Chapter 02: Scientific concepts under variable Biological fields

I-Ecological concepts:

1- Organization of living beings:

Levels of organization in ecology help scientists generally study the anthropogenic impact**,** energy flow and changes in population dynamics. Natural organisms can be studied at small or large levels, which are:

- **Organism:** The specimen or the first unit of living beings. We focus at this level on the relationship of an individual organism with its abiotic environment (temperature, moisture, light, soil etc….).
- **Population:** A group of organisms of the same species in a specific area. Ecologists are interested in the biotic and abiotic factors that affect a population's size and distribution.
- **Community:** It's about populations of different species in an area, with a focus on community structure, composition and the biotic interactions between these groups, such as predation and competition.
- **Ecosystem:** A community together with its function, which is the pools and fluxes of energy and matter within and between biotic and abiotic factors.
- **Ecoregion (Landscape):** Recurring patterns of ecosystems, associated with characteristic combinations of soil and landform. Ecosystems within an ecoregion are more similar to each other than to ecosystems elsewhere.
- **Biosphere:** It represents all of the Earth's organisms interacting with each other and the global environment.

Figure 01. Organization levels of living beings

1-1- Concept of Ecology:

The word **ecology** is derived from the Greek "oikos" meaning house and "logos" meaning study (Study of the natural house of species). The word ecology is of recent origin having been first proposed by the

German biologist **Ernst Haeckel** in **1869**; as the study of organisms, populations, and communities, as they relate to one another and interact in the ecosystems they comprise.

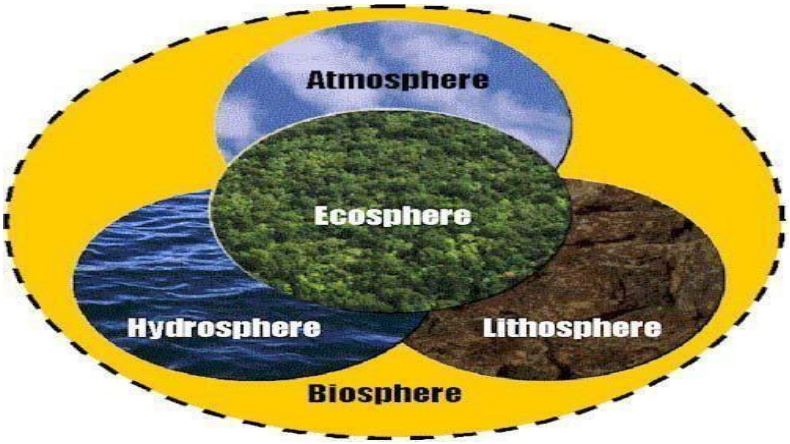


Figure 02. Position of the Ecosphere in the Biosphere

1-2- Types of Ecology:

According to the group of organisms to be studied, there are three types of Ecology:

- **Autecology or species ecology:**

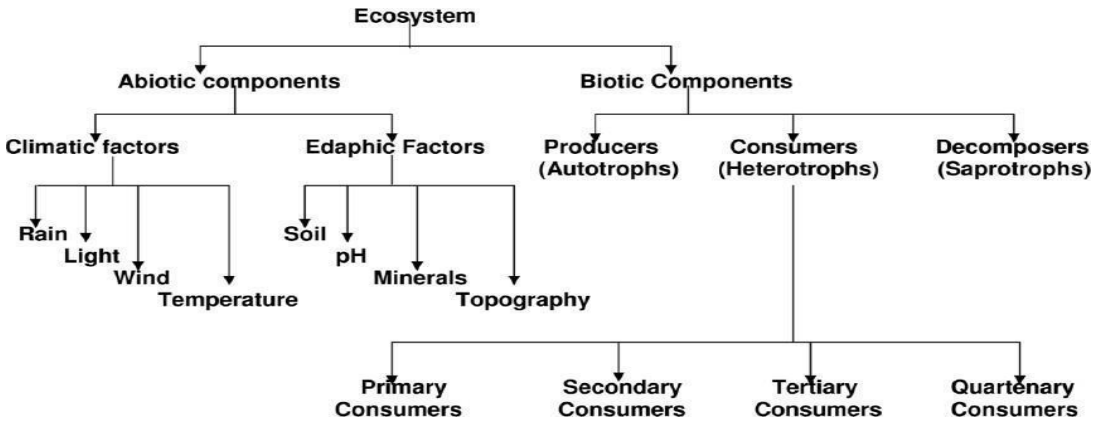
It deals with the study of an individual species of organisms in its population. The ecologists study the behavior and adaptations of a particular species to the environmental condition at every stage of that individual's life cycle.

- **Demecology or Ecology of population:**

It includes the study of populations of different species with concern to birth rate, death rate, different factors affecting number, growth, and sizes of populations.

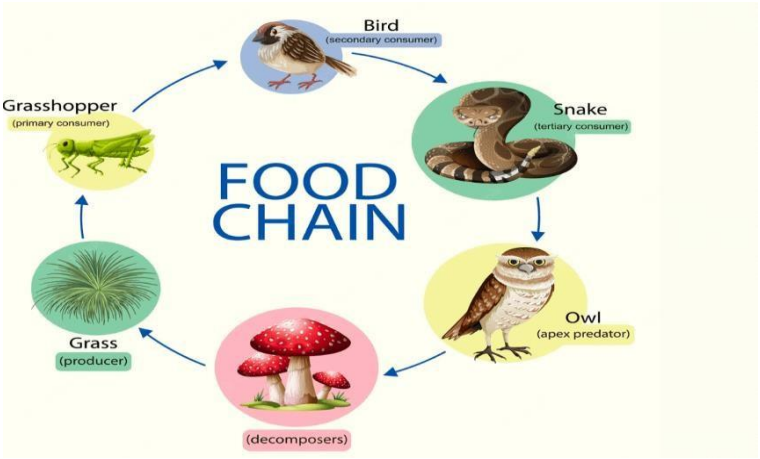
- **Synecology or Ecology of communities**:

It deals with the study of communities and Ecosystems, their composition, their behavior and their relation with the environment.



