Algerian People's Democratic Republic
Ministry of Higher Education and Scientific Research
Abdelhafid Boussouf University Center - Mila
Institute of Natural and Life Sciences
Department of Biotechnology

COURSE:

INTRODUCTION TO BIOTECHNOLOGIES

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For use by L2 « Biotechnology » students.

Preface

Biotechnology is a clearly multidisciplinary field involving biochemistry, molecular biology, genetics, immunology, microbiology, pharmacology, fermentation, agriculture, to name just a few. Each of these contributing areas brings its own specialized vocabulary, and the standards of nomenclature and the considerable difficulties of communication are the result. It is intended for second-year L2 students; Field: Biotechnology, as well as for anyone in other disciplines interested in this science.

Prerequisites

Solid foundations in General Biology, biochemistry, genetics, and molecular biology. The student should also have a general understanding of pathogens.

Objective

This unit aims to introduce the concepts and evolution of biotechnology by developing a well-founded understanding of the history and definitions of biotechnology, including general principles, the integration of different fields, specialized knowledge, and developments on specific topics.

Like any work, errors and shortcomings may occur. Therefore, it is always beneficial and motivating to receive corrections, advice, and recommendations from colleagues who are teachers and researchers working in the field.

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Abbreviations

1. **GM** : Genetically Modified
2. **RNAi** : RNA Interference
3. **dsRNA** : Double-Stranded RNA
4. **Bt** : Bacillus thuringiensis
5. **rDNA** : Recombinant DNA
6. **ANR** : National Research Agency (Agence Nationale de la Recherche)
7. **ICST** : Information and Communication Sciences and Technologies
8. **PAHs** : Polycyclic Aromatic Hydrocarbons
9. **NOx** : Nitrogen Oxides
10. **SO2** : Sulfur Dioxide
11. **CO** : Carbon Monoxide
12. **VOCs** : Volatile Organic Compounds
13. **O3** : Ozone
14. **PM** : Particulate Matter
15. **DDT** : Dichlorodiphenyltrichloroethane
16. **VOCs** : Composés Organiques Volatils
17. **PE** : Polyéthylène
18. **PP** : Polypropylène
19. **PVC** : Chlorure de Polyvinyle
20. **PS** : Polystyrène
21. **PET** : Téréphtalate de Polyéthylène
22. **PU** : Polyuréthane
23. **PCR** : Réaction de Polymérisation en Chaîne
24. **ELISA** : ImmunoSorbant Enzyme-Linked Assay
25. **IBD** : Maladie Inflammatoire de l'Intestin
26. **IOC** : Comité International Olympique
27. **EPO** : Érythropoïétine

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CHAPTER I: INTRODUCTION

INTRODUCTION

«Biotechnology encompasses a set of powerful tools that utilize living organisms, or parts thereof, to obtain or alter products, enhance plant and animal species, or develop microorganisms for specific applications».

«It involves manipulating living organisms to produce goods beneficial to humanity».

«It applies principles of science and engineering to process materials using biological agents to obtain products and services».

«It integrates natural sciences and engineering to apply organisms, cells (or their parts), and molecular analogs in the production of goods and services».

«It involves the industrial use of living organisms or biological techniques derived from fundamental research. Biotechnological products include antibiotics, insulin, interferon, recombinant DNA, and monoclonal antibodies. Biotechnological techniques encompass genetic engineering, cell cultures, tissue cultures, biotreatment, protein engineering, biocatalysis, biosensors, and bioengineering».

«Biotechnology is not limited to a single technology; it encompasses various techniques that manipulate living cells and their molecules to improve life in a practical manner».

1.1. The origins of biotechnologies

1.1.1. Etymological origin of the term "Biotechnology"

The term "biotechnology" is composed of two elements:

- **"Bio"** comes from the Greek **"Bios,"** which means life. This term evolved to give rise to the word "Biology" in the early 19th century
- **"Technology"** comes from the Greek **"Technologia."** This word appeared in French texts in 1656 to refer to "the study of techniques, tools, machines, and materials."

1.1.2. Origin and developments of biotechnologies - Brief history:

The history of "biotechnologies" can be divided into three distinct stages (table 1).

Table 1: The history of biotechnologies (https://sms-bse-bgb.ac-normandie.fr/Les-biotechnologies-un-peu-d-histoire)

1. From the Neolithic period to the early 20th century.	2. From the 1920s to the 1970s.	3. Since the early 1970s.
- The use of bacteria, yeasts, and molds in various fields such as food, beverages, and textiles. - Standardization of fermentation processes. **-1650:** Introduction of the Orleans method for vinegar production. **-1664:** Establishment of a renowned brewery in Alsace producing beer. **-1890:** Louis Pasteur and Robert Koch pioneering the development of the first vaccines.	- Antibiotic and vitamin industry, etc. **-1927:** Alexander Fleming discovers penicillin. **-1953:** DNA is recognized as the carrier of genes.	- Advances in genetics, cell biology, immunology. - Mastery of the genome: molecular cloning. - 1972: Beginnings of "genetic engineering" by Stanley Cohen and Georges Köhler. - 2002: Announcement of the complete decoding of the human genome.

The term "biotechnology" was introduced by Karl Ereky in 1919 to describe the interaction between biology and technology. However, biotechnology is not limited to the simple combination of biology and technology; it represents a multidisciplinary effort that has been implemented by humanity for over 5,000 years. The beginnings of plant cultivation, animal breeding, and cheese production illustrate the application of biotechnology principles in a broader sense.

The first stage of biotechnological development was marked by the use of fermentation techniques. It was only later, in the 1970s, that these techniques were applied to the remarkable results of emerging molecular biology techniques. The term "biotechnology" has appeared relatively recently in common language. Additionally, the main areas of biotechnological processes in the past include:

- Bread making (3,000 BC) ;
- Vinegar production (14th century) ;
- Description of yeast cells by Leeuwenhoek (1689);
- Discovery of yeast fermentation properties by Erxleben (1818).

Traditional applications of biotechnology are also numerous. A simple example is composting, which improves soil fertility by promoting the decomposition of organic matter by soil microorganisms. Other common applications include the production and use of vaccines. The food industry also offers many examples of biotechnological processes, including the production of cheese, yogurt, and bread.

1.2. Evolution of biotechnologies over time

Biotechnology has a long history dating back to the time of farming and animal husbandry, when humans began to interact with nature and modify the environment in which they lived. Thus, these techniques, although very ancient, possess an unprecedented transformative power today.

Biotechnology can be divided into three periods:

1.2.1. Ancient Biotechnology (before 1800)

This period was marked by the history of domestication and agriculture, as well as the emergence of the first fermented foods such as bread, yogurt, and cheese. The end of this period is marked by Louis Pasteur's discovery of the direct link between yeast and fermenting sugars in 1866, and the industrial production of baker's yeast in 1915.

1.2.2. Classic Biotechnology

This new period of biotechnology (from 1800 to the mid-20th century) corresponds to a phase of industrial exploitation of the fermentation process for the production of a wide variety of products, including wine, cider, vinegar, glycerin, acetone, butanol, lactic acid, citric acid, antibiotics, etc. Chemical reactions are used for the production of therapeutic products, where the substrate reacts with a microbial enzyme to produce the final product.

1.2.3. Modern Biotechnology

World War II, a period marked by major scientific discoveries and advancements, marks the beginning of the modern era of biotechnology. These discoveries paved the way for modern biotechnology as we know it today. In 1953, JD Watson and FHC Crick unraveled the mysteries surrounding DNA by proposing the structural model of the DNA double helix. This event marks the beginning of modern biotechnology.

1.3. The major current challenges of biotechnologies and bionanotechnologies

For over twenty years, nanosciences and nanotechnologies have been the subject of numerous research endeavors, within and at the intersection of various scientific disciplines such as physics, chemistry, information and communication sciences and technologies (ICST), biology, engineering sciences, as well as humanities and social sciences. Research efforts in nanotechnologies inspire considerable hopes due to the unique properties of matter at the nanoscale, paving the way for previously unimaginable functionalities.

