Introduction to Environmental Microbiology

Course 1

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Microorganism & Microbiology

Microorganism

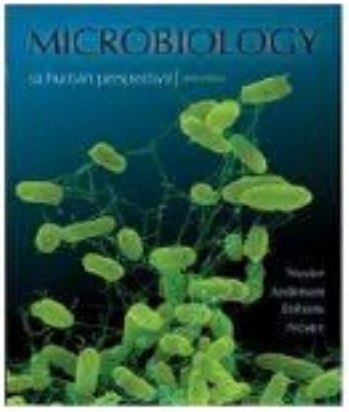
- Living things which individually are too small to be seen with the naked eye.

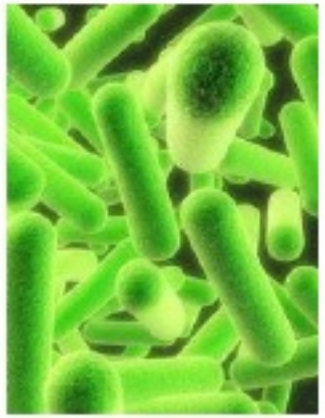
- All of the following may be considered microorganisms:
  - bacteria (eubacteria, archaebacteria)
  - fungi (yeasts, molds)
  - protozoa
  - microscopic algae
  - viruses
  - various parasitic worms

Microbiology

- Study of microorganisms
- Foundation of modern biotechnology
- Among the many specialized fields of microbiology

  -Virology, Mycology, Bacteriology, Immunology, Microbial Ecology, Biotechnological Microbiology, Environmental Microbiology, Food Microbiology, Forensic Microbiology, Molecular Biology





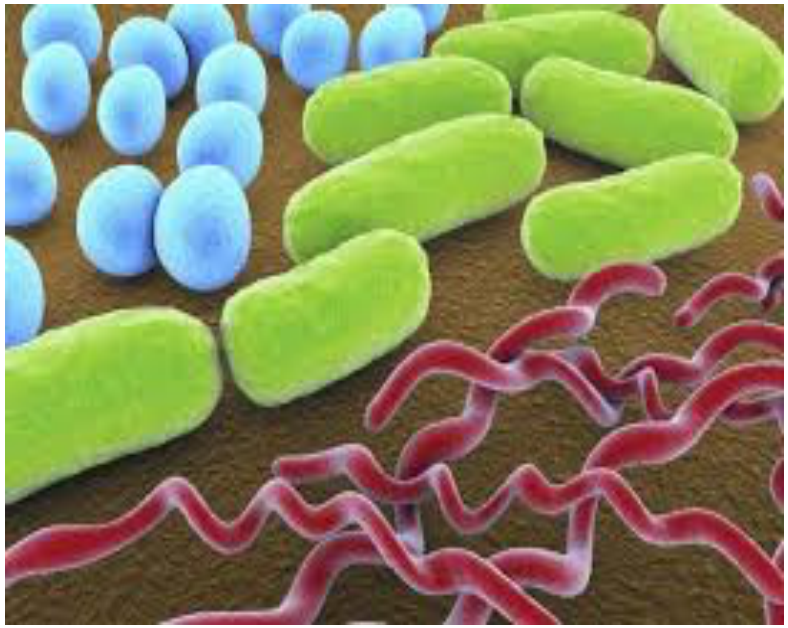
Microorganism

- Too small
- Germ-rapidly growing cell
- Has habitat
- Live in population (not alone)
- Communities are either swimming freely or attached to a surface (biofilm)
- Interact between communities; may either be

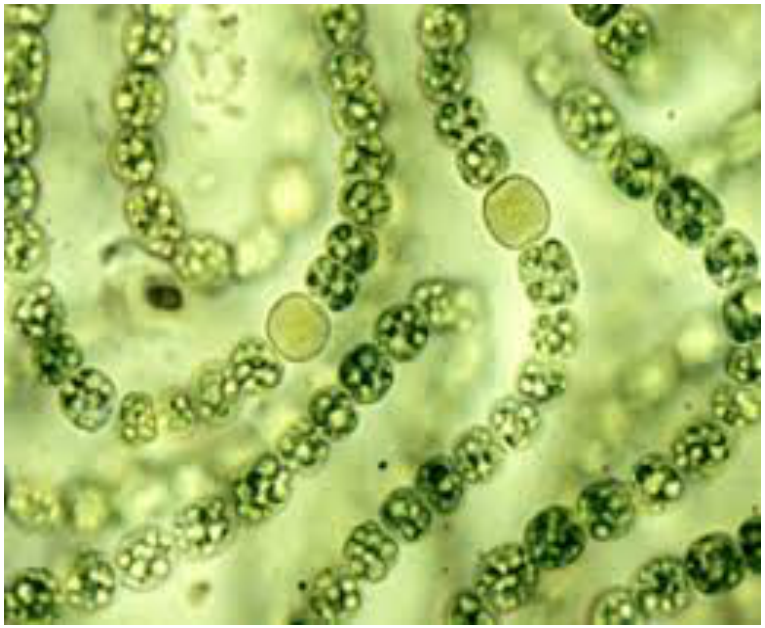
  - harmful (because of waste product)

  - beneficial (cooperative feeding efforts-waste→nutrient)

Prokaryotes

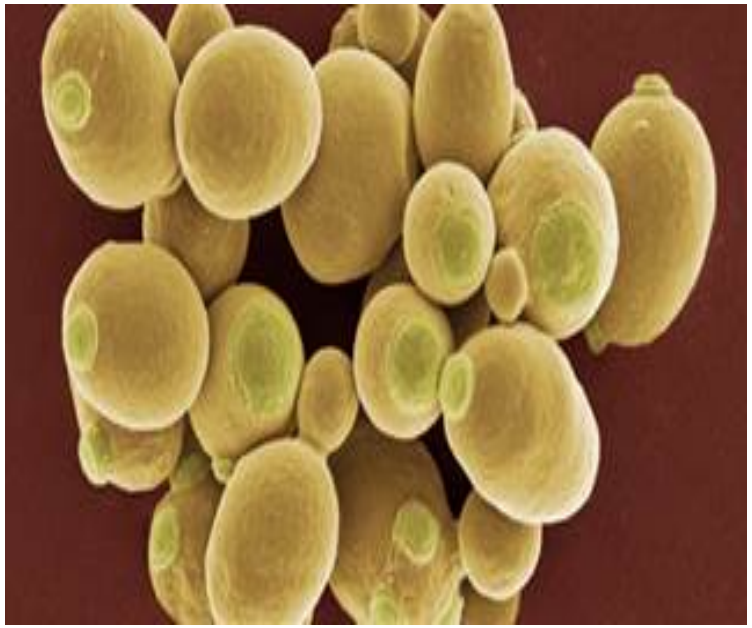


Bacteria (coccus and bacille)



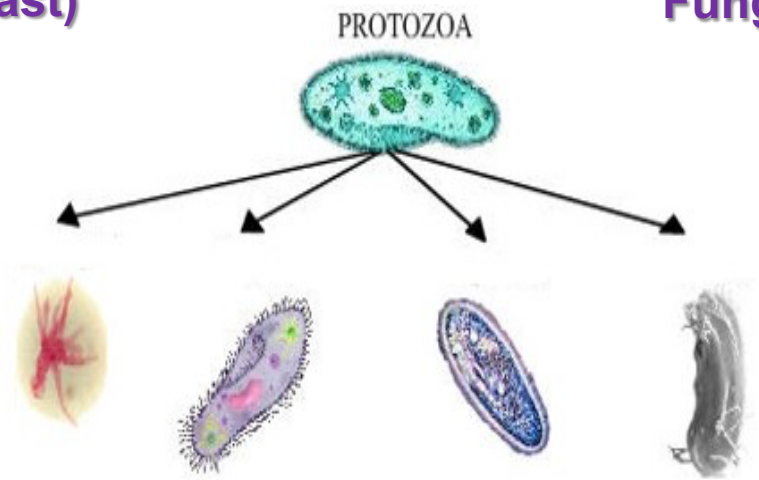
Cyanobacteria

Eukaryotes



Fungus(Yeast)

Fungus (Mold)



History of Microbiology

ROBERT HOOKE

One of the most important discoveries of biology occurred in 1665, with the help of a crude microscope, when Robert Hooke stated that life's smallest structural units were cells.

ANTONY VAN LEEUWENHOEK

- First to observe living microbes
- His single-lens magnified **50-300X magnification**
- Between 1674-1723 he wrote series of papers describing his observations of bacteria, algae, protozoa, and fungi **(Animalcules)**

History

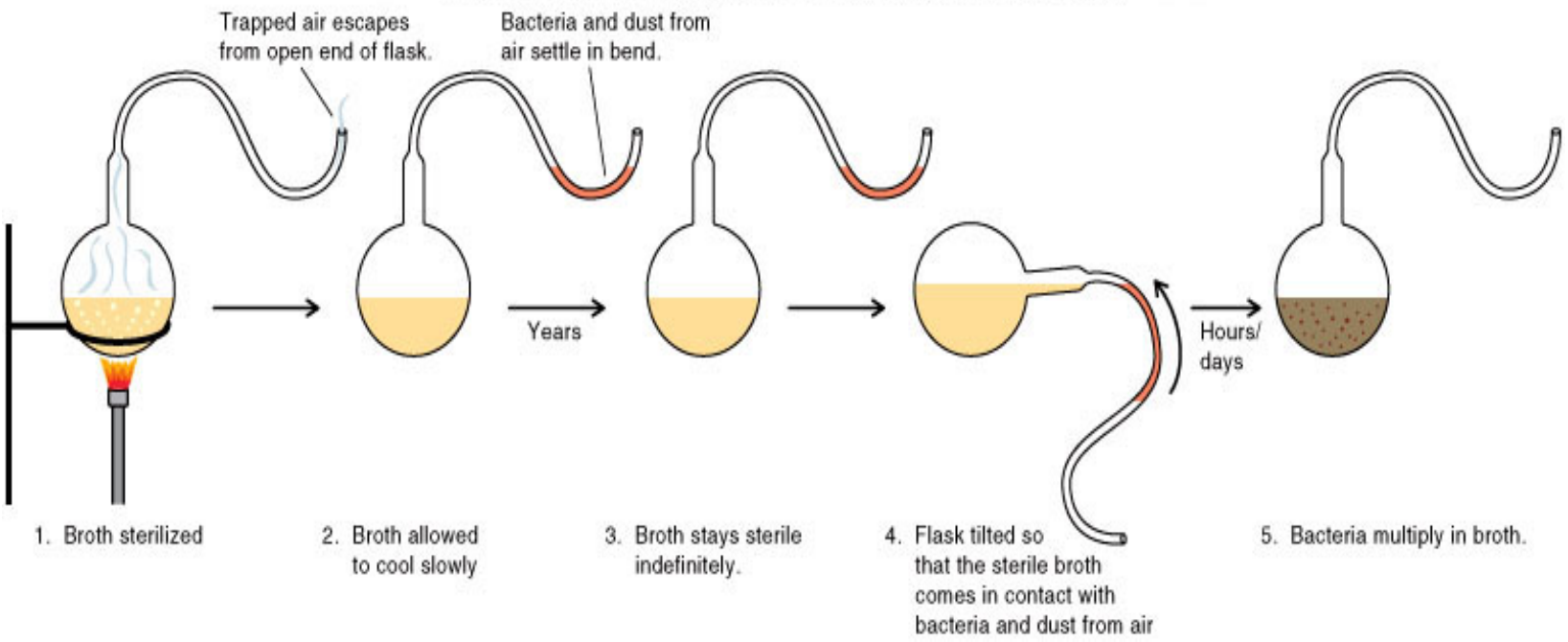
- 1796 – First vaccine (smallpox)
  Edward Jenner

History

- 1885 - Vaccine against Rabies

Louis Pasteur

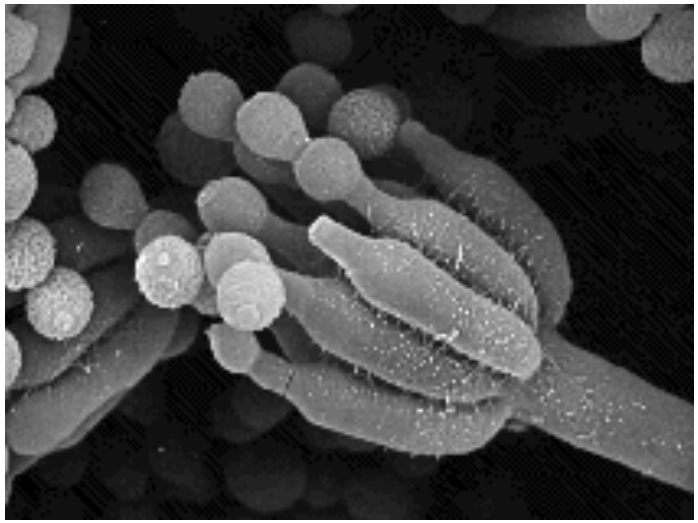
PASTEUR'S EXPERIMENT



trapped airborne organisms in cotton; he also heated the necks of flasks, drawing them out into long curves, sterilized the media, and left the flasks open to the air.