1-1- Concept of food chains:

A food chain is a linear sequence of organisms where nutrients and energy are transferred from one organism to another organism. It begins with the producer, follows the chain with the consumers and ends with the decomposer organisms. After understanding the food chain, we realize how one organism is dependent upon another one for survival. Every food chain is consisted of:



- **Producers:**

Producers are plants that produce, or create, their own food by using light energy from the sun, carbon dioxide from the air, and water from the soil. The process that makes them Autotrophs is called photosynthesis.

- **Consumers:**

Animals are consumers. They cannot produce their own food, so they get their nutriments and their energy by consuming (eating) other plants and animals. There are 3 groups of consumers: carnivores, herbivores, and omnivores.

- **Decomposers:**

Bacteria and fungi are decomposers. They eat dead plants and animals, break them down and decompose or dispose of them. When that happens, they release nutrients and minerals back into the soil, which are then used by plants during photosynthesis.

II- Agrosystem concepts:

1- Definifion of an agrosystem:

An agrosystem is an ecosystem supporting the food production systems in farms and gardens. It is defined as a set of plant and animal communities that interact with the physical and chemical environment and are used by humans to produce food, fibre, fuel, and other products for human consumption and processing.

Agroecosystems are natural communities that occupy about 40% of a global land surface and whish have been modified by humans for agricultural purposes and transformed to cultivable lands and grasslands.

Figure 01. Agricultural land

2- Components of Agroecosystems:

The components of an agroecosystem are variables depending on the specific type of agricultural system. However, some common components of agroecosystems include:

- **Abiotic Components**
  - Climate (Temperature, light intensity, day length, CO_2 ….).
  - Resources (Water availability, nutrient supply…..).
  - Landscape (Topography and relief).
  - Soil (Fertility, salinity and pH levels).
- **Biopic Components**
  - Pests (Parasites, herbivores…..).
  - Competition relationships between plants.
  - Symbiotic relationships (Subterranean organisms and pollinators).
  - Farmers (Including their management of natural factors).
  - Livestock (Raising of livestock, such as cows, chickens, or pigs, for the production of meat, milk, or other products).
  - Crops **(**Cultivation of crops for human consumption or other purposes, such as animal feed or industrial use).

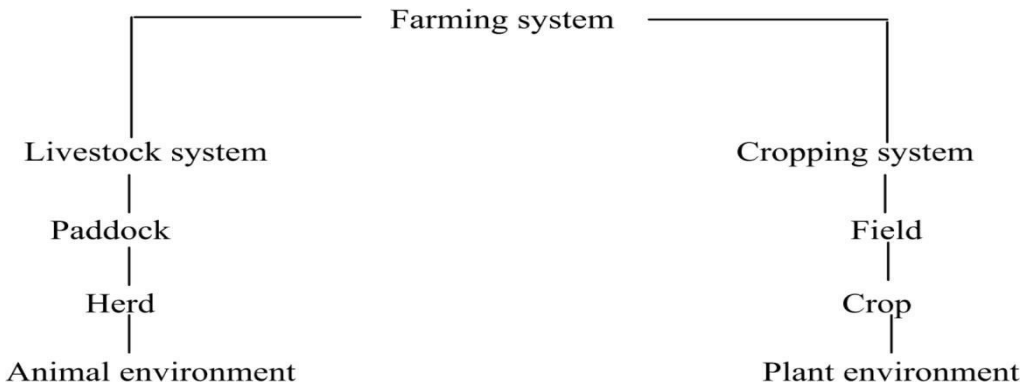


Figure 02. Farming land system

3- Agroecosystem food chain elements:

Components of agroecosystem food chain are:

3-1- Producers (Autotrophs):

Producers are also called autotrophs because they make use of abiotic factors, to produce their food using the energy from the sun along with water and carbon dioxide. In agriculture, producers are green plants and algae.

3-2- Consumers (heterotrophs):

Dependent components of an Agroecosystem, they do not make their food but rather depend on the autotrophs for food. In the food chain, they are referred as secondary or tertiary organisms. For Agroecosystems, consumers are human beings that eat crops, vegetables, fruits, or other animals' products. They can also be predators or parasites.

3-3- Decomposers (Saprotrophs):

Organisms that feed on death and decayed plants and animal materials. They break down organic matter into inorganic components (carbon and nitrogen). The inorganic matter broken down by these organisms will return to the soil as nutrients for plant use (bacteria, fungi, earthorms)

Figure 03. Agricultural production cycle.

4- Agroecosystem types:

There are many different types of agroecosystems:

4-1- Small-scale subsistence farming:

It involves the production of crops or livestock for the purpose of feeding a family or small community. These systems are often found in developing countries and are characterized by low levels of inputs and technology.

4-2- Large-scale commercial agriculture:

It involves the production of crops or livestock for sale on a larger scale (For export). These systems are typically characterized by high levels of technology and inputs and are found in many developed countries.

4-3- Intensive horticulture:

It deals with the production of high-value crops (Vegetables and fruits), using intensive growing techniques. These systems are found in urban areas and are characterized by a high level of inputs and technology.

4-4- Agroforestry:

It deals with the integration of trees and shrubs into agricultural systems in order to provide a range of benefits, including increased productivity, soil conservation, and carbon sequestration.

