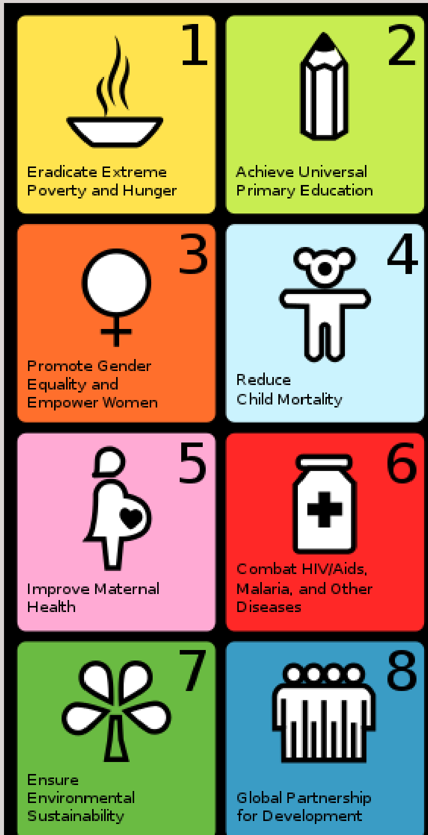
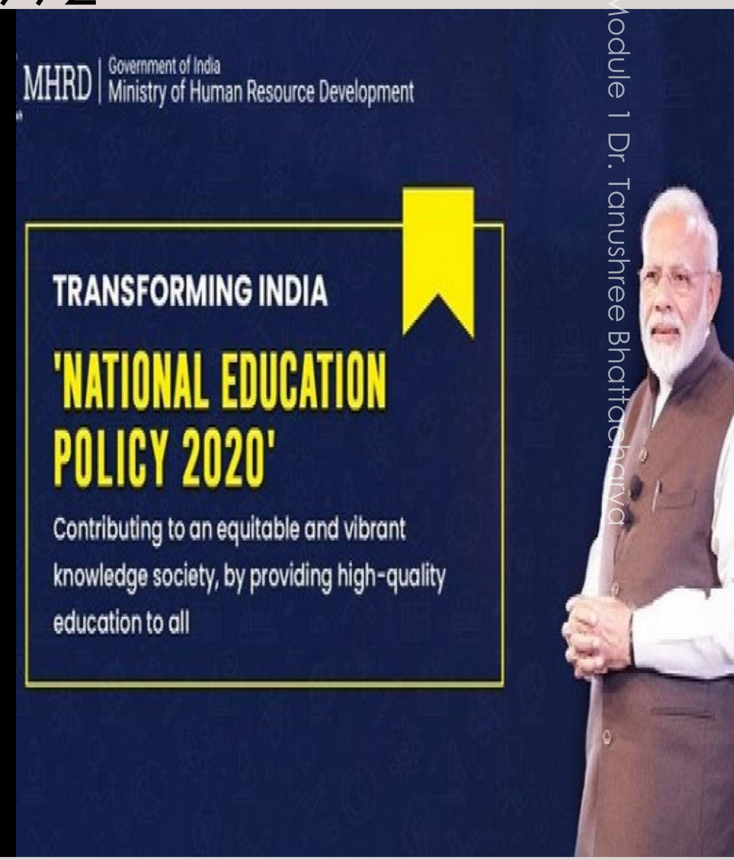
CE 101: ENVIRONMENTAL SCIENCE
MODULE 1

QUERIES

- NEED OF CE 101?
- Stockholm conference 1972
- Earth Summit 1992





Indian constitution

On a world scale environmental awareness often finds expression at the Conferences of Human Environment organised by the United Nations Environment Programmes. India is an active member and also an original signatory to the protocall adopted at the UN conference held at Stockholm in the year 1972. The concern of India toward environment is also reflected in articles 48A and 51A of the Constitution which read as follows:

Article 48A

The State shall endeavour to protect and improve the environment and to safeguard the forest and wild life of the country.

Article 51

It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers, and wild life, and to have compassion for living creatures.

COURSE INFORMATION SHEET

Course code: CE101
Course title: ENVIRONMENTAL SCIENCE
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: L:2 T:0 P:0
Class schedule per week: 02
Class: B.Tech
Semester / Level: 03/01
Branch: All
Name of Teacher:

Course Objectives
This course enables the students:

1	To develop basic knowledge of ecological principles and their applications in environment. (K_1,K_2)
2	To identify the structure and composition of the spheres of the earth, the only planet sustaining life. (K_1,K_2)
3	To analyse, how the environment is getting contaminated and probable control mechanisms for them. (K_1,K_2)
4	To generate awareness and become a sensitive citizen towards the changing environment. (K_1,K_2)

Course Outcomes
After the completion of this course, students will be:

1	Able to explain the structure and function of ecosystems and their importance in the holistic environment. (K_1,K_2)
2	Able to identify the sources, causes, impacts and control of air pollution. (K_1,K_2)
3	Able to distinguish the various types of water pollution happening in the environment and understand about their effects and potential control mechanisms. (K_1,K_2)
4	Able to judge the importance of soil, causes of contamination and need of solid waste management. (K_1,K_2)
5	Able to predict the sources of radiation hazards and pros and cons of noise pollution. (K_1,K_2)

Module 1. Ecosystem and Environment

Concepts of Ecology and Environmental science, ecosystem: structure, function and services, Biogeochemical cycles, energy and nutrient flow, ecosystem management, fate of environmental pollutants, environmental status and reports on climate change.

Module 2: Air Pollution

Structure and composition of unpolluted atmosphere, classification of air pollution sources, types of air pollutants, effects of air pollution, monitoring of air pollution, control methods and equipment for air pollution control, vehicular emissions and control, indoor air pollution, air pollution episodes and case studies.

Module 3: Water Pollution

Water Resource; Water Pollution: types and Sources of Pollutants; effects of water pollution; Water quality monitoring, various water quality indices, water and waste water treatment: primary, secondary and tertiary treatment, advanced treatments (nitrate and phosphate removal); Sludge treatment and disposal.

Module 4: Soil Pollution and Solid Waste Management

Lithosphere – composition, soil properties, soil pollution, ecological & health effects, Municipal solid waste management – classification of solid wastes, MSW characteristics, collection, storage, transport and disposal methods, sanitary landfills, technologies for processing of MSW: incineration, composing, pyrolysis.

Module 5: Noise pollution & Radioactive pollution

Noise pollution: introduction, sources: Point, line and area sources; outdoor and indoor noise propagation, Effects of noise on health, criteria noise standards and limit values, Noise measurement techniques and analysis, prevention of noise pollution; Radioactive pollution: introduction, sources, classification, health and safety aspects, Hazards associated with nuclear reactors and disposal of spent fuel rods-safe guards from exposure to radiations, international regulation, Management of radioactive wastes.

- Text books:
- 1. **A, K. De. (3rd Ed). 2008. Environmental Chemistry. New Age Publications India Ltd.**
- 2. R. Rajagopalan. 2016. Environmental Studies: From Crisis to Future by, 3rd edition, Oxford University Press.
- 3. Eugene P. Odum. 1971. Fundamentals of Ecology (3rd ed.) -. WB Sunders Company, Philadelphia.
- 4. C. N. Sawyer, P. L. McCarty and G. F. Parkin. 2002. Chemistry for Environmental Engineering and Science. John Henry Press.
- **5. S.C. Santra. 2011. Environmental Science. New Central Book Agency**.
- Reference books:
- 1. D.W. Conell. Basic Concepts of Environmental Chemistry, CRC Press.
- 2. **Peavy, H.S, Rowe, D.R, Tchobanoglous, G. Environmental Engineering, Mc-Graw - Hill International**
- 3. G.M. Masters & Wendell Ela. 1991. Introduction to Environmental Engineering and Science, PHI Publishers.

Assessment Methods:

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Sem Examination Marks	25
End Sem Examination Marks	50
Quiz (s) (1 & 2)	10+10
Teacher's assessment	5

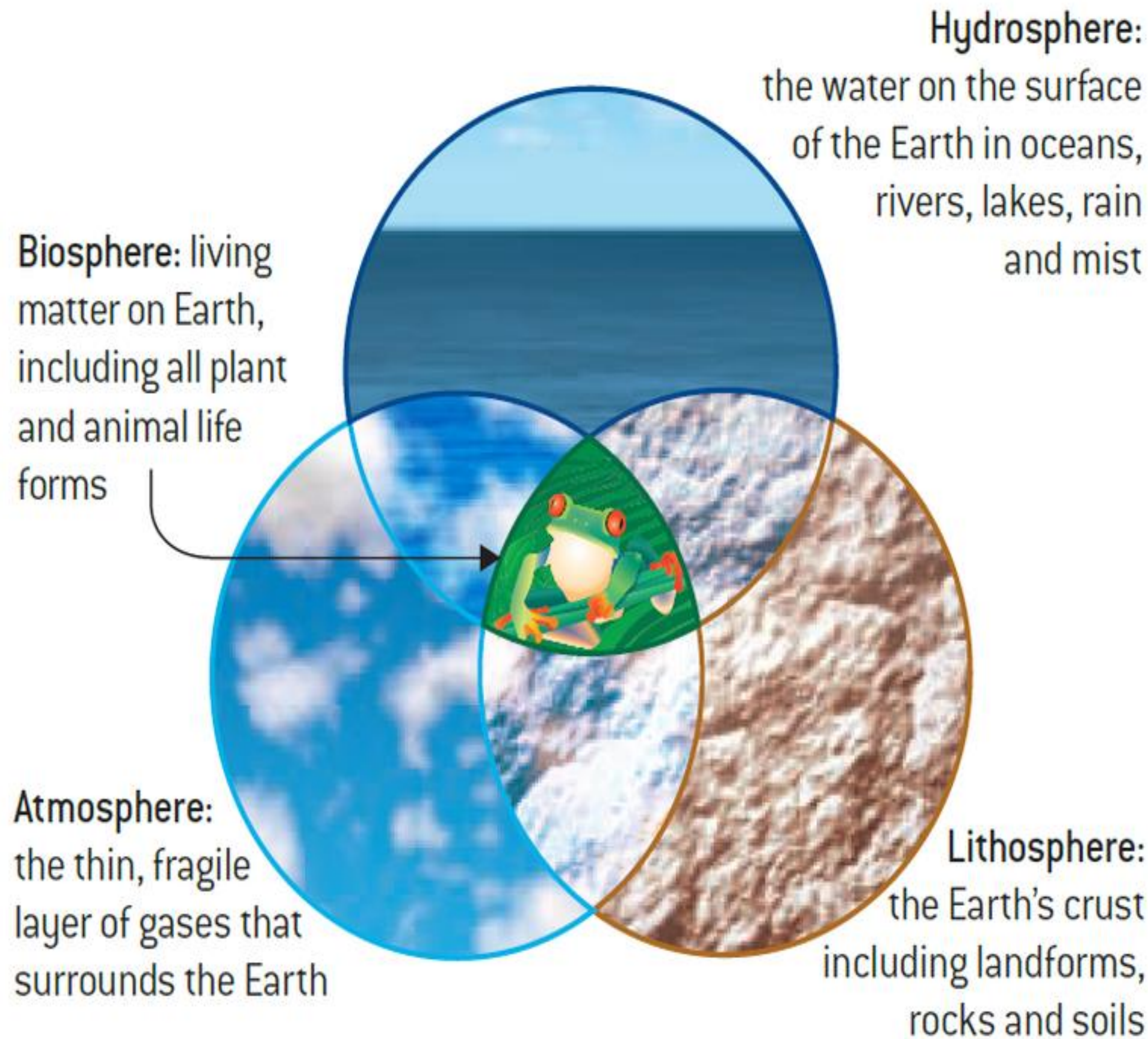
Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid sem exam	✓	✓	✓		
End Sem Examination Marks	✓	✓	✓	✓	✓
Quiz 1	✓	✓			
Quiz 2			✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Module 1. Ecosystem and Environment

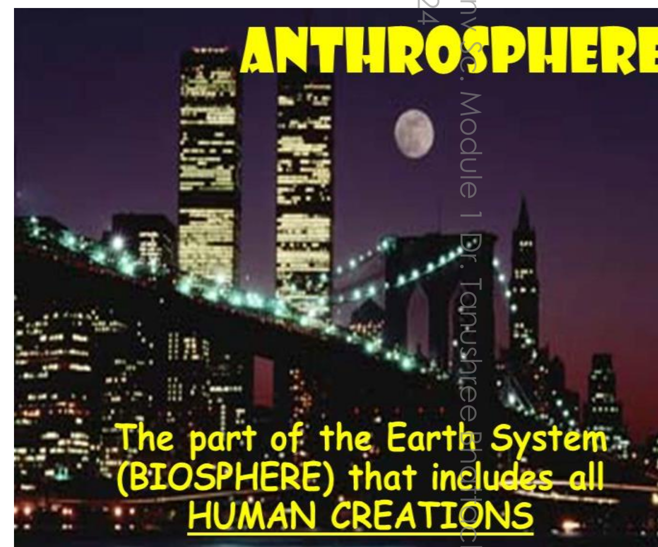
Concepts of Ecology and Environmental science, ecosystem: structure, function and services, Biogeochemical cycles, energy and nutrient flow, ecosystem management, fate of environmental pollutants, environmental status and reports on climate change.

Ecology

- **Ecology**- The study of the relationships between different species in a given area.
- **Environment-** The surroundings or conditions in which a person, animal, or plant lives or operates.
- Any external force, substance, or condition that affects organisms in a way, is known as factor. The sum of all such factors constitute the environment.



The physical elements of the Earth

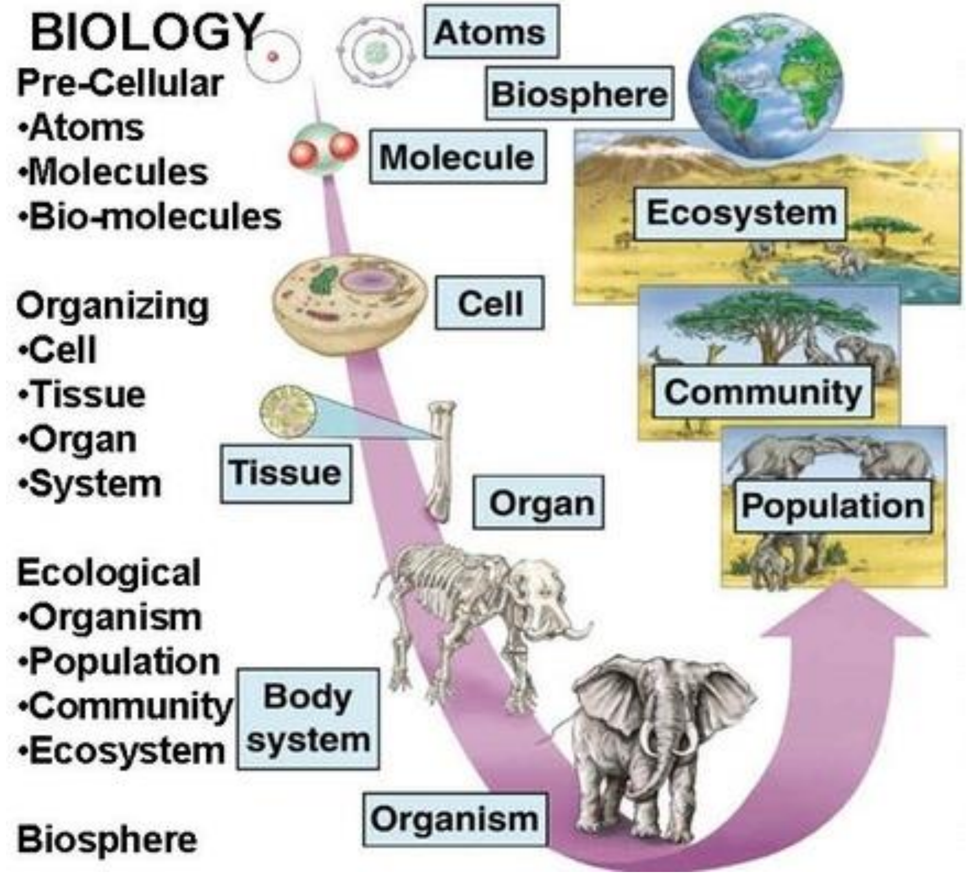


Level of Organization

- Species- a group of organisms which can interbreed and produce fertile offspring
- Population- Groups of individuals of a certain species living in a certain area
- Community- Different populations that live in the same area.
- Ecosystem- Collection of both the community and the abiotic factors in a certain area or Ecosystem: An ecosystem is the whole biotic community in a given area and its abiotic environment.
- Biome- Group of ecosystems that have the same climatic conditions

- Biosphere: The Earth's living organisms interacting with their physical environment may be considered as a vast ecosystem, which is the largest, self sufficient biological system we know, and this is termed as biosphere.