In this way Pasteur disproved the theory of spontaneous generation

History



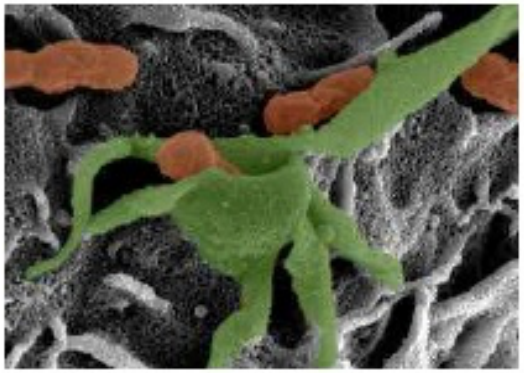
- 1929 Discovery of Penicillin
  (first antibiotic)
  Alexander Fleming

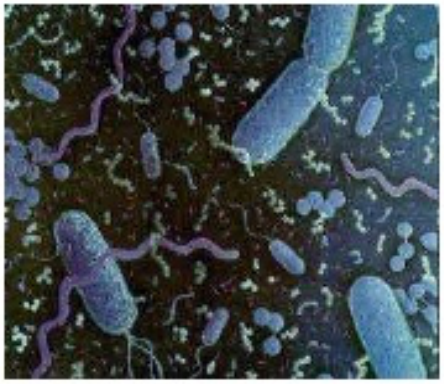
Microorganism & Microbiology cont'd

Two main themes involved in Microbiology

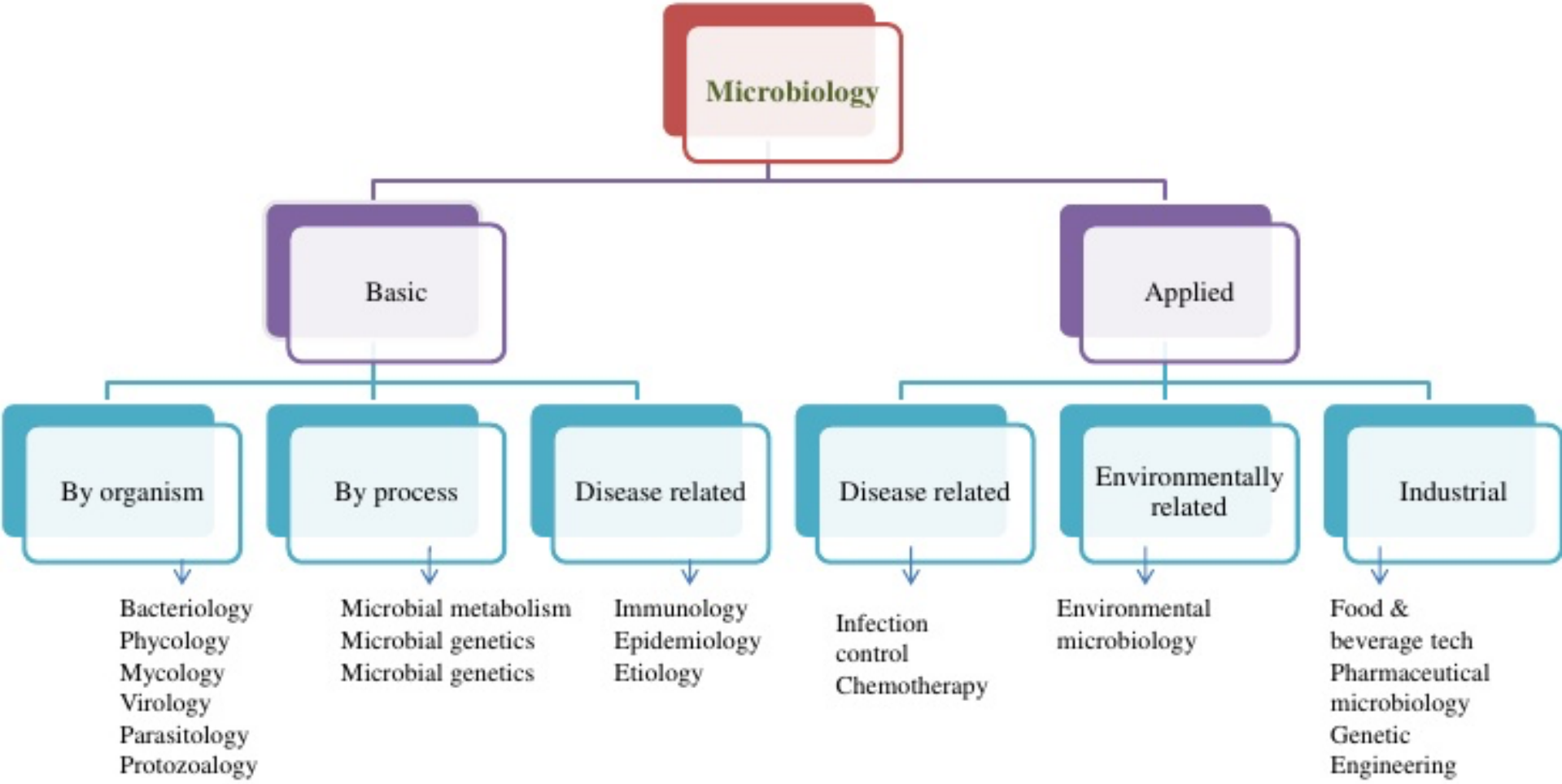
1- Basic- cellular processes

2-Applied- concerning agriculture, industry and health





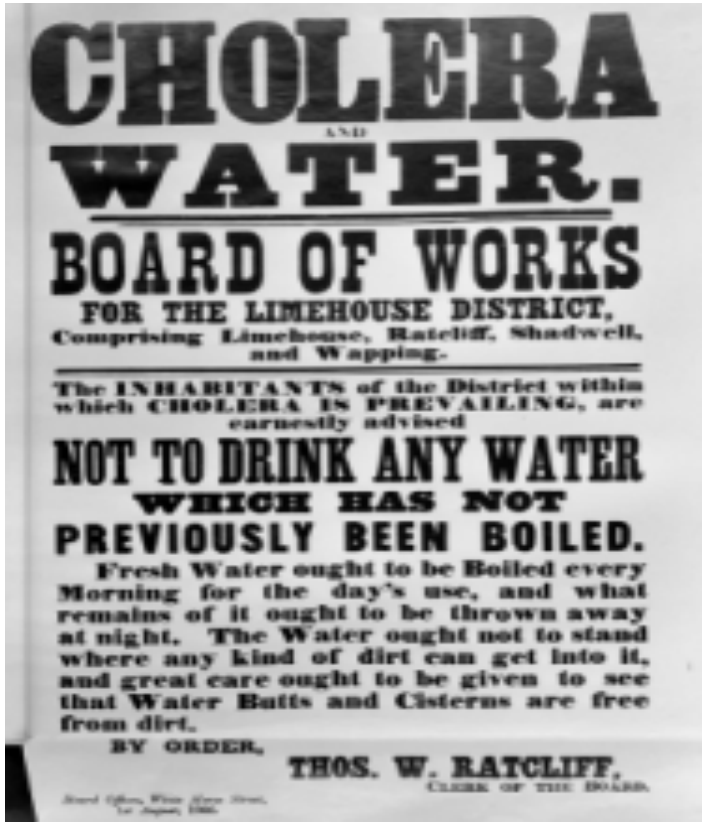
Themes in Microbiology and its field



Introduction

- Environmental microbiology is the study of the beneficial and harmful effects of microbes on the environment.
- This discipline includes microorganisms in
- water
- soil
- air

Cholera Outbreak in London in 1854



CHOLERA
AND
WATER.

BOARD OF WORKS
FOR THE LIMEHOUSE DISTRICT,
Comprising Limehouse, Ratcliff, Shadwell, and Wapping.

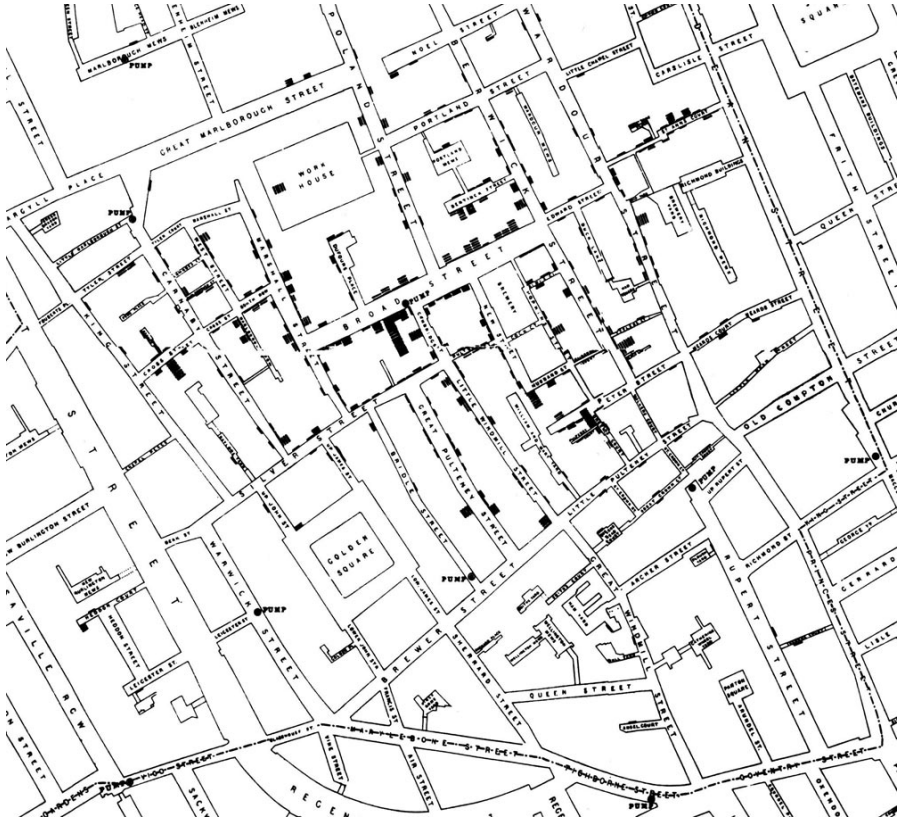
The INHABITANTS of the District within which CHOLERA IS PREVAILING, are earnestly advised

NOT TO DRINK ANY WATER
WHICH HAS NOT
PREVIOUSLY BEEN BOILED.

Fresh Water ought to be Boiled every Morning for the day's use, and what remains of it ought to be thrown away at night. The Water ought not to stand where any kind of dirt can get into it, and great care ought to be given to see that Water Butts and Cisterns are free from dirt.

BY ORDER,

THOS. W. RATCLIFF,
CLERK OF THE BOARD.