The fabrication, observation, and manipulation of nanoscale objects, the study and understanding of their properties and interactions with their environment, especially with living organisms, their modeling and simulation, as well as their integration into communication systems, represent and continue to represent significant scientific challenges necessary for the development of numerous and substantial applications, while ensuring appropriate control and mastery.

The applications of nanotechnologies are becoming increasingly important in everyday life, in industry and commerce, in the fields of health and society at large. Currently, research and development in the field of nanotechnology applications are experiencing explosive growth, covering areas such as energy, chemistry, sensors, materials, information and communications, biology, medicine, and the environment.

However, this rich landscape should not overshadow other aspects, including emerging risks associated with nanotechnologies for health, the environment, privacy protection, and even potential developments in human evolution. The challenges to be addressed are therefore considerable, and competition among major powers is becoming increasingly intense.

1.3.1. Nanotechnology

A nanometer is about 500,000 times thinner than the width of a ballpoint pen line, 30,000 times thinner than the width of a hair, and 100 times smaller than a DNA molecule. Nanotechnologies encompass nano-objects, particles, fibers, or tubes ranging in size from 1 to 100 nm. Nanomaterials, composed or consisting of nano-objects, exhibit enhanced properties associated with their nanoscale dimension. These nanotechnologies, emerging in the early 1980s, have major applications in the fields of information technology, healthcare, new materials, and energy.

1.3.2. Nanobiotechnology

Nanobiotechnology can be defined in various ways. Some describe it as the application of nanotechnological techniques for the development and improvement of biotechnological products and processes. Others use the term "bionanotechnologies" to describe the use of biological components at the nanoscale. In practice, these terms are often grouped under the general category of "nanobiotechnology."

1.3.3. The various implications of nanotechnologies:

- **Fundamental implications,** as they collaborate with nanosciences to expand the frontiers of knowledge.
- **Applicative implications across multiple sectors,** encompassing not only information and communication technologies but also fields such as health, environment, energy, sustainable development, security…
- **Strategic implications,**
- **Industrial implications,** as mastering nanotechnologies is crucial for maintaining an industrial sector necessary for the development.
- **Societal implications,** involving the assessment of the impact of nanotechnologies and their regulation. In this regard, it is important to note that the ANR (National Research Agency) finances several projects aimed at understanding the ecological impact of nanotechnologies, toxicity phenomena, as well as societal and human mutations they generate.

1.4. Definition of green, white, and red biotechnologies

Biotechnologies find applications in various sectors and are classified under a color-coded system (Figure 1).

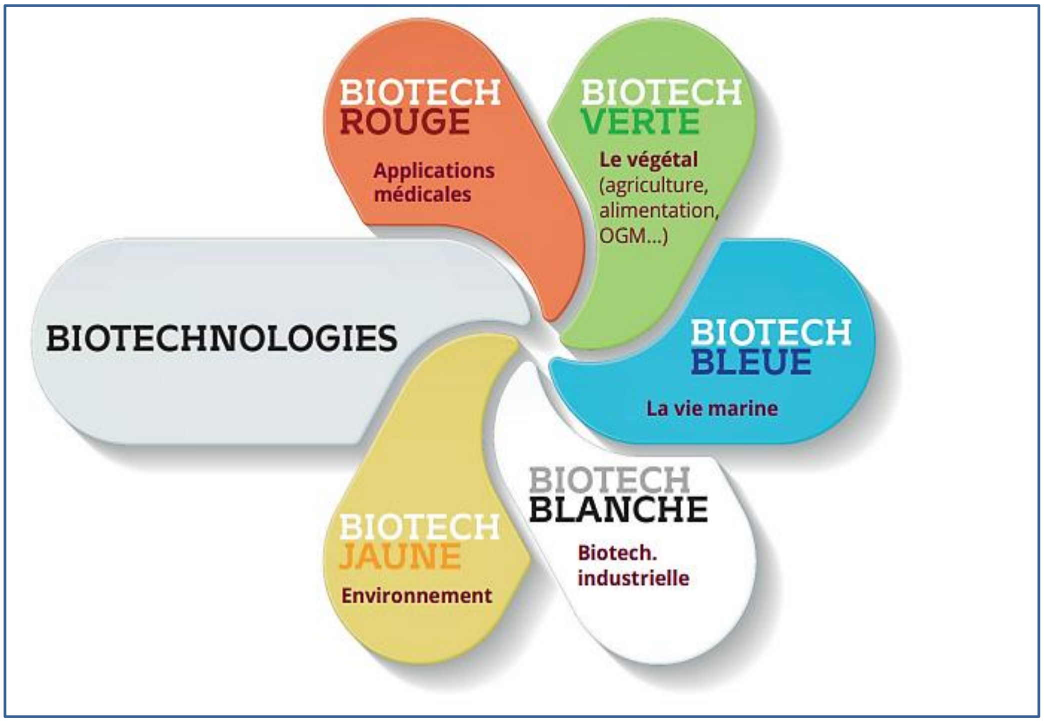


Figure 1. The five colors of biotechnologies **(Barcelos et *al.*, 2018)** .

There are five main groups of biotechnologies, identified as follows:

1.4.1. Red biotechnologies (Medicine)

They encompass the fields of health, medicine, diagnostics, tissue engineering, and the development of genetic or molecular processes for therapeutic purposes. This category has been the subject of major efforts, particularly in the production of vaccines and antibiotics, molecular diagnostics, regenerative/genetic therapies, etc. Medications such as human insulin, growth hormones, anti-hemophilic factors, antibodies, as well as products derived from synthetic chemistry but developed using biotechnologies, are notable examples. DNA sequencing techniques, which have revolutionized human medicine by enabling a better understanding of genetic information organization, also belong to this domain.

1.4.2. White biotechnologies (Industry):

They involve the manufacturing of products (polymers, sweeteners, amino acids, etc.), the invention of processes (biorefinery), and the large-scale production of bioenergy from biomass, considered a renewable raw material. These raw materials are transformed into finished products using microorganisms.

These biotechnologies aim to promote sustainable development by using renewable carbon sources, limiting energy consumption, avoiding solvents, and reducing water consumption. They also contribute to the creation of "integrated biorefineries," where different plant raw materials are transformed into various products used in different industrial sectors.

1.4.3. Yellow biotechnologies (Environment):

They encompass technologies related to environmental preservation and pollution control, including wastewater treatment, solid waste valorization, purification of residual gases and air, as well as bioremediation of polluted environments. These applications mainly aim to eliminate pollutants and/or contaminants, as well as to maintain biodiversity. For example, the use of microorganisms and plants to clean soils from heavy metals or hydrocarbons.

Yellow biotechnologies also encompass energy production. For example, the production of biofuels offers a more environmentally friendly alternative to fossil fuels. The process of refining oilseed produces oils used to make biodiesel or biolubricants. However, from a sustainable development perspective, yellow biotechnologies should promote the production of renewable energy from biomasses whose regeneration is at least equal to their consumption and does not compete with biomasses intended for food.

1.4.4. Green biotechnologies,

Also known as plant biotechnologies, offer solutions to address the challenges of agriculture, ensuring food and energy security while preserving the environment. Regulatory changes and new societal expectations have encouraged farmers to adopt more sustainable practices, beneficial to populations, the environment, and territories. These approaches include the creation of new plant varieties for agriculture, the use of biocontrol products as alternatives to synthetic pesticides, and biostimulants.

1.4.5. Blue biotechnologies

Harness marine resources to develop products and industrial applications. Unlike red, green, or white biotechnologies (determined by the target market), blue biotechnologies are defined by their base material: marine resources. They can be used in areas such as cosmetics, the food industry, energy, and pharmacology. Due to the vast marine biodiversity, these biotechnologies have significant potential for a variety of sectors.

Finally, it is worth mentioning the emergence of a new form of biotechnology, that of insects. Ynsect, a pioneering company in this field, is developing insect production and transformation technologies to provide products and services in the fields of green chemistry, food, and agriculture.