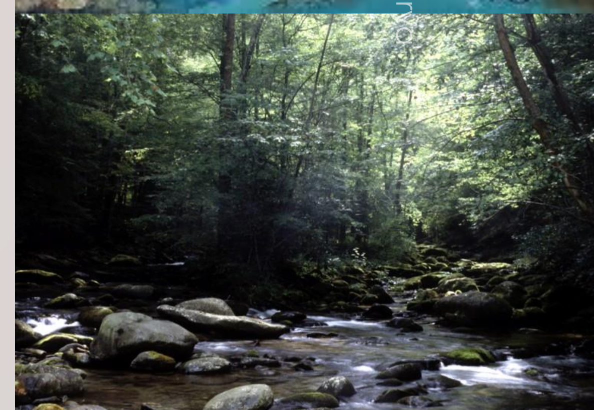
Level of Organization



Individual

Population

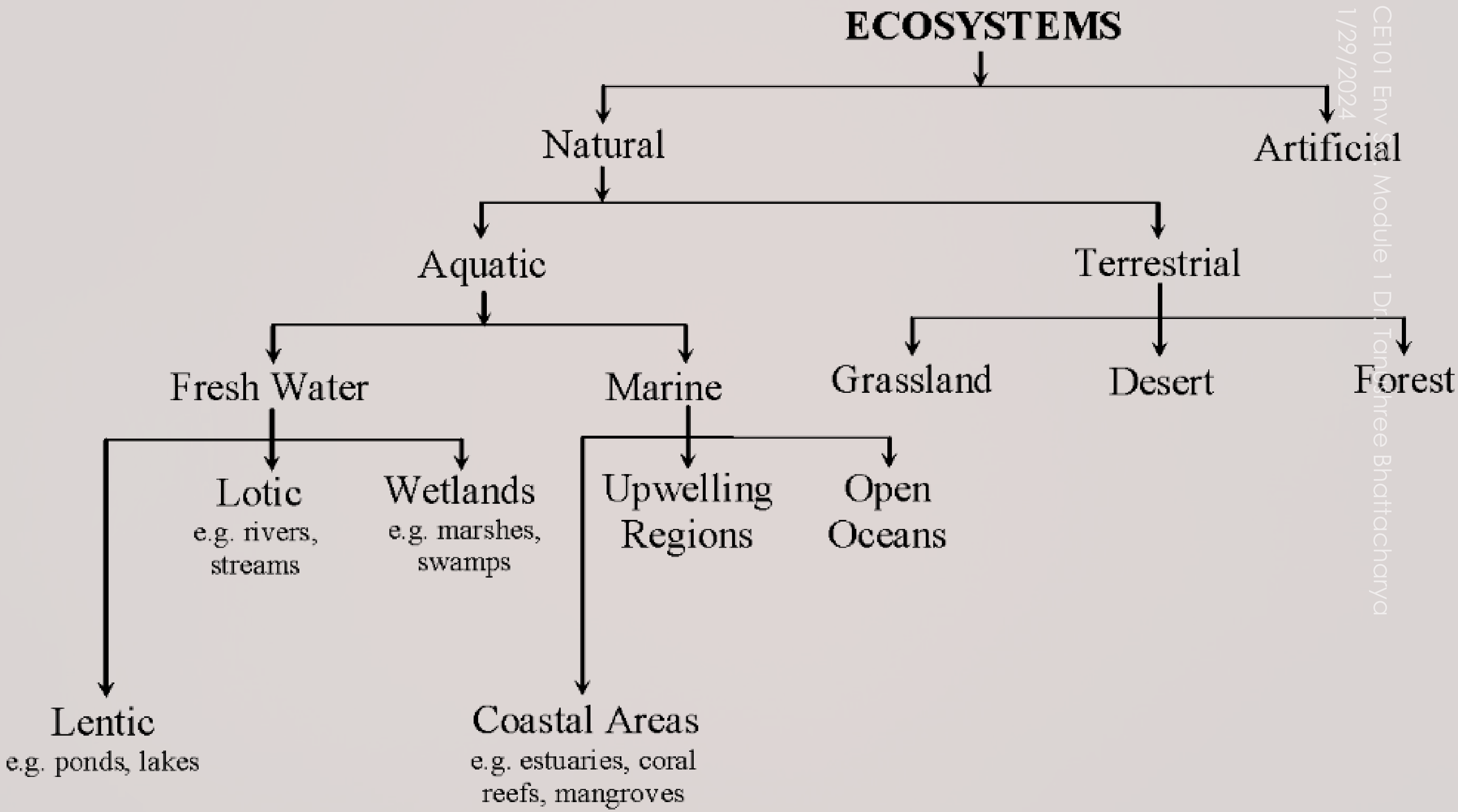
Ecosystem



Community

Biomes

Types of ecosystem



Types of Ecosystem with Examples

I: Natural: Terrestrial

Grassland

Forest

Desert

www.plantscience4u.com

Natural: Aquatic

a) Marine: Oceans

b) Freshwater: Lakes

II: Artificial or Manmade

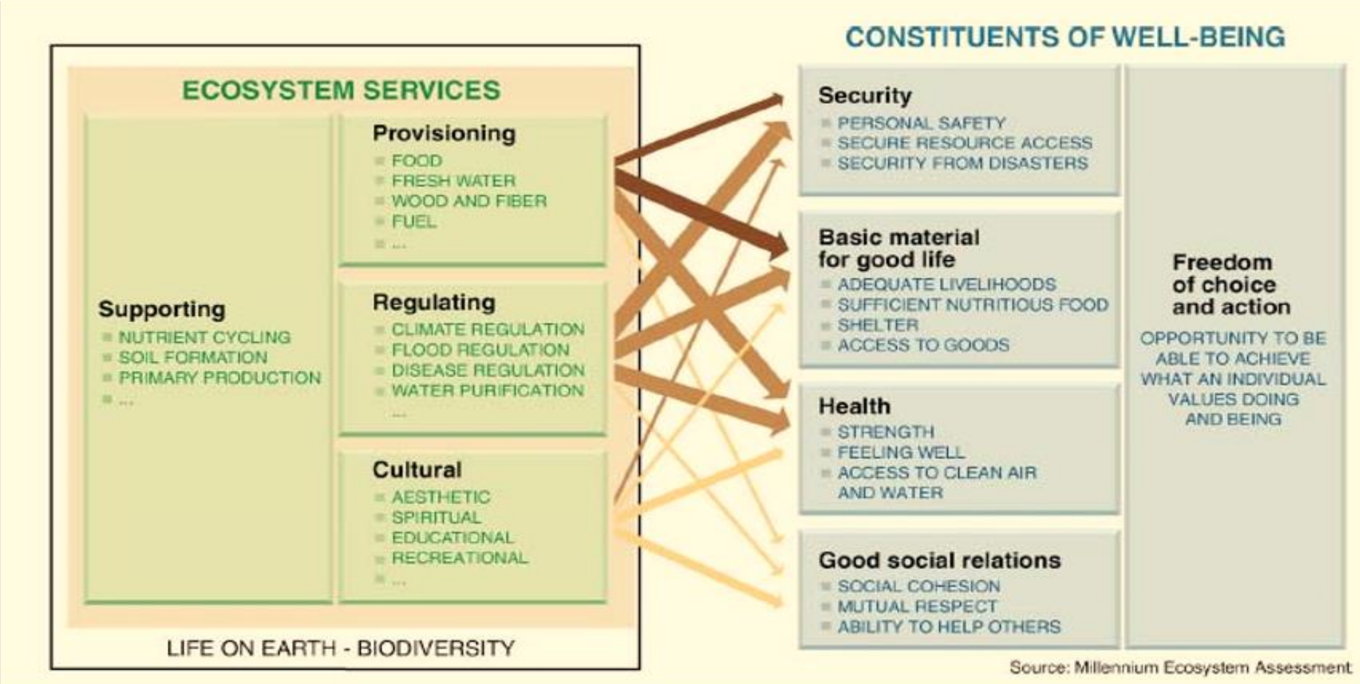
Aquarium

Crop field

Ecosystem Services

- **Ecosystem services** is the capacity of natural processes and components to provide goods and services that satisfy **human needs, either directly or indirectly**
- Ecosystem services are subset of ecological processes and ecosystem structures
- Each service is the result of the natural processes of the total ecological sub-system of which it is a part
- Natural processes, in turn, are the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) components of ecosystems through the universal driving forces of matter and energy

Ecosystem services



- **Provisioning services**, or the supply of goods of direct benefit to people, and often with a clear monetary value, such as timber from forests, medicinal plants, and fish from the oceans, rivers and lakes.
- **Regulating services**, the range of functions carried out by ecosystems which are often of great value but generally not given a monetary value in conventional markets. They include regulation of climate through the storing of carbon and control of local rainfall, the removal of pollutants by filtering the air and water, and protection from disasters such as landslides and coastal storms.
- **Cultural services**, not providing direct material benefits, but contributing to wider needs and desires of society, and therefore to people's willingness to pay for conservation. They include the spiritual value attached to particular ecosystems such as sacred groves, and the aesthetic beauty of landscapes or coastal formations that attract tourists
- **Supporting services**, not of direct benefit to people but essential to the functioning of ecosystems and therefore indirectly responsible for all other services. Examples are the formation of soils and the processes of plant growth.

1. **Provisioning services** (Food, water and other resources)

Food

- Ecosystems provide the conditions for growing food
- Food comes principally from managed agro-ecosystems but marine and freshwater systems or forests also provide food for human consumption
- Wild foods from forests are often underestimated

Raw Materials

- Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species

Fresh water

- Ecosystems play a vital role in the global hydrological cycle, as they regulate the flow and purification of water
- Vegetation and forests influence the quantity of water available locally

Medicinal resources

- Ecosystems and biodiversity provide many plants used as traditional medicines as well as providing the raw materials for the pharmaceutical industry
- All ecosystems are a potential source of medicinal resources

2. **Regulating services** (regulating the quality of air and soil or by providing flood and disease control)

- **Air quality regulation:** Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality
- **Climate regulation**:
  - Ecosystems influence climate both locally and globally
  - For e.g., at a local scale, changes in *land cover* can affect both temperature and precipitation
  - At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases
- **Water regulation:** Timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in **land cover**, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas
- **Erosion regulation:** Vegetative cover plays an important role in soil retention and the prevention of landslides

- **Water purification and waste treatment:** Ecosystems can be a source of impurities (e.g., in fresh water) but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and assimilate and detoxify compounds through soil and sub-soil processes
- **Disease regulation:** Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes
- **Pest regulation:** Ecosystem changes affect the prevalence of crop and livestock pests and diseases
- **Pollination:** Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators
- **Natural hazard regulation:** The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves

3. **Supporting services**

- Supporting services are those that are necessary for the production of all other ecosystem services
- They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people
- Some services, like erosion regulation, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people

- **Soil Formation**: Many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways
- **Photosynthesis:** Photosynthesis produces oxygen necessary for most living organisms
- **Primary Production:** The assimilation or accumulation of energy and nutrients by organisms
- **Nutrient cycling:** Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems
- **Water cycling:** Water cycles through ecosystems and is essential for living organisms

4. **Cultural Services**

(These are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences)

- **Cultural diversity:** The diversity of ecosystems is one factor influencing the diversity of cultures
- **Spiritual and religious values:** Many religions attach spiritual and religious values to ecosystems or their components
- **Knowledge systems (traditional and formal):** Ecosystems influence the types of knowledge systems developed by different cultures
- **Educational values:** Ecosystems and their components and processes provide the basis for both formal and informal education in many societies
- Inspiration: Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising

Cultural Services …..

- **Aesthetic values:** Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations
- **Social relations:** Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for e.g., differ in many respects in their social relations from nomadic herding or agricultural societies
- **Sense of place**: Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem
- **Cultural heritage values:** Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species
- **Recreation and ecotourism:** People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area

Fast Facts

- Ecosystem services do the following:
  - Moderate weather extremes and their impacts (ex. drought, floods, etc.)
  - Mitigate climate change
  - Absorb and store CO_2
  - Protect water channels and shores from erosion
  - Regulate disease-carrying organisms
  - Provide ingredients for pharmaceutical, biochemical and industrial products
  - Are a source of energy and biomass fuels
  - Decompose waste and detoxify pollution
  - Generate, maintain and renew soil fertility (nutrient cycling)
  - Pollinate crops and plants, and disperse seeds
  - Control agricultural pests and diseases
  - Produce food (such as crops, wild foods and spices, seafood)
  - Produce wood and fibre
  - Produce oxygen, purify air and water
  - Give cultural, intellectual, artistic and spiritual inspiration
  - Allow recreation (ex. ecotourism)
  - Hold answers to scientific questions
  - Hold the cures to diseases
- Conserving forests avoids greenhouse gas emissions worth US$ 3.7 trillion
- Ecotourism is the fastest-growing area of the tourism industry with an estimated increase of global spending of 20% annually (TIES 2006)
- Bee keeping generates US$ 213 million annually in Switzerland by ensuring agricultural production through pollination—some five times the value of honey production alone
- Under a 'business as usual' scenario, where ecosystem services keep declining, the cost to compensate for the lost services (the cost of inaction) over a 50 year period will amount to US$ 2.0 to 4.5 trillion per year

Example of ecosystem services: Medicines

Chemical compounds for industrial and pharmaceutical uses

	Deep sea species	Function	Reference
Marketed	*T. thermophilus* enzymes - deep sea bacteria	Enzymes; Skin protection products (UV-resistant)	Arico (2005)
	T. thermophilus, Thermus aquaticus and *Thermatoga maritime* - deep sea bacteria	DNA polymerases; enzyme that builds new strands of DNA	Arico (2005)
Clinical trials	*Discodermia dissolute* - deep water sponge	Discodermolide; cancer treatment	Maxwell (2005)
	Lissodenroyx sp - deep sea sponge	E7389; lung cancer and other cancer treatment	Maxwell (2005)
	Salinospora tropica – deep sea bacteria	Salinosporamide-1; antibiotic and anti-cancer agent	Maxwell et al (2005)
Research	*Lithistida* (family: *Coalistadae*) - deep sea sponge	Dictyostatin-1; Cancer treatment	Maxwell (2005a)
	Spongosporites ruetzleri - deep sea sponge	Topsentin; Anti-inflammatory agent for arthritis and skin irritations	Isbrucker et al (2003)
	Isidae – deep sea bamboo corals	Bone grafts	Maxwell (2005)
	Vibrio diabolicus – deep sea hydrothermal vent bacteria	HE 800 Exopolysaccharide; bone grafts	Zanchetta et al (2003)

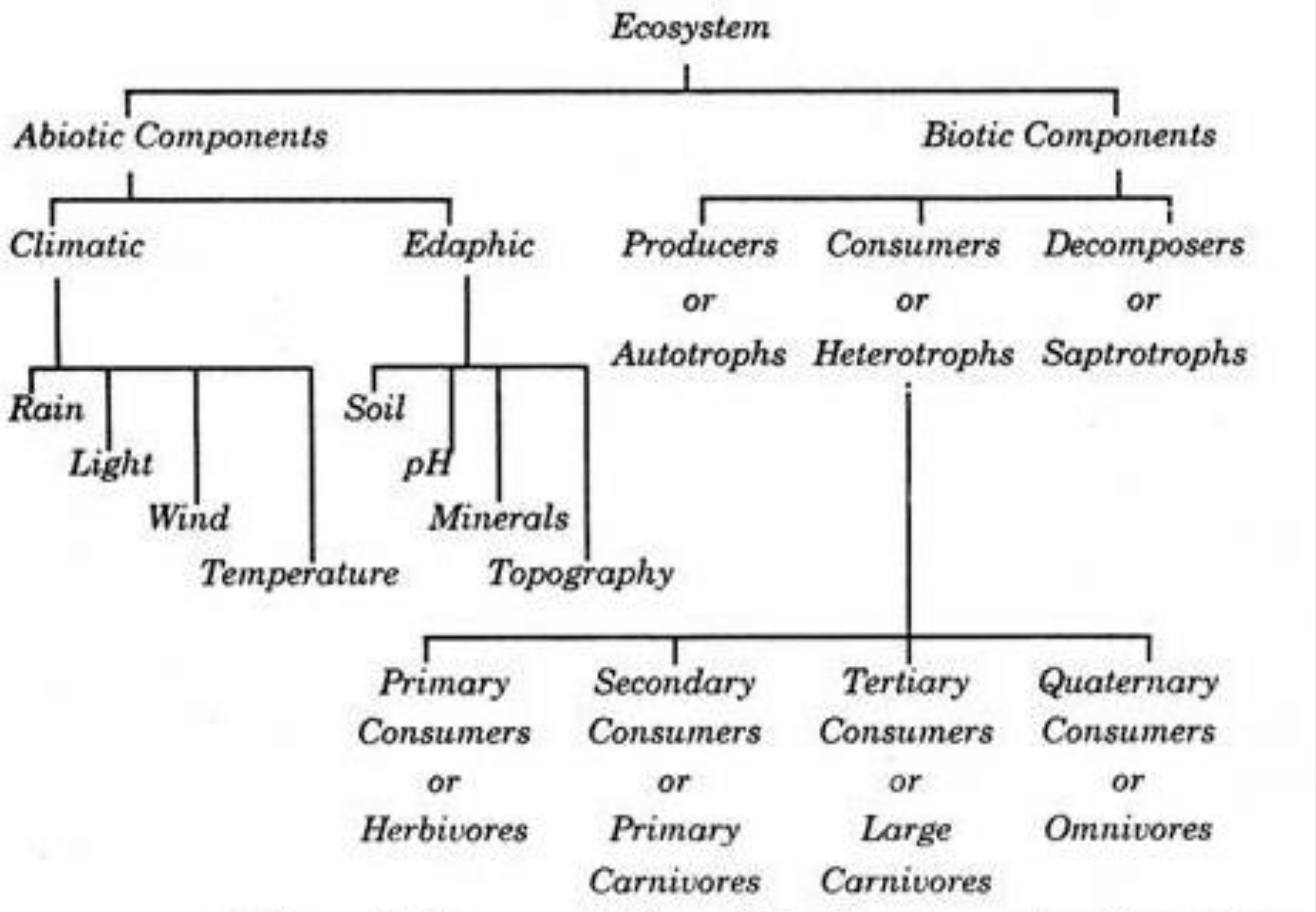
Table 2: Examples of products derived from deep-sea species and materials.

Armstrong et al 2010

Scientific Methods

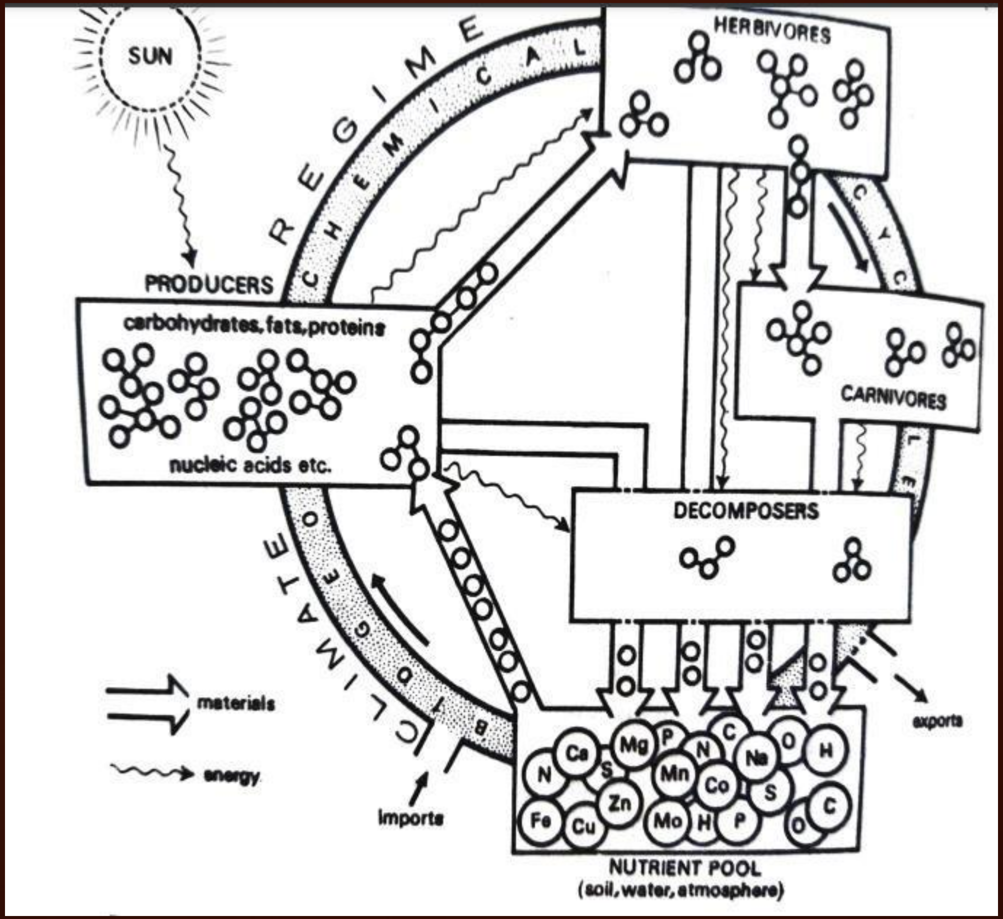
- We can't do experiments on whole, natural ecosystems
- Instead we use several tools to explore ecosystems:
  - Observations- We watch and take detailed notes about an ecosystem
  - Experimenting-Taking an artificial environment and using the scientific method on it.
  - Modeling- Using computers to show what has happened and what will happen in an ecosystem.

Ecosystem Structure



Schematic Representation of the Structure of an Ecosystem.

Structure and function….