Snow's Map for water supplies

Introduction:

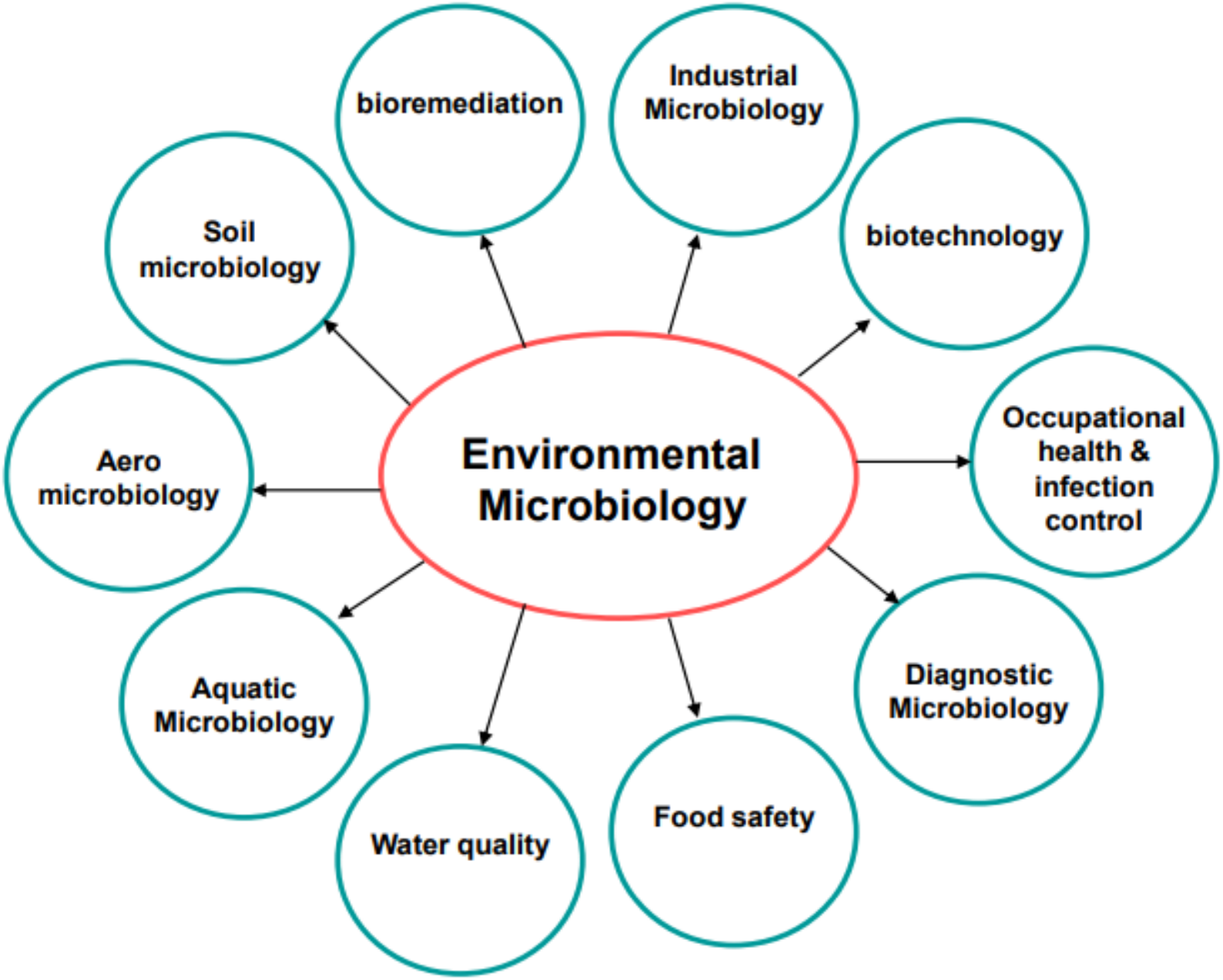
Definition

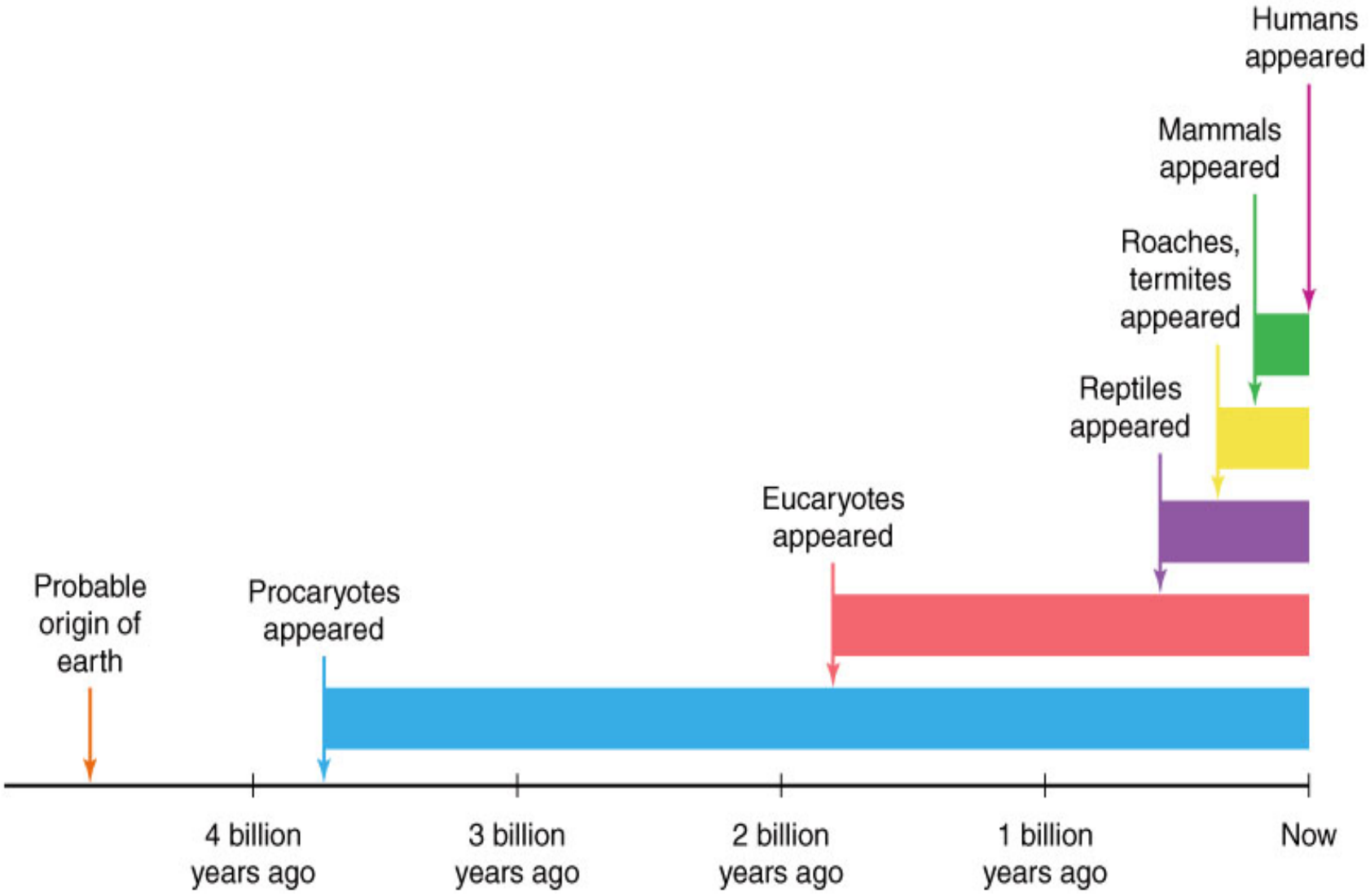
Environmental microbiology is the study of microbial interactions microbial processes and microbial communities in the environment.

Environmental microbiology includes:

Study of

- Structure and activities of microbial communities.
- Microbial interaction and interaction with macroorganisims.
- Population biology of microorganisms.
- Microbial communities genetic and evolutionary processes.
- Element cycles and biogeochemical processes.
- Microbial life in extreme and unusual environment.


Environmental Microbiology
bioremediation
Industrial Microbiology
biotechnology
Occupational health & infection control
Diagnostic Microbiology
Food safety
Water quality
Aquatic Microbiology
Aero microbiology
Soil microbiology



Evolutionary Timeline: Bacteria appeared 3.5 billion years ago

- **Soil Microbiology**
- **Billions of organisms in soil**
  - **Over 80 % are bacteria**
    - **Millions in each gram of soil**
  - **Most are in the top few centimeters of soil**
  - **Biomining**
  - **Many antibiotics come from Actinomycetes**
    - **Streptomycin, tetracycline**
  - **Bacterial populations estimated by plate count**

- **Biogeochemical cycles for carbon, nitrogen, sulfur and phosphorus are vital for life**
  - **Elements oxidized and reduced by microbes to meet their metabolic need**
  - **Recycles elements into the environment**
    - **Production**
    - **Consumption**
    - **Decomposition**

Abundance of soil organisms

Organism	Number per gram soil (~1 tsp)	Biomass[1] (lbs per acre 6")
Earthworms	-	100 - 1,500
Mites	1-10	5 - 150
Nematodes	10 - 100	10 - 150
Protozoa	up to 100 thousand	20 - 200
Algae	up to 100 thousand	10 - 500
Fungi	up to 1 million	1,000 - 15,000
Actinomycetes	up to 100 million	400 - 5,000
Bacteria	up to 1 billion	400 - 5,000

[1] Biomass is the weight of living organisms

Aquatic microorganism

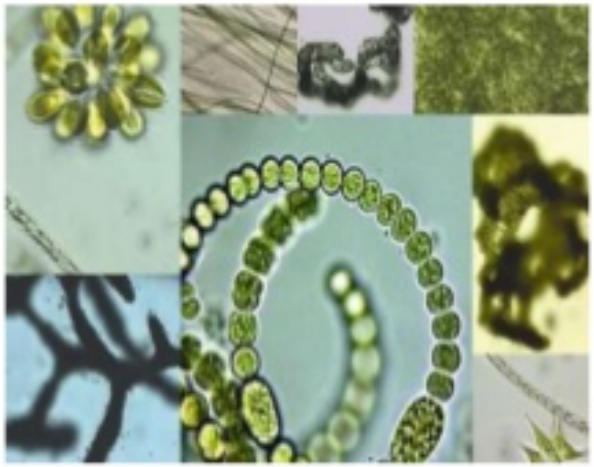
- Bacteria
- viruses
- fungi

These are widely distributed throughout aquatic environments. They can be found in fresh water rivers, lakes, and streams, in the surface waters and sediments of the world's oceans, and even in hot springs. They have even been found supporting diverse communities at **hydrothermal vents** in the depths of the oceans.

Aquatic microorganism

Aquatic microorganisms can be found living in environments where there are extremes in other physical parameters such as:

- **Pressure**
- **Sunlight**
- **Organic substances**
- **Dissolved gases**
- **And water clarity.**



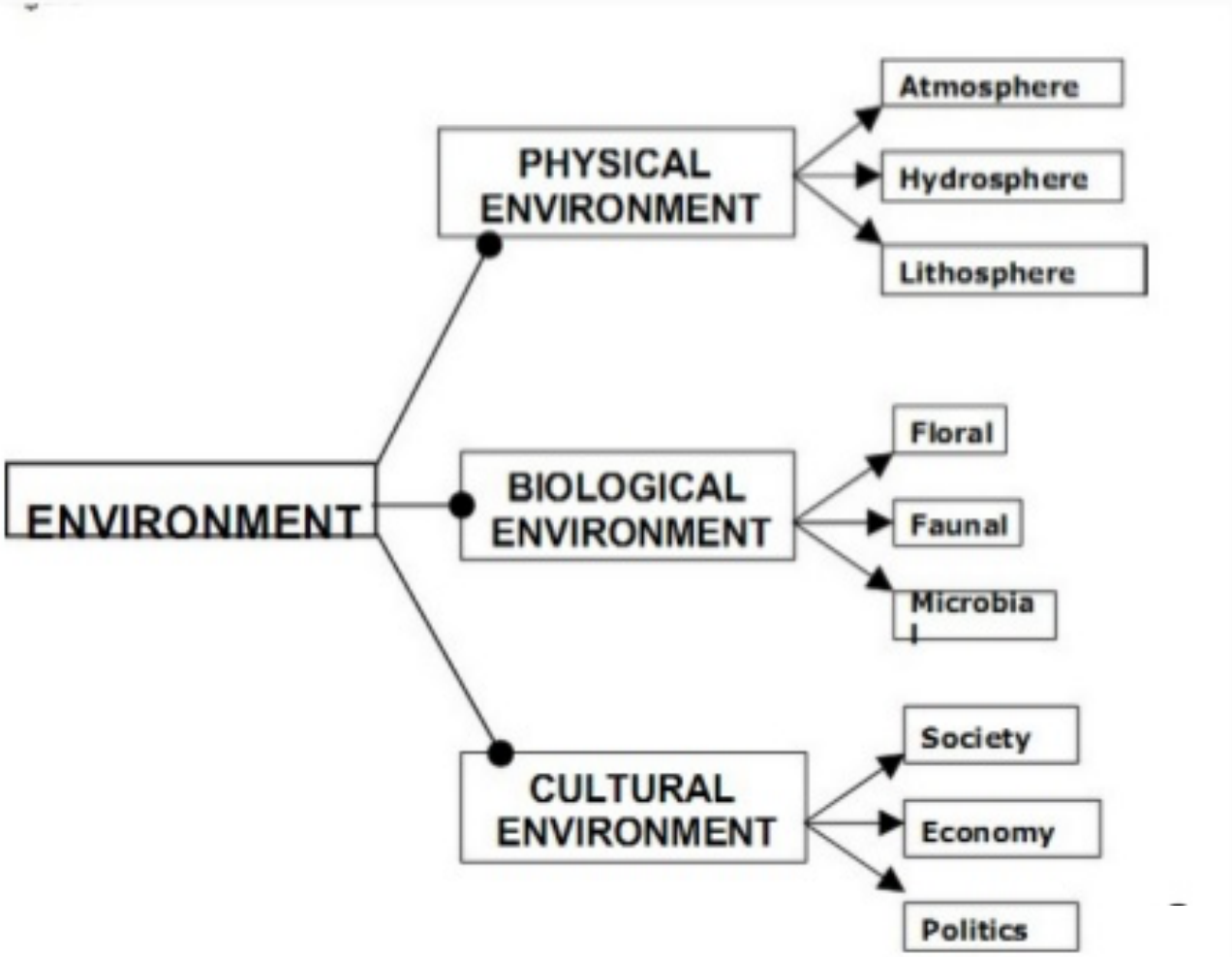
Microorganisms in Air

- There are soil microorganisms up to 100-150 meters in height in the air we breathe.
- These microorganisms live in the air for a while according to their resistance to sunlight and drying
- These can include microorganisms (pathogens) that sometimes cause disease while not causing the disease in general

Environment-Definition

- **Environment involves all physical, chemical, biological and social factors that affects;**
  - living organisms including human beings
  - Their actions during their lifetimes

Classification of Environment



Types of Environment

- Natural Environment
  - The environment that comes in its existence by its own or naturally.
  - Without interference of humans
  - It operates through self regulating mechanism(Homeostasis)
- Man-made Environment(Anthropogenic)
  - Env. Is modified by human activity
  - Scientific technology which is result of human brain is decorating the natural environment.