4-5- Regenerative agriculture:

It's about the use of techniques such as cover cropping, composting, and crop rotation in order to improve soil health and increase resilience to environmental stresses

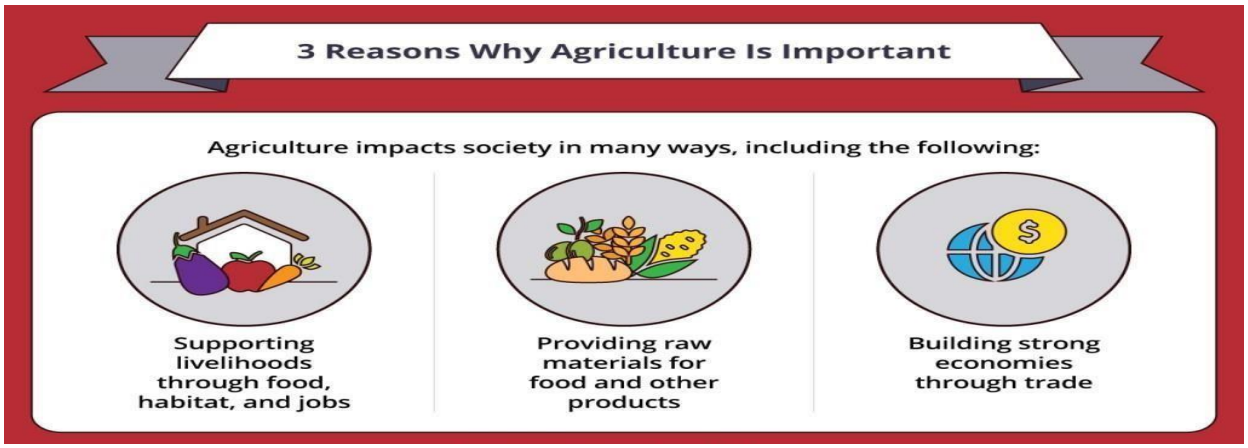


Figure 04. Agroecosystem importance

5- Friendly ecological practices in agroecosystems:

5-1-1- Composting process:

It is a natural process of recycling organic matter (Leaves, food scraps, yard tree trimmings) to a valuable

fertilizer for soils, by providing an ideal environment for bacteria, fungi, and other decomposing organisms (Worms, sowbugs, and nematodes). Composting methods are used to improve soil's physical, chemical, and biological properties in gardening, horticulture, and agriculture.

Figure 05. Compost cycle principal steps

5-1-2- Crop rotation process:

Crop rotation is the practice of planting different crops sequentially on the same plot of land to improve soil health, optimize nutrients in the soil, and combat pest and weed pressure through a considerable period of years (3 to 7 years). It's a sequence of crops grown in a specific field, including cash crops, cover crops and green manures. A simple rotation might involve two or three crops, and complex rotations might incorporate a dozen or more. An example of crop rotation is maize, followed by a legume.

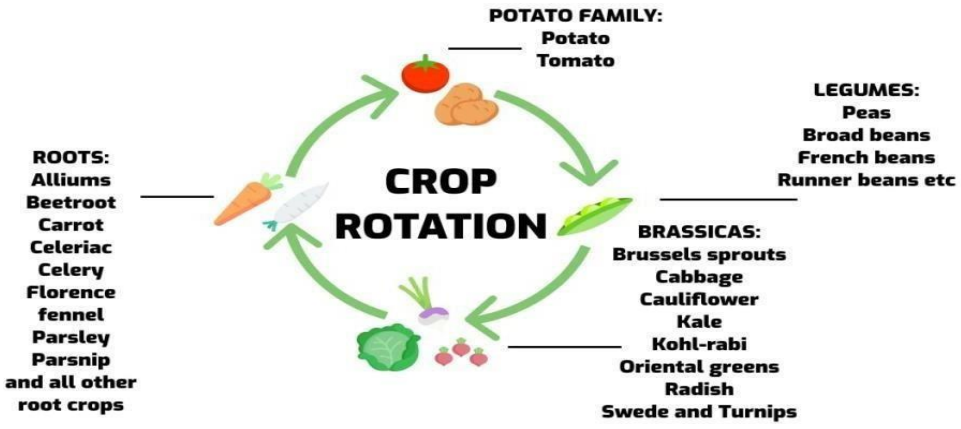


Figure 06. Crop rotation process

5-1-3- Sustainable agriculture:

Sustainable agriculture is farming in sustainable ways meeting society's present needs, without compromising

the ability for current or future generations to meet their needs and to conserve the planet's health. Sustainable agriculture consists of environment friendly methods of farming that allow the production of crops or livestock without causing damages to human or natural systems. Sustainable farming goals are:

- Satisfy human food and fiber needs.
- Enhance environmental quality and natural resource bases.
- Make the most efficient use of renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls.
- Sustain the economic viability of farm operations.
- Enhance the quality of life for farmers and society as a whole.