Structure and Function of an Ecosystem:

- **Each ecosystem has two main components:**
- (1) Abiotic
- (2) Biotic
- **(1) Abiotic Components:**

The nonliving factors or the physical environment prevailing in an ecosystem form the abiotic components. They have a strong influence on the structure, distribution, behaviour and inter-relationship of organisms.

Abiotic components are mainly of two types:
(a) Climatic Factors:
Which include rain, temperature, light, wind, humidity etc.
(b) Edaphic Factors:
Which include soil, pH, topography minerals etc.?

The Functions of Abiotic Components

- Soils are much more complex than simple sediments. They contain a mixture of weathered rock fragments, highly altered soil mineral particles, organic matter, and living organisms.
- Soils provide nutrients, water, a home, and a structural growing medium for organisms.
- The vegetation found growing on top of a soil is closely linked to this component of an ecosystem through nutrient cycling.

- The atmosphere provides organisms found within ecosystems with carbon dioxide for photosynthesis and oxygen for respiration.
- The processes of evaporation, transpiration and precipitation cycle water between the atmosphere and the Earth's surface.

The Functions of Abiotic Components

- Solar radiation is used in ecosystems to heat the atmosphere and to evaporate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis.
- Photosynthesis provides the energy for plant growth and metabolism, and the organic food for other forms of life.
- Most living tissue is composed of a very high percentage of water, up to and even exceeding 90%. The protoplasm of a very few cells can survive if their water content drops below 10%, and most are killed if it is less than 30-50%.
- Water is the medium by which mineral nutrients enter and are translocated in plants. It is also necessary for the maintenance of leaf turgidity and is required for photosynthetic chemical reactions. Plants and animals receive their water from the Earth's surface and soil. The original source of this water is precipitation from the atmosphere.

Biotic Components

(A) Producers
(B) Consumers
(C) Decomposers or Reducers.

(A) Producers:

The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrates using simple inorganic compounds namely water and carbon dioxide. This process is known as photosynthesis. As the green plants manufacture their own food they are known as Autotrophs (i.e. auto = self, trophos = feeder) The chemical energy stored by the producers is utilised partly by the producers for their own growth and survival and the remaining is stored in the plant parts for their future use.

(B) Consumers:

The animals lack chlorophyll and are unable to synthesise their own food. Therefore, they depend on the producers for their food. They are known as heterotrophs (i.e. heteros = other, trophos = feeder)

- **The consumers are of four types, namely:**

(i) Primary Consumers or First Order Consumers or Herbivores:

These are the animals which feed on plants or the producers. They are called herbivores. Examples are rabbit, deer, goat, cattle etc.

(ii) Secondary Consumers or Second Order Consumers or Primary Carnivores:

The animals which feed on the herbivores are called the primary carnivores. Examples are cats, foxes, snakes etc.

(iii) Tertiary Consumers or Third Order Consumers:

These are the large carnivores which feed on the secondary consumers. Example are Wolves.

iv). **Omnivores:** These are the largest carnivores which feed on the tertiary consumers and are not eaten up by any other animal. Examples are lions and tigers.

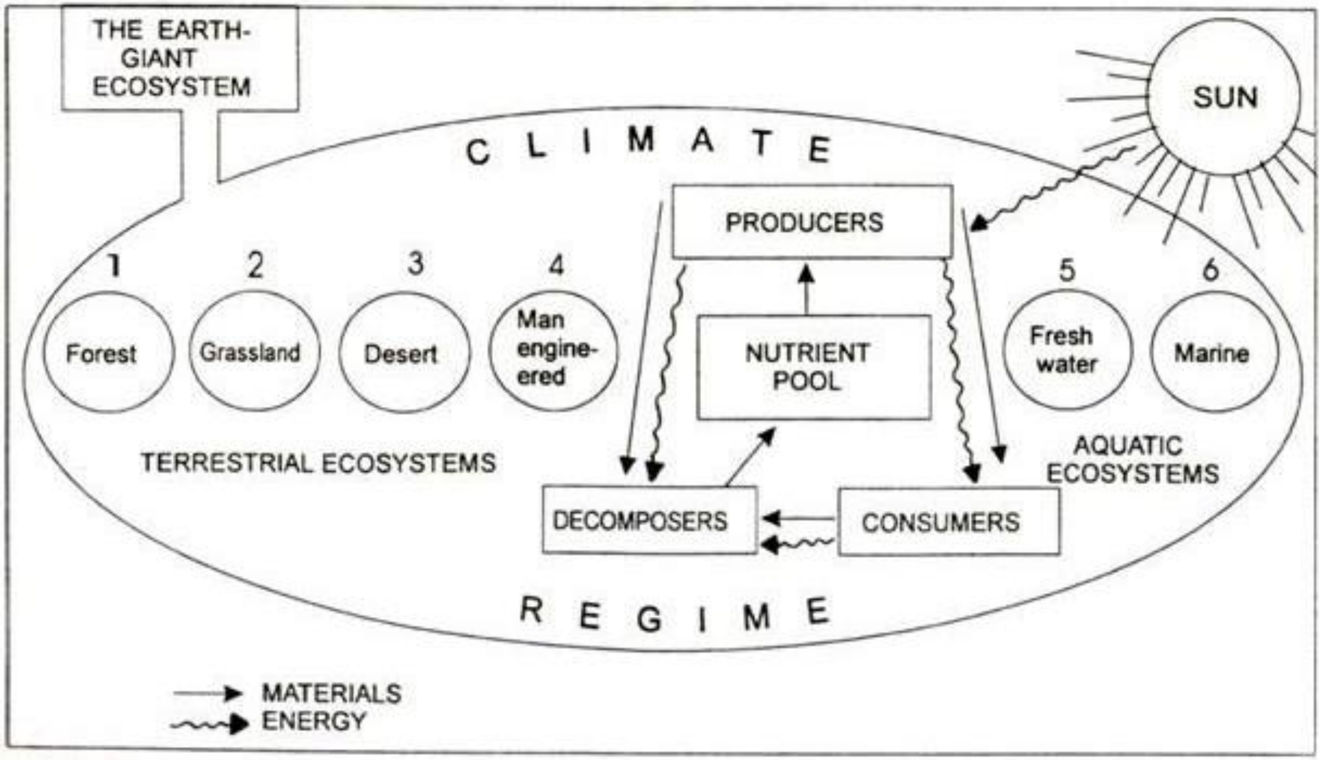
(C) Decomposers or Reducers:

Bacteria and fungi belong to this category. They breakdown the dead organic materials of producers (plants) and consumers (animals) for their food and release to the environment the simple inorganic and organic substances produced as by-products of their metabolisms.

Major Trophic Levels

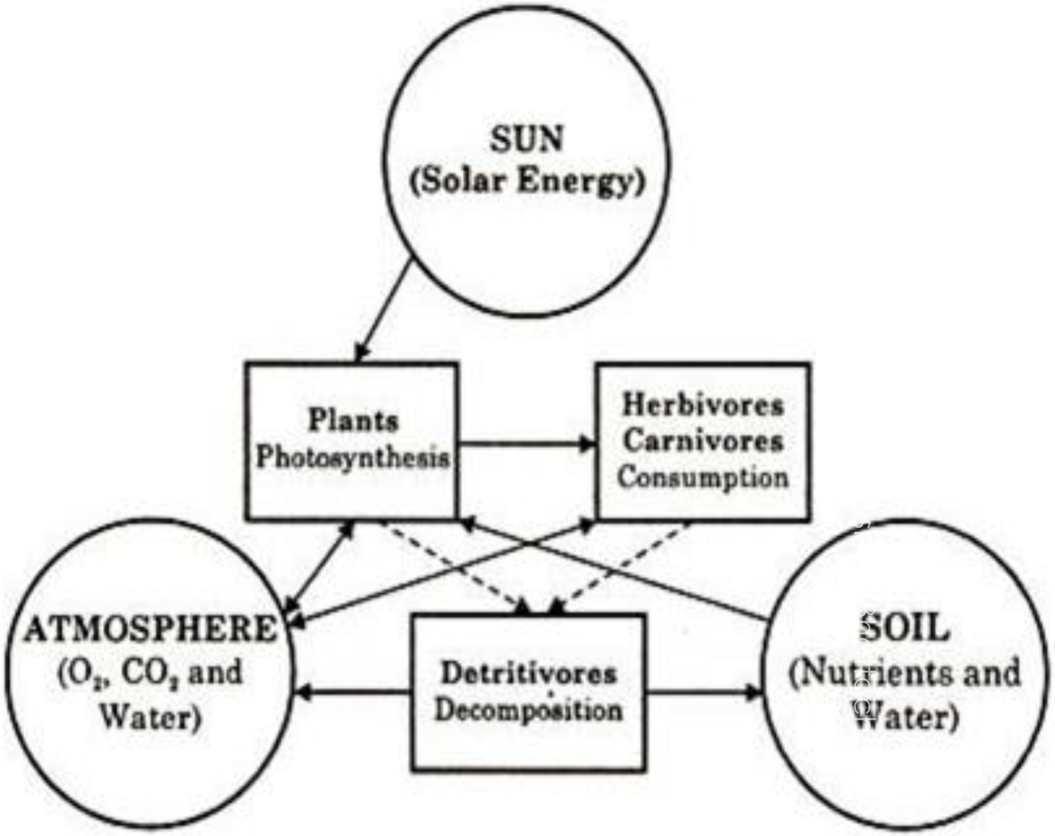
Trophic Level	Source of Energy	Examples
Producers	Solar energy	Green plants, photosynthetic protists and bacteria
Herbivores	Producers	Grasshoppers, water fleas, antelope, termites
Primary Carnivores	Herbivores	Wolves, spiders, some snakes, warblers
Secondary Carnivores	Primary carnivores	Killer whales, tuna, falcons
Omnivores	Several trophic levels	Humans, rats, opossums, bears, racoons, crabs
Detritivores and Decomposers	Wastes and dead bodies of other organisms	Fungi, many bacteria, earthworms, vultures

Ecosytems combine to form a Giant ecosystem



Energy and Matter Flow

- Both Energy and Matter flow through an ecosystem
- Energy flows into and out of the ecosystem
- Matter is usually recycled



Relationship within an Ecosystem.

Energy

- All energy from an ecosystem comes from the sun, originally
- Plants convert sunlight into chemical energy
- Other organisms eat plants and each other for that stored sunlight energy

Thus the principal steps in the operation of ecosystem are as follows:

- (1) Reception of radiant energy of sun,
- (2) Manufacture of organic materials from inorganic ones by producers,
- (3) Consumption of producers by consumers and further elaboration of consumed materials; and.
- (4) After the death of producers and consumers, complex organic compounds are degraded and finally converted by decomposers and converters into such forms as are suitable for reutilization by producers.

TROPHIC LEVELS

eagle 0.1 kcal

- 0.9 kcal

snake 1 kcal

- 9 kcal

frog 10 kcal

- 90 kcal

grass-hopper 100 kcal

- 900 kcal

grass 1000 kcal

As organisms eat one another, energy is transferred up the food chain.

However, as energy is moved from one trophic level to the next, only 10 % of the energy makes it to the next level.

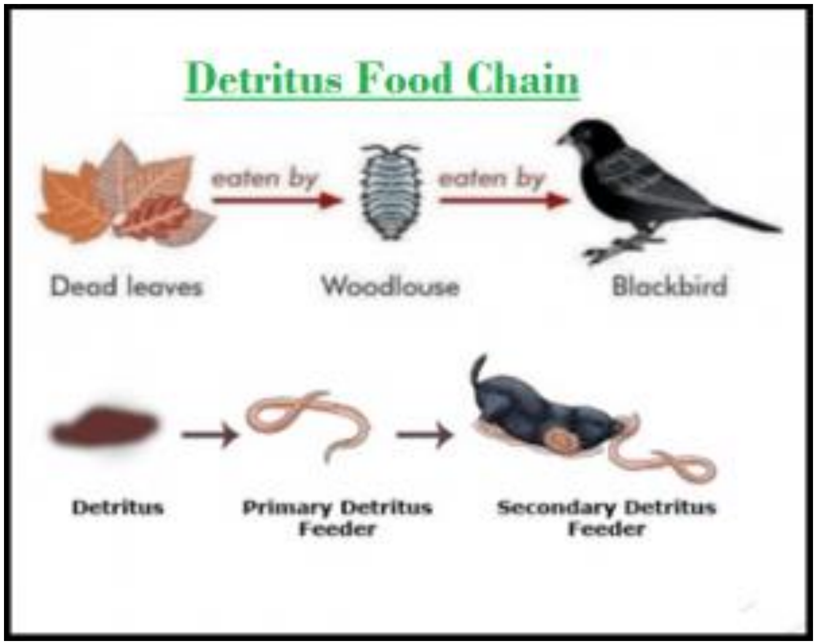
This 10 % is used to build biomass as well as to fuel bodily functions.

This means that 90 % of the energy is lost, mostly in the form of detritus and as heat from metabolic processes.

Dr. Tanushree

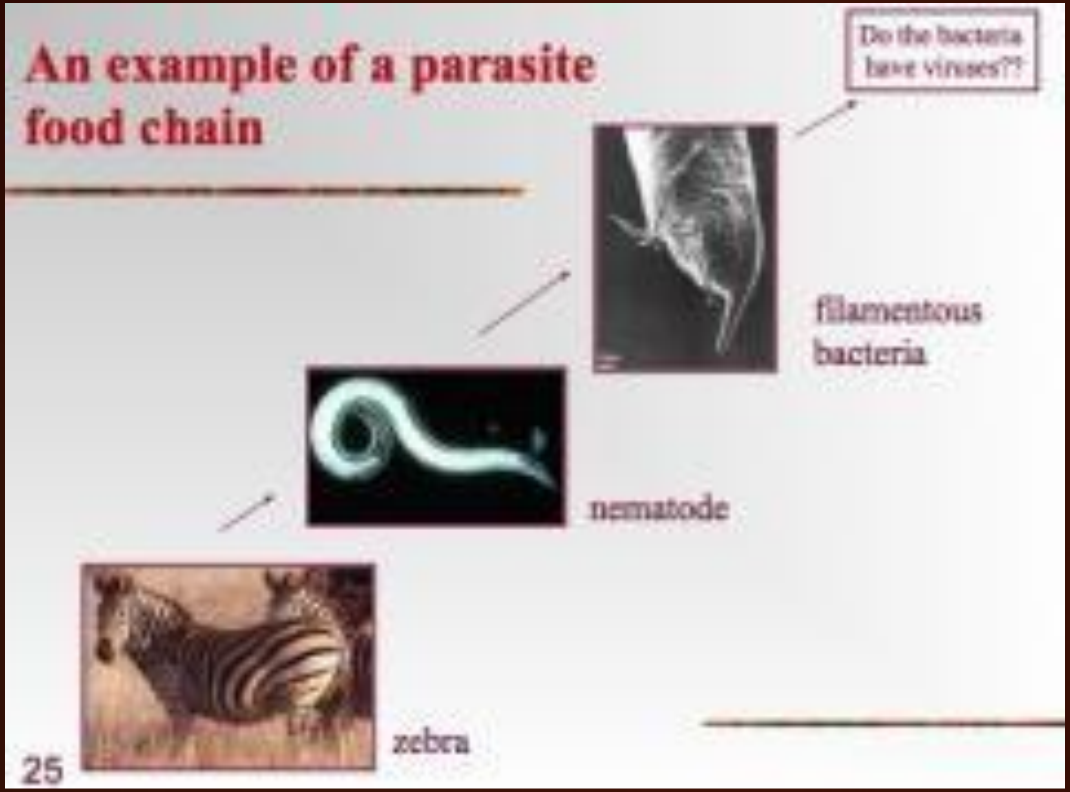
Food Chain

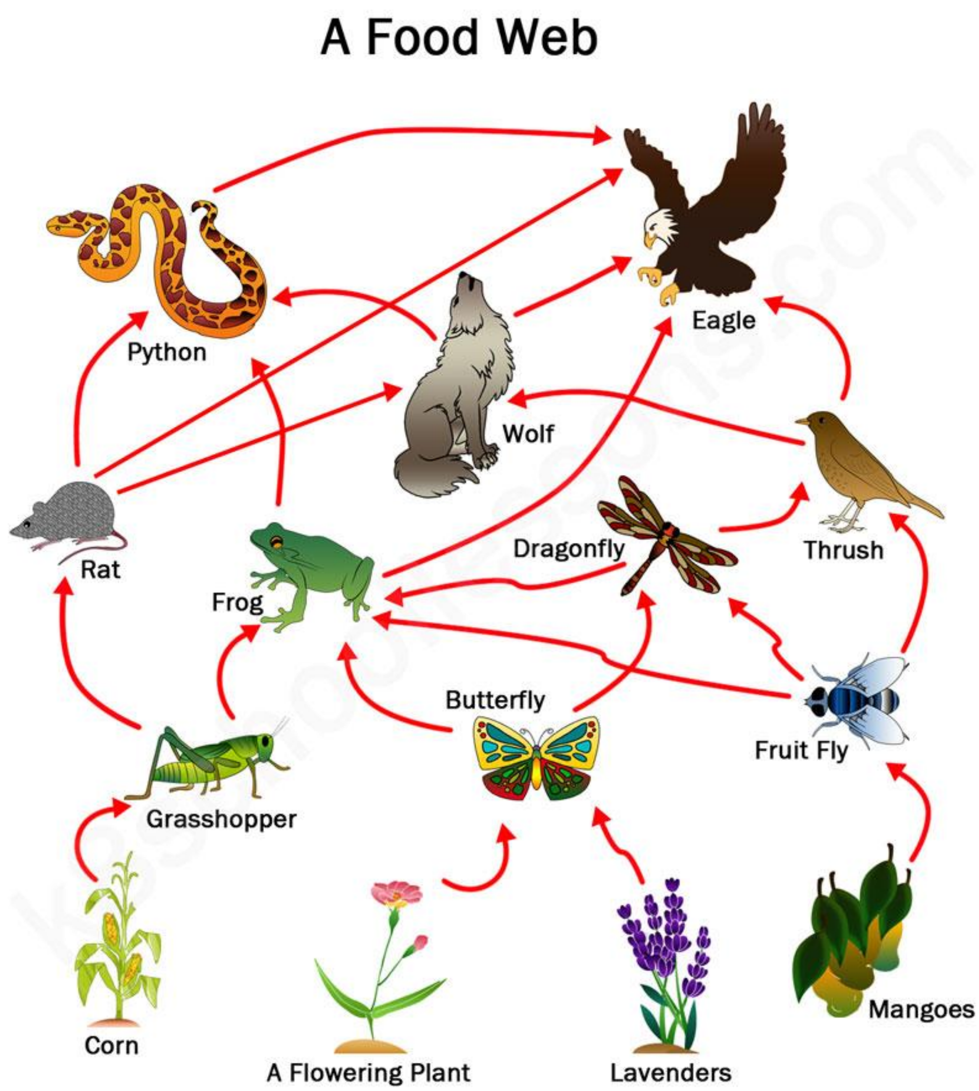
- The simple chain of eating and being eaten away is known as food chain. In a food chain of an ecosystem, energy flows from one trophic level to another.
- There are 3 types of food chains, namely **Grazing food chain, Detritus food chain and Parasitic food chain**.
- **Grazing food chain (GFC)** starts from producers or plants and passes on to herbivorous primary consumers to carnivorous secondary consumers and ends with tertiary carnivorous animals. Thus, it is directly dependant on influx of solar radiation.
- **Detritus food chain (DFC)** starts with dead organic matter and goes to microorganisms and then passes on to organisms that feed on detrivores and their predators. This ecosystems are less dependant on solar energy and depends on the organic matter inflow in the system.
- **Parasitic food chain (PFC) –** In this type of food chain, large organisms either producer or consumer is exploited and therefore the food passes to the smaller organisms