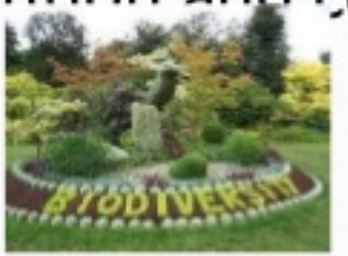
Importance of Environmental science

- Solving the issues related to environment
  - Pollution
  - Over exploitation of non-renewable sources
  - Food problem
  - Sustainable development
  - Maintain the ecological balance
  - Eco friendly product
  - Conservation of natural sources
  - Understand the food chain
  - Inculcating attitude and value
  - Encouraging Environment protection

Scope of Environmental Science

- Natural Resources
- Ecology
- Biodiversity and its conservation
- Environment pollution and control

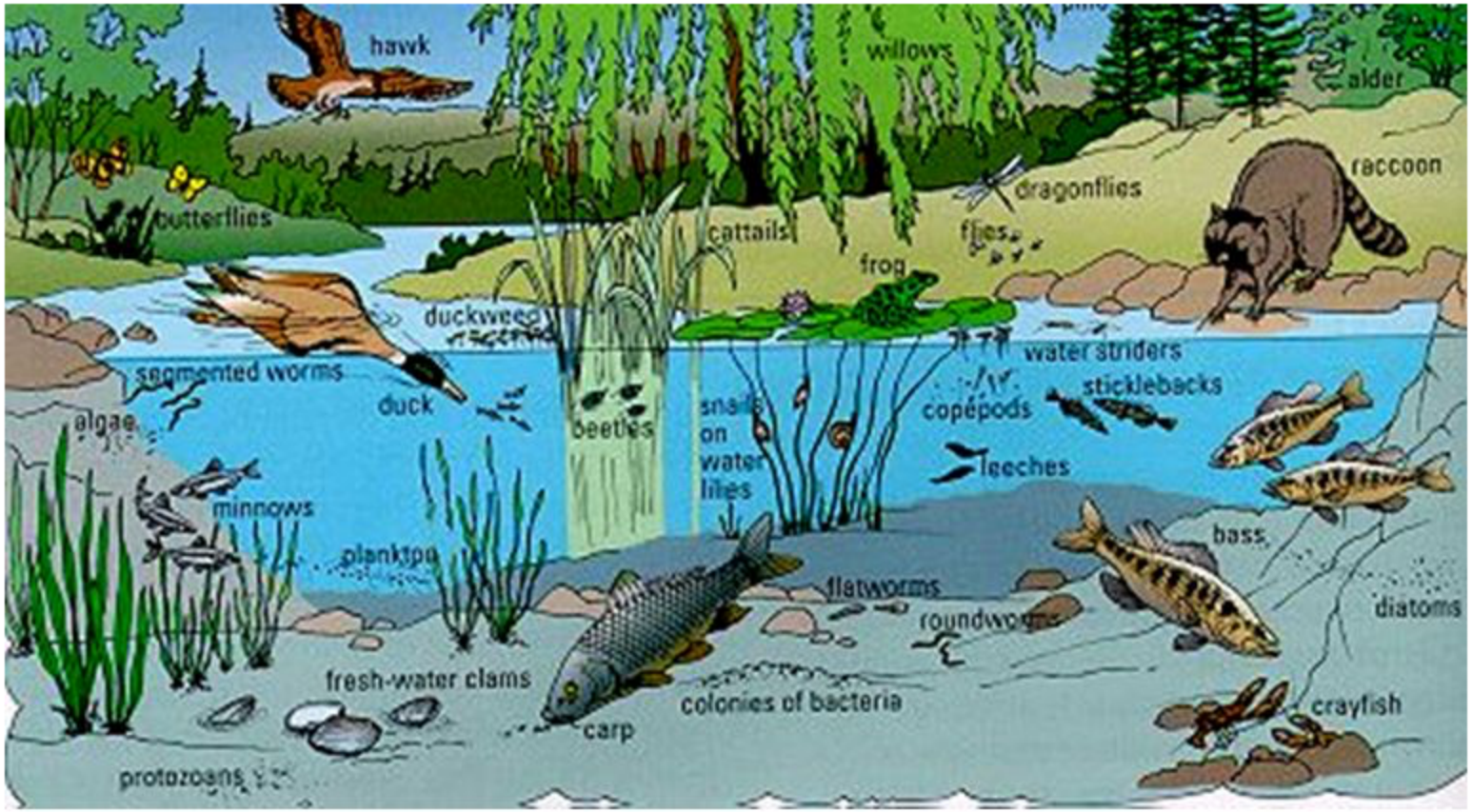
- Natural disaster



- Development
- Social issues in relation to development and environment

- Human population and environment

Define Ecosystem

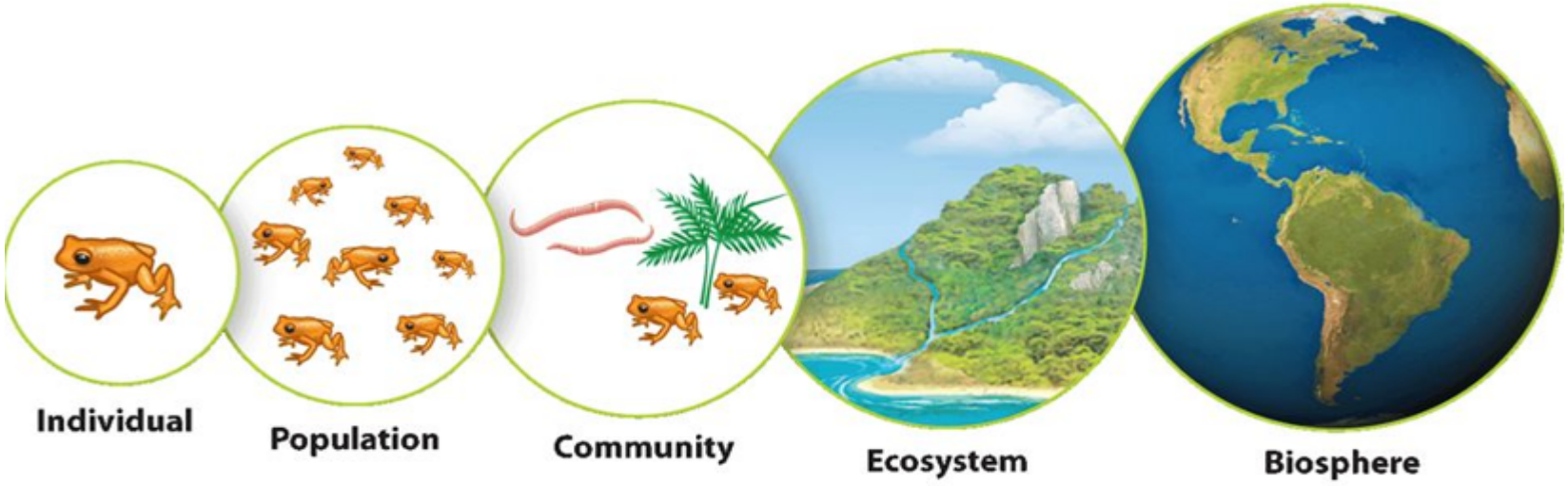


Ecosystem = the network of relationships (interactions) among <u>living</u> (plants, animals) and the <u>non-living parts</u> (soil, climate, water etc.) in an environment.

Ecosystem

- Ecosystems have been defined as "communities of organisms and their physical and chemical environments that function as self-regulating units." These self-regulating biological units respond to environmental changes by modifying their structure and function.

- It includes a wide range of biological, physical, and chemical processes that connect organisms and their environment.



Comparison between Environment and Ecosystem:

	Environment	**Ecosystem**
Description	An environment is a surrounding, in which living organisms dwell.	An ecosystem is a community of biotic and aboitic elements.
Function	It provides a place for elements.	It provides an interaction between the elements.
Components	It consists of the physical environment provided by man.	It involves the biological conversions.
Provides	It provides the condition to live.	It provides the relation between the components to live.

What is an Ecosystem?

- Living organisms in an ecosystems are "classified" into:

POPULATIONS

Total individuals belonging to **ONE SPECIES** in a habitat

COMMUNITIES

All the combined populations in a habitat

ECOSYSTEM

Levels of Ecological Study

- Population – distinct group of individuals of a *species* that live, interbreed, and interact in the same geographic area.

- Community – includes all of the populations of organisms that live and interact with one another in a *given area* at a *given time* .

Definitions

Habitat

- The natural home or environment of an animal, plant, or other organism.

The Structure of Ecosystem

- Ecosystem is composed of different biological levels :

a. Biosphere: the region where the living organisms are located, from the deepest point of the earth's oceans to a few thousand meters above the atmosphere

b. Hidrosphere: covering the ¾ of the world, forming the source of water

c. Litosphere: a layer covering the land and rock of the earth's crust

d. Atmosphere: creates the gas layer surrounding the earth. This layer contains 78% nitrogen, 21% oxygen, 0.03% carbon dioxide gas

Types of Ecosystems

- Terrestrial
  - Coastal Chaparral and Scrub
  - Coniferous Forest
  - Desert
  - Prairie Grassland
  - Deciduous Forest

- Fresh Water
  - Lakes
  - Rivers
  - Streams
- Marine
  - Estuaries
  - Coastlines
  - Coral Reefs
  - Deep Ocean

Physical environment

- Microorganisms, as they interact with each other and with other organisms in biogeochemical cycling, are influenced by their immediate physical environment whether this might be soil, water, the deep marine environment, or a plant or animal host.

- **Microenvironment:** the specific physical location of a microorganism.

- **Niche,**includes the microorganism, its physical habitat, the time of resource use, and the resources available for microbial growth and function

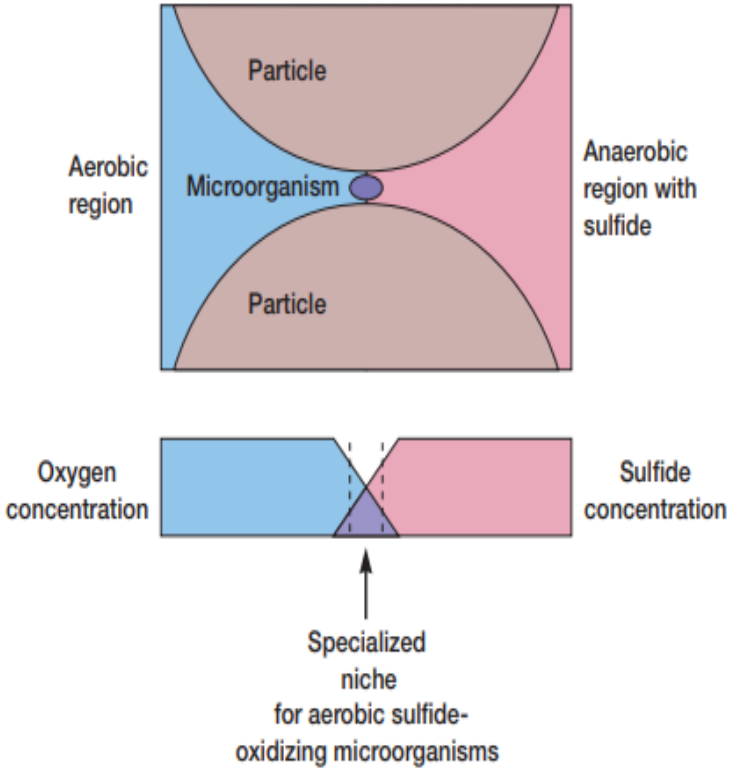


Figure2. The Creation of a Niche from a Microenvironment.