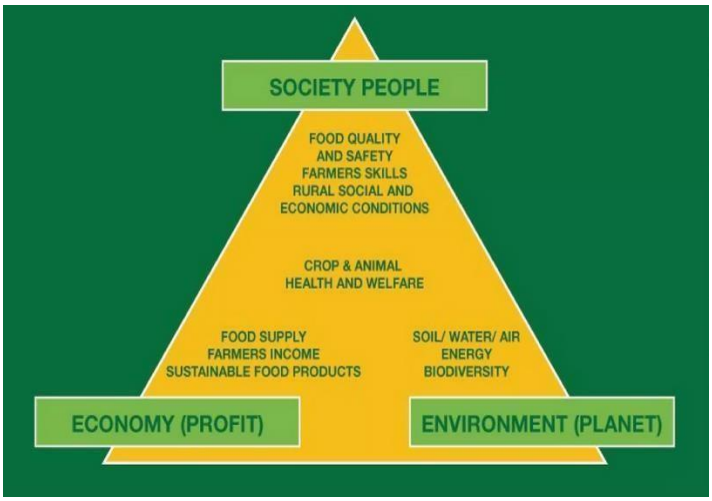


Figure 07. Sustainable agroecosystem principal axes

III- Food quality and safety concepts:

1-Definition of Food Quality

Food quality refers to the characteristics of food that determine its value to consumers. It is a combination of attributes that determine a food's acceptability to consumers, including sensory properties, nutritional value, and processing standards that include:

- ***Appearance*:** Color, shape, size, and visual appeal.
- ***Texture**:* Firmness, crispiness, or smoothness.
- ***Flavor and taste***: Sweetness, saltiness, bitterness.
- ***Nutritional value***: Presence of vitamins, minerals, proteins, and fats.
- ***Shelf life**:* How long food remains safe and palatable.

2-Definition of Food Safety

Food safety means assurance that food is acceptable for human consumption according to its intended use. It refers to the conditions and practices that preserve the integrity and safety of food and prevent contamination. An understanding of food safety is improved by defining toxicity and hazard concepts which indicate the capacity of a substance to produce harm or injury of any kind under any conditions.

Figure 08. Principal elements in food system

Hazards can be physical, chemical, biological or allergic, causing harmful effects on the health of consumers:

- Physical hazard is any physical material not normally found in food, which causes illness or injury and includes wood, stones, parts of pests, hair…. Etc.
- Chemical hazards are chemicals or deleterious substances which may be intentionally or un-intentionally added to foods. This category of hazards includes pesticides, chemical residues, toxic metals, polychlorinated biphenyls, preservatives, food colors and other additives.
- Biological hazards are living organisms and include microbiological organisms. Those micro-organisms which are associated with food may cause diseases as food-borne pathogens which can be generated from microbial pathogens infections and poisoning.
- Allergenic hazards substances in food can cause allergic reactions in some people. Allergens are often proteins and can be found in many foods and drinks (Peanuts, dairy, gluten, shellfish…Etc).

Figure 09. Physical hazards in food

3-Food Management Systems

To ensure safety and good quality of food, industries apply international systems like:

a) Hazard analysis and critical control points (HACCP)

HACCP is a systematic preventive approach (Analyses) to food safety that identifies physical, chemical, and biological hazards in production processes that can cause the finished product to be unsafe.

b) Good manufacturing practices (GMP)

GMP covers all aspects of production, from the starting materials, premises, and equipment to the training and personal hygiene of staff.

c) Standard operating procedures (SOPs)

SOPs are detailed, written instructions to achieve uniformity of the performance of a specific function.

d) Prerequisite programs (PRPs)

PRPs are procedures, including good manufacturing practices, that address operational conditions providing the foundation for the HACCP system.

e) Traceability and recall systems

These systems ensure that in the event of a problem, the food can be removed from sale quickly and efficiently, and the source of the problem can be identified.

f) Food safety culture

This refers to the attitudes, beliefs, practices, and values that determine what is happening when no one is watching, influencing food safety performance and compliance.

Figure 10. Principal characteristics for food quality

4-How can food safety be guaranteed?

Ensuring food safety is not only the responsibility of the food industry, but also a public health concern. By understanding and following these practices, we can contribute to safer, healthier, quality food for everyone:

1. **Good Hygiene Practices:** From production to consumption, it is essential to adopt strict hygiene practices. This includes proper hand washing, using drinking water, sanitizing utensils and equipment, and handling food correctly to avoid contamination.
2. **Quality Control:** Implementing quality control systems throughout the food chain is crucial. This involves constantly monitoring the production, storage and distribution of food, ensuring that acceptable standards are maintained at all stages.
3. **Proper Storage:** Food must be stored under suitable temperature and humidity conditions to preserve its quality and safety. This includes adequate refrigeration for perishable foods and dry storage for non-perishable foods.
4. **Safe transportation:** During transportation, food must be protected from contamination and physical damage. Vehicles and containers must be cleaned regularly and follow established safety standards.
5. **Education and Training:** Training everyone involved in the food chain, from farmers to food handlers and consumers, in safe food handling and preparation practices is essential. This helps minimize the risk of foodborne illness.
6. **Regulation and Enforcement:** Governments and regulatory agencies play a crucial role in drafting and implementing food safety regulations. Regular inspections ensure compliance with established standards and the protection of public health.

IV-Biotechnology and plant improvement Concepts:

1-Biotechnology:

It is a multidisciplinary field that applies biological knowledge, techniques, and technological innovations to the use and manipulation of living organisms, their cells, or their components for the development of products and processes that benefit humans, animals, and the environment. It integrates principles from molecular biology**,** genetics**,** biochemistry**,** microbiology**,** and engineering to modify and enhance the functions of organisms for specific purposes. Biotechnology can be classified into several types or branches, each identified by a color to represent its field of application:

Table 01: Different types of biotechnology with main applications and activities

Color and fields	Domain	Objectives and activities
Green Biotechnology	**Agricultural and Plant Biotechnology**	-Improves crops and agricultural systems. -Uses genetic engineering, molecular markers, and tissue culture -Promotes sustainable farming with biofertilizers and biopesticides.
Red Biotechnology	**Medical and Pharmaceutical Biotechnology**	-Develops vaccines, antibiotics, therapeutic proteins, and diagnostic tools. -Advances gene therapy.
White (Industrial) Biotechnology	**Industrial and Manufacturing Biotechnology**	-Uses microorganisms, enzymes, or cell systems for industrial processes -Replaces polluting chemical methods with eco-friendly biological ones.
Brown Biotechnology	**Environmental and Soil Biotechnology**	-Focuses on soil restoration, waste recycling, and biodiversity preservation -Uses microorganisms and plants to clean polluted environments (bioremediation).
Blue Biotechnology	**Marine and Aquatic Biotechnology**	-Explores marine organisms for new bioactive compounds and enzymes. -Develops marine pharmaceuticals and biofuels.
Yellow Biotechnology	**Food and Nutrition Biotechnology**	-Applies biotechnology to food production, preservation, and quality enhancement. -Uses fermentation and microbial technology.