Detritus Food Chain
eaten by
eaten by
Dead leaves
Woodlouse
Blackbird
Detritus
Primary Detritus Feeder
Secondary Detritus Feeder


Grazing Food Chain
Owl
(consumer)
Flower
(producer)
Caterpillar
(consumer)
Frog
(consumer)
Snake
(consumer)

Parasitic food chain

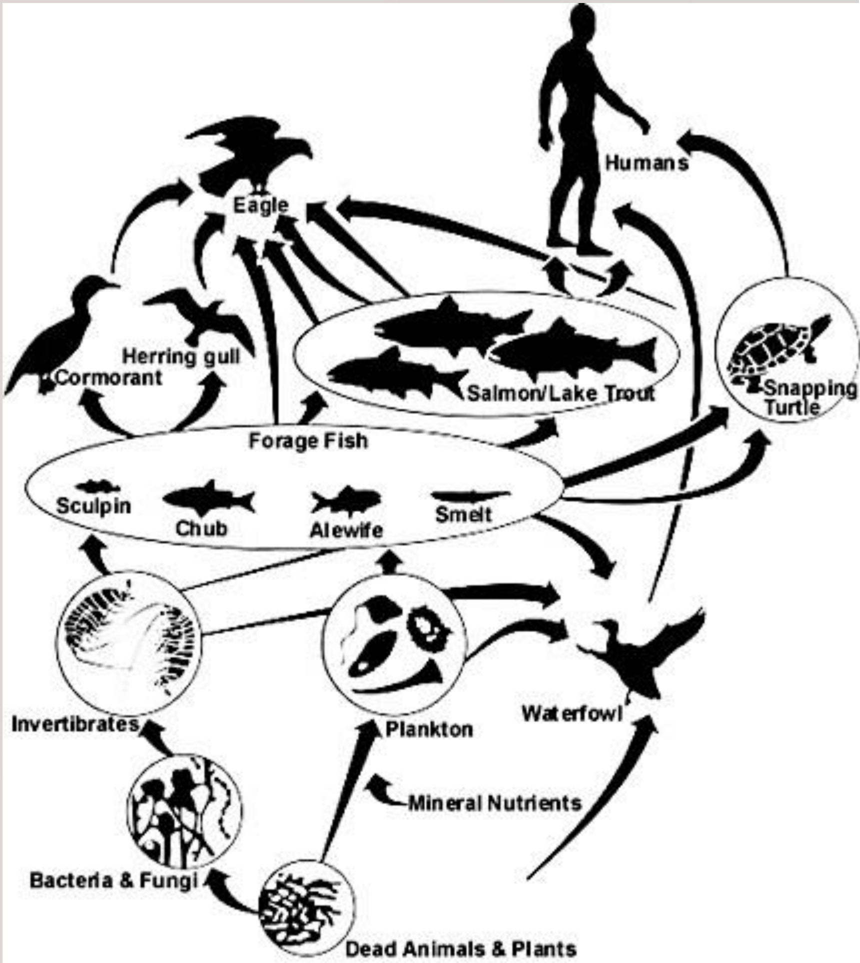




Food web
However, food chains in the natural conditions never operate as isolated sequences, but are interconnected with each other forming some sort of interlocking patterns, which is referred as food web.

Types and Patterns of Food Webs

- **Connectedness webs**: These are based on the concept of **who eats whom**, emphasizing on feeding relationships (also known as **topological food webs**)
- **Energy flow food webs**: in this type energy flow through a food web is estimated. Connections between populations are quantified by the **flux of energy** between resource and consumers
- **Functional food webs**: On the basis of the **impact of species on the structure of community.** It shows the feeding relationships within the topological food webs



Ecological pyramids

- Ecological Pyramid refers to a graphical (pyramidal) representation to show the number of organisms, biomass, and productivity at each trophic level. There are three types of pyramids.

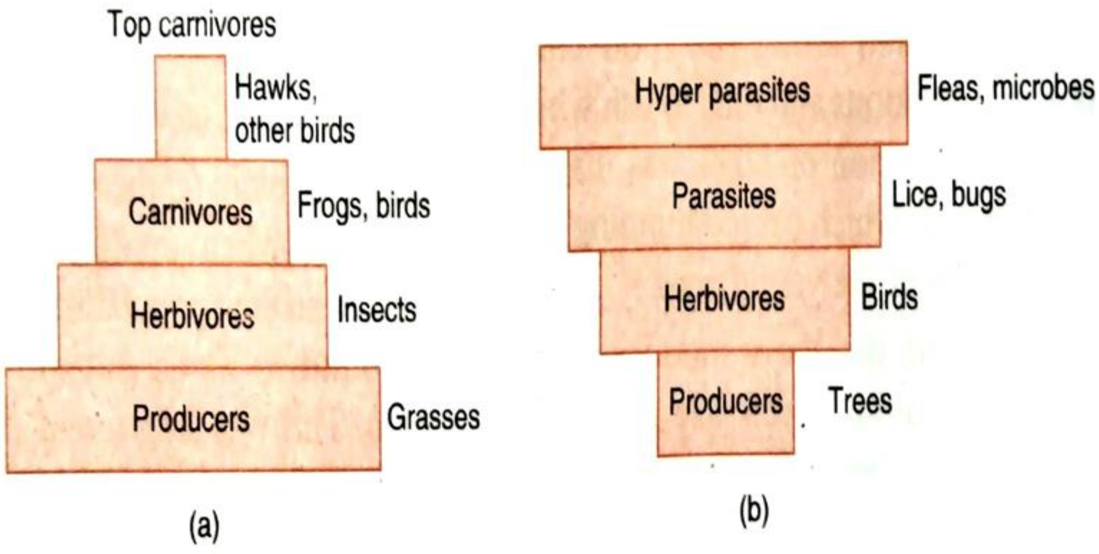


Fig. Pyramid of numbers (*a*) grassland (*b*) Parasitic food chain.

It is the graphic representation of number of individuals per unit area of various trophic levels. Large number of producers tend to form the base whereas lower number of top predators or carnivores occupy the tip. The shape of the pyramid of numbers varies from ecosystem to ecosystem.

For example, in an aquatic ecosystem or grassland areas, autotrophs or producers are present in large number per unit area. The producers support a lesser number of herbivores, which in turn supports fewer carnivores.

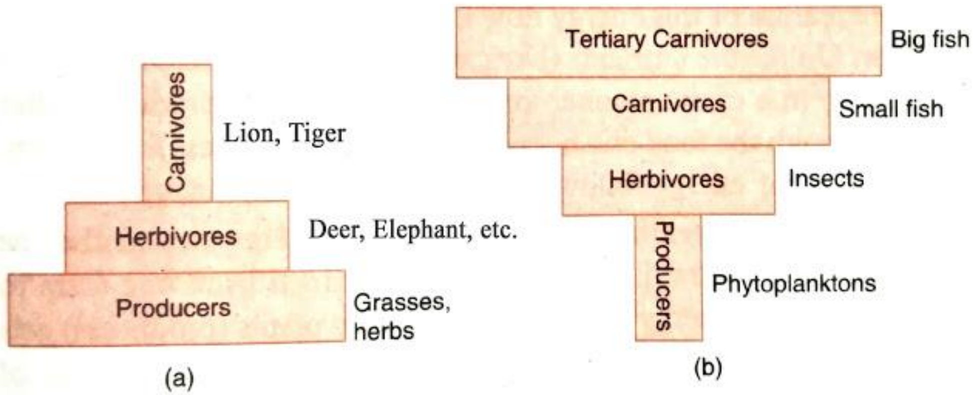
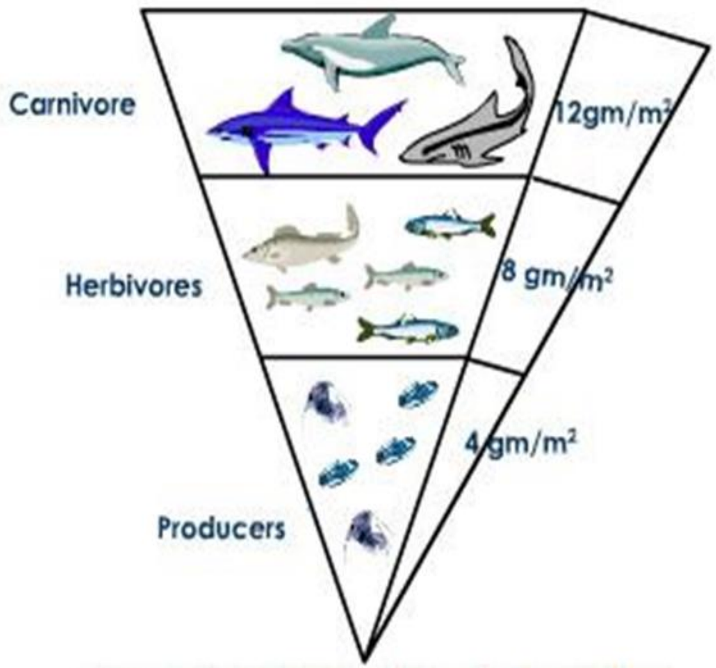


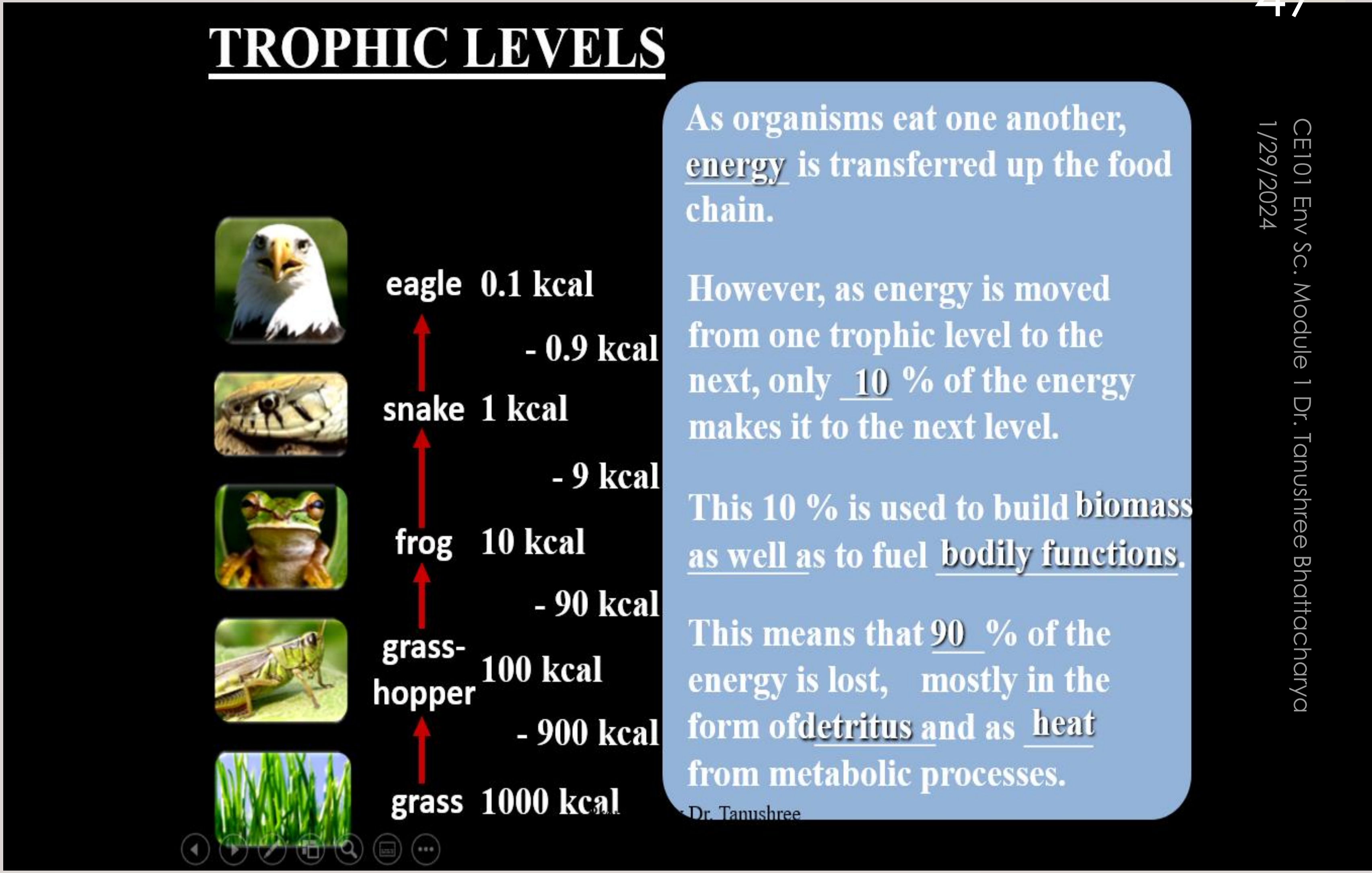
Fig. Pyramid of biomass (*a*) Forest (*b*) Pond.



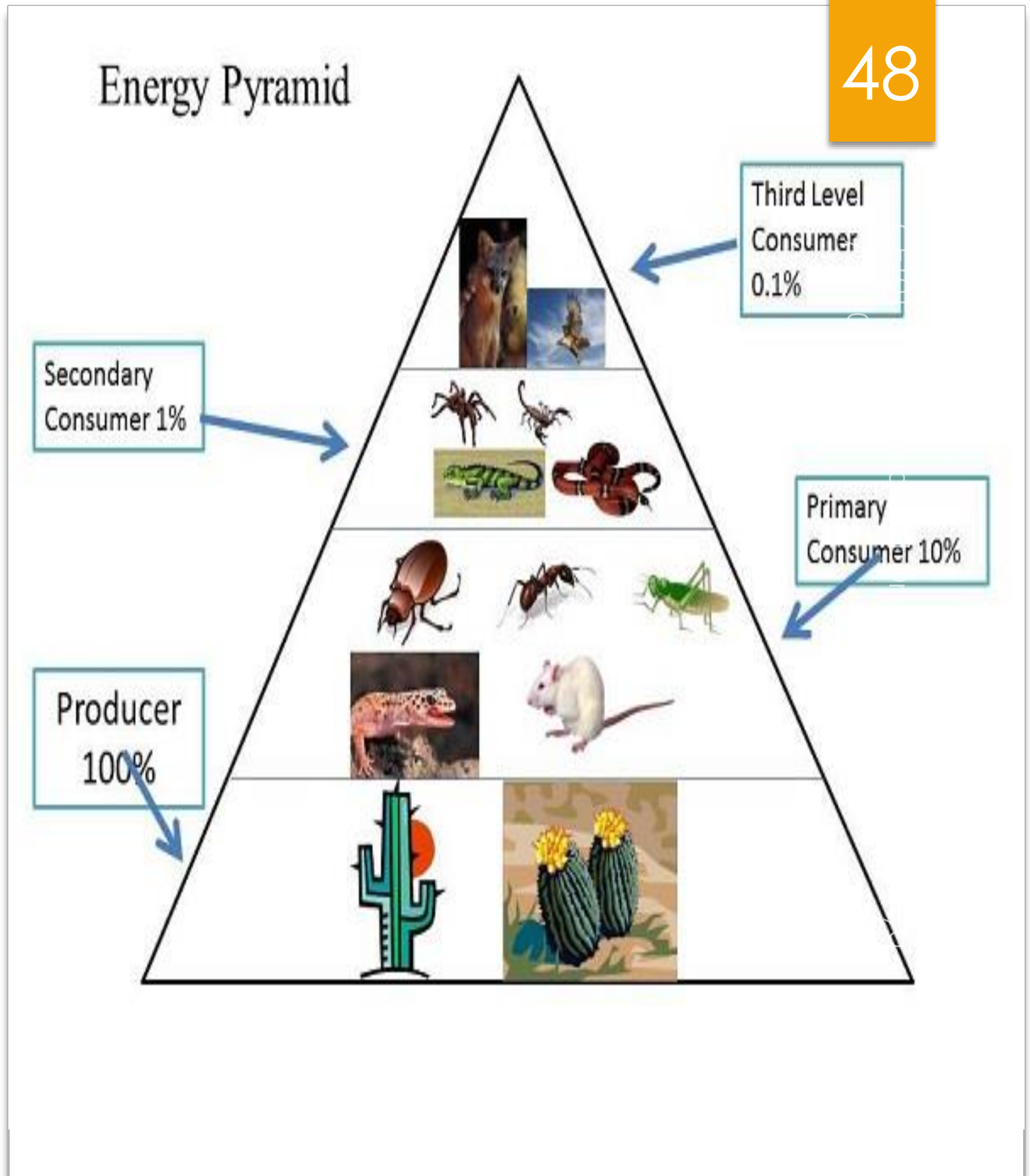
Inverted Pyramid in an Aquatic Ecosystem

Pyramids of biomass

As the name suggests, the Biomass Pyramids show the amount of biomass (living or organic matter present in an organism) present per unit area at each trophic level. It is drawn with the producers at the base and the top carnivores at the tip. Pyramid of biomass is generally ascertained by gathering all organisms occupying each trophic level separately and measuring their **dry weight**. Each trophic level has a certain mass of living material at a particular time called **standing crop**, which is measured as the mass of living organisms (biomass) in an unit area.

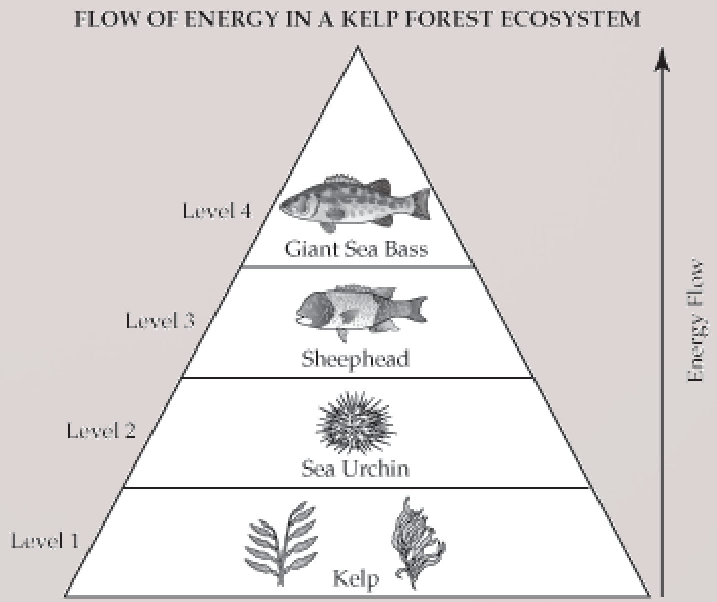

TROPHIC LEVELS
eagle 0.1 kcal
- 0.9 kcal
snake 1 kcal
- 9 kcal
frog 10 kcal
- 90 kcal
grass-
hopper
100 kcal
- 900 kcal
grass 1000 kcal
As organisms eat one another, energy is transferred up the food chain.
However, as energy is moved from one trophic level to the next, only 10 % of the energy makes it to the next level.
This 10 % is used to build biomass as well as to fuel bodily functions.
This means that 90 % of the energy is lost, mostly in the form of detritus and as heat from metabolic processes.
Dr. Tanushree

- **Pyramid of Energy**
- It is a graphical structure representing the flow of energy through each trophic level of a food chain over a fixed part of the natural environment.
- An energy pyramid represents the amount of energy at each trophic level and loss of energy at each is transferred to another trophic level.