Biofilms

- Protect pathogens from disinfectants, create a focus for later occurrence of disease, or release microorganisms and microbial products that may affect the immunological system of a susceptible host.

For example:

- Air-conditioning and other water retention systems where potentially pathogenic bacteria, such as *Legionella* species, may be protected from the effects of chlorination by biofilms

- Teeth, where biofilm forms plaque that leads to tooth decay

- Contact lenses, where bacteria may produce severe eye irritation, inflammation, and infection

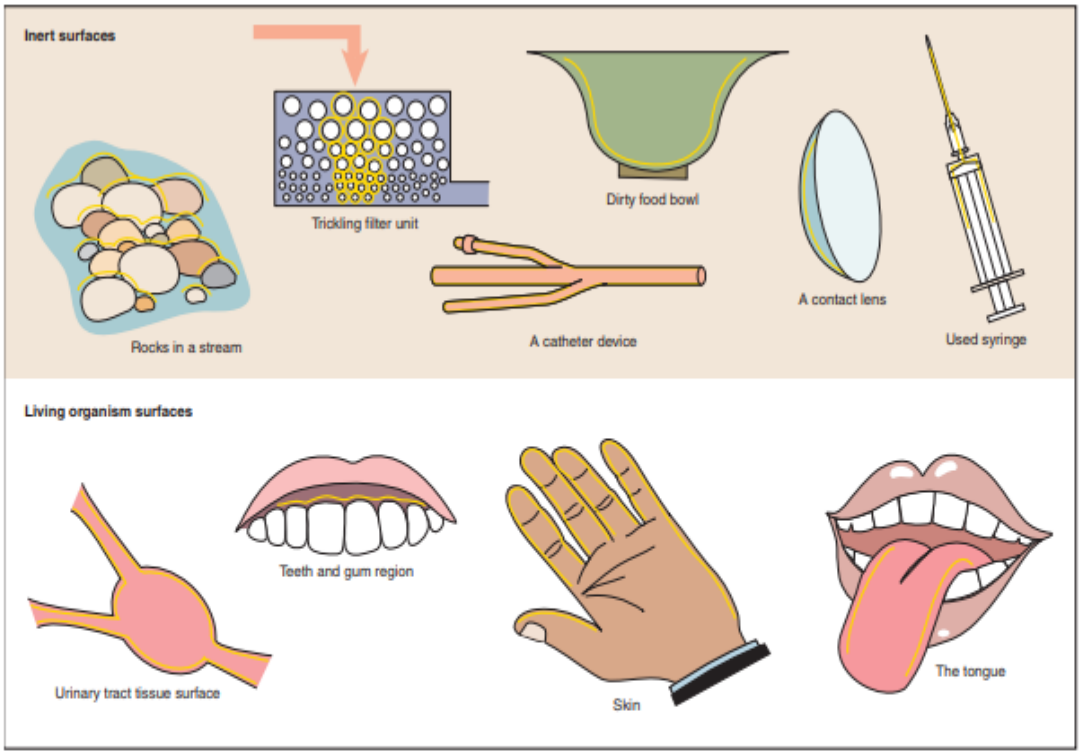
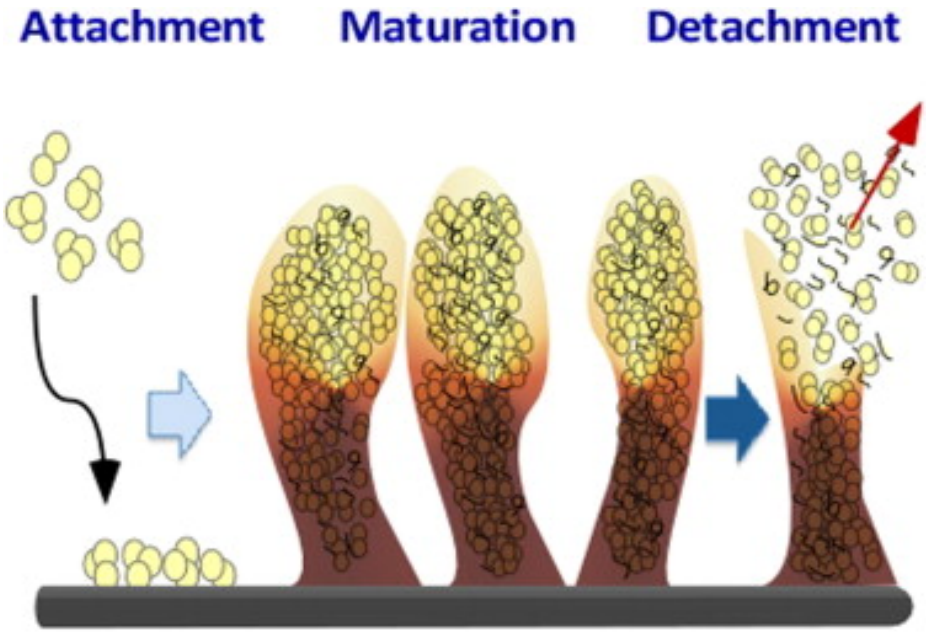


figure.4, Biofilm Formation on living and nonliving surfaces

Biofilms

Microorganisms tend to create their own microenvironments and niches, even without having a structured physical environment available, by creating **biofilms.**

Biofilms are organized microbial systems consisting of layers of microbial cells associated with surfaces



Biofilm development

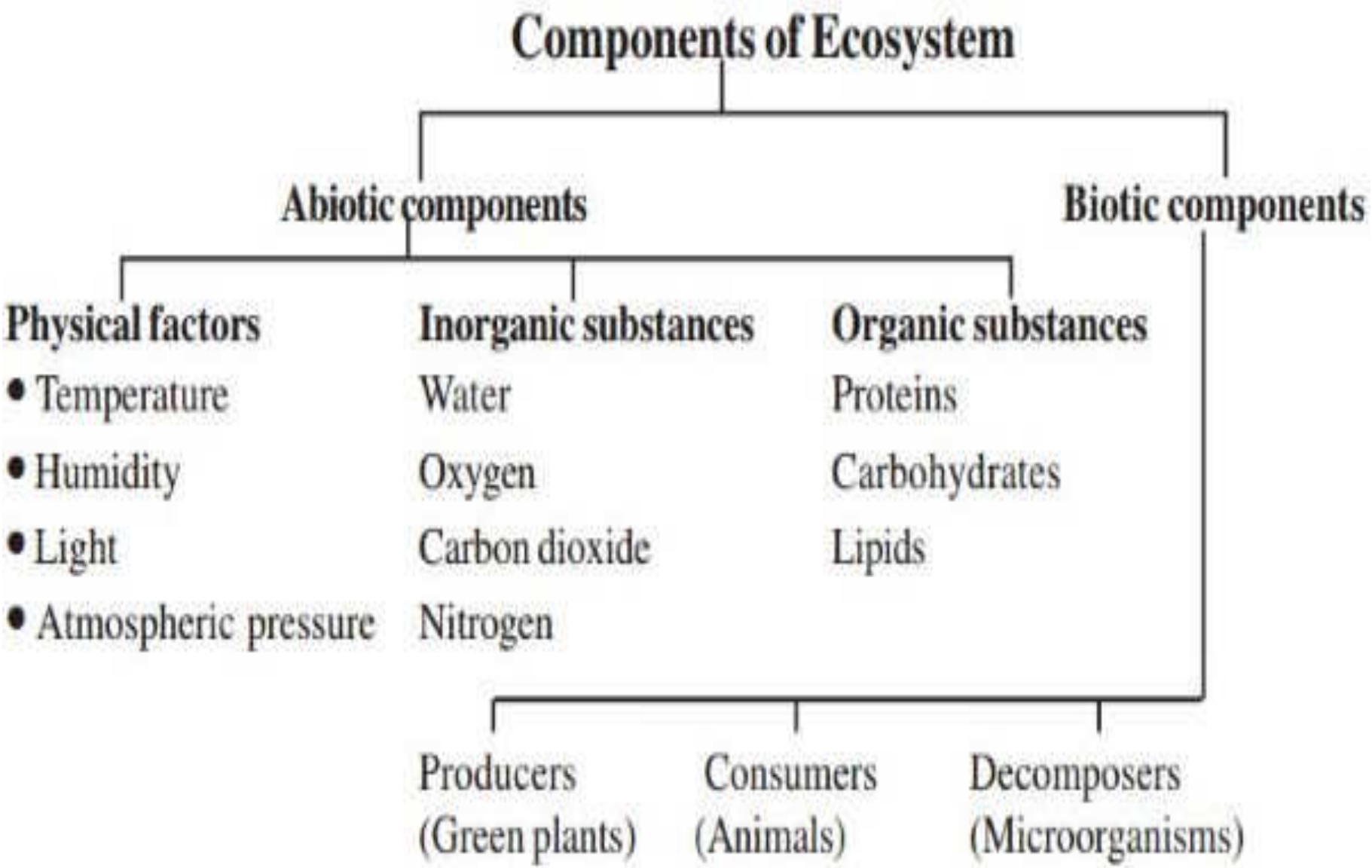
Components of ecosystem

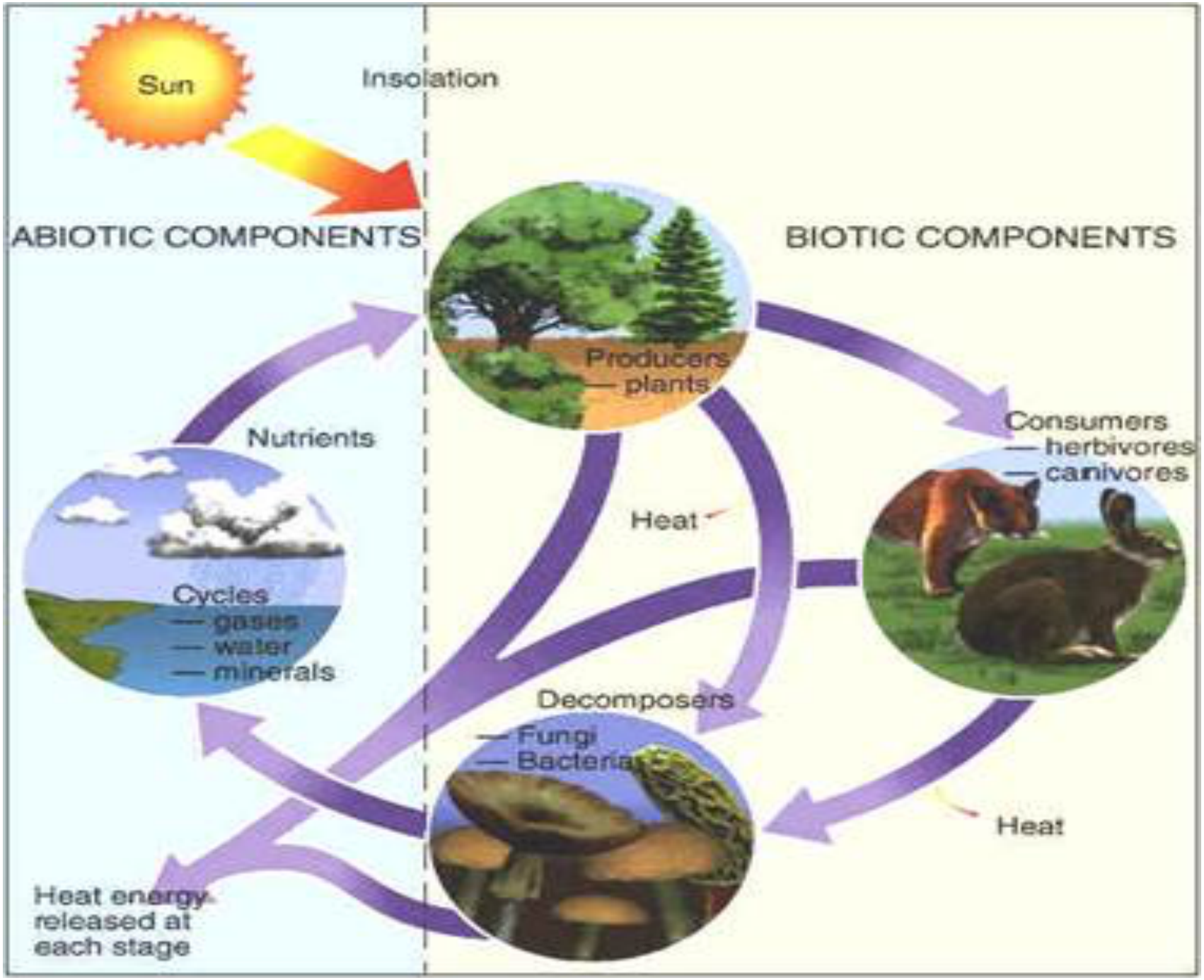
1)Abiotic components

include the non-living or physico-chemical factors like air, soil, water and the basic compounds and elements of the environment

2) Biotic components

It consists of the living parts of the environment, including the association of a lot of interrelated populations that belong to different species inhabiting a common environment.