1-1-Applications of Biotechnology:

Biotechnologies relying in several disciplines (biochemistry, immunology, microbiology, genetics, computer science), they use components of living beings, generally after modification of their genetic characteristics, to

produce developed materials. They are based on three specific properties:

- Identical propagation: ability of microorganisms, animal or plant cells to reproduce by them.
- Molecular recognition: the ability of living beings to recognize and eliminate all structures and molecules that are foreign to them (Immunology responses).
- Enzymatic catalysis: Acceleration of simple or complex chemical reactions by enzymatic proteins.

1-2-The biological tools used in biotechnology:

Living biotechnology tools used in variable domain can be:

- Microorganisms (bacteria, yeasts, fungi, etc.).
- Animal and plant cells.
- Genes and enzymes (extracted from animal and plant tissues or cultures of microorganisms)
- Antibodies (proteins capable of specifically recognizing molecules foreign to an organism).

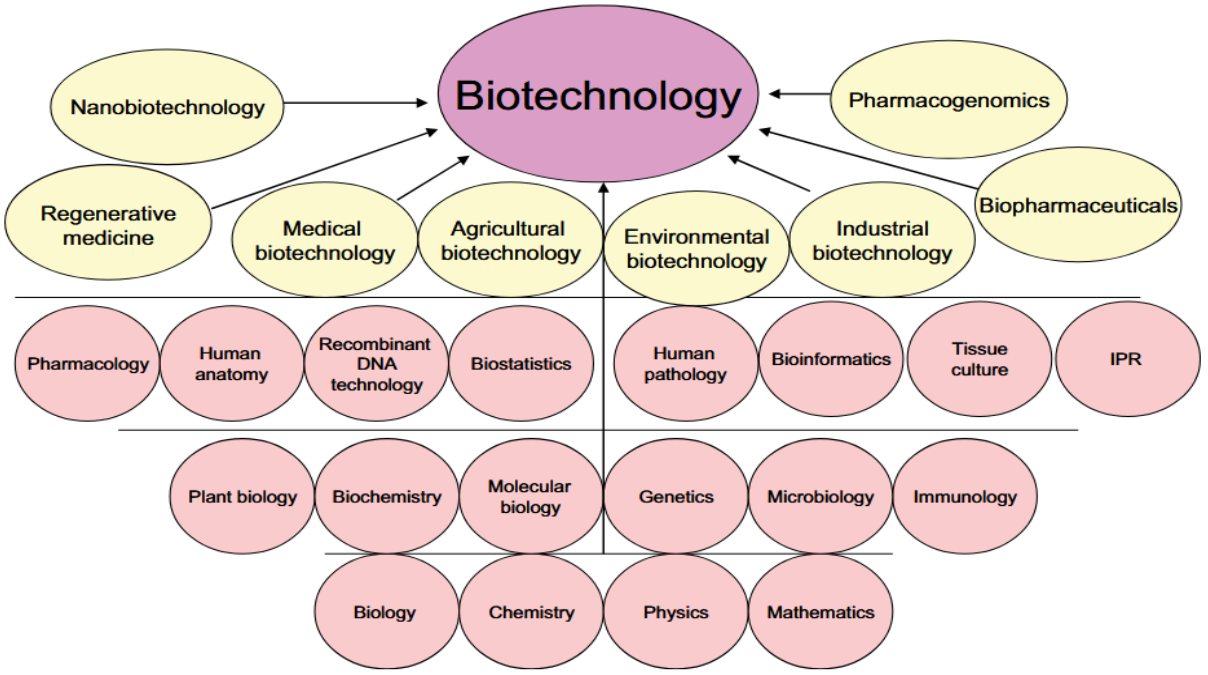


Figure 11. Various domain of biotechnology use

1-2-The Plant World

The plant world, encompassing all of Earth's flora from towering redwoods to microscopic algae, forms the essential foundation of life on our planet. Through photosynthesis, plants capture solar energy to produce oxygen and form the base of nearly every food web. Beyond sustaining the atmosphere and feeding herbivores, plants provide critical resources for human civilization, including food, medicine, lumber, and clothing fibers, while also regulating water cycles and shaping global climates. From the Amazon rainforest to arctic tundra, these organisms are master engineers, creating and sustaining the habitats that all other life depends upon. Plants

are multicellular, eukaryotic, and autotrophic organisms, meaning they are made of complex cells and can produce their own food.

1-2-1- Pant life cycle:

The life cycle of a plant begins with a dormant seed, which germinates when conditions are right, sending down a root and up a shoot to become a seedling. The plant then enters a vegetative growth stage, maturing and developing stems and leaves to perform photosynthesis. Upon reaching maturity, it reproduces by developing flowers, where pollination transfers pollen (male gametes) into the stigma (Pistil), which is the female reproductive organ within the flower and leads to fertilization. The pistil becomes a fruit, while the ovules inside the ovary mature into seeds, which is often enclosed in a fruit and dispersed away from the parent plant, allowing the cycle to begin again. This entire process from seed to seed is completed in one year for annuals, two for biennials, or repeated over many years for perennials.