1.5. Typical products of biotechnologies

1.5.1. Pest-resistant Plants

Plant parasites and insects such as nematodes pose significant challenges to the survival of crops and plants. For instance, Meloidogyne incognita, a deadly nematode, parasitizes tobacco plants and significantly reduces yield by damaging the roots.

RNAi (RNA Interference) technology has enabled scientists to develop pest-resistant plants, a process occurring in all eukaryotes as a means of creating cellular defense mechanisms.

Pest-resistant genetically modified (GM) crops have been a major success in biotechnology, involving the suppression of the translation of specific mRNA in a host plant using complementary dsRNA extracted from a different infection-causing virus carrying transposons or an RNA genome. Bacillus thuringiensis, a microorganism, has long been utilized to produce GM crops (also known as Bt crops). Following genetic modification, these plants become toxic to certain herbivores while causing little to no harm to beneficial beetles that aid in pollination.

An outstanding benefit of GM crops is their ability to reduce reliance on chemical-based sprays and pesticides. These chemical products can pose significant health risks by impacting the human nervous, reproductive, and endocrine systems.

1.5.2. Genetically Engineered Insulin

Another life-saving biotech product is artificial human insulin that can help manage and control adult-onset diabetes – which caused the death of around 1.5 million people worldwide in 2019.

Though insulin was being collected from the pancreas of slaughtered cows and pigs earlier, it induced some allergy issues or immune responses against the foreign proteins in the human body. Moreover, animal insulin was not economically viable for mass production and commercialisation.

Thanks to rDNA technology that has made the mass production of biosynthetic insulin possible, inserting human insulin genes into the plasmid of *Escherichia Coli* bacteria.

The benefits of artificial human insulin over highly purified animal insulin are many:

- The subcutaneous injection of human insulin causes fewer/no allergic reactions
- They get absorbed quickly and
- Synthetic human insulin produces lower titers of circulating anti-insulin antibodies than animal insulin.

1.5.3. Transgenic Animals

When a particular animal's DNA is exploited by altering its genome with the gene/genes of an animal of other species, a transgenic animal gets developed. For successful transgenesis, the transgene must be dispatched through the germline to ensure each cell, even the transgenic animal's germ cells carry the identical modified genetic material.

Though more than 95% of transgenic animals are rats, transgenic pigs, cattle, and sheep can also be found.

Why are these genetically modified species so important? Besides improving reproductive performance and prolificacy in livestock generation, transgenic animals show promising results in producing complex proteins as they carry the cellular mechanism vital for complex protein production.

While conventional breeding can be time-consuming, transgenesis helps develop animals with desired traits like producing more milk and meat at a higher growth rate.

What is more impressive is that some transgenic animals are used to understand the role of genes in disorders like Alzheimer's, cancer, etc.

1.5.4. Bioplastics

Industrial biotech processes are helping the world boost the transition from hydrocarbon-based polymerised plastic compounds to biomass-based plastics. Bioplastic is another promising biotech breakthrough which is forecast to be the major player in reclaiming ecological balance.

Currently, bioplastics represent about 1% of the 368 million tonnes of total plastic products manufactured annually.

Some plant-based bioplastics and their equivalents can also be recycled.

1.5.5 Vaccines

Advancements and continuous research in medical biotechnology have sped up vaccine development against various infectious and deadly diseases.

A vaccine usually includes an agent identical to a specific disease-causing pathogen and comprises live-attenuated or inactivated microorganisms, their toxins, or some portion of surface antigen. However, scientists have managed to develop various highly efficient novel vaccines and commercialised them successfully using biotechnology.

For instance, biotechnology has helped scientists develop a vaccine against lymphoma by genetically modifying tobacco plants to manifest RNA from malignant B-cells.

Lymphoma is a chronic and incurable cancer that affects the lymphatic system in humans.

Plant-grown vaccines have far fewer after-effects than traditional cancer treatments like chemotherapy and allow more rigorous cancer management cost-efficiently.

Today, when the world is facing a severe crisis due to the Covid-19 pandemic, the vaccine against this fatal infection got a biotech boost.

1.6. Industrial sectors involved

The industrial applications of enzymatic processes represent essential "clean" solutions that extend to various sectors, including the textile industry, food, cosmetics, paper manufacturing, fermentation, antibiotic production, enzyme utilization, alternative fuel industry, molecular biology, and many others.

1.7. The challenges of biotechnological innovation

Biotechnological innovation is increasingly acknowledged as a vital instrument for enhancing global health. However, the challenge lies in delineating the role of technology transfer in creating treatments for diseases prevalent in developing nations. Over the past decade, a significant gap has arisen between the developed and developing worlds in accessing affordable medications, mainly due to the pharmaceutical industry's concentration on areas of health that yield the highest profits. Various mechanisms are discussed here that offer partial solutions to address this challenge.

CHAPTER II: Biotechnologies Applied to Environmental Issues

2.1. Climate change and evolution of ecosystems

2.1.1. Climate change

Climate change refers to long-term variations in temperatures and weather conditions. These fluctuations can be natural, attributed to changes in solar activity or large volcanic eruptions. However, since the 1800s, human activities have become the primary driver of climate change, mainly due to the use of fossil fuels such as coal, oil, and gas.

2.1.2. Climate change threatens ecosystems

Climate change could become one of the main causes of extinction and population decline for plants and animals in the coming decades. It is now essential to assess the vulnerability of ecosystems to this threat, particularly in islands, which represent both major biodiversity hotspots and are already heavily impacted by human pressures.

The ability of species to adapt to the impacts of climate change depends on both internal and external factors, such as their exposure to this threat, their biological and ecological traits that allow them to survive thermal changes, as well as the characteristics of habitats that can facilitate their movement from areas that have become less favorable to areas more conducive to their survival (figure 2).

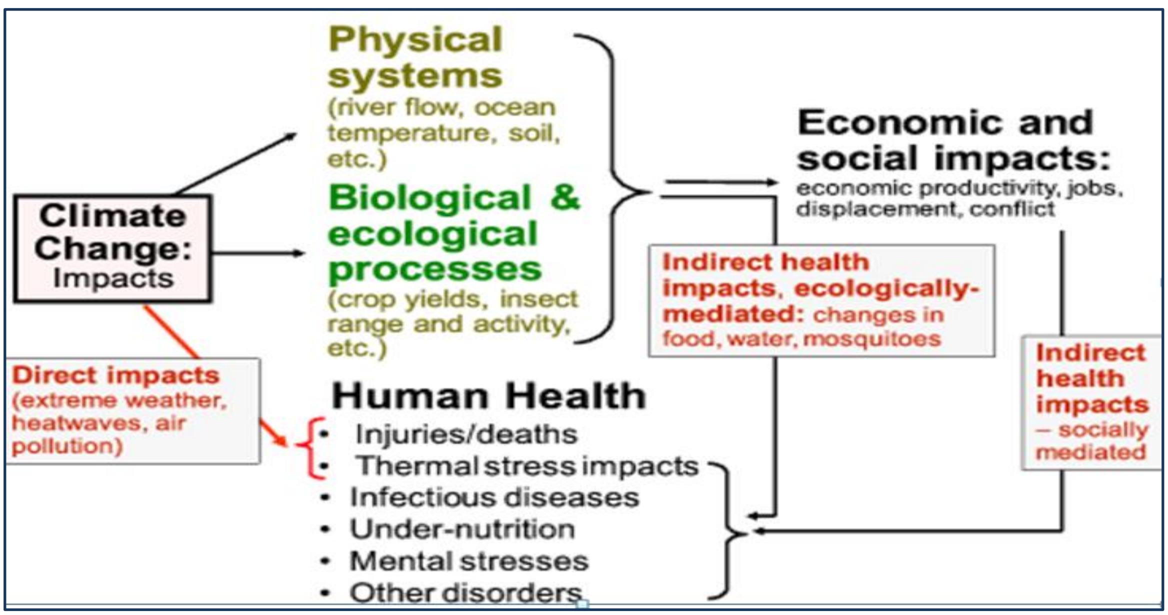


Figure 2. Schematic diagram of the main categories of climate change-influenced health **(McMichael, 2015)**

2.2. Management of microbiological, plant, and animal resources

2.1.1. Biological Resources

- **Definition:**

Biological resources encompass genetic resources, organisms or their parts, populations, or any other biotic element of ecosystems that have current or potential value to humanity. The management of microbiological, plant, and animal resources aims to:

• Organize the collection and conservation of genetic resources of species selected and used by humans, in the form of samples representing animal, plant, and microbial genetic heritage;

• Promote research in the field of resource conservation.