Energy Pyramid

- Less energy is transferred to the next trophic level.
- This is due to some energy lost due to metabolic activities
- Only about 10% of energy is available (in the form of body structure) to the next trophic level.
- First law of thermodynamics and 2nd law of thermodynamics is followed in ecological energy flow too!!!!



Energy Flow

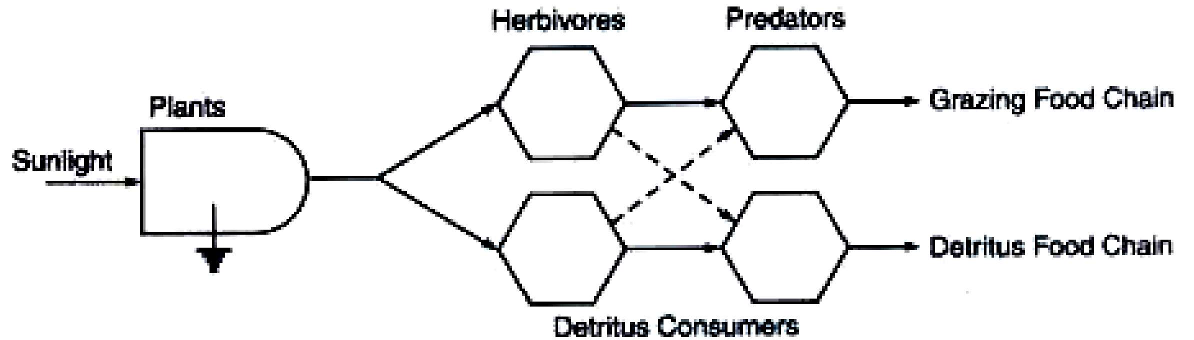


Fig. 3.2. The Y-shaped energy flow model showing linkage between the grazing and detritus food chains

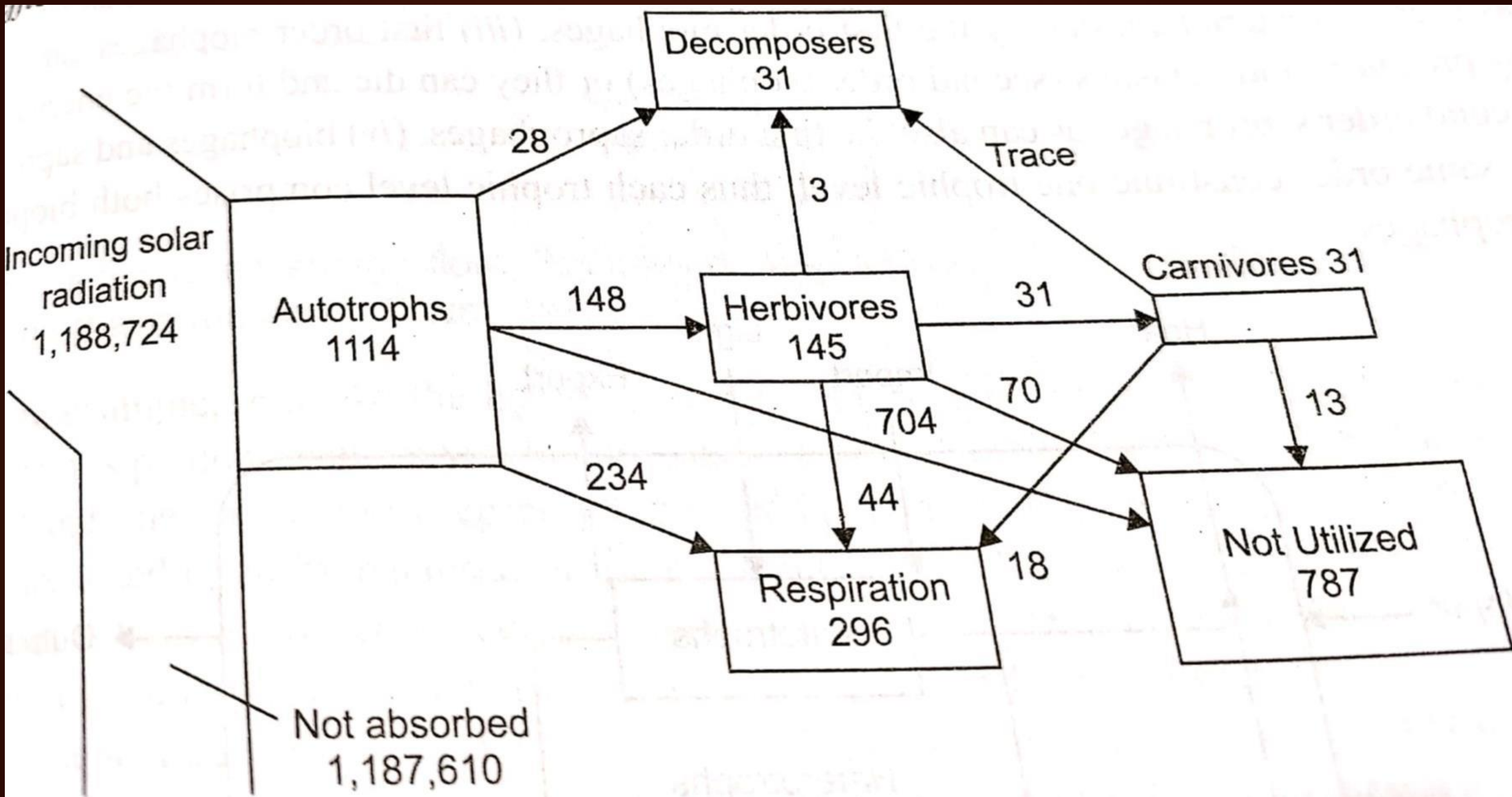
Y-Shaped Energy Flow

- Confirms to the stratified structure of ecosystems
- Direct consumption of living plants and utilization of dead organic matter are usually separated in both time and space
- Macroconsumers (phagotrophs) and microconsumers (saprotrophs) differ greatly in size-metabolism relations
- Lake as an example – Green belt (top of water) and brown belt (sediment)
- Forests and marshes – operate as detritus systems

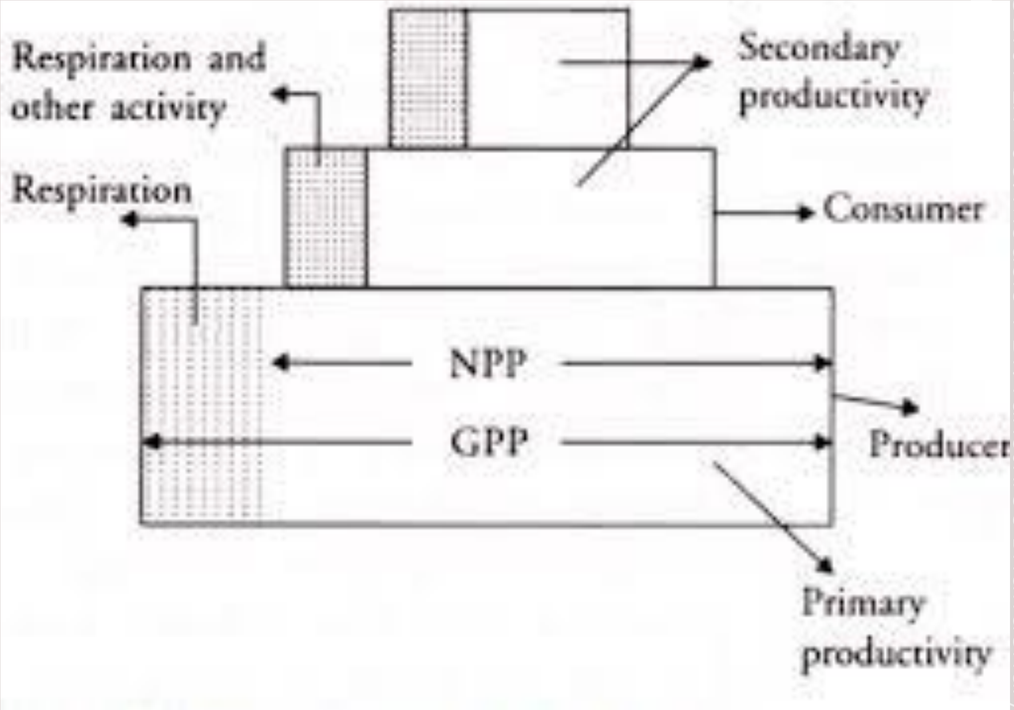
Y Shaped Energy Flow Model

- Grazing and detritus food chains are inter-connected
- Not all food eaten by grazers is actually assimilated, as some (feces containing undigested material) is diverted to the detritus pathway
- Also, the amount of net production energy that flows down the two pathways varies in different kinds of ecosystems and, often in the same ecosystem; it may vary seasonally or annually
- Energy flow in case of shallow waters and heavily grazed pastures or grassland shows larger energy flow via the **grazing food chain** than in the **detritus** pathway. The reverse is true in case of the forest, marshes and oceans

Energy flow diagram in a Lake (Kcal/m²/yr)



Ecological Productivity



GPP=Gross Primary Productivity, NPP=Net Primary Productivity

Productivity

Definitions

* Gross Primary Production = GPP

GPP = All CO_2 fixed by the plant in photosynthesis.

* Respiration = R

R = CO_2 lost from metabolic activity

R_p = Respiration by Plants
R_h = Respiration by Heterotrophs
R_d = Respiration by Decomposers

* Net Primary Production = NPP

$$NPP = GPP - R_p$$

* Net Ecosystem Production = NEP

$$NEP = GPP - (R_p + R_h + R_d)$$

Net primary productivity

- Net primary productivity is the energy that producers can make available to a community at any one time.
- Net productivity determines how much life an ecosystem supports.
- Productivity can be measured in calories (units of energy) or biomass (amount of organic material) g/m^2

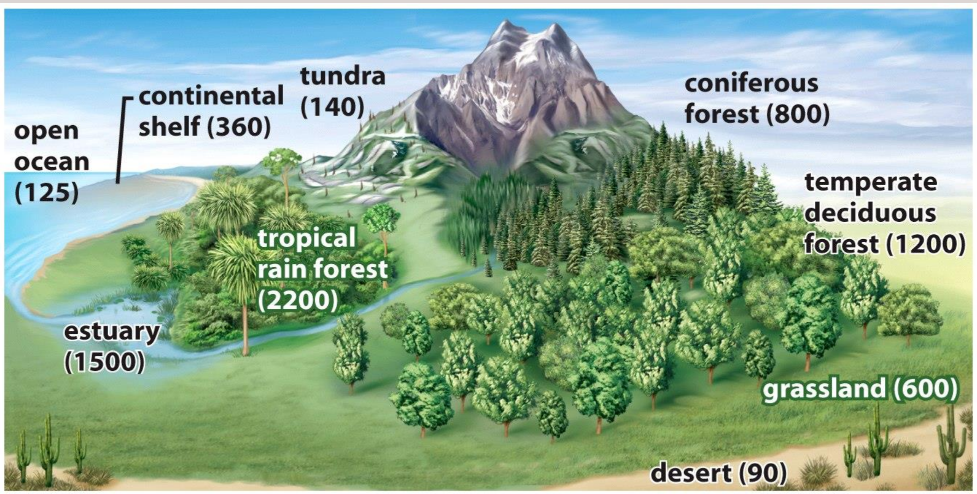
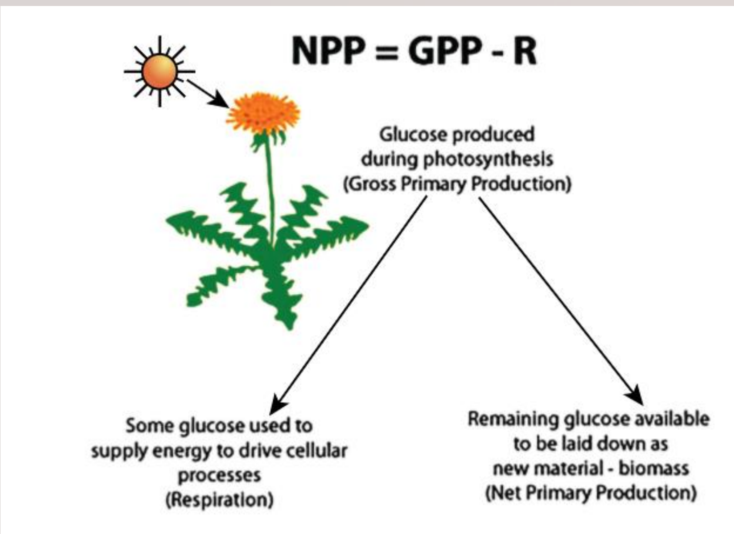
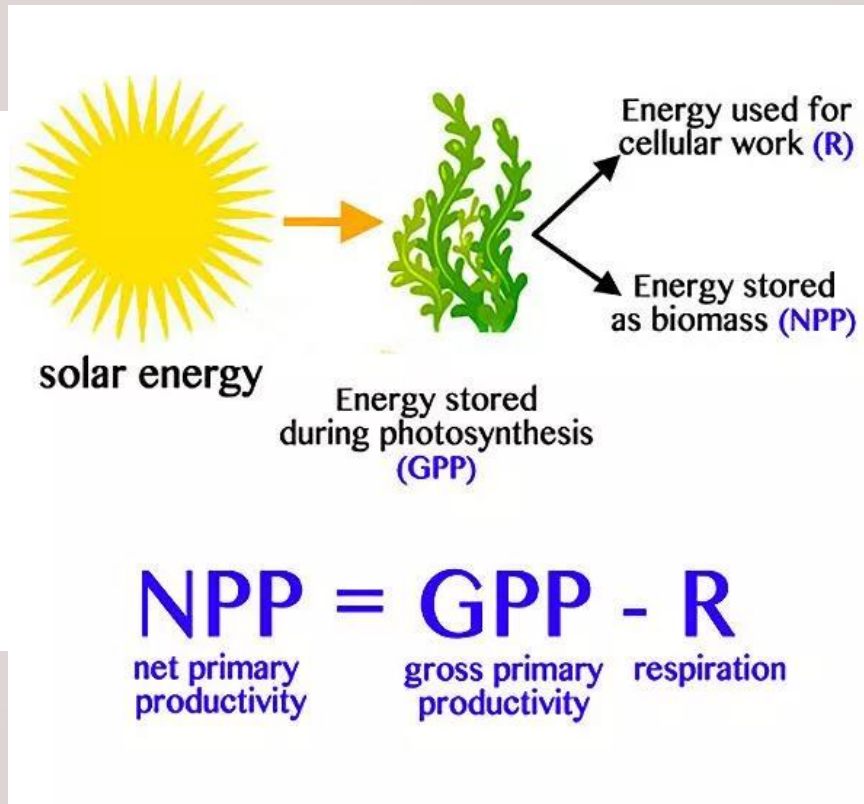


Figure 28-3 Biology: Life on Earth, 8/e

Image Source: Biology: Life on Earth, 8/e. 2008 Pearson Prentice Hall, Inc.

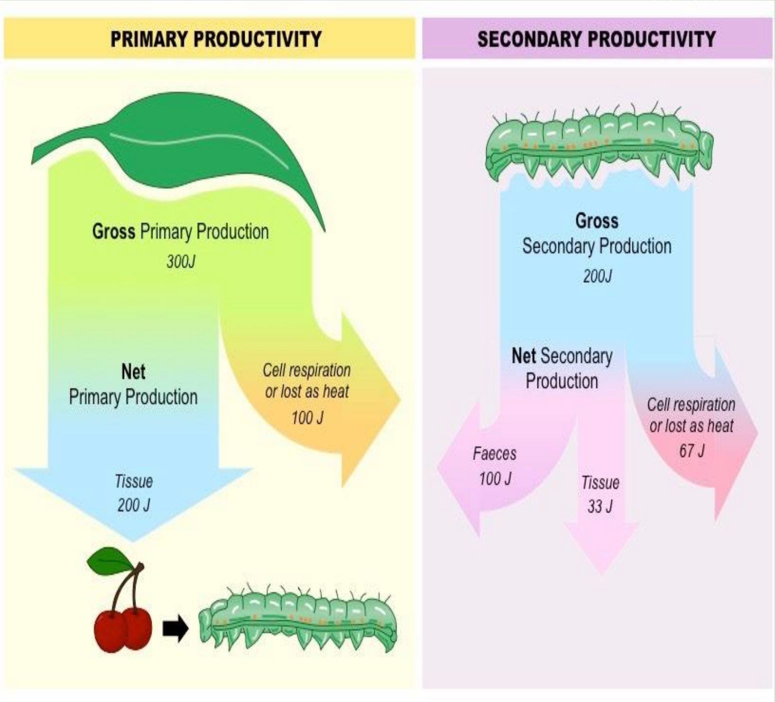
- **Gross primary productivity** is the amount of carbon fixed during photosynthesis by all producers in the ecosystem. However, a large part of the harnessed energy is used up by the metabolic processes of the producers (respiration).





Secondary Productivity

- Secondary productivity describes the generation of biomass by heterotrophic organisms (consumers)
- This biomass generation is driven by the transfer of organic compounds between trophic levels via feeding



Ecological efficiencies

- Assimilation efficiency:
  - for plants, energy fixed by (plants/light absorbed)*100
  - For consumers, (food energy assimilated/food energy ingested)*100
- Consumption efficiency:
  - (Ingestion at trophic level n/net production at trophic level n)*100
- Production efficiency:
  - (Production at trophic level n/assimilation at trophic level n)*100
- Ecological growth efficiency:
  - (Production at trophic level n/ingestion at trophic level n)*100
- Transfer efficiency:
  - (Production at trophic level n/production at trophic level n-1)*100

1. Why are ecological interactions important?

- ✓Interactions can affect distribution and abundance.
- ✓Interactions can influence evolution.

2. How are ecological interactions classified?

- Ecological interactions are classified as intraspecific or interspecific interactions and as harmonious or inharmonious interactions.

3. What are intraspecific and interspecific ecological interactions?

- Intraspecific ecological interactions are those between individuals of the same species.
- Interspecific ecological interactions are ecological interactions between individuals of different species.

4. What is inharmonious ecological interaction?

- Inharmonious, or negative, ecological interaction is that in which at least one of the participating beings is harmed.

5. What is harmonious ecological interaction?

- Harmonious, or positive, ecological interaction is that in which none of the participating beings is harmed.

6. What are the main harmonious intraspecific & inharmonious intraspecific ecological interactions?

- The main harmonious intraspecific ecological interactions are colonies and societies.
- The main inharmonious intraspecific ecological interactions are intraspecific competition and cannibalism.

11. What are the main interspecific ecological interactions?

- The main harmonious interspecific ecological interactions are:
  - protocooperation, synergism and mutualism and commensalism.
- The main inharmonious interspecific ecological interactions are:
  - interspecific competition, parasitism, predatism and ammensalism.

What is an example of intraspecific competition?