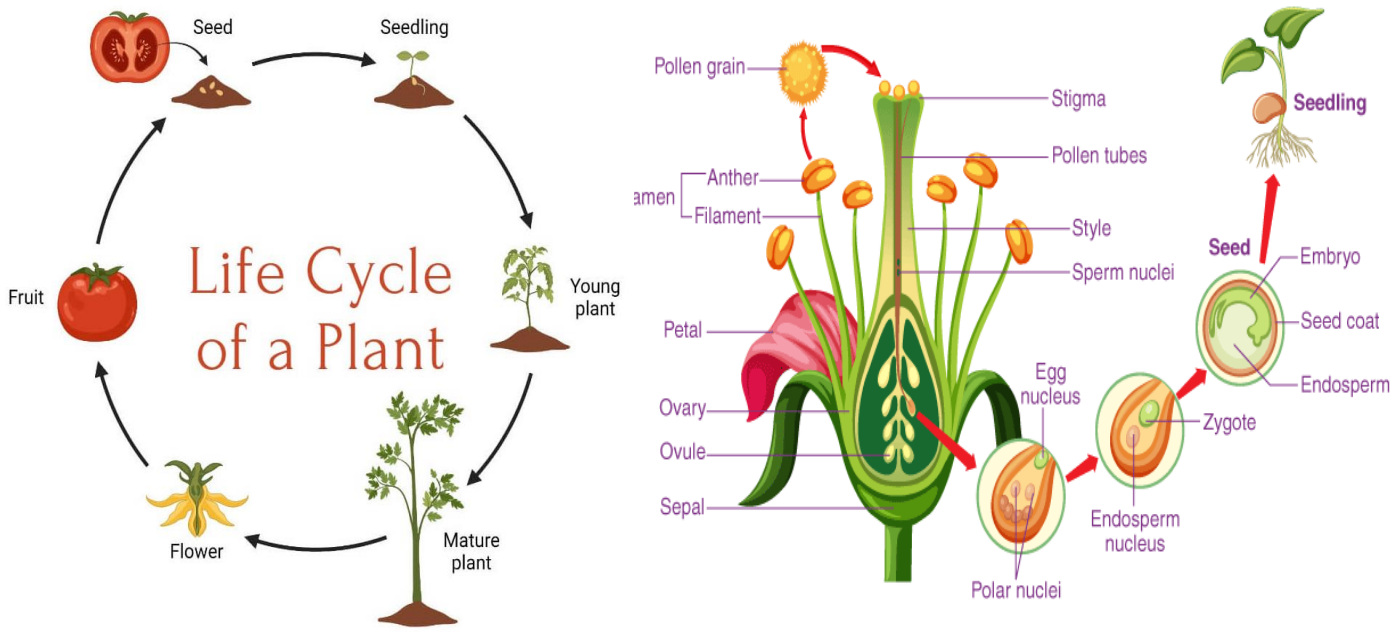


Figure 12. Pant life cycle

1-2-2- Classification of plant kingdom

The kingdom of plants includes a vast diversity of species ranging from microscopic algae to giant trees from a biological perspective, the plant world is classified into several major groups according to their structure and mode of reproduction:

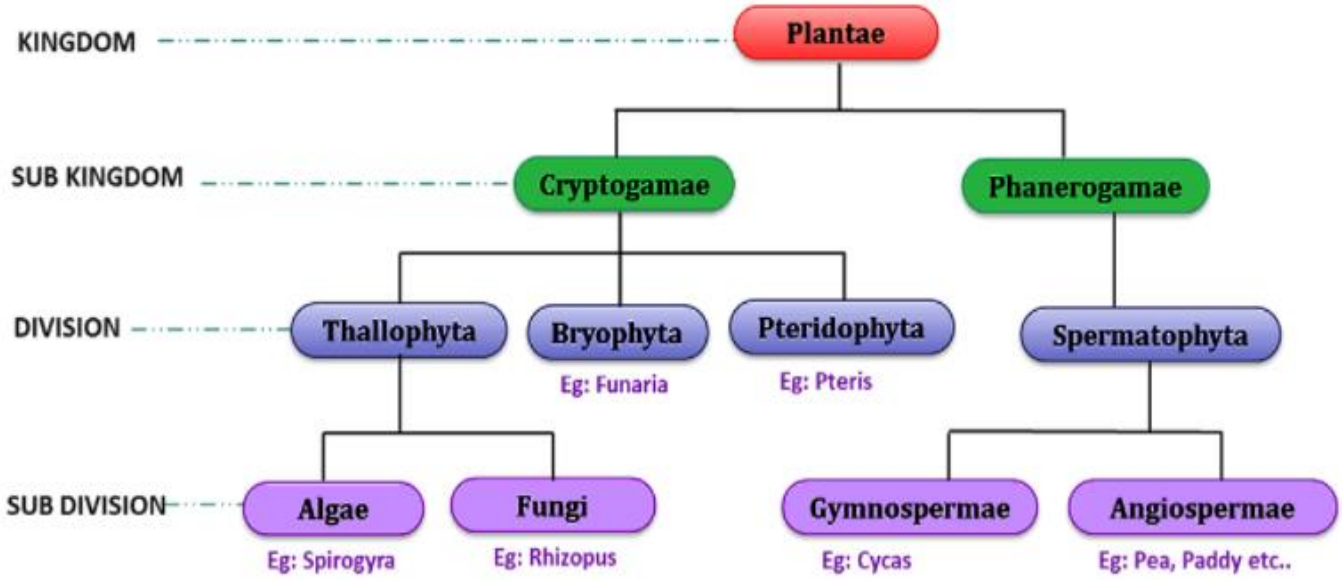


Figure 13. Classification of plant kingdom

1-3-How technology participates in the amelioration of plant quality

Technology plays a crucial role in the amelioration of plant quality by providing advanced tools and methods that enhance plant productivity, resistance, and nutritional value. Through the application of biotechnology, genetic engineering, and molecular biology scientists can modify or select plant traits to meet agricultural and industrial needs.