This management aims to preserve useful plant varieties, animal breeds, and microbial strains, thus contributing to human history and food supply. The ultimate goal is to counteract the erosion of the diversity of this heritage caused by the abandonment of old varieties presumed to be less productive and more fragile, as well as the standardization of productions.

The conservation of genetic heritage is carried out by preserving species in their natural habitat whenever possible (in situ conservation), as well as by collecting and/or cryopreserving genetic heritages (ex situ conservation).

2.1.2. Conservation of Plant Cultivars and Informal Networks

Plant cultivars are preserved through informal networks involving both public and private actors, requiring regular cycles of multiplication.

2.3. Agro-environmental pollution (water, air, soil)

2.3.1. Pollution

Pollution refers to the deterioration of a natural environment by external substances, introduced directly or indirectly. It can have long-lasting repercussions on human health, the quality of ecosystems, and aquatic or terrestrial biodiversity. Pollution occurs when ecosystems can no longer break down the introduced substances, exceeding their critical threshold of natural capacity to eliminate them, thus disrupting the ecosystem's balance. The sources of pollution are multiple, and identifying them, along with different pollutants and their impacts on ecosystems, is complex.

They can result from natural disasters or human activities, such as oil spills, chemical pollution, nuclear accidents, the introduction of invasive species, or the dumping of waste into nature. The nuisances caused by these sources of pollution are diverse and can accumulate, leading to increased mortality of human, animal, or plant species, even the extinction of certain species, the destruction of natural habitats, and the degradation of soil, water, and air quality. Preventing pollution and applying the precautionary principle to pollution risks stemming from human activities are systematic elements in applying the principles of sustainable development. The goal is not only to address existing pollution but also to anticipate and avoid future sources of pollution to preserve the environment and public health (figure 3).

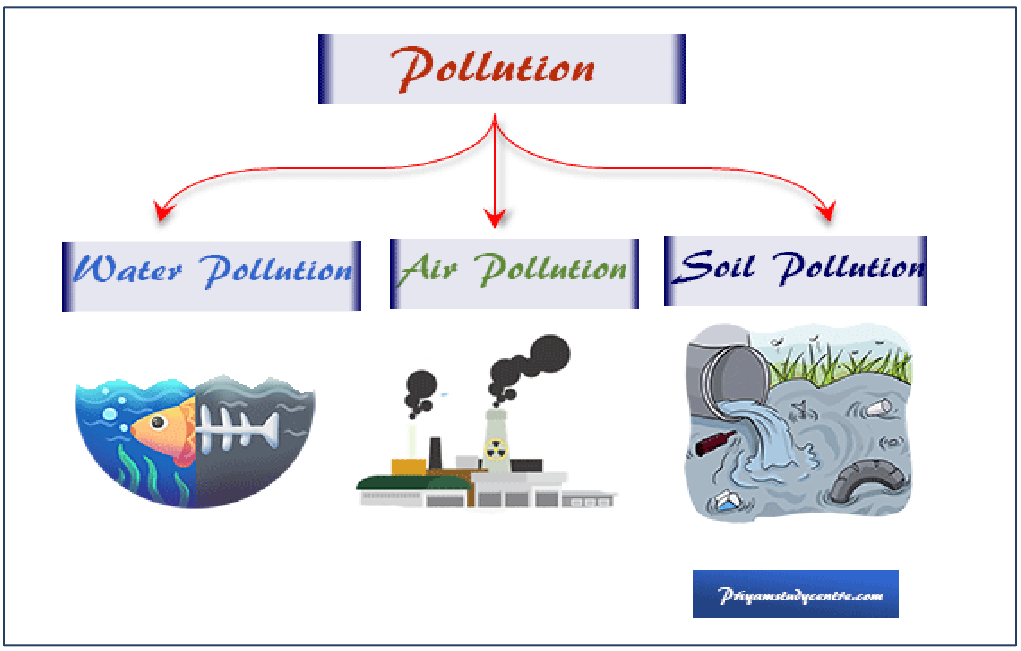


Figure 3. The major kinds of environmental pollution (http://pryamsendycenter.com/)

2.3.2. Main categories of atmospheric pollutants

Air pollution is often distinguished based on its impact at various levels: local, regional, and global.

a) Local atmospheric pollution:

Is the primary form of pollution emanating from nearby sources such as industrial facilities or vehicles.

The main characteristic pollutants at this scale of impact include:

- Particulate matter (PM)
- Nitrogen oxides (NOx)
- Sulfur dioxide (SO_2)
- Carbon monoxide (CO)
- Volatile organic compounds (VOCs)
- Polycyclic aromatic hydrocarbons (PAHs)
- Metals.

b) Regional almospheric pollution:

The second form of pollution results from more or less complex physico-chemical phenomena leading to the formation of so-called "secondary" pollutants in the atmosphere from "primary" pollutants (notably those mentioned previously); an important example of such "secondary" pollutants is ozone (O3). This form of pollution is termed "regional" because the geographical scale affected by these phenomena is large (for example, the entire Paris Basin).

c) Global atmospheric pollution

The third form of pollution concerns substances involved in climate change phenomena, such as greenhouse gases, particularly CO_2. Regulations define reference concentrations for certain pollution indicators to guide the action of public authorities.

2.3.3. Main categories of water pollutants

a) Physical pollutants:

These include turbidity, thermal pollution, and radioactive materials.

b) Chemical pollutants: They encompass substances such as nitrogen, metals, pesticides, and hydrocarbons, Organic matter.

c) Microbiological pollutants: These include bacteria, viruses, and fungi.

2.3.4. Primary Soil Contaminants

- **Heavy metals** from agriculture and diffuse atmospheric fallout.
- Cyanides from herbicides.

- **Nitrates:** Their adsorption in soil is difficult, making them prone to denitrification and leaching into water.

- **Sodium salts** from herbicides and irrigation water, leading to soil salinization and decreased fertility.
- **Pesticides:** They can dissolve in soil solutions and gradually leach into groundwater, with a highly variable lifespan; for example, DDT is particularly persistent.
- **Pathogenic organisms:** Animal diseases can be transmitted to humans through soil, such as tetanus, botulism, brucellosis, foot-and-mouth disease, etc.
- **Radioactive pollution:** Whether natural (like radon), industrial, medical, accidental (such as in the case of Chernobyl), or linked to military activities such as atomic bomb tests (for example, Reggane in Algeria from February 13, 1960, to April 25, 1961).

2.3.5. Environmental biotechnology as a catalyst for sustainable development

As a Catalyst for Sustainable Development Environmental biotechnology emerges as a crucial driver of sustainable development, mainly influencing key sectors such as the decontamination of polluted sites, waste and odor treatment and recycling, water treatment, monitoring of pathogens in the environment, and renewable energies.

a) Sustainable Waste Management

The concept of "waste management" generally encompasses all actions involved in organizing waste management, from their production to their final treatment. This includes collection, transportation, trading, brokerage, and treatment - whether for valorization or disposal- of waste. Each of these actions is regulated by rules established in the environmental code, and each stakeholder is subject to various obligations.

b) Molecular-scale purification

The biofilm consists of cells and a matrix of polymeric substances secreted by these cells, holding them together and attaching them to the surface. Bacteria within biofilms often develop specific physiology, making them more resistant to harmful substances such as biocides and antibiotics. Moreover, biofilms promote the release and dispersion of different strains during the dispersion phase

CHAPTER III: Biotechnologies in Agronomy for Food Purposes

3.1. Biotransformation and preservation

The production of food involves the use of raw materials of plant, animal, or mineral origin that undergo transformations through various means such as physical processes (like grinding or mixing, heat, cold...), physico-chemical processes (alteration of water activity through salting or sugaring, pH modification through acidification...), biochemical processes (use of enzymes, various stabilizers, antioxidants...), and microbial processes.