- Intraspecific competition occurs in practically all species, for example, the competition of humans for a job.

10. Why is cannibalism an inharmonious intraspecific ecological interaction?

In cannibalism an individual eats other of the same species (occurs in some insects and arachnids). Since it is an interaction between beings of the same species and at least one of them is harmed (the other is benefited) the classification as inharmonious intraspecific ecological interaction is justified.

Possible combinations for interactions: Source Ecology and Environment by P.D. Sharma

Table-1. **Possible combinations of 0, + and – to give different kinds of interactions** (Burkholder, 1952).

Combinations	Detailed effect (s)	Interaction type
0 0	Neither population affects the other	**Neutralism**
- -	Direct-inhibition of each species by the other	**Competition** (Direct interference type)
- -	Indirect inhibition where common resource is in short supply	**Competition** (Resource use type)
- 0	Population 1 inhibited, 2 not affected	**Amensalism**
+ -	Population 1, the parasite, generally smaller than 2, the host	**Parasitism**
+ -	Population 1, the predator, generally larger than 2, the prey	**Predation**
+ 0	Population 1, the commensal, benefits while 2, the host, is not affected	**Commensalism**
+ +	Interaction favourable to both but not obligatory	**Protocooperation**
+ +	Interaction favourable to both and obligatory	**Mutualism**

8. What is competition? Which type of ecological interaction is competition?

- Competition is the ecological interaction in which the individuals explore the same ecological niche or their ecological niches partially coincide and therefore competition for the same environmental resources takes place.
- Competition is harmful for all participating beings and thus it is classified as an inharmonious (negative) ecological interaction.

Competition – two species share a requirement for a limited resource → reduces fitness of one or both species

Competitive exclusion principle:

If two species have the same niche, the stronger competitor will eliminate the other competitor.

"Complete competitors cannot coexist."

Symbiotic Relationships

Symbiosis- two species living together

3 Types of symbiosis:

1. Commensalism
2. Parasitism
3. Mutualism

Symbiosis : Source: Ecology and Environment P.D Sharma

Artificial key to the various types of interactions included under symbiosis

Either one or both the species benefited ...	***Positive Interactions***
Both the species derive benefit Association more or less obligatory, essential for survival of both	**Mutualism** e.g. pollination, Fruit and seed dissemination, Lichens, Symbiotic nitrogenfixers, Mycorrhizae, Zoochlorellae etc.
Association non-obligatory, not essential for survival of either population ...	**Protocooperation** or **Non-obligatory mutualism** e.g. Sea anemone attached to hermit crab shells
Only one species benefited, neither is harmed ...	**Commensalism** e.g. Lianas, Epiphytes, Barnacles attached to whales, Hydroids on fish, Crab in the mantle cavity of oyster, Rhizosphere and Phyllosphere micro-organisms
Either one or both the species harmed ...	***Negative Interactions***
One species harms the other making its direct or indirect use ...	**Exploitation**
Use for shelter or support ...	Some ants and birds inhabiting other's dwelling sites
Use for food	
Food derived from the host without causing its death ...	**Parasitism**
Food derived by killing the host ...	**Predation** e.g. Browsing, Grazing, Seedling destruction, Plants as food, Carnivorous plants

What is protocooperation?

- Protocooperation is the ecological interaction in which both participants benefit but which is not obligatory for their survival.
- Protocooperation is a harmonious (positive) interspecific ecological interaction.
- Examples of protocooperation are:
  - **the action of the spur-winged plover that using its beak eats residuals from crocodile teeth;**
  - **the removal of ectoparasites from the back of bovines by some birds that eat the parasites;**
  - **the hermit crab that live inside shells over which sea anemones live (these offer protection to the crab and gain mobility to obtain food).**

Ox-pecker on the back of hippopotamus

What is mutualism?

- Mutualism is the ecological interaction in which both participants benefit and that is obligatory for their survival.
- Mutualism is a harmonious (positive) ecological interaction.
- Mutualism is also known as symbiosis.
- Examples of mutualism are:
  - the association between microorganisms that digest cellulose and the ruminants or insects within which they live;
  - the lichens, formed by algae or cyanobacteria that make organic material for the fungi and absorb water with their help;
  - nitrifying bacteria of the genus Rhizobium that associated to leguminous plants offer nitrogen to these plants.

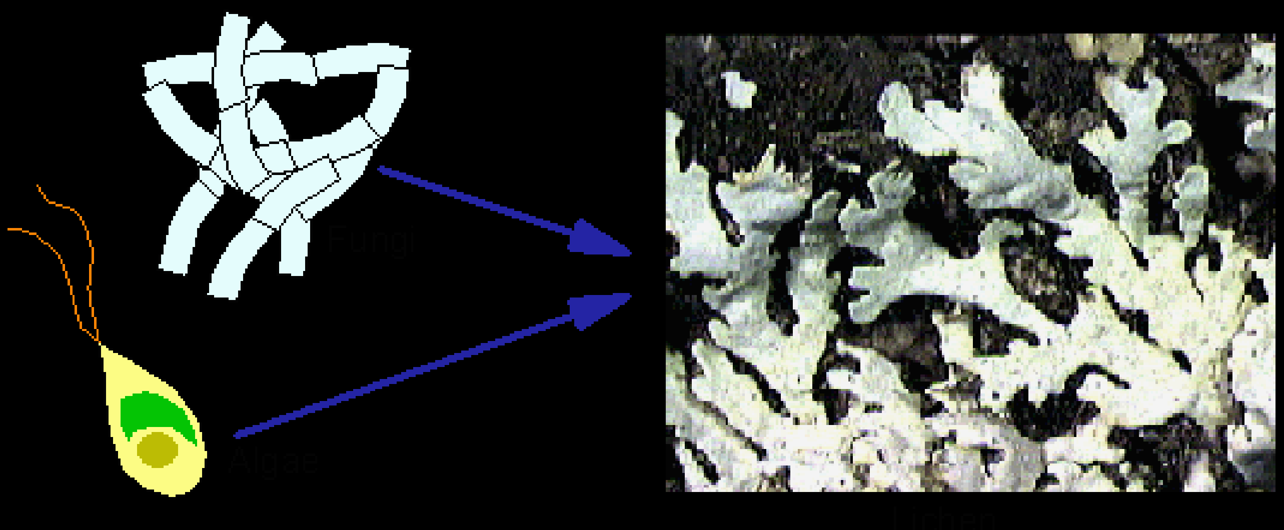
Symbiosis - Lichens

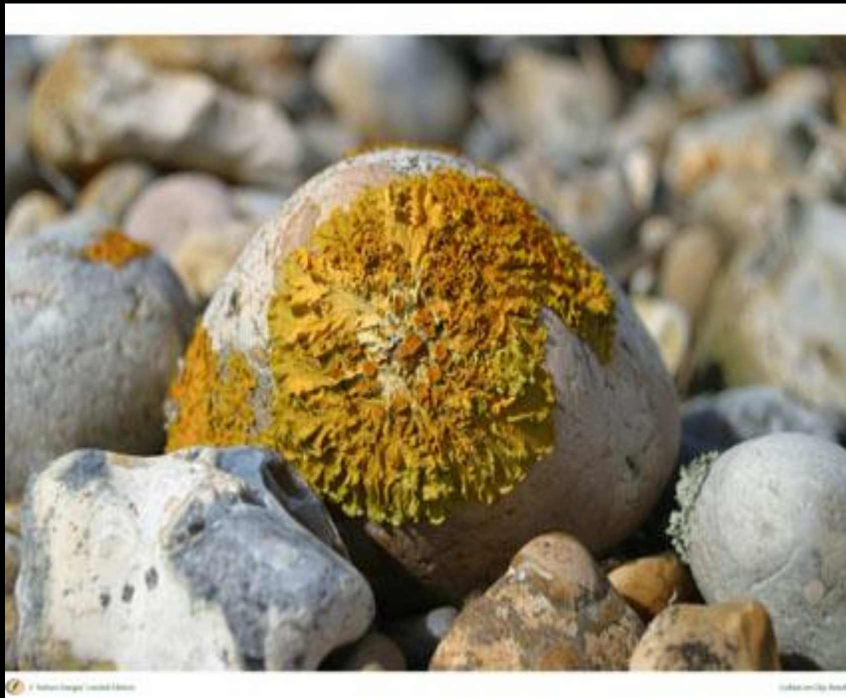
Symbiotic Relationships

Mutualism-

beneficial to both species

Ex. lichen





What is commensalism?

- Commensalism is the ecological interaction between two species where one species obtains a benefit from the relationship and the second species is unaffected by it.
- Commensalism is a harmonious (positive) ecological interaction, since none of the participants is harmed.
- An example of commensalism is the numerous bacteria that live in the skin and in the digestive tube of humans without being pathogenic or beneficial.
- They are innocuous bacteria living in commensalism with humans.

In the picture below, two barnacles are attached to the shell of a scallop. The barnacle gains a place to live and, presumably, the scallop is not harmed by the presence of the barnacles. Therefore the relationship is commensalism.

What benefits can commensalism offer to a species?

- Commensalism may involve obtainment of food (for example, the innocuous bacteria of the human gut), shelter or support (epiphytes on trees) and transportation (pollen carried by insects or birds).
- The commensalism that involves obtainment of shelter is also called inquilinism.

Symbiotic Relationships

Commensalism-

one species benefits and the other is neither harmed nor helped

Ex. orchids on a tree

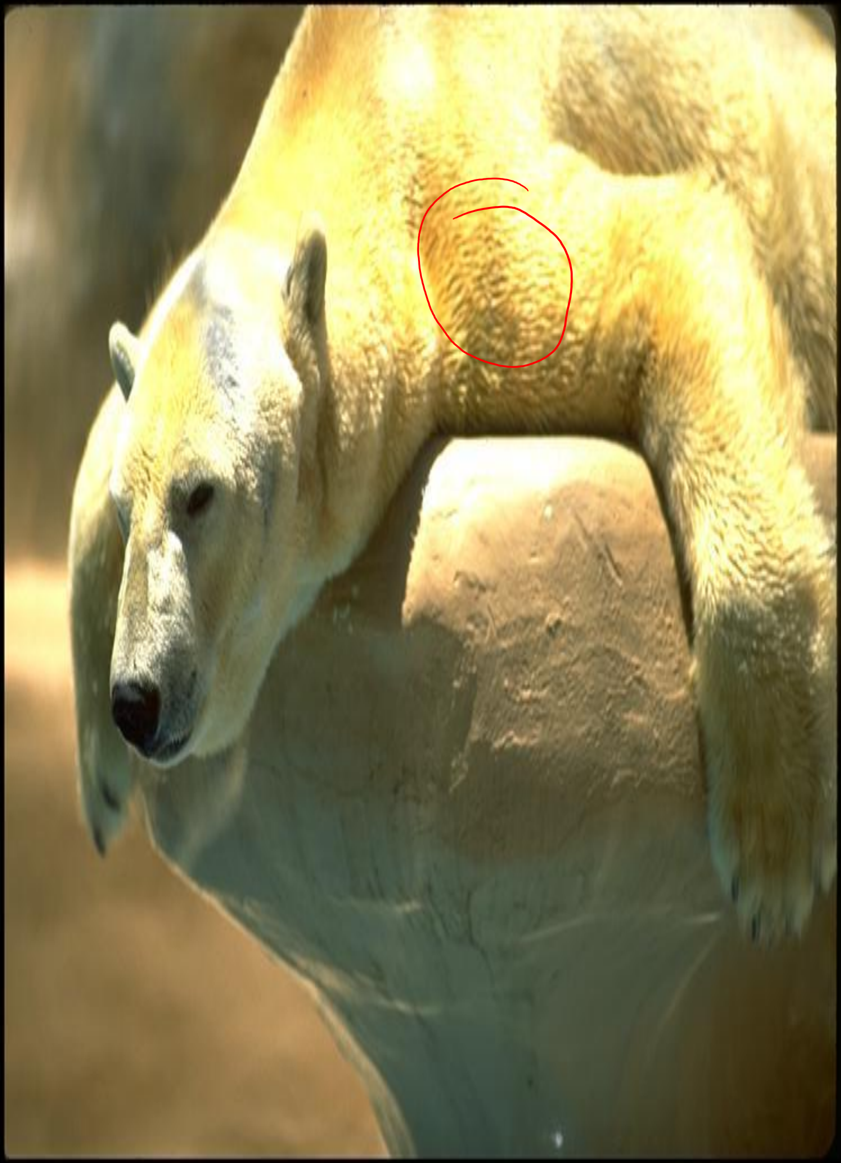
Epiphytes: A plant, such as a tropical orchid or a bromeliad, that grows on another plant upon which it depends for mechanical support but not for nutrients. Also called *xerophyte*, *air plant*.

Symbiotic Relationships

Commensalism-

one species benefits and the other is neither harmed nor helped

Ex. polar bears and cyanobacteria



What is ammensalism?

- Ammensalism is the ecological interaction in which an individual species harms other without obtaining benefit.
- Ammensalism is an inharmonious (negative) ecological interaction since one participant is harmed.
- It is a -/0 relationship.
- For example, algal blooms can lead to the death of many species of fish and other animals, however the algae do not benefit from the deaths of these individuals.
- **One of the best examples of ammensalism is the one established between humans and other species under extinction due to human actions like habitat devastation by fires, ecological accidents, leisure hunting, etc.**

Examples of Ammensalism

- **One of the best examples of ammensalism is the one established between humans and other species under extinction due to human actions like habitat devastation by fires, ecological accidents, pollution of water, etc.**

What is predatism?

- Predatism is the ecological interaction in which one individual mutilates or kills other to get food. Predatism is an inharmonious (negative) ecological interaction since one participant is harmed.

Is herbivorism a form of predatism?

- Herbivorism is the form of predatism in which first order consumers feed from producers (plants or algae). For example, birds and fruits, humans and eatable vegetable, etc. (There are proposals to consider the herbivorism of leaves a form of parasitism and the herbivorism of entire plants and seeds a form of predatism).

Symbiotic Relationships

Parasitism-

one species benefits (parasite) and the other is harmed (host)

- Parasite-Host relationship

Symbiotic Relationships

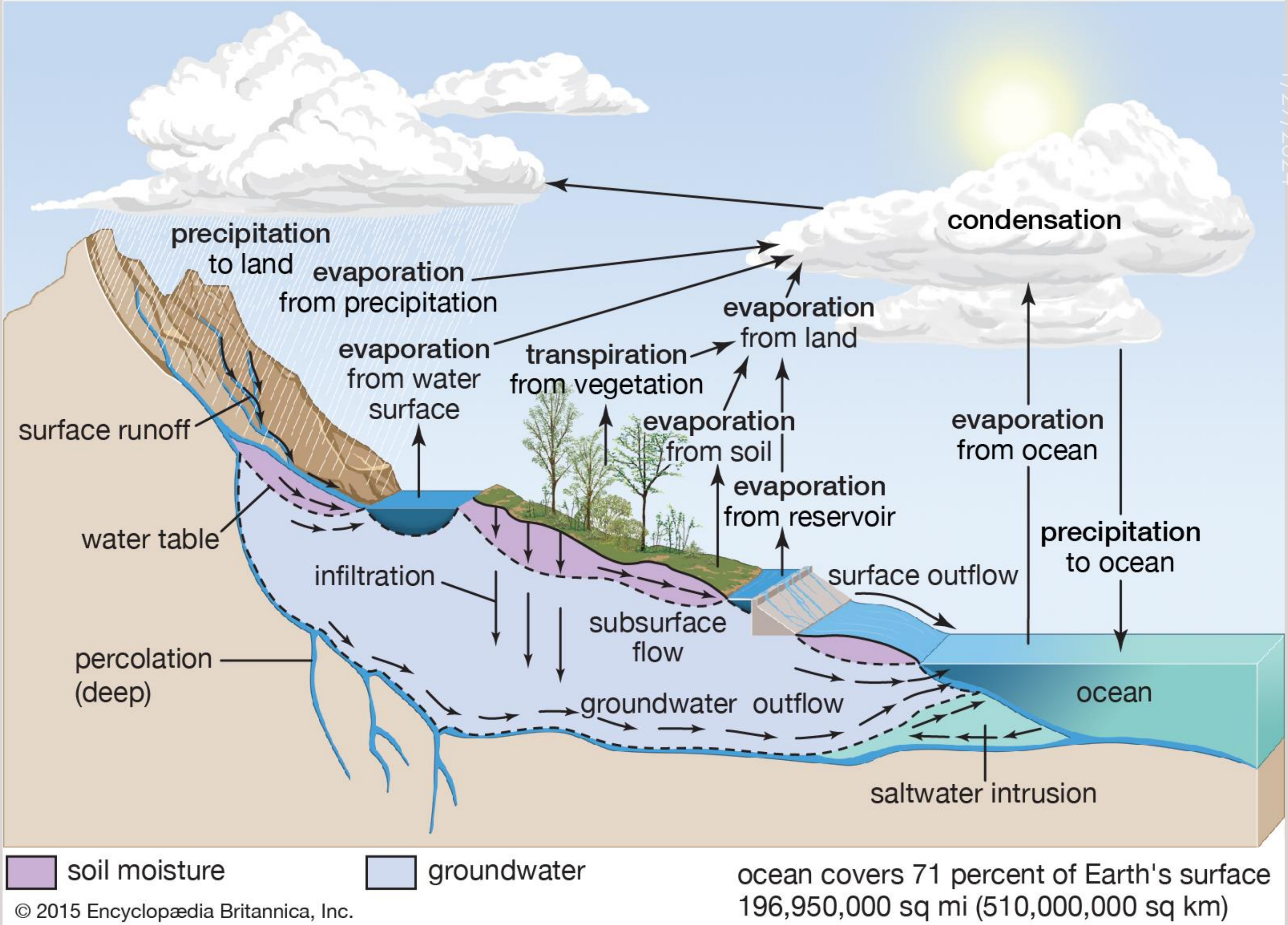
Parasitism- parasite-host

Ex. lampreys, leeches, fleas, ticks, tapeworm

Cycles of Matter or Biogeochemical cycles

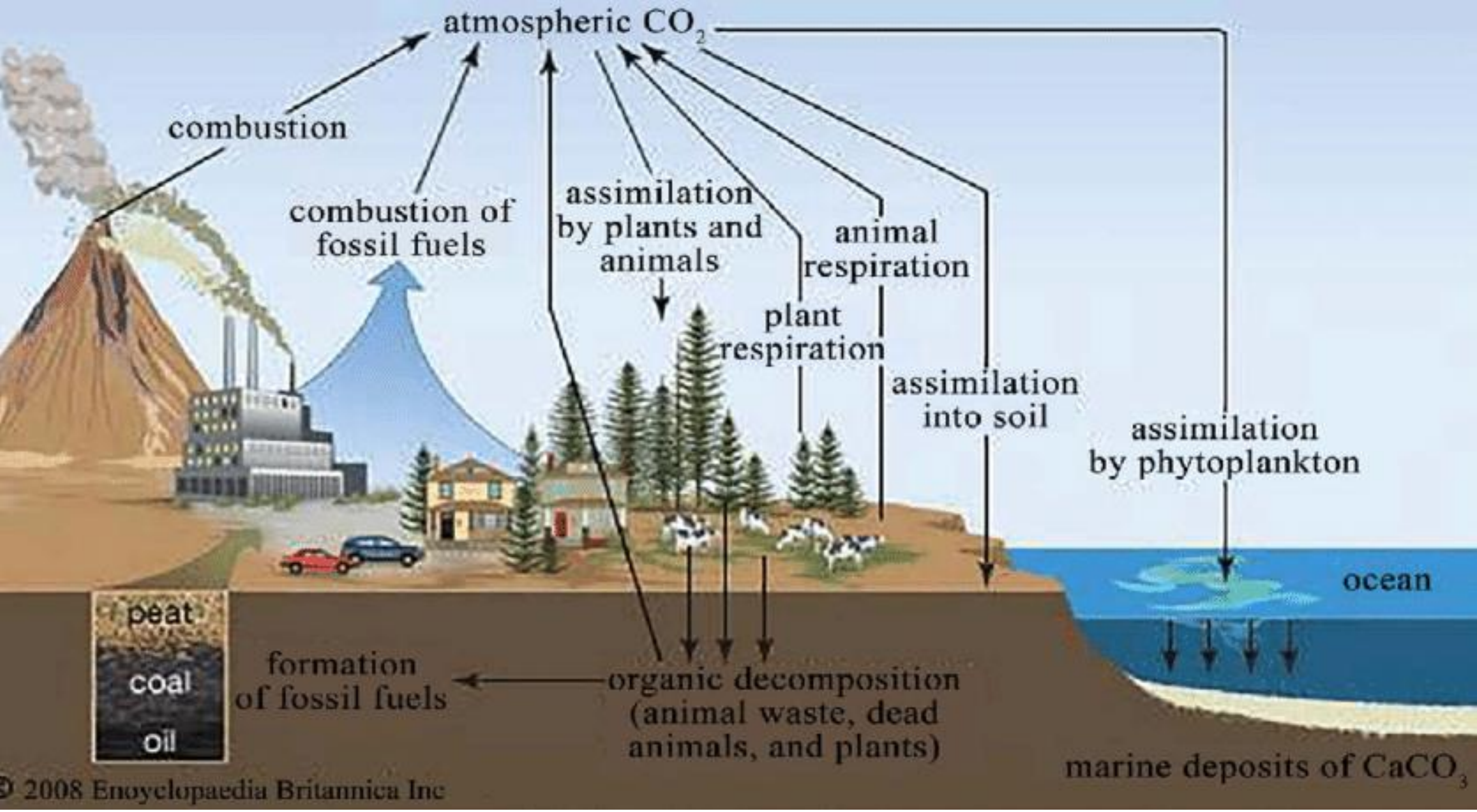
- Water cycle- Water, through evaporation and condensation, cycles through ecosystems
- Carbon Cycle- Carbon travels through ecosystems by photosynthesis and respiration
- Nitrogen Cycle- Nitrogen travels through ecosystems by chemical processes
- Phosphorus cycle:
- Sulphur cycle:

WATER CYCLE


condensation
precipitation to land
evaporation from precipitation
evaporation from water surface
transpiration from vegetation
evaporation from land
evaporation from soil
evaporation from reservoir
evaporation from ocean
precipitation to ocean
surface runoff
water table
infiltration
subsurface flow
surface outflow
percolation (deep)
groundwater outflow
ocean
saltwater intrusion
soil moisture
groundwater
ocean covers 71 percent of Earth's surface
196,950,000 sq mi (510,000,000 sq km)
© 2015 Encyclopædia Britannica, Inc.

Hydrological Cycle

1. Reservoir – oceans, air (as water vapor), groundwater, lakes and glaciers; evaporation, wind and precipitation (rain) move water from oceans to land.
2. Assimilation – plants absorb water from the ground, animals drink water or eat other organisms which are composed mostly of water.
3. Release – plants transpire, animals breathe and expel liquid wastes.



Carbon Cycle

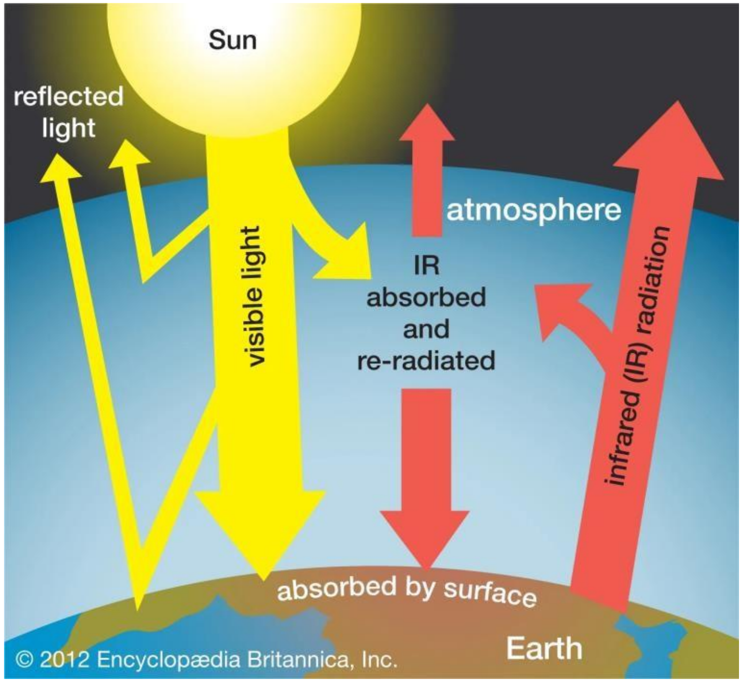
Carbon Cycle

Carbon is required for building organic compounds

1. **Reservoir** (stock)– atmosphere (as CO_2), fossil fuels (oil, coal), organic materials (for example: cellulose).
2. **Assimilation (**the absorption and digestion of food or nutrients by the body or any biological system.**)** – 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.

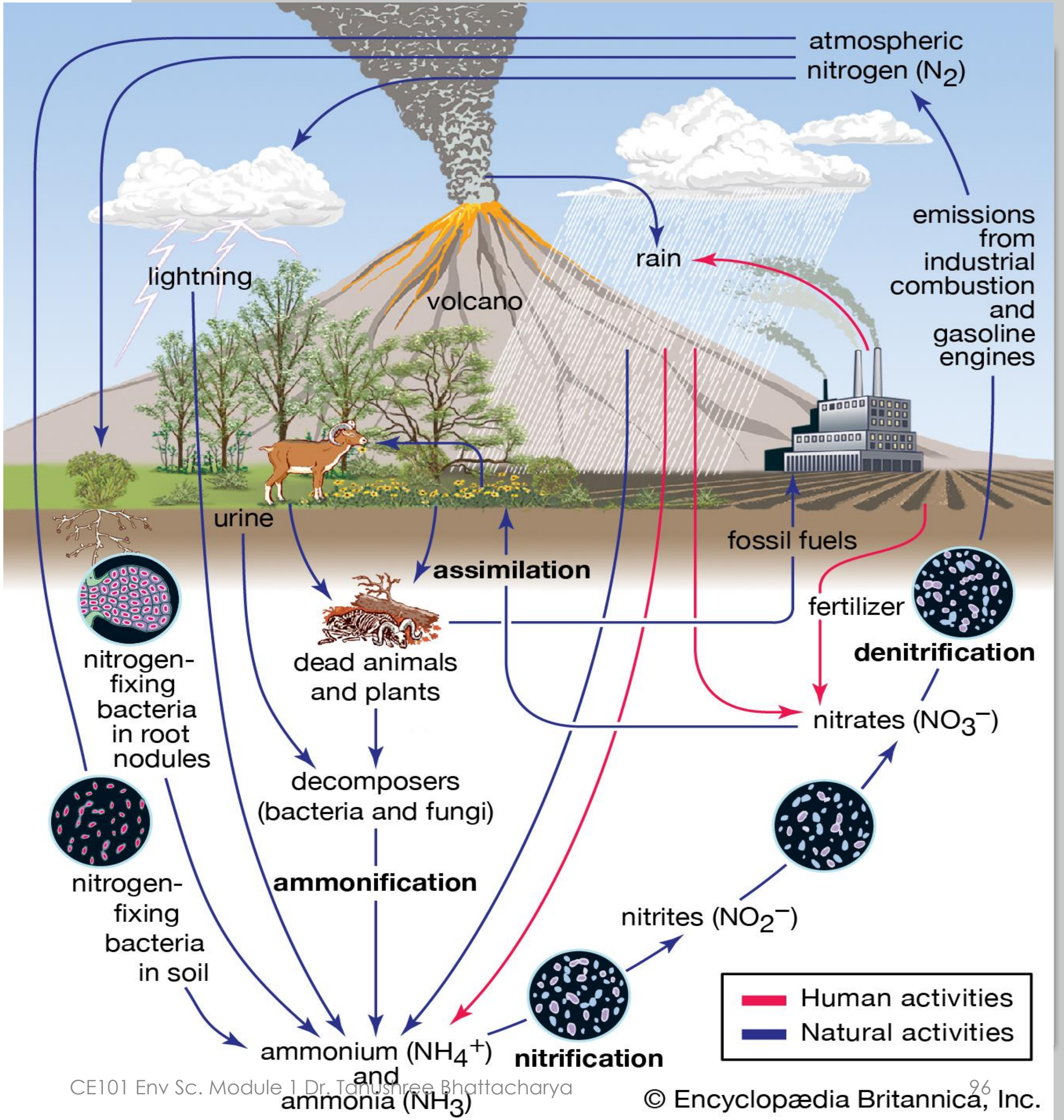
Global “Warming”

- “Global Warming” - has been strongly linked to levels of carbon dioxide in the atmosphere.
- While natural events add carbon dioxide to the atmosphere, human activities also contributes to carbon levels.
- GREENHOUSE EFFECT



https://www.britannica.com/science/greenhouse-effect

Nitrogen Cycle



Nitrogen Cycle

- The earth's atmosphere is 78% nitrogen, but in this form, it cannot be used by producers.
- Nitrogen-fixing bacteria convert nitrogen gas into nitrogen compounds that plants can absorb and use in making amino acids to build proteins.

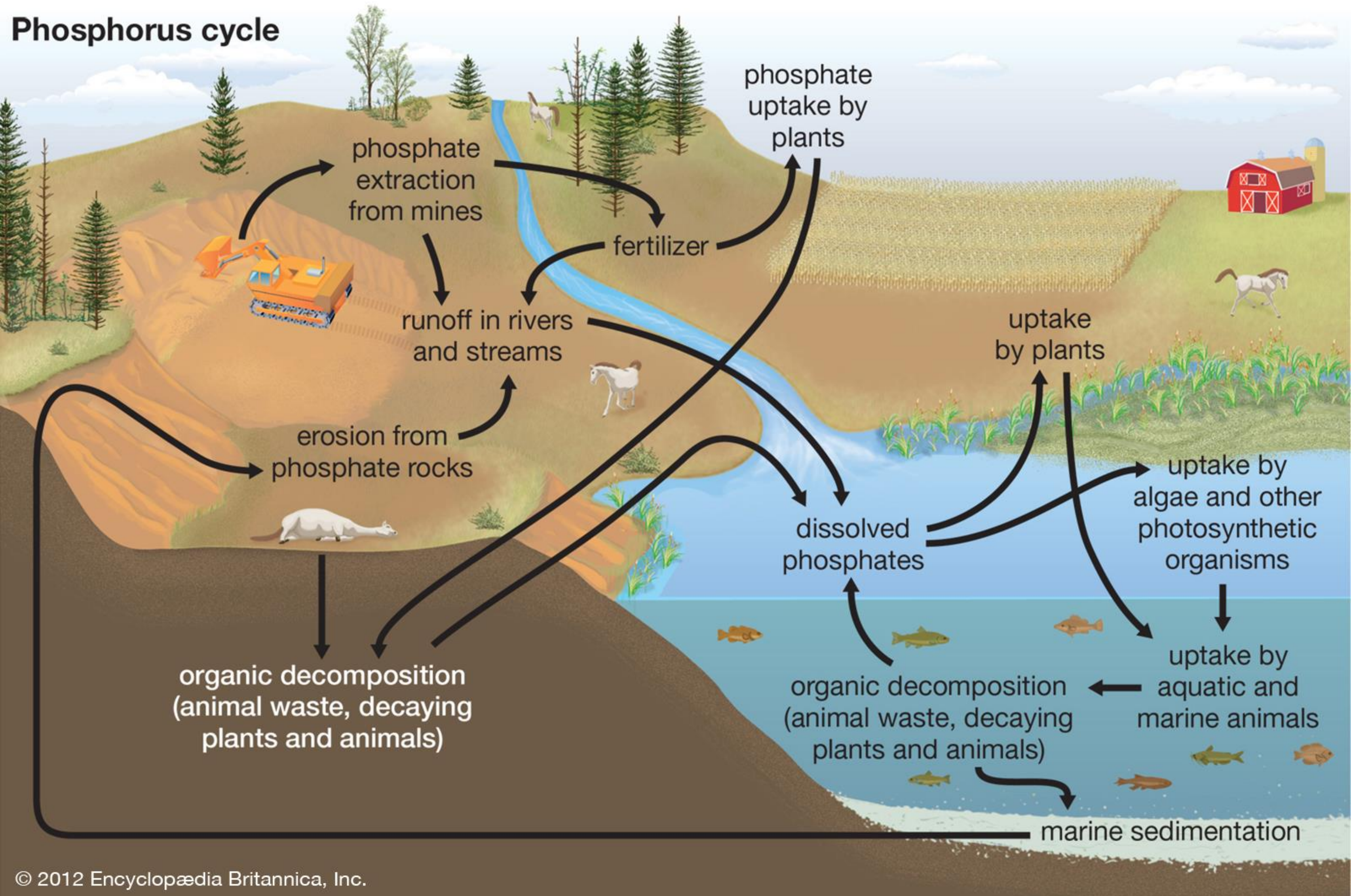
Nitrogen Cycle

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

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

   - **Nitrogen Fixation:** N_2 to NH_4^+ by nitrogen-fixing bacteria (prokaryotes in the soil and root nodules), N_2 to $N0_3^-$ by lightning and UV radiation
   - **Nitrification:** NH_4^+ to $N0_2^-$ and $N0_2^-$ to $N0_3^-$ by various nitrifying bacteria.

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


Phosphorus cycle
phosphate extraction from mines
fertilizer
phosphate uptake by plants
runoff in rivers and streams
erosion from phosphate rocks
uptake by plants
dissolved phosphates
uptake by algae and other photosynthetic organisms
organic decomposition (animal waste, decaying plants and animals)
uptake by aquatic and marine animals
organic decomposition (animal waste, decaying plants and animals)
marine sedimentation
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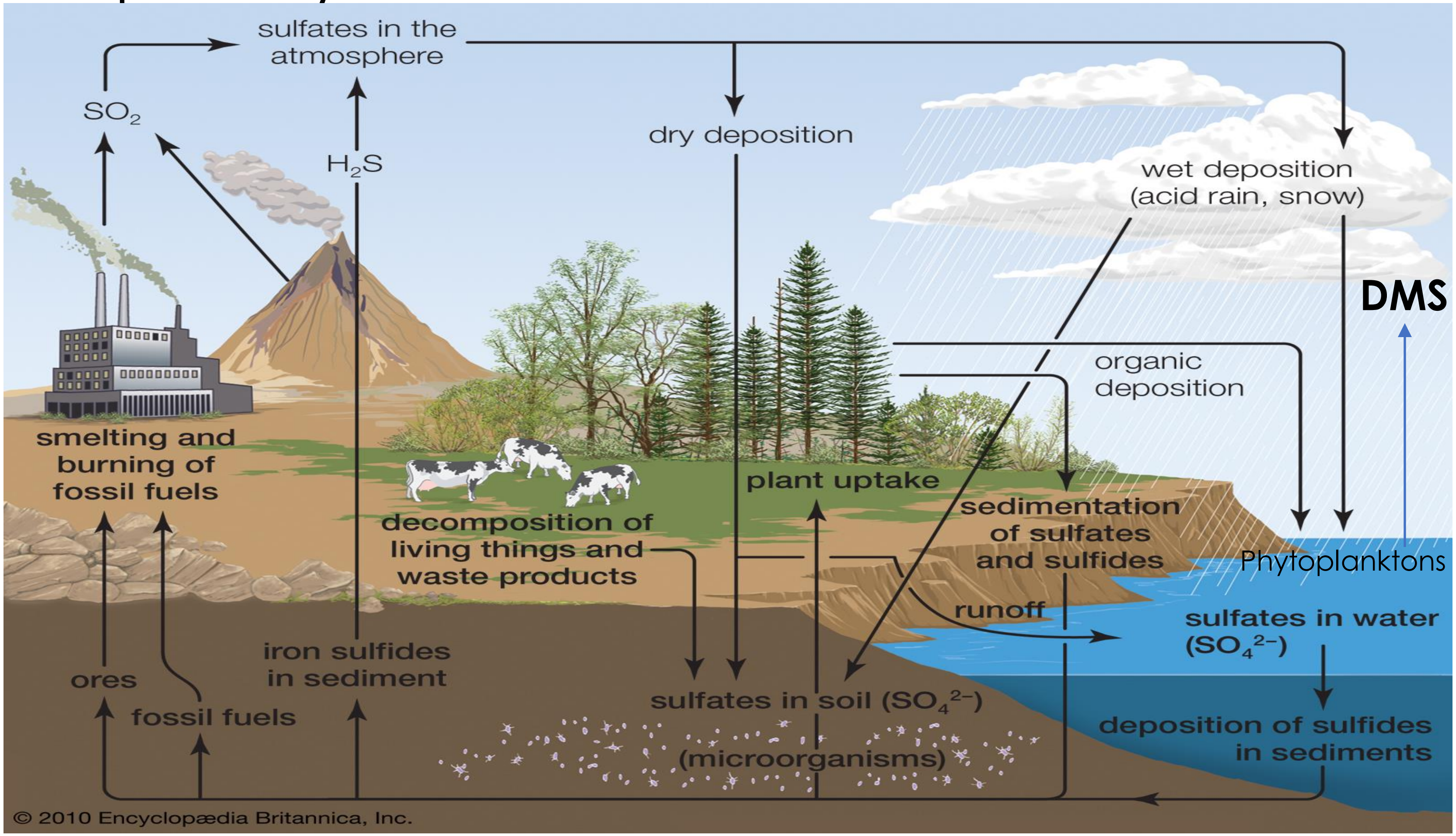
Phosphorus Cycle

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

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

Sulphur cycle



Marine phytoplankton are the primary source of DMS. A portion of the DMS is oxidized above the sea surface to sulfur dioxide (S02) resulting in acid precipitation. Aerosols of DMS which act as cloud condensation nuclei (CCN), enhancing cloud formation with potential influences on global climate

Sulfur Cycle

(Sulfur is required for the synthesis of proteins)