1-4-Main Axes of plant biotechnology

1-4-1-Plant genetic transformation:

Plant genetic transformation is the process of introducing foreign DNA into a plant to alter its characteristics, using methods to deliver the DNA and then regenerate the transformed cells into a whole plant to create genetically modified plants (GM plants or transgenic plants) in order to improve traits such as yield, disease resistance, or stress tolerance.

1-4-2-Plant tissue culture techniques:

A group of methods that grow plant cells, tissues, or organs on artificial nutrient media under sterile and controlled conditions. The technology is used to rapidly multiply plants from a small piece of tissue in artificial medium. It includes bioreactors for controlled, large-scale growth, robotic automation for tasks and artificial intelligence (AI) for optimizing growth conditions through data analysis.

1-4-3-Molecular markers in plant breeding:

Molecular markers are DNA variations used in plant breeding to identify and select plants with desirable traits more quickly and accurately than traditional methods. The DNA sequences which are linked to genes controlling important traits. They help identifying beneficial alleles without waiting for visible characteristics.

1-4-4-Abiotic stress tolerance in plants:

Abiotic stress refers to non-living environmental factors (Drought, salinity, cold, or heat) that limit plant growth and productivity. In other words, it's the ability of plants to withstand conditions challenges like drought, extreme temperatures, and salinity through a combination of physiological, biochemical, and molecular mechanisms.

1-4-5-Use of biotechnology for crop quality improvement:

Biotechnology participates in improving nutritional content through biofortification, increasing resistance to pests and diseases with genetic engineering and gene editing, and accelerating breeding for needed traits using marker-assisted selection. These techniques result in more resilient, nutritious (More vitamins and minerals), and productive crops.

V-Microbiology Concepts:

1-Definition of microbiology:

Microbiology is the study of microscopic organisms, which are defined as any living organism that is either a single cell (unicellular), a cell cluster. This includes eukaryotes, such as fungi and protists, prokaryotes cells as bacteria, they also include viruses. It also includes the study of the immune system, or immunology which generally deals with pathogenic microbes. Microbiology participates in many fields in scientific domain, among these fields we can name:

Figure 15. Bacteria colored colonies in petri dishes

Table 02. Importance of microbiology in today's world

Topic	Description
Medical Microbiology	Study of microorganisms that cause diseases in humans and animals, and development of treatments and vaccines.
Environmental Microbiology	Study of microorganisms in the environment, including their roles in nutrient cycling, bioremediation, and climate change.
Food Microbiology	Study of microorganisms in food, including their roles in food spoilage, foodborne illness, and food preservation.
Industrial Microbiology	Study of microorganisms in industrial processes, including their roles in fermentation, biotechnology, and biofuels.
Research and Development	Microbiology research is essential for the development of new technologies, medicines, and treatments.
Public Health	Microbiology plays a crucial role in monitoring and controlling infectious diseases, and in ensuring the safety of our water and food supplies.

2-Biological organisms' tools in Microbiology:

Microorganisms are tiny living organisms that can only be seen under a microscope. They are classified into several groups based on their characteristics and include bacteria, viruses, fungi, and protozoa.

1. Bacteria

Single-celled organisms (Procaryotic), without a membrane-bound nucleus. Their DNA, instead of being contained in the nucleus, exists as a long, folded thread with no specific location within the cell and use appendages like flagella to move.

Bacteria are the first living organism to appear on earth about 4 billion years ago, they can be found in various environments such as soil, water, and the human body. They can be beneficial or harmful to humans. Some bacteria help with digestion and produce vitamins, while others cause diseases such as pneumonia and tuberculosis.

Beneficial bacteria include *Lactobacillus spp* and *Bifidobacterium spp*, which aid digestion and gut health, while pathogenic bacteria examples include *Streptococcus spp*, *Staphylococcus spp*, and *Salmonella spp*, which can cause infections and diseases like strep throat, skin infections, and food poisoning

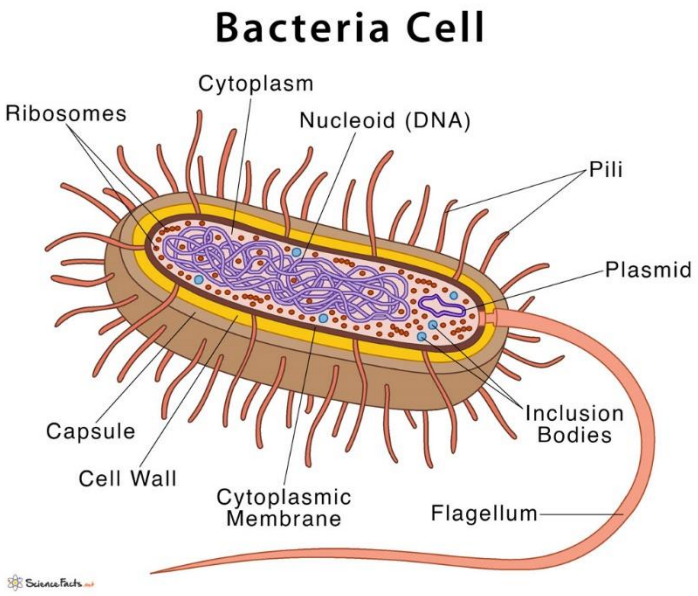


Figure 14. Bacteria global structure

2. Viruses

A virus is a microscopic infectious agent that replicates only inside the living cells of other organisms. It consists of genetic material (DNA or RNA) enclosed in a protein shell called a capsid, and some viruses also have an outer envelope. To multiply, viruses must infect a host cell and use its resources to make copies of themselves Virus are smaller than bacteria and cannot reproduce on their own. They can cause a wide range of diseases in humans, including the common cold, flu, and HIV, AIDS….Etc. With the electron microscope it is possible to determine the morphological characteristics of viruses.