3.1.1. Biotransformation

Biotransformation is the process by which a substance is transformed (modified) from one chemical into another by a chemical reaction in the body. Biotransformation is essential for survival as absorbed nutrients (food, oxygen, etc.) are converted into substances required for normal bodily function. For some medications, this may involve a metabolite that is therapeutic rather than the active pharmaceutical ingredient of the medication itself.

a) Size reduction operations

Size reduction operations (such as crushing and grinding), mechanical separation (sedimentation, magnetic separation, etc.), agglomeration (pelletization, briquetting, etc.), suspension, etc., are among the processes carried out under ambient conditions. These processes can be physically modeled while maintaining similarity criteria/dimensionless numbers at laboratory scales. Additionally, there are other ambient temperature processes, such as leaching, precipitation, liquid extraction, iron exchange, etc., which involve phenomena like chemical reactions, fluid flow, and mass balance. Modeling these processes at the laboratory scale can be challenging. At times, achieving a full resemblance between the model and plant processes may prove difficult.

- **Grinding:** This is the process of reducing a solid material into very small pieces, typically achieved through pressure or mechanically (for example: wheat seeds).
- **Bolting:** This step, which follows grinding, involves separating the bran from soft wheat seeds to obtain flour.
- **Sifting:** This is the stage where bran from hard wheat seeds and semolina are separated, as hard wheat resists crushing and is transformed into semolina.
- **Cutting:** A common operation in processing chains, involving the division of a product into pieces (for example: cutting meat, cheese...).

- **Liquid component separation:** This process aims to isolate or separate certain constituents present in liquid mixtures. For example, milks, juices, and waters can undergo this operation.
- **Extrusion:** This technique involves passing a compressed material (such as dough) through a tube with the cross-sectional shape of the final product. It is used in the pasta industry (to obtain different pasta shapes) and in biscuit manufacturing.

b) Extraction, decantation, and filtration operations

- **Solvent extraction:** This technique involves extracting a substance dissolved in a solvent (feed phase) using another extraction solvent in which it is more soluble. The two solvents must not be miscible. For example, this method is used to extract oil from oilseeds such as soybeans and rapeseed.
- **Pressure extraction:** This process allows for the extraction of oil from seeds and nuts without the use of chemical compounds. For example, pressure extraction is the primary method used in the processing of camelina oils, as well as in the extraction of fruit juice and vegetable oil (such as olive oil).
- **Static decantation:** This technique is used to separate suspended matter and colloids that group together into flakes after the coagulation-flocculation step. It is widely used in wastewater treatment plants, for example, in the process of purifying wastewater from sewage treatment plants.
- **Decantation:**

- Decantation involves letting a heterogeneous mixture sit for a sufficient period of time so that solid particles in suspension settle at the bottom of the container. Then, the mixture floating above can be gently poured into another container, producing an almost homogeneous mixture.

- This process works particularly well for separating components that tend to easily fall to the bottom of the liquid, such as sand or mud, and is commonly used in wastewater treatment.

- Decantation is often a slow process. To speed it up, a centrifuge can be used; by rapidly spinning the heterogeneous mixture in tubes, the particles are pressed to the bottom and separated from the liquid.

- To separate two immiscible liquids, a separating funnel is used. This funnel has the shape of a funnel extended by a long narrow tube with a tap. During decantation, the denser liquid settles under the less dense liquid, and by opening the tap, the two liquids can be separated.

- **Filtration:**

  - To separate components of a heterogeneous mixture, filtration can also be used. For this, a fine sieve or filter paper (such as a coffee filter) can be used to retain certain components of the mixture, with the largest solid particles being retained by the filter. The recovered liquid is called the filtrate.

  - The choice of filter type (sieve, filter paper) should be adapted to the size of the particles to be separated.

  - Filtration is also used in wastewater treatment.

c) Separation operations

The separation operation aims to isolate or separate certain constituents from the mixtures in which they are present.

To obtain a pure substance, it is often necessary to separate it from all other accompanying substances. This separation can be achieved through physical methods. The choice of technique depends on the type of mixture, the substance to be isolated from the rest of the mixture, and the constituent phases of the mixture.

- **Distillation**: is a method of separating mixtures used to isolate the components of a homogeneous liquid or a heterogeneous mixture containing at least one liquid phase.

Using this technique, we rely on the property of boiling point. The mixture is heated until the boiling point of one of its components is reached. This liquid then evaporates, and the vapor is collected and condensed in another container. While the first liquid evaporates (distillate), the second one does not reach its boiling temperature and remains in liquid form in the original container (residue).

- **Crystallization:** This operation in chemical engineering aims to isolate a product in the form of crystals. Crystallization is one of the oldest physical operations, such as the evaporation of seawater to isolate salt.

- **Condensation:** The term "condensation" refers to a physical phenomenon of changing the state of matter, involving the transition from the gaseous state to the condensed state, solid, or sometimes liquid. In the latter case, it is more accurate to speak of "liquid condensation" or even to use the term "liquefaction". For example: condensed milk.

d) Mixing, texturing, shaping operations

- **Coating:** A process involving coating centers made of fatty acids with a relatively low melting point in a thin layer of stearic acid with a higher melting point.
- **Granulation:** A shaping process that involves binding powders using binding agents to form granules. For example: flour, semolina, milk powder.
- **Texturing:** A frequent step in food processing, it is used to create a smooth, homogeneous product with consistent quality.
- **Mixing:** A common practice in the food industry, it is used to achieve a smooth, homogeneous product with consistent quality. For example: mixing dry and liquid ingredients.

3.1.2. Main reasons for food deterioration

Here are the various factors that can cause changes in a food item (table 2):

Table 2: the different factors that can cause changes in food

Physical agents These are external factors that can directly influence the appearance of canned goods:	✓ Temperature. ✓ Humidity. ✓ Drought. ✓ Air.
Chemical agents These substances relate to the internal aspects of foods, which contain nutrients in their natural state and undergo chemical modifications that can reduce the effectiveness of the nutrients absorbed by the body.	✓ Fermentation of carbohydrates, giving an acidic taste and potentially producing gas. ✓ Rancidity of lipids. ✓ Alteration of vitamins due to oxidation. ✓ Formation of dark pigments, known as the Maillard reaction, resulting from the association of sugar derivatives with certain proteins. ✓ Degradation of proteins resulting in a foul odor.
Biological agents Include intrinsic compounds	✓ Such as enzymes, which can cause oxidation and browning, as is the case when peeling an apple or a raw potato. These biological agents can also include extrinsic elements, such as parasites or microorganisms.

3.1.3. Methods of food preservation

Throughout history, humans have sought to preserve food in order to keep it edible for as long as possible. Of course, the methods used today are very different from those employed in the past, but the knowledge acquired by our ancestors remains the foundation of everything we know today.

There are various food preservation techniques that slow down their deterioration, prevent food poisoning, and extend their shelf life.The techniques used for food preservation are based on:

- **Heat:** pasteurization, sterilization, appertization, semi-preserved products;
- **Cold:** freezing, freezing, refrigeration;
- **Other methods:** vacuum packaging or modified atmosphere packaging, freeze-drying, dehydration and drying, fermentation.

a) Methods of food preservation at low temperature

- **Refrigeration:** A preservation process using refrigerators to lower the temperature between 0 and 5 ºC in order to slow down the growth of bacteria and reduce the enzymatic activity of foods.
- **Freezing:** This method is similar to the previous one, but with a temperature lowered to -18 ºC, allowing the water in the food to solidify into ice, thus preventing the growth of bacteria that require liquid water. Although they are not destroyed, their development is halted.
- **Flash freezing:** This is a technique where foods are exposed to temperatures below -40 ºC for a short period - maximum of 2 hours - before being subsequently stored by normal freezing.