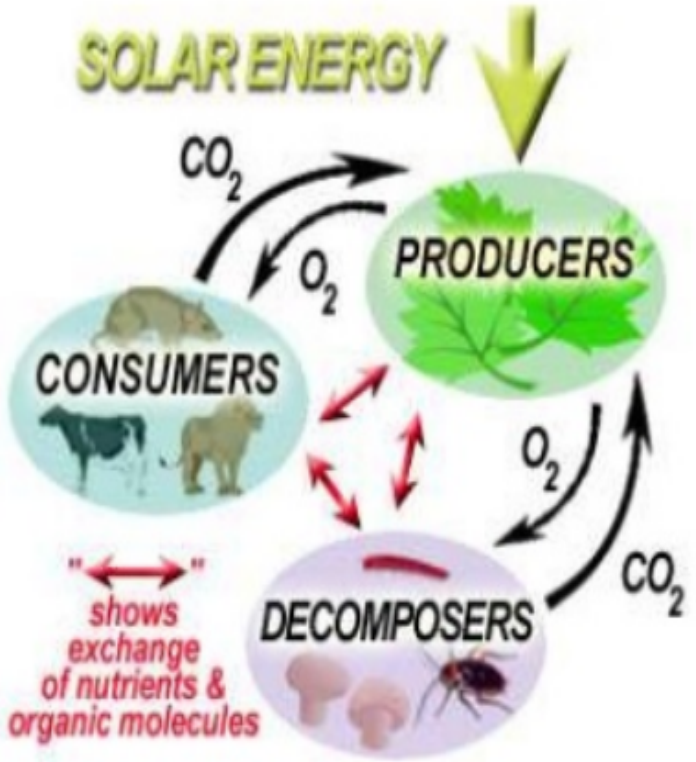

Components of Ecosystem
Abiotic components
Biotic components
Physical factors
• Temperature
• Humidity
• Light
• Atmospheric pressure
Inorganic substances
Water
Oxygen
Carbon dioxide
Nitrogen
Organic substances
Proteins
Carbohydrates
Lipids
Producers
(Green plants)
Consumers
(Animals)
Decomposers
(Microorganisms)

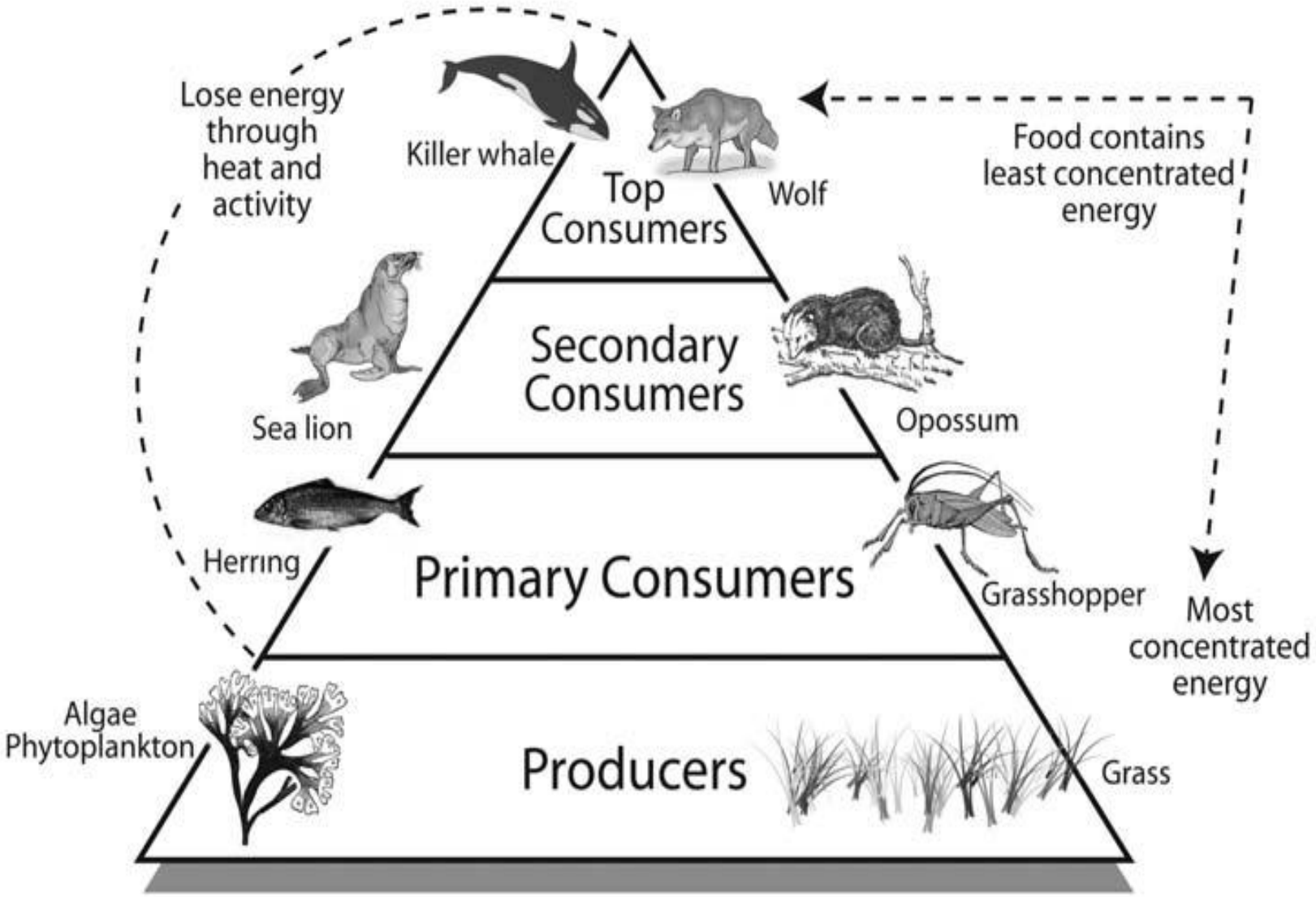

Sun
Insolation
ABIOTIC COMPONENTS
BIOTIC COMPONENTS
Producers
— plants
Nutrients
Consumers
— herbivores
— carnivores
Heat
Cycles
— gases
— water
— minerals
Decomposers
— Fungi
— Bacteria
Heat
Heat energy released at each stage

Biotic factors

- The biotic/living components of the ecosystem can be classified as flora and fauna based on their structure and other features.
- Functionally the living organisms can be classified as,

  - Producers
  - Consumers
  - Decomposers




Lose energy through heat and activity
Killer whale
Wolf
Top Consumers
Food contains least concentrated energy
Secondary Consumers
Sea lion
Opossum
Herring
Primary Consumers
Grasshopper
Most concentrated energy
Algae Phytoplankton
Producers
Grass

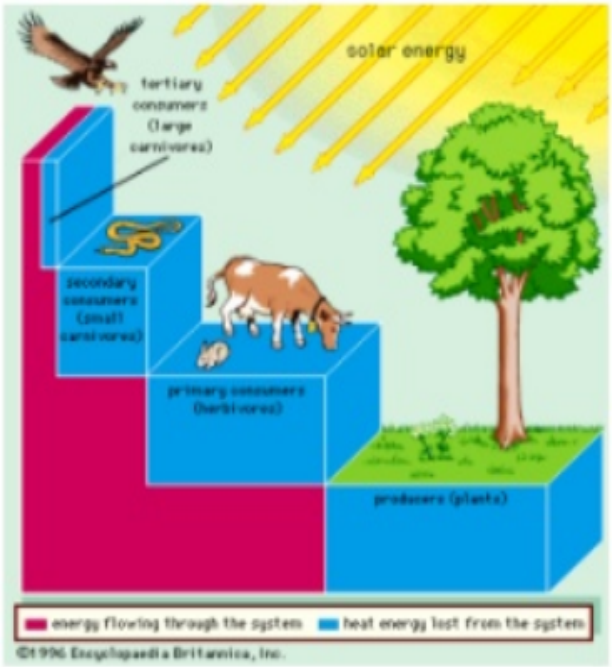
1.Producers

- Producers are called as autotrophs .
- They can be of two main types; Photosynthetic forms, chemosynthetic forms.
- The photosynthetic forms are green plants that covert solar energy into chemical energy-Photosynthesis
- The producers therefore include green plants, photosynthetic bacteria and chemosynthetic bacteria.
- On land photosynthesis is carried out mainly by higher plants.
- In the sea the main photosynthetic organisms are the microscopic algae, planktons, diatoms and the flagellates.

2.Consumers

- Heterotrophic organisms are unable to synthesize their own food and hence obtain them by feeding on other organisms.
- The decomposers also fit in to this definition.
- The consumers are classed into various categories based on the nature of the food they consume. Such as Herbivores, Carnivores and Omnivores
- And also be classified as,

  - Primary consumers
  - Secondary consumers
  - Tertiary consumers



Primary consumers

- Primary consumers are herbivores, which feed on plant material.
- The amount they consumed are commonly referred to as the consumption rate. Based on these the ecosystem can be grouped as high rated, low rated.
- Primary consumers can be grazers or browsers.

Plant eating insect

Grazing cattle

Secondary consumers

- Heterotrophic animals which feed on herbivorous organisms or primary consumers are termed as the secondary consumers.
- These animals therefore carnivrous.

Fox

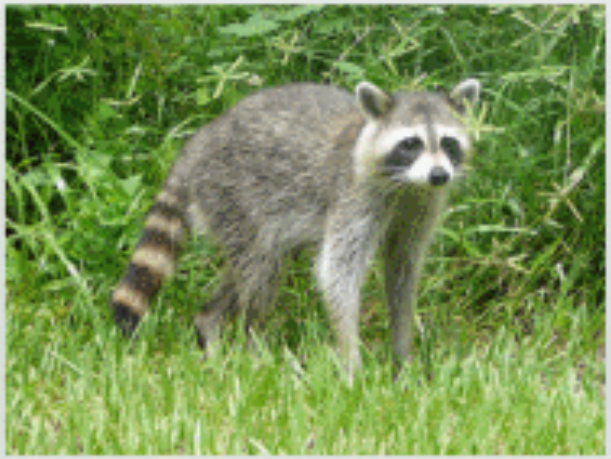
Tertiary consumers

- These are carnivorous heterotrophs that feed on other carnivorous animals.
- Top carnivorous are few in number.
- Most birds of pray and cats fit this category.

Hawk

Leopard

Omnivores



- Omnivores eat plants and animals.
- Bears are omnivores that can eat fish and also berries.
- Raccoons will eat fish, amphibians and fruits and nuts.

Decomposers

- **Decomposers** – organisms that *break down* dead or decaying organisms in order to carry out the natural process of decomposition.