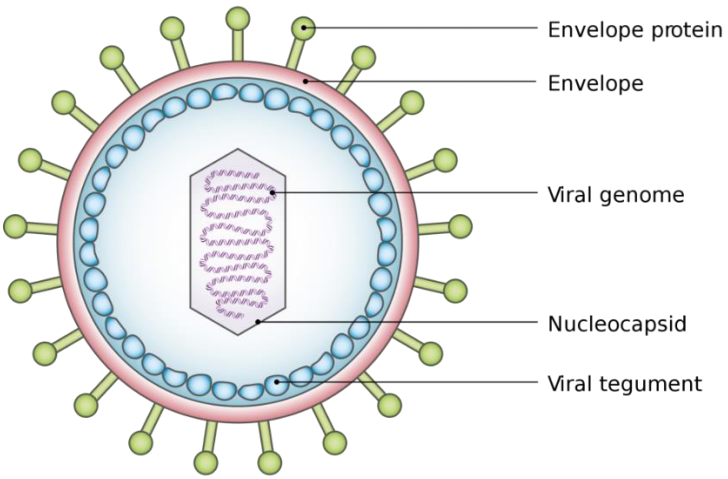


Figure 16. Virus global structure

3. Fungi

Fungi are a diverse group of eukaryotic microorganisms that include yeasts and molds. As microorganisms, they are single-celled (yeasts) or multicellular (molds) and obtain nutrients by absorbing dissolved organic

matter from their surroundings. They are neither plants nor animals, belong to their own kingdom, and lack chlorophyll, which prevents them from performing photosynthesis. They can be found in soil, water, and air. Fungi play an important role in decomposition and nutrient recycling. Some fungi can also cause infections in humans, such as athlete's foot and yeast infections.

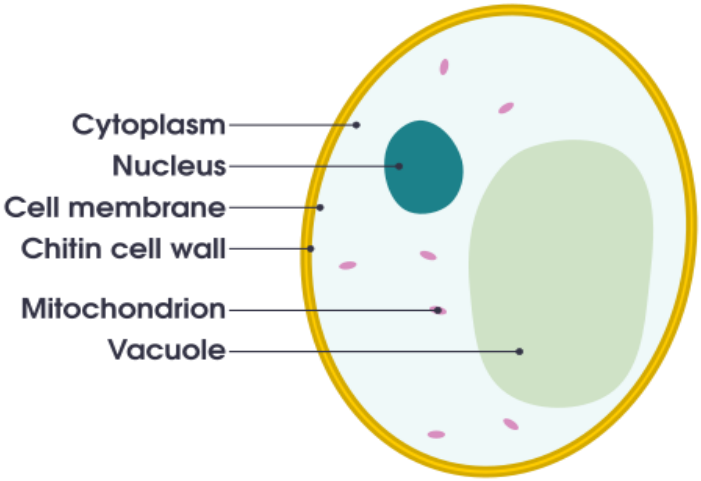


Figure 16. Yeast global structure

4. Protozoa

Protozoa are a polyphyletic group of single-celled eukaryotes, either free-living or parasitic, that feed on organic matter such as other microorganisms or organic debris are single-celled organisms that are found in water and soil. They have a true nucleus (Eucaryotic) and various organelles that help them move, feed, and reproduce. Some protozoa cause diseases such as malaria and amoebic dysentery.

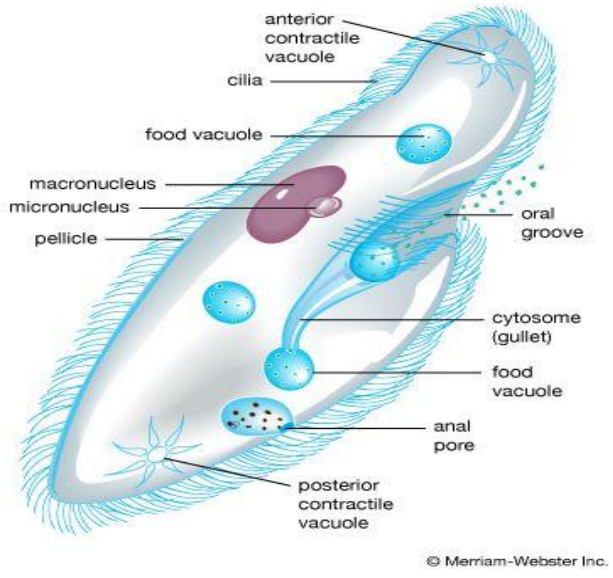


Figure 17. Protozoa global structure

3-Reproduction of microorganisms:

Microorganisms have different methods of reproduction.

- Bacteria reproduce through binary fission, where one cell divides into two identical cells.
- Viruses replicate by hijacking the machinery of host cells to produce more viruses.
- Fungi reproduce through spores, which are released into the environment and can germinate into new organisms.
- Protozoa reproduce through binary fission or by forming cysts.