Table 3 explained to us the advantages and disadvantages of the method

Table 3: Methods of food preservation at low temperature (Advantages and disadvantages)

Advantages	disadvantages
✓ The cold slows down the growth of germs and preserves the nutritional properties of food for a certain period. ✓ Freezing and flash freezing are among the most effective and least altering methods of food preservation. Moreover, both methods allow food to be preserved for an extended period, ranging from several months to several years.	✗ Low-temperature preservation methods do not eliminate the possibility of microbial growth, which can become active during the thawing process. ✗ Low-temperature food preservation allows them to be stored for a limited period - a few days, weeks, or months - and of course, requires refrigeration during transport and storage.

- **Blanchiment or Boiling:** This method is not a preservation technique per se. Generally, it precedes freezing, especially for vegetables. Vegetables are submerged for a few seconds in boiling water to eliminate any potential pathogens on the surface before freezing.
- **Sterilization:** Sterilization is a process involving subjecting a tightly sealed food item to high temperatures for a certain duration to completely destroy any potential microorganisms, pathogenic or not, as well as their spores. All types of meat, fish, vegetables, fruits, as well as jams, syrups, pickles, creams, soups, sauces, stews, among others, can be sterilized.
- **Pasteurization**: Unlike sterilization, pasteurization uses lower temperatures, below 100 ºC, and does not completely eliminate microorganisms and their spores. It is mainly used for milk and dairy products, fruit juices, flavored beverages, prepared dishes, and sauces:

Table 4 explained to us the advantages and disadvantages of the method

Table 4: Methods of food preservation at high temperature (Advantages and disadvantages)

Advantages	disadvantages
✓ Sterilization represents the safest method from a microbiological standpoint for food preservation. It eliminates virtually all bacteria, including spores. ✓ This technique extends the shelf life beyond 4 months, and in some cases, this period can extend from 2 to 5 years, depending on the type of food. ✓ Pasteurization is a process that preserves flavors without excessively volatilizing them, thereby maintaining the taste and nutritional properties of food. ✓ These methods do not involve the use of chemical additives, allowing for the production of canned food or natural cooked dishes, without any addition of artificial additives or preservatives.	× During sterilization, due to the application of very high temperatures - exceeding 100°C - the properties of the food can be altered, leading to the loss of certain nutrients and vitamins. Pasteurization does not kill all bacteria. × Therefore, once opened, pasteurized products must be stored refrigerated, and their shelf life can be 2 to 3 weeks.

c) Methods of food preservation by modifying their water content

Since bacteria and other microorganisms thrive in the presence of water, the possibility of contamination can be reduced by controlling the moisture content of the food.

The most common techniques are:

• **Dehydration:** This involves the total or partial removal of water from food by applying heat.

• **Drying:** A traditional method that involves removing moisture from food by exposing it to natural environmental conditions, especially sunlight, so that it loses most of its water content through evaporation. Mojama (salted tuna), dried cod, and raisins are some of the products obtained by this method.

• **Lyophilization:** This involves subjecting the product to very rapid freezing (below -30°C), then heating it under vacuum to remove the water. The water thus transitions from a solid state (ice) to a gaseous state (vapor) through sublimation, i.e., without passing through the liquid state.

• **Concentration:** By removing some of the water from the food, sugars or salt become concentrated, imparting a more pronounced flavor and reducing water activity, i.e., decreasing the water available for microorganisms.

Table 5 explained to us the advantages and disadvantages of the method

Table 5: Methods of food preservation by modifying their water content(Advantages and disadvantages)

Advantages	**disadvantages**
✓ Dehydration prevents the growth of microorganisms and limits enzyme activity.	× Lyophilization is a highly effective method of food preservation that also maintains their properties perfectly intact. However, due to the numerous steps involved, it is more cost-effective on a large scale, which is why it is primarily used in the industrial sector.

d) Food Preservation Methods by Irradiation

• **Irradiation:** This involves exposing the product to ionizing radiation or electromagnetic radiation (electromagnetic rays), or high-energy particles for a certain duration. It is a widely used method in the food industry.

Table 6 explained to us the advantages and disadvantages of the method

Table 6 : Food Preservation Methods by Irradiation (Advantages and disadvantages)

Advantages	disadvantages
✓ Numerous studies have been conducted by international organizations such as the Food and Agriculture Organization (FAO), and they all agree that irradiated foods do not become radioactive, and their nutritional properties and sensory characteristics are not altered.	✗ Not all foods can be subjected to irradiation, but only certain meats, fruits, vegetables, shellfish, mollusks, spices, and condiments. ✗ This technique is not accepted in all countries and must be carried out in external food irradiation facilities.

e) Food Preservation Methods by High Pressure Application

• **Pascalization or High Pressure Processing:** Named after a 17th-century scientist who studied the effects of pressure on fluids. It involves subjecting a food item to high hydrostatic pressure (HHP), affecting its cellular membranes and the structure of certain proteins. This way, microorganisms can be inactivated without altering the organoleptic quality or nutrients of the product. (Table 7 explained to us the advantages and disadvantages of the method)

Table 7: Food Preservation Methods by High Pressure Application (Advantages and disadvantages)

Advantages	disadvantages
✓ This is a food preservation method that doesn't require any additives or preservatives. ✓ It doesn't alter the organoleptic properties of foods, which retain their taste, texture, and appearance. ✓ Not all foods can undergo this treatment, which works best on acidic foods, such as yogurt and fruits.	✗ Some foods subjected to pascalization require storage at a controlled temperature. ✗The use of high hydrostatic pressures (HHP) on a food product eliminates many microorganisms but does not eliminate spores. ✗ Foods must be packaged in a flexible container during processing for optimal pressure transmission. Glass jars or cans cannot be used."

f) Methods of preserving food by chemical alteration

These are very old techniques, used since prehistoric times, which extend the shelf life of foods by helping to reduce the microbial load and slow down the rate of chemical degradation of products.

They are classified into two types, depending on whether the food is preserved in a dry or liquid medium.

- **In a dry environment:**

✓ **Smoking:** consists of applying smoke directly to the food to prevent the proliferation of micro-organisms thanks to its antiseptic properties and the effect of heat. This technique is mainly used for sausages, cheese, meat, fish, etc.

✓ **Salting:** The food to be preserved is covered in dry brine, sometimes with sugar to protect the outside. This dehydrates the product and prevents the proliferation of micro-organisms. This technique is used to produce anchovies, dried meat and dried fish roe, among others.

- **In a liquid medium:**

The food is covered with various preserving liquids, with the aim of stopping the multiplication or preventing the appearance of micro-organisms.

"Adobo" (a type of marinade): A liquid preparation made up of various ingredients such as oil, vinegar, spices, salt and aromatic herbs. It is applied cold, covering the raw food. In this way, the oil protects the product from the action of oxygen, and the vinegar prevents the proliferation of micro-organisms.

- **Maceration:** An aqueous mixture made up of three parts oil to one part vinegar, wine or other alcohol, in which the immersed food is cooked. It is mainly used for meat, poultry, vegetables, fish and seafood.

- **Marinating:** This technique consists of covering the food with wine and a vegetable base such as onion, celery, carrots and aromatic herbs for a few hours, depending on the quantity and size of the product. It is mainly used for fish and game.