  Examples:

  – bacteria (microbes)

  – fungi (such as mushrooms)

  – worms

Decomposers and Detritivores

- These organisms feed on **waste or dead organic matter** such as dead leaves, dead bodies, or waste products, decomposing it by producing enzymes to break it down. Action of *detritivores* increases the activity of *decomposers*:-

DETRITIVORES :

- Detritus eating soil invertebrates *e.g.* Earthworms, woodlice, spiders and nematodes.
- Physically reduce **detritus** particle sizes to produce **humus** *[**FRAGMENTATION**= Larger surface area for decomposers to work on!]*
- Enhance fertility of the soil by incorporating leaf surface litter into the soil
- **PHYSICAL DECOMPOSITION**

DECOMPOSERS :

- Fungi & Bacteria
- Use waste materials as energy, carbon & nutrient sources
- Carry out respiration to release CO_2
- Chemically breakdown [using **ENZYMES**] **detritus** (decaying matter) to release inorganic ions (**mineralisation**)

- **CHEMICAL DECOMPOSITION**

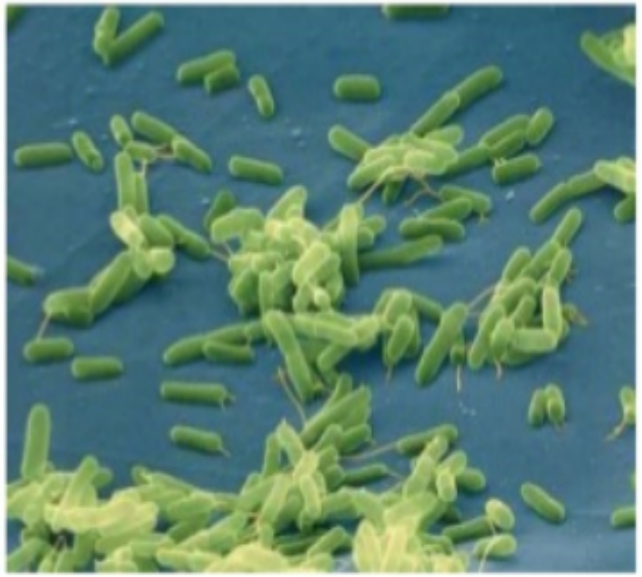
Detritivores vs. Decomposers

- The two groups are very, very similar
- DETRITIVORES help break organic wastes into smaller pieces, but they DO NOT actually get rid of it
- DECOMPOSERS break organic wastes back into its basic nutrients and return it to the environment
- DETRITIVORES can ingest clumps of matter while DECOMPOSERS cannot

3.Decomposers

- Decomposers feed on dead meterial,and that is first broken down before being absorbed.
- The detritivores ,plays the initial role of breaking up large bodies in to small particles.
- Decomposers are mainly fungi and bacteria

Fungus



Bacteria

Detritivores and Decomposers

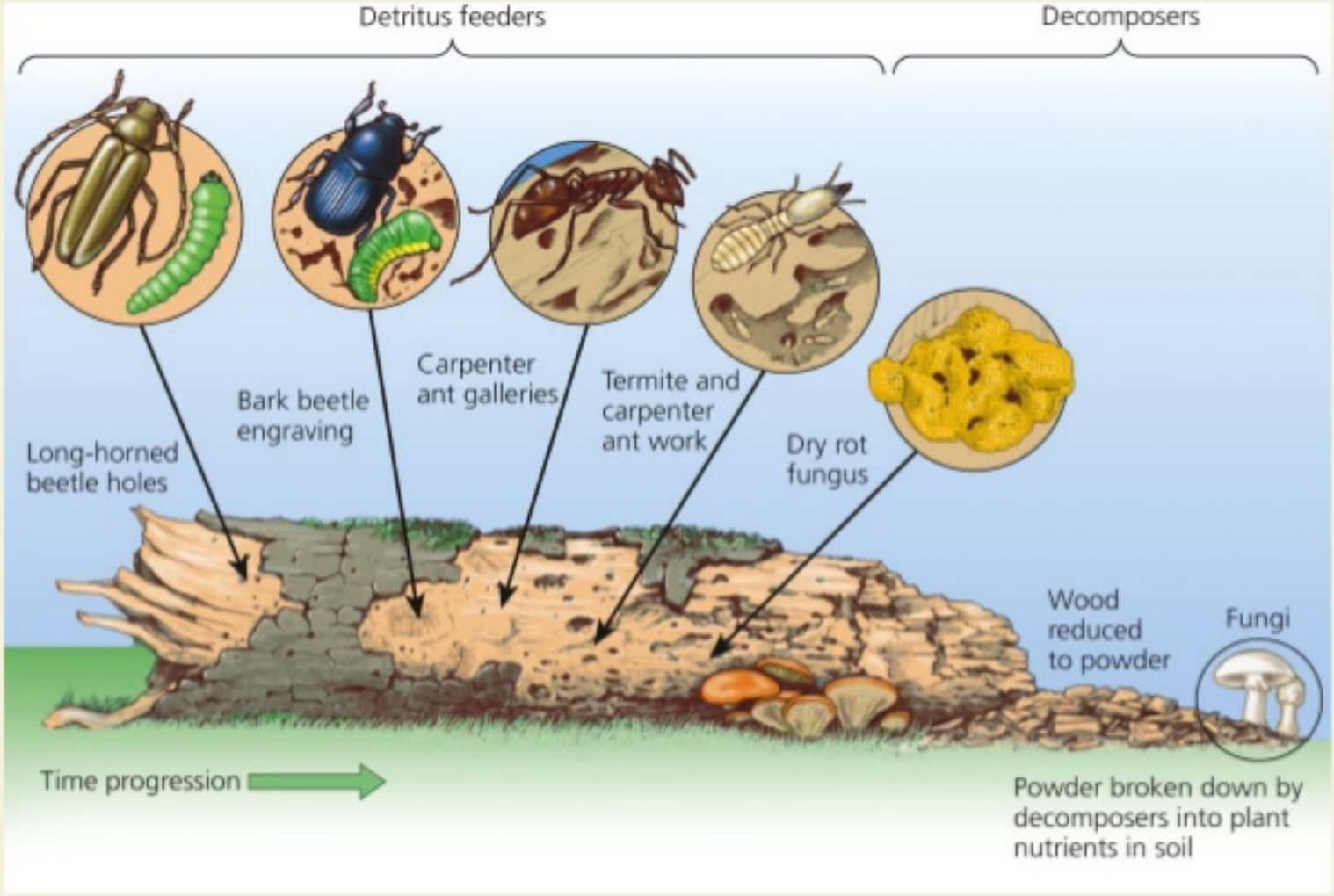
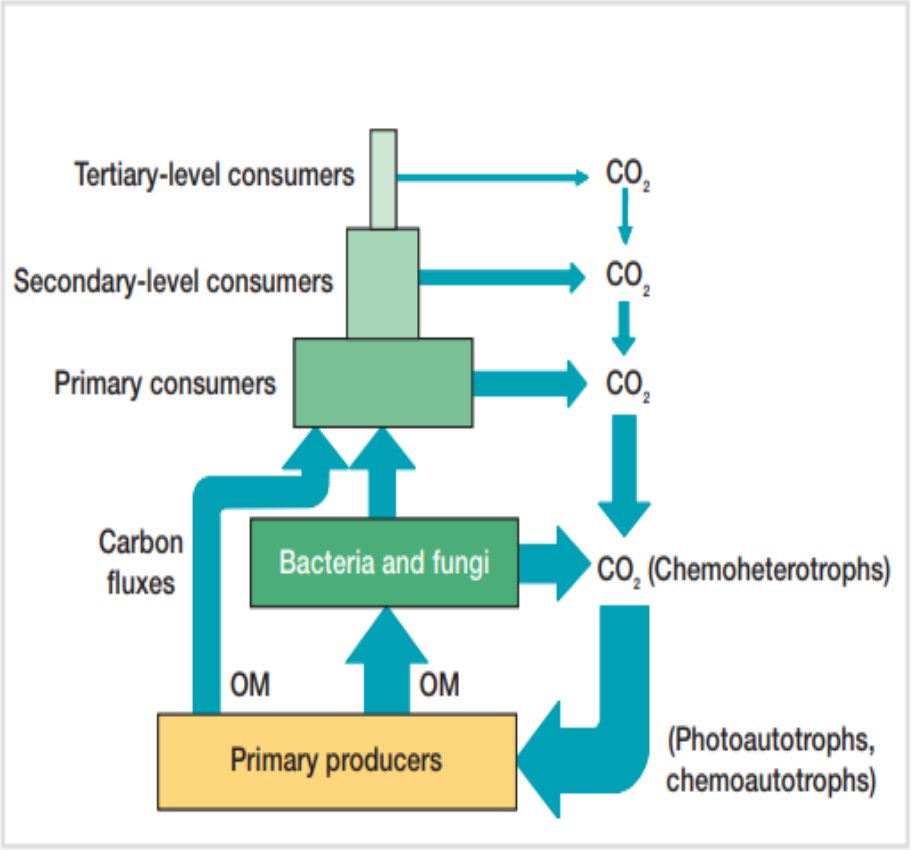


Fig. 3-10, p. 61

Ecological role of microorganisms

Microorganisms in ecosystems can have two complementary roles: (1) the synthesis of new organic matter from CO_2 and other inorganic compounds during **primary production** and (2) de- composition of this accumulated organic matter.

- primary producers, decomposers, and primary consumers.



Feeding Methods

Autotrophy
self-feeding

Organisms which produce their own food from organic molecules

Producers

Photoautotrophy
photosynthesis

Green plants, phytoplankton and algae

Chemoautotrophy
chemosynthesis

Deep-sea chemosynthetic bacteria

Heterotrophy
other source-feeding

Organisms which derive energy from other living organisms

Consumers
ingest organic matter which is living or recently killed

Primary
eat producers

herbivores

Secondary
eat other consumers

carnivores, omnivores

Decomposers
derive energy from non-living organic matter

Detritivores
ingests non-living organic matter

earthworms, woodlice

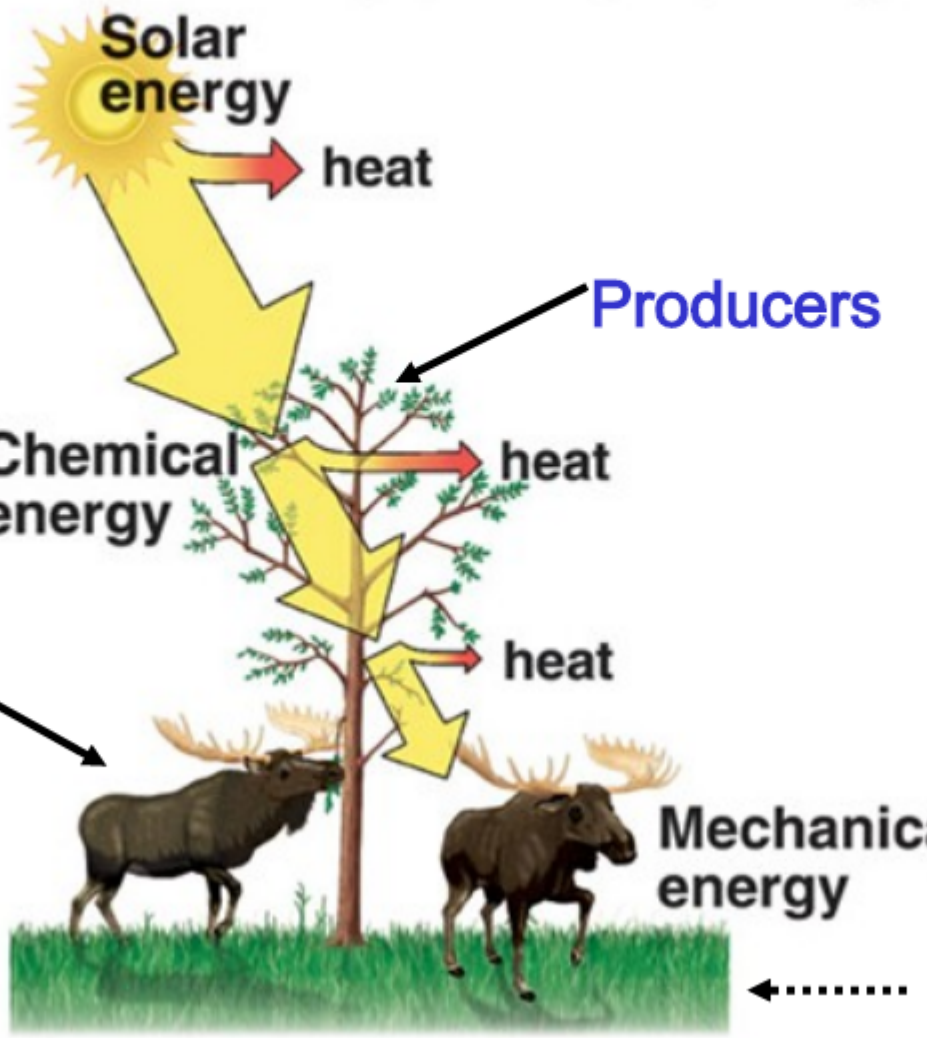
Saprotrophs
lives in or on non-living organic matter, *secreting digetive enzymes into it* and absorbing digestive products

bacteria and fungi

What are the important effects of microbial groups in nature

Ecological role	***Principal Microbial groups involved***
Primary producers	photoautotrophs (microalagae&photosynthetic bacteria) Chemoautotrophs(bacteria& archaea)
Secondary producers, assimilating dissolved organic matter	***Bacteria, archaea,fungi,protozoa***
a food source for consumers	***Microalgae, cyanobacteria, bacteria,archaea, protozoa***
important links between producers and top consumers	***protozoa***
Decomposing organic matter	***Bacteria, archaea, fungi***
biogeochemical cycling	***All***
structuring communities	***Viruses, Bacteria***
Soil formation	***Fungi, bacteria***