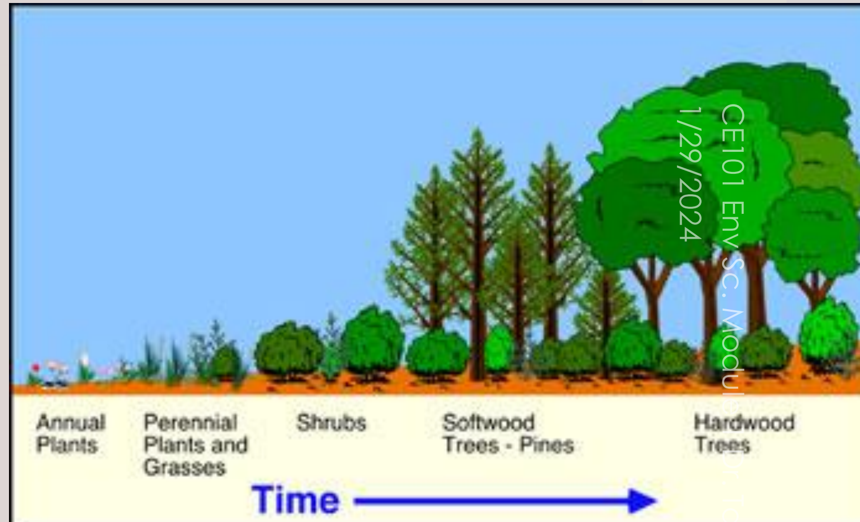
1. **Reservoir** – erosion transfers sulfur to water and soil; sediments and rocks that accumulate on ocean floors return to the surface as a result of uplifting by geological processes
2. **Assimilation** – plants absorb sulfate from soils and water; animals obtain organic sulfur when they consume plants and other animals
3. **Release** – plants and animals release sulfur when they decompose; animals excrete sulfur in their waste products

Limiting Nutrients

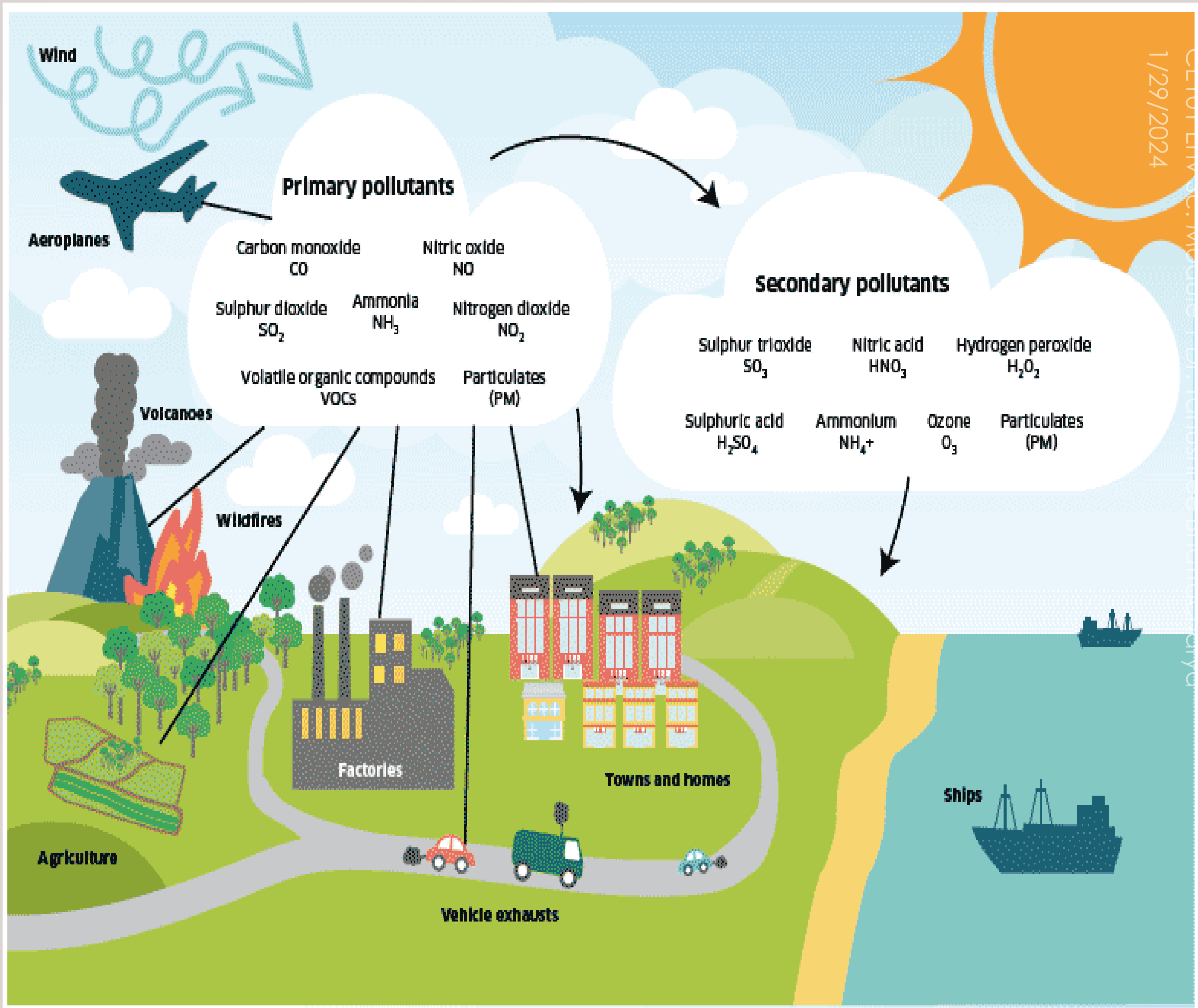
- Some nutrients are in short supply in an ecosystem
- These nutrients are called limiting nutrients
  - E.g. water in a desert ecosystem
  - Nitrogen and phosphorus in the cropland.

Ecological Succession

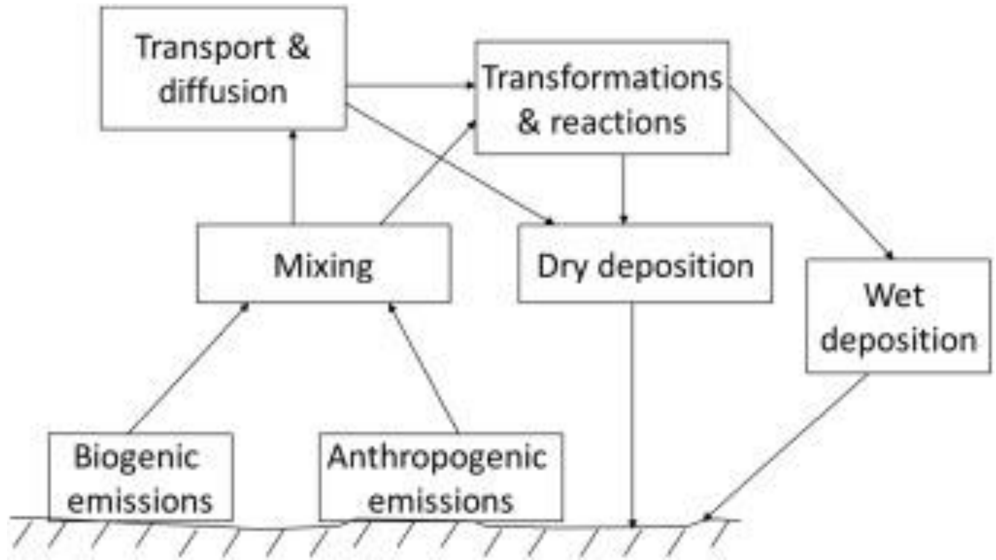
- Ecological succession is the process by which an ecosystem is established by natural process.
- A natural process by which different communities colonise the same area over a period of time in a definite sequence.
- The final community is climax community.
- There are stages, and at each stage there are distinct species
- Two types of succession:
  - Primary succession- the ecosystem suffered a total loss, and species from the outside are recolonizing
  - Secondary succession- the ecosystem was disturbed, but not totally wiped out, so its own members can recover the disturbed space.

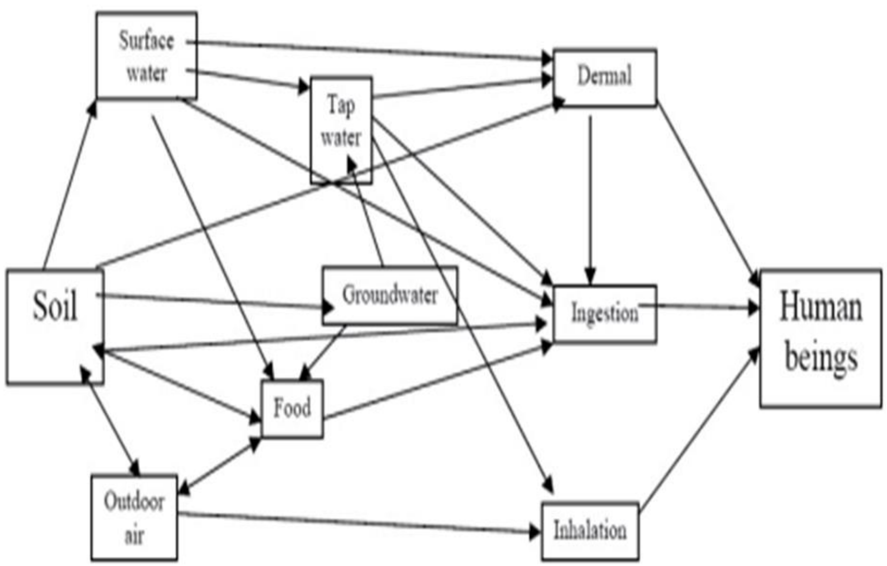


Fate of environmental pollutants



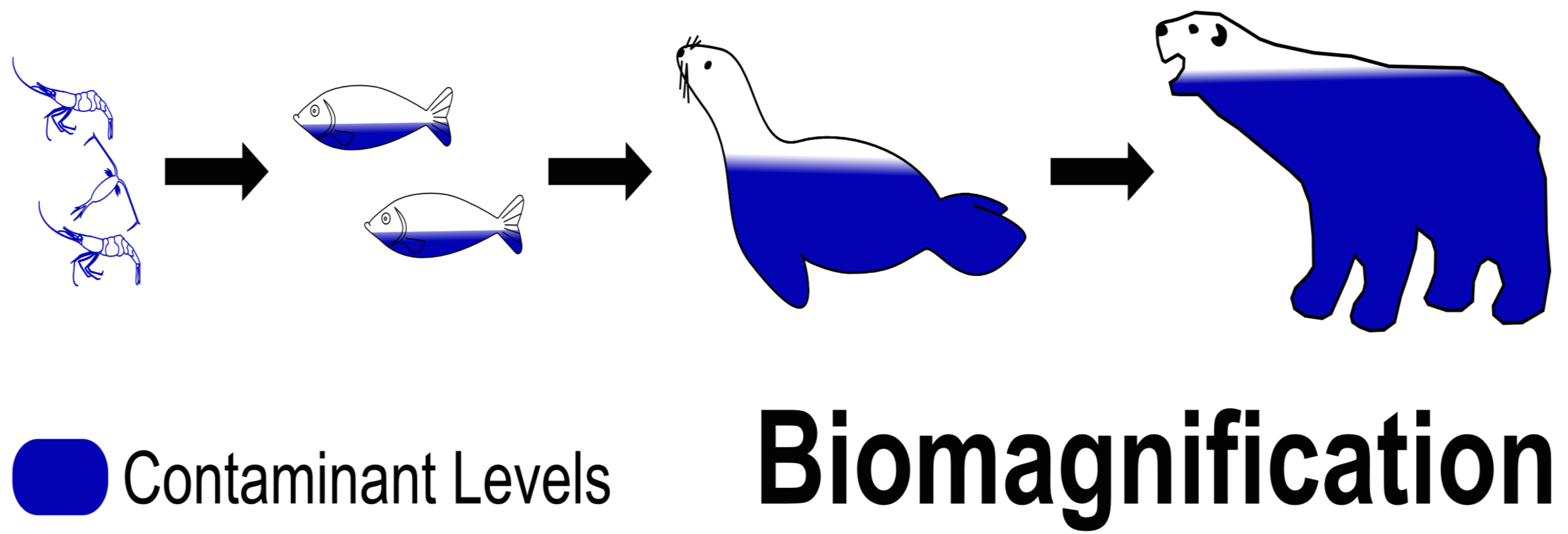
Pathways or fate of pollutants





Bioaccumulation is the gradual accumulation of substances, such as pesticides or other chemicals, in an organism. Bioaccumulation occurs when an organism absorbs a substance at a rate faster than that at which the substance is lost or eliminated by catabolism and excretion.

Biomagnification, also known as bioamplification or biological magnification, is any concentration of a toxin, such as pesticides, in the tissues of tolerant organisms at successively higher levels in a food chain.



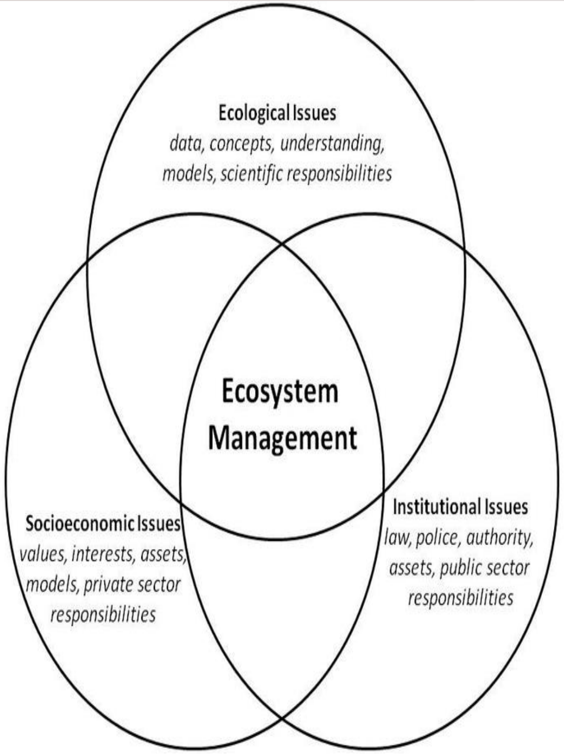
Ecosystem Management

- To address this concern of reviving Ecosystem services, IUCN promotes the sound management of ecosystems through the wider application of the Ecosystem Approach – a strategy for the integrated management of land, water and living resources that places human needs at its centre, through the Ecosystem Management Programme.

- The Ecosystem Management Programme works on five key programmatic areas for IUCN:

- Red List of Ecosystems, compiles information on the state of the world's ecosystems at different geographic scales. Its central objective is to assess the risk of ecosystem collapse.

- Ecosystem based Adaptation, where the Initiative aims to include biodiversity concerns in adaptation and mitigation polices and practice, as well as furthering natural resource management strategies that help biodiversity and people to adapt to the impacts of climate change. The Initiative coordinates Climate Change work across IUCN's programmes, regions, Commissions and member organizations.



- Cilmate change and Disaster Risk Reduction, where the programme aims to promote integration of ecosystem management, livelihoods, community vulnerability and climate change adaptation to disaster management.
- Drylands, where the programme demonstrates the high value of ecosystem services and shows how to adapt development and conservation approaches to the unique challenges of aridity and climatic uncertainty.
- Global Island Partnership, this is a voluntary partnership for all islands, regardless of size or political status, to take bold steps to build resilient and sustainable island communities through innovative partnerships.

Recent status of climate change according to IPCC report and its impact

- Anthropogenic activities have caused a temperature rise by 1 degree Celsius than the preindustrial era.
- This further may increase upto 1.5°C by 2052 if business as usual continues.
- The mean surface temp was higher during 2006-2015 by 0.75°C to 0.99°C as compared to 1850-1900.
- Intention to hold the rise in temperature upto 1.5°C rather than 2°C.
- Extreme hot days in mid-latitudes will increase upto 3°C at 1.5°C global warming.
- Extreme cold nights in high latitude will also warm up by 4.5°C at 1.5°C global warming.
- Risk associated with drought/cyclone will rise globally.
- By 2100, mean sea level will rise by 0.1m at 1.5°C global warming - coastal islands/ countries/ cities are at risk.

- Continued….
- 8% plants, 6% insects, 4% vertebrates will lose their geographic presence by 50% at 1.5°C global warming.
- 4% terrestrial ecosystem will change at 1.5°C global warming.
- Woody shrubs will encroach over tundra/boreal regions.
- 70-90% coral reef decrease at 1.5°C global warming.
- Ocean acidification will rise due to carbon dioxide concentration.
- Invasive species will increase.
- Net reduction in yield of rice, maize, wheat globally.
- Adaptation needs will be lower at 1.5°C global warming.
- RFC's - Reasons for concerns due to 1.5°C global warming
  - Priority - 1. Threatened species increase 2. Extreme weather events

Recent report, 9th August 2021

- **Faster warming**
- The report provides new estimates of the chances of crossing the global warming level of **1.5°C in the next decades**, and finds that unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limiting warming to close to 1.5°C or even 2°C will be beyond reach.
- The report shows that emissions of greenhouse gases from human activities are responsible for **approximately 1.1°C of warming since 1850-1900,** and finds that averaged over the next 20 years, global temperature is expected to reach or exceed **1.5°C of warming**. This assessment is based on improved observational datasets to assess historical warming, as well progress in scientific understanding of the response of the climate system to human-caused greenhouse gas emissions.
- "This report is a reality check," said IPCC Working Group I Co-Chair Valérie Masson-Delmotte. "We now have a much clearer picture of the past, present and future climate, which is essential for understanding where we are headed, what can be done, and how we can prepare."

- **Every region facing increasing changes**
- Many characteristics of climate change directly depend on the level of global warming, but what people experience is often very different to the global average. For example, **warming over land is larger than the global average, and it is more than twice as high in the Arctic**.
- "Climate change is already affecting every region on Earth, in multiple ways. The changes we experience will increase with additional warming," said IPCC Working Group I Co-Chair Panmao Zhai.
- The report projects that in the coming decades climate changes will increase in all regions. For 1.5°C of global warming, there will be increasing **heat waves, longer warm seasons and shorter cold seasons.** At 2°C of global warming, heat extremes would more often reach **critical tolerance thresholds for agriculture** and health, the report shows.
- But it is not just about temperature. Climate change is bringing multiple different changes in different regions – which will all increase with further warming. These include **changes to wetness and dryness, to winds, snow and ice, coastal areas and oceans**. For example: **Climate change is intensifying the water cycle. This brings more intense rainfall and associated flooding, as well as more intense drought in many regions.**
- Climate change is affecting rainfall patterns. In high latitudes, precipitation is likely to increase, while it is projected to decrease over large parts of the subtropics. **Changes to monsoon precipitation are expected, which will vary by region.**

Continued….

- **Coastal areas will see continued sea level rise throughout the 21st century,** contributing to more frequent and severe coastal flooding in low-lying areas and coastal erosion. Extreme sea level events that previously occurred once in 100 years could happen every year by the end of this century.
- Further warming will **amplify permafrost thawing, and the loss of seasonal snow cover, melting of glaciers and ice sheets, and loss of summer Arctic sea ice.**
- Changes to the ocean, including warming, more frequent marine heatwaves, ocean acidification, and reduced oxygen levels have been clearly linked to human influence. **These changes affect both ocean ecosystems and the people that rely on them, and they will continue throughout at least the rest of this century.**
- For cities, some aspects of climate change may be amplified, including heat (since urban areas are usually warmer than their surroundings), flooding from heavy precipitation events and sea level rise in coastal cities.
- For the first time, the Sixth Assessment Report provides a more detailed regional assessment of climate change, including a focus on useful information that can inform risk assessment, adaptation, and other decision-making, and a new framework that helps translate physical changes in the climate – **heat, cold, rain, drought, snow, wind, coastal flooding and more – into what they mean for society and ecosystems**.