- **Brining:** This is a process in which the food is immersed in a mixture of vinegar and salt. This acidic medium prevents the development of micro-organisms. It is mainly used for raw or cooked vegetables: gherkins, small onions, carrots, turnips, cabbage and garlic, as well as various aromatic herbs. (Table 8 explained to us the advantages and disadvantages of the method)

Table 8: Methods of preserving food by chemical alteration (Advantages and disadvantages)

Advantages	disadvantages
✓ These are food preservation techniques that use natural additives and preservatives to extend their shelf life. ✓ Foods stored in a dry environment can be preserved for up to 2 years.	✗ Food preservation methods by chemical alteration alter the taste, texture, and appearance of food. ✗ It is advisable to sterilize foods preserved in liquids before they are marketed, and once the container is opened, to store them in the refrigerator and consume them quickly.

g) Methods of preserving food using additives

- **Food additives** are substances added to food to improve its colour, texture or taste, or simply to extend its shelf life. They may be of natural origin, such as vegetable pectin and agar obtained from seaweed, or of synthetic origin, duly authorised.
- **Antioxidants:** They prevent the chemical degradation of food caused by heat, light or traces of metals that promote oxidation. They are used in fatty products such as margarines, mayonnaises, etc. A natural antioxidant usually used in cooked dishes is ascorbic acid, or vitamin C (naturally present in lemon juice).
- **Preservatives:** These prevent the biological degradation of food by destroying bacteria, yeasts and fungi, or by preventing or reducing their activity. They are used in particular in meat preserves, bakery products, sauces, etc.

Table 9: Methods of preserving food using additives (Advantages and disadvantages)

Advantages	disadvantages
✓ They help enhance the taste and appearance of the foods they are added to.	✗ These are preservation techniques that involve the use of additives and preservatives, whether they are of artificial or natural origin. ✗ Some additives or preservatives may be harmful or poorly tolerated by people with certain conditions such as asthma, allergies, etc.

k) Methods of preserving food by controlling the atmosphere

These are techniques designed to reduce the presence of substances which promote food spoilage, or to incorporate substances into the packaging which prevent spoilage.

- **Vacuum packaging:** Elimination of all the air in the container in which the food is stored, such as vacuum bags or trays. In this way, oxidation processes and germ multiplication are stopped and the product's shelf life is extended. Micro-organisms that require oxygen to live (aerobic) cannot develop, but those that do not require oxygen (anaerobic) continue to grow.

- **Modified atmosphere packaging:** This technique consists of vacuum-packaging a food and then introducing a mixture of gases into the packaging, the main aim of which is to eliminate oxygen or modify the percentage of gases that make up the air. The gases usually used are carbon dioxide (CO_2) and nitrogen (N_2). Carbon dioxide itself has some preservative power, whereas nitrogen is an inert gas. Its only action is to act as a "filler" so that the food is not crushed as if it were vacuum-packed.

A good example of this method are bags of crisps, into which nitrogen is introduced because oxygen has to be eliminated to prevent them going rancid. It is therefore necessary to introduce a gas that prevents the bag from being under vacuum, crushing the crisps.

This technique allows the product to be preserved in its fresh state, without chemical or thermal treatments, while preserving its original organoleptic properties. However, the atmosphere varies over time as the food changes.

Products packaged in a modified atmosphere that are not dry, such as snacks, must be kept refrigerated.

Controlled atmosphere packaging

This technique consists of creating a vacuum, but replacing the air with other gases whose composition will be kept constant over time thanks to continuous monitoring of the atmosphere. This system guarantees prolonged product preservation.

Table 10 explained to us the advantages and disadvantages of the method.

Table 10: Methods of preserving food by controlling the atmosphere (Advantages and disadvantages)

Advantages	disadvantages
✓ These preservation methods maintain most of the sensory characteristics of food and ensure a long shelf life.	✕ In general, food preservation techniques involving atmosphere control should be combined with other methods such as refrigeration or freezing.

Factors to consider when choosing the most suitable preservation method for producing gourmet preserves and ready meals

When choosing the most suitable process, both for your facilities and for the food to be preserved, it is important to ensure that the technique selected: guarantees maximum shelf life for the preserved food, or at least the shelf life you want; minimises changes to the organoleptic and nutritional characteristics of the food.

Similarly, when choosing between the different methods, it is important to take into account the requirements of each, such as the field of application, the equipment and appliances needed, storage space, distribution methods, etc.

In the case of gourmet preserves and ready meals, sterilisation is the method that offers the best results. And it's not because we make autoclaves for cooking, sterilising and pasteurising gourmet preserves and ready meals that we say so, but because our customers confirm it! You can see for yourself by visiting our Success Stories page.

The sterilisation guarantees the total destruction of micro-organisms and spores and, although it is true that it can affect the organoleptic characteristics of the product, this change is minor, especially for sterilisation.

3.2. Production of food matrices in bioreactors

Bioreactors and fermentation systems are equipment used in the field of biotechnology to cultivate microorganisms, cells, or cell cultures under controlled conditions.

3.2.1 Bioreactors:

A bioreactor is a closed system designed to provide an optimal environment for the growth of microorganisms or cells under controlled conditions. These conditions may include parameters such as temperature, pH, nutrient concentration, oxygen pressure, and agitation speed. Bioreactors can vary in size and shape, ranging from small laboratory devices to large industrial installations. They are widely used in the production of biotechnological products such as medicines, enzymes, recombinant proteins, biofuels, and many others.

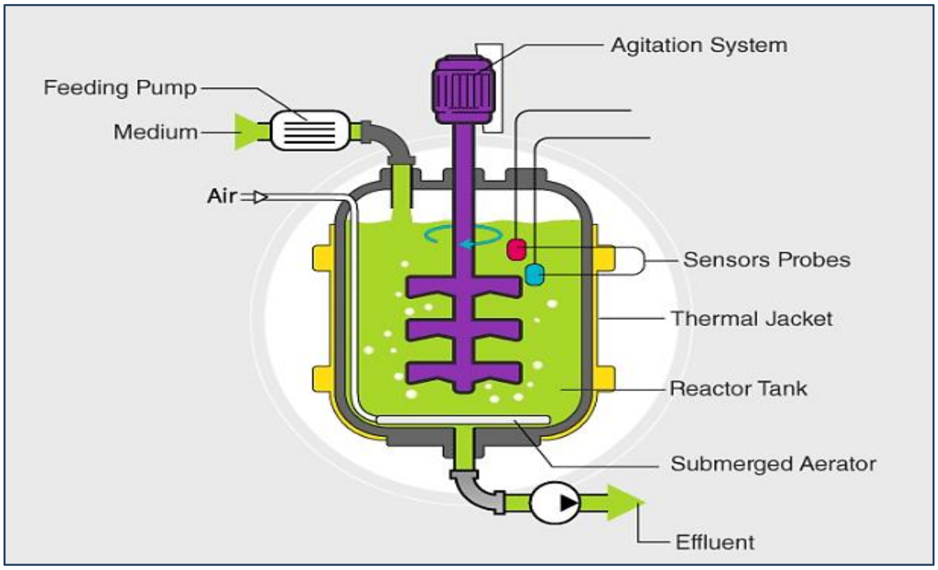


Figure 4. Description of a bioreactor

- **Some important applications of the bioreactor are (table 11)**

Table 11: applications of the bioreactor

Type of bioreactor	Applications
Stirred tank fermenter	Antibiotics, citric acid, Exopolysaccharides, cellulose, Chitinolytic enzymes, Laccase, Xylanase, Pectic, and pectate lyase, Tissue mass culture, Lipase, Polygalacturonases, Succinic acid
Bubble column fermentor	Algal culture, Chitinolytic enzymes
Airlift fermentor	Antibiotics, Chitinolytic enzymes, Exopolysaccharides, Gibberelic acid, Laccase, Cellulase, Lactic acid, Polygalacturonases, Tissue mass culture
Fluid bed fermentor	Laccase
Packed bed fermentor	Laccase, Hydrogen, Organic acids, Mammalian cells,
Photobioreactor	Wastewater treatment, water quality management, remediation of contaminated soil
Membrane bioreactor	Alginate, Antibiotic, Cellulose hydrolysis, Hydrogen production, Water treatment, VOCs treatment

3.2.2. Fermentation systems:

Fermentation systems are equipment specifically designed to carry out fermentation processes. Fermentation is a biological process in which microorganisms use organic substrates to produce useful chemicals such as enzymes, organic acids, antibiotics, alcohols, vitamins, etc.