Energy Flow in Ecosystems

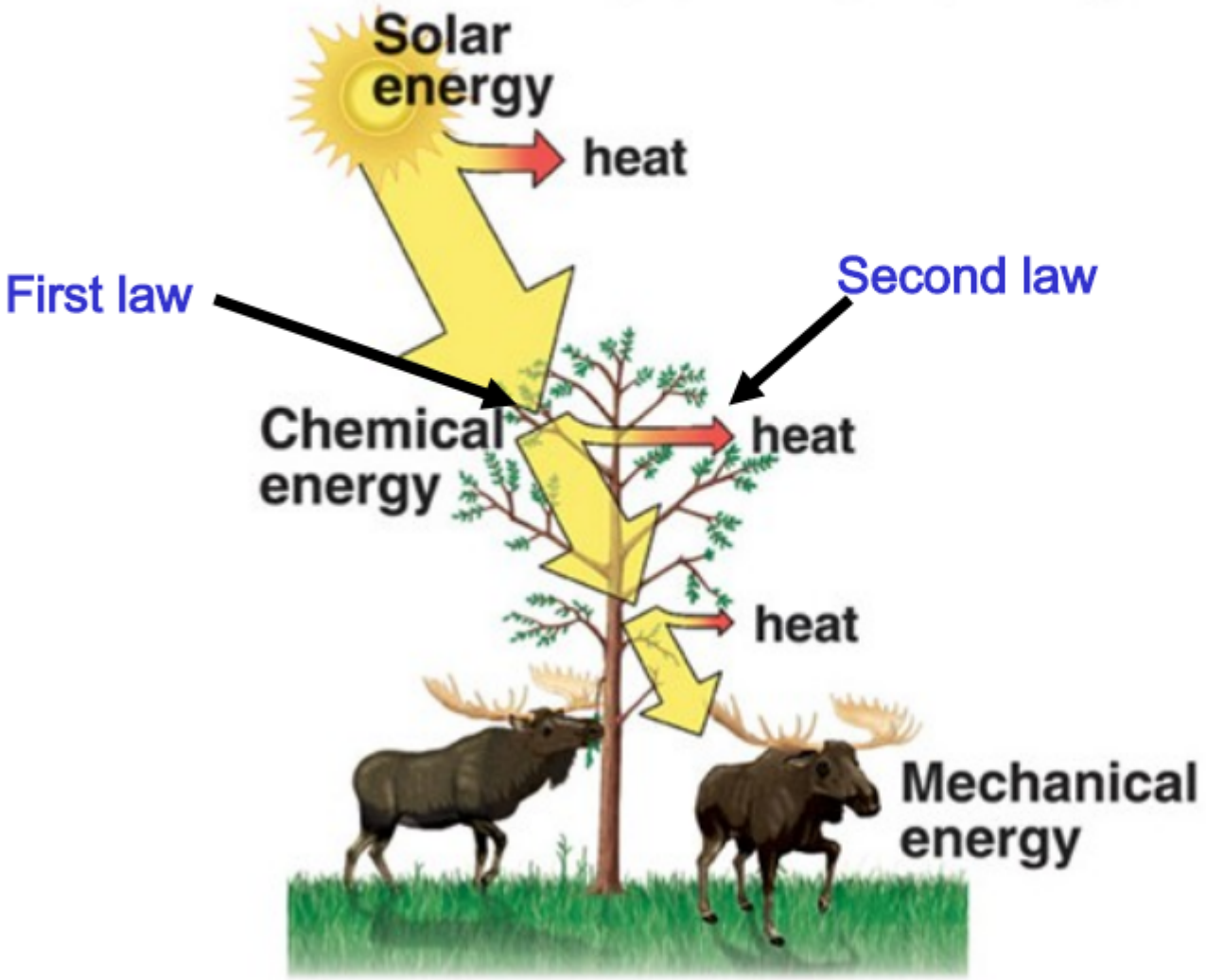


Two Laws of Thermodynamics

- *First Law* : Energy cannot be created or destroyed, but it can be changed from one form to another.

- *Second Law* : Energy cannot be changed from one form to another without loss of usable energy.

One Way Flow of Energy



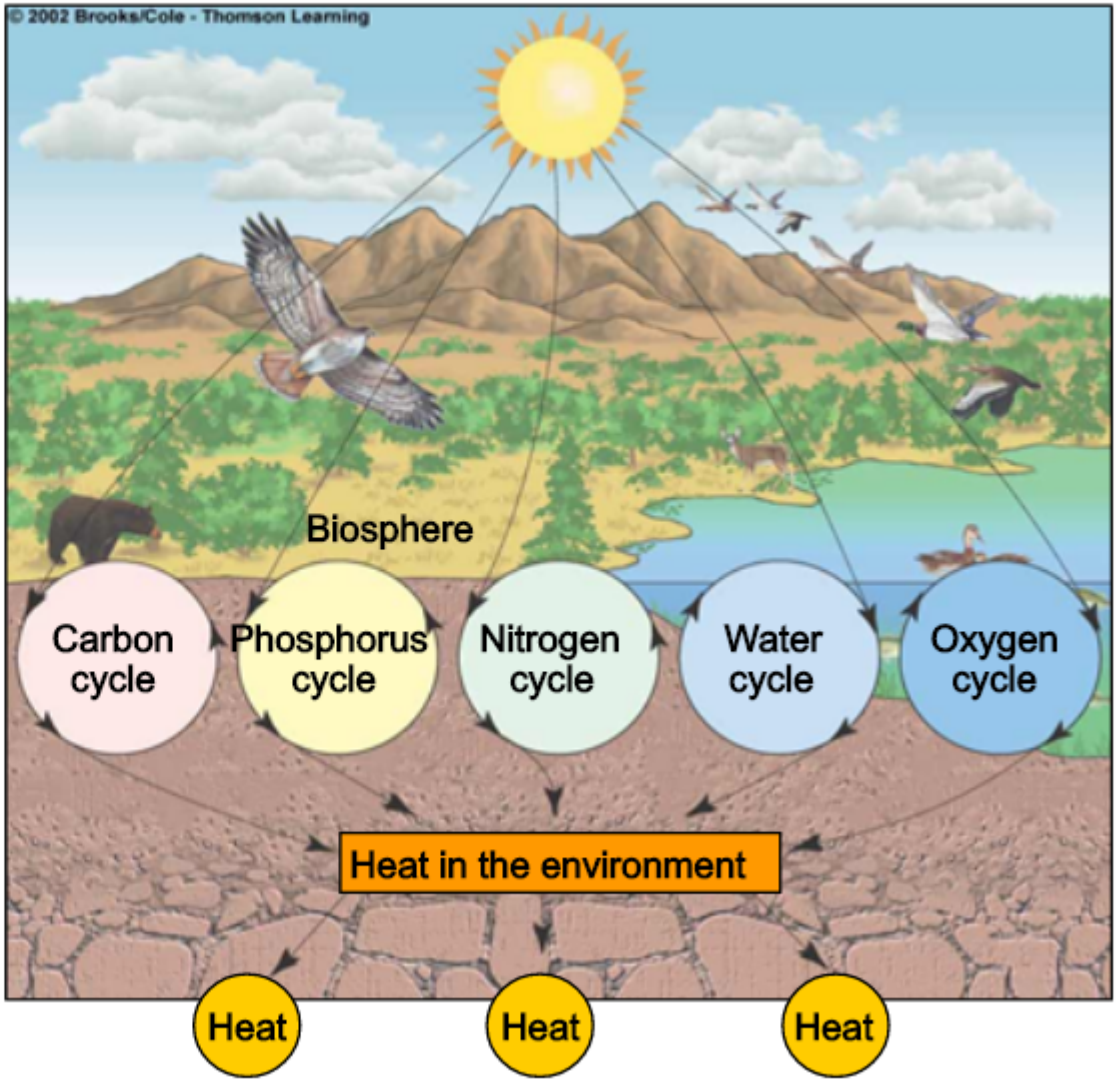
When *energy transformations* occur, energy is neither created nor destroyed (1st Law) but there is always *loss of usable energy*, usually as *heat* (2nd Law).

While energy has a unidirectional flow through ecosystems, nutrients are cycled .

All nutrients are already here.

They are cycled from one organism to another and may have a long abiotic existence.

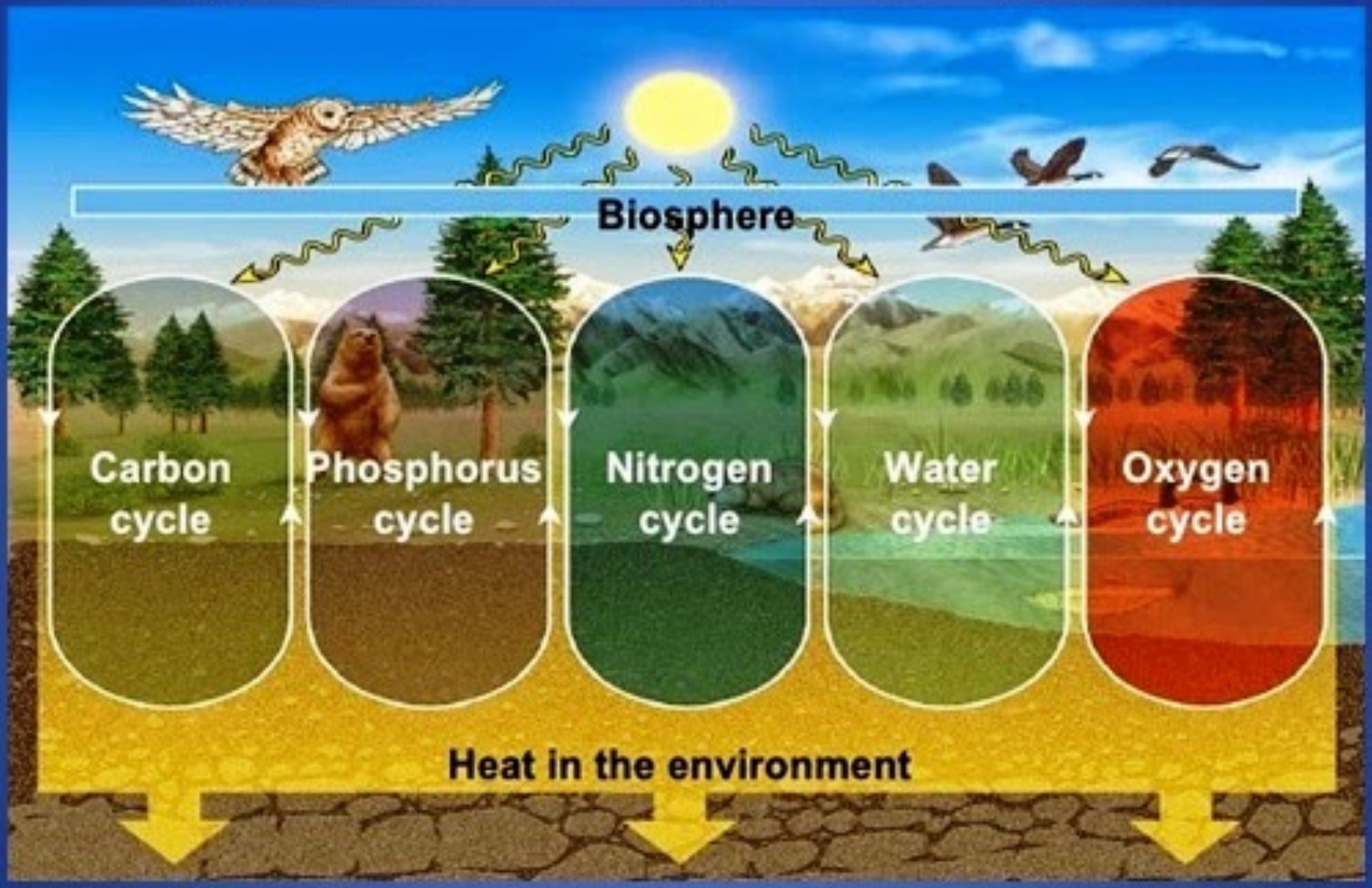
Some nutrients are lost from ecosystems due to runoff.



How Do Ecosystems Gain Lost Nutrients?

- Carbon – Photosynthetic fixation
- Nitrogen – nitrogen fixing bacteria and atmosphere
- Phosphorous – original deposits on land and shallow ocean sediments (artificial fertilizers)
- Oxygen – Photosynthesis
- Water – Precipitation

Biogeochemical Cycle Components



What IS a "biogeochemical cycle"?

- BIO = "life"
- GEO = "earth"
- CHEMICAL = "elements – C, O, N, P, S

- **a cycling of nutrients (water, carbon, oxygen, nitrogen, phosphorus, sulphur) from the abiotic components of the ecosystem (water, air, soil, rock) through the biotic components (plants, animals, fungi, bacteria)**

Biogeochemical cycles

- Matter can neither be created or destroyed
- A constant amount of matter in the environment must be recycled
- Microbes are essential in the conversion of nutrients into organic and usable formats
- Microbes are essential in the conversion of nutrients into the inorganic form