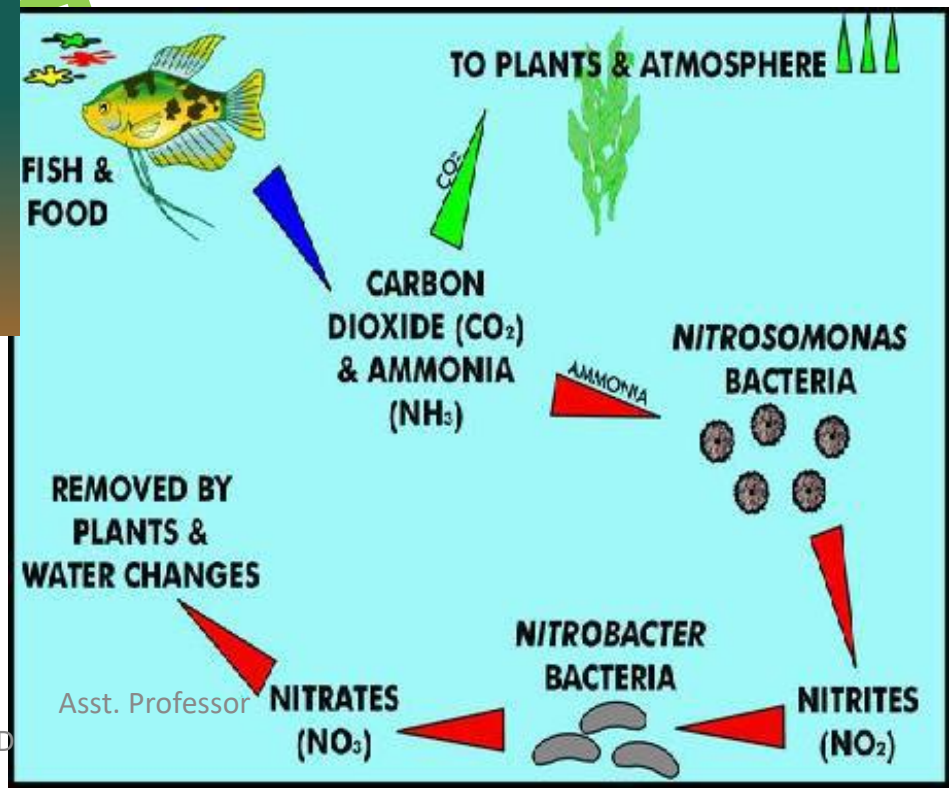
Nitrite(NO_2)-Nitrobacter → Nitrate

Nitrate(NO3)-Denitrification (Pseudomonas)→ Nitrogen

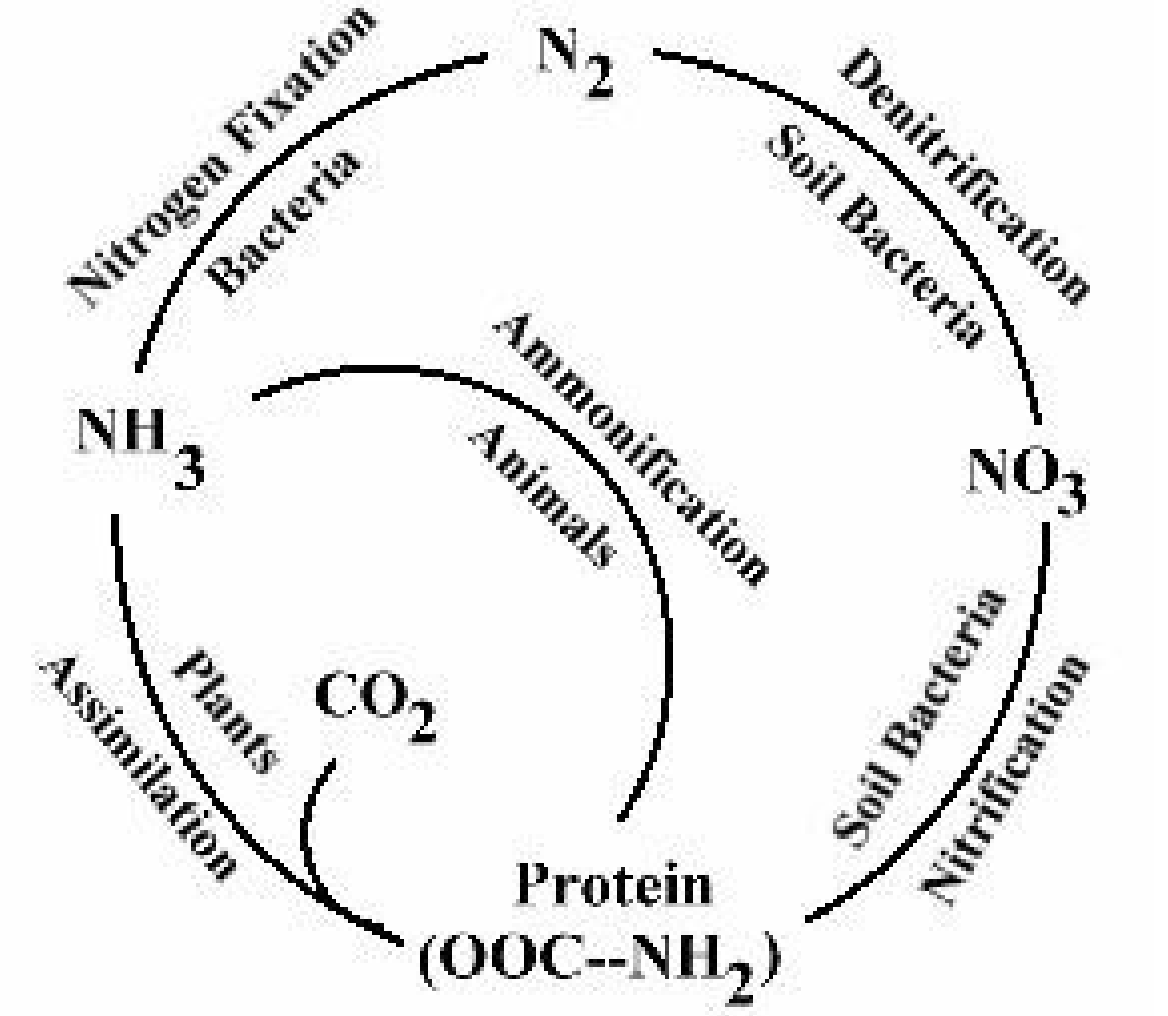
- Denitrifying bacteria convert $(N0_3)^-$ back to N_2 (denitrification); detrivorous bacteria convert organic compounds back to NH_4 (ammonification); animals excrete NH_4 (or NH_3) urea, or uric acid.


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


Precipitation
Gaseous Losses
Organic Residues
Plant Consumption
Denitrification
Organic Matter
Mineralization
Nitrates
Nitrification through bacteria
Ammonium
Fixation
Leaching
Nitrites
Clay Minerals


TO PLANTS & ATMOSPHERE
FISH & FOOD
CO2
CARBON DIOXIDE (CO_2) & AMMONIA (NH_3)
AMMONIA
NITROSOMONAS BACTERIA
REMOVED BY PLANTS & WATER CHANGES
NITROBACTER BACTERIA
NITRATES (NO_3)
NITRITES (NO_2)

Nitrogen Cycle



Human Impact

- Harvesting of timber (increases pH)
- Automobile and industrial exhaust (NO_x)
- Acid rain is caused by emissions of sulfur dioxide and nitrogen oxide, which react with the water molecules in the atmosphere to produce acids.

  $NO_2 + OH^- \rightarrow HNO_3$
- Eutrophication : excessive richness of nutrients in a lake or other body of water, frequently due to run-off from the land, which causes a dense growth of plant life.