Fermentation systems can vary in size and complexity, ranging from simple culture flasks used in laboratories to massive industrial fermentation tanks. These systems are used in various sectors such as food production, pharmaceutical production, energy production, bioremediation, etc.

In summary, bioreactors and fermentation systems are essential tools in the field of biotechnology, enabling the controlled production of various biotechnological and chemical products of industrial, agricultural, pharmaceutical, and environmental interest.

3.3. Food safety, traceability, and quality

Food safety, traceability, and quality are essential concepts in the field of food and nutrition. Here is an explanation of each:

3.3.1. Food safety:

Food safety concerns the assurance that the foods we consume are safe for health. This involves preventing the risks of food contamination by pathogens such as bacteria, viruses, parasites, toxins, or chemical contaminants. Measures are taken at various stages of the food chain, from agricultural production to final consumption, to ensure food safety.

Food Safety refers to handling, preparing and storing food in a way to best reduce the risk of individuals becoming sick from foodborne illnesses.

Food safety is a global concern that covers a variety of different areas of everyday life.

The principles of food safety aim to prevent food from becoming contaminated and causing food poisoning. **This is achieved through a variety of different avenues, some of which are:**

- ✓ Properly cleaning and sanitising all surfaces, equipment and utensils
- ✓ Maintaining a high level of personal hygiene, especially hand-washing
- ✓ Storing, chilling and heating food correctly with regards to temperature, environment and equipment
- ✓ Implementing effective pest control
- ✓ Comprehending food allergies, food poisoning and food intolerance.

Regardless of why you are handling food, whether as part of your job or cooking at home, it is essential to always apply the proper food safety principles. Any number of potential food hazards exist in a food handling environment, many of which carry with them serious consequences.

3.3.2. Food traceability: Food traceability involves tracking the journey of a food product throughout the supply chain, from production to distribution, in order to be able to trace its origin if needed. This allows for the rapid identification of the origin of foods in case of food safety issues, product recalls, or food fraud. Traceability can be achieved through data management systems, barcodes, labels, or traceability certificates.

- **Types of traceability :**

- **"Upward traceability"** is a tool used to support good production practices.
- **"Downward traceability"** is a valuable tool for implementing targeted product recall procedures.

3.3.3. Food quality: Food quality refers to the intrinsic characteristics of foods that influence their nutritional value, taste, texture, appearance, and shelf life. Food quality can be influenced by factors such as agricultural production methods, food processing practices, storage and transportation conditions, as well as regulations and food standards in place. High-quality food contributes to the health and well-being of consumers.

It is important to know the difference and have a proper Food Safety and Food Quality management system in place.

In summary, food safety, traceability, and quality are crucial aspects to ensure a healthy, safe, and nutritious diet for consumers. These concepts are closely monitored and regulated by health and food authorities worldwide to protect public health and ensure consumer confidence in the food supply.

CHAPTER IV : Biotechnologies and Industry for Non-Food Purposes

4.1. Bioenergy:

Bioenergy is among the various resources accessible to fulfill our energy needs. It constitutes a renewable energy form extracted from organic materials known as biomass, which were recently alive. Biomass can be utilized to generate transportation fuels, heat, electricity, and various products.

- **Benefits of bioenergy :** An abundant and renewable bioenergy sector can play a significant role in fostering a more secure, sustainable, and economically viable future by:

✓ Providing domestic sources of clean energy

✓ Creating employment opportunities

✓ Reviving rural economies.

4.2. Biomaterials and Agro-polymers

4.2.1. Definition

- **Biomaterials:** Biomaterials are materials derived from biological sources such as plants, animals, bacteria, or fungi. They are used in various fields, particularly in medicine to manufacture medical implants, diagnostic devices, controlled-release drugs, etc. Biomaterials can also be used in industrial, environmental, and agricultural applications.

- **Agro-polymers (or agricultural polymers):** Agro-polymers are polymers of plant or agricultural origin, made from renewable raw materials such as starches, proteins, vegetable oils, etc. These polymers are used in many industrial applications, including the production of bioplastics, biodegradable packaging films, edible coatings for food, etc. Agro-polymers are considered a more environmentally friendly alternative to conventional petroleum-derived polymers.

4.2.2. Classification of Polymers:

The fundamental categorization of polymers comprises two distinct categories: natural polymers and synthetic polymers. Natural polymers refer to polymer compounds that exist in our environment, whereas synthetic polymers are polymer compounds created artificially. This serves as the primary distinction between natural and synthetic polymers.

a) **Natural Polymers:** Natural polymers are polymers that occur naturally in living organisms or the environment. They are derived from renewable resources and are often biodegradable.

Examples of natural polymers include:

- ✓ **Proteins:** Found in hair, skin, muscles, and other tissues. Examples include collagen, keratin, and silk.
- ✓ **Polysaccharides:** Complex carbohydrates found in plants and animals. Examples include cellulose, starch, and glycogen.
- ✓ **Nucleic Acids:** DNA and RNA, which are responsible for storing and transmitting genetic information.
- ✓ Rubber: Natural rubber obtained from the latex sap of certain trees, such as the rubber tree (*Hevea brasiliensis*).
- ✓ **Chitin:** Found in the exoskeletons of arthropods, such as insects and crustaceans, as well as in the cell walls of fungi.

These natural polymers have a wide range of applications in various industries, including food, pharmaceuticals, cosmetics, textiles, and construction.

b) **Synthetic Polymers:** Synthetic polymers are man-made polymers that are synthesized through chemical reactions in laboratories or industrial settings. Unlike natural polymers, which occur in nature, synthetic polymers are produced artificially from various raw materials derived from petroleum or other sources.

Examples of synthetic polymers include:

- ✓ **Polyethylene (PE):** A widely used plastic in packaging, bottles, and containers.
- ✓ **Polypropylene (PP):** Used in textiles, packaging, automotive components, and medical devices.
- ✓ **Polyvinyl chloride (PVC):** Commonly used in pipes, cables, flooring, and window frames.
- ✓ **Polystyrene (PS):** Used in packaging, disposable cups, and insulation materials.
- ✓ **Polyethylene terephthalate (PET):** Found in bottles, polyester fibers, and food packaging.
- ✓ **Nylon:** Used in textiles, ropes, carpets, and engineering plastics.
- ✓ **Polyurethane (PU):** Used in foams, adhesives, coatings, and synthetic leather.

Synthetic polymers offer a wide range of properties and applications due to their versatility, durability, and ease of processing. They play a crucial role in various industries, including automotive, construction, electronics, healthcare, and consumer goods.

c) **Semisynthetic polymers:** Polymers obtained by making some modification in natural polymers by artificial means, are known as semi synthetic polymers, e.g., cellulose acetate (rayon), vulcanised rubber etc.

4.2.3. Application Areas:

The application areas of polymers are diverse and extensive, spanning across various industries. Some common application areas of polymers include (table 12):

Table 12: Some common application areas of polymers

Area	Application
Agriculture	Polymers are utilized in agriculture for mulch films, irrigation pipes, greenhouse covers, seed coatings, and crop protection materials due to their water resistance, UV stability, and durability.
Packaging	Polymers are widely used in packaging materials such as plastic films, bags, bottles, and containers due to their lightweight, durability, and barrier properties.
Automotive	Polymers are utilized in automotive applications for components such as bumpers, dashboards, interior trim, tires, and seals due to their lightweight, strength, and corrosion resistance.
Construction	Polymers find applications in construction materials such as pipes, insulation, roofing, flooring, adhesives, and sealants due to their versatility, weather resistance, and ease of processing.
Electronics	▪ Polymers are used in electronic devices for insulating materials, circuit boards, connectors, and protective coatings due to their electrical properties, heat resistance, and mechanical strength.
Healthcare	Polymers play a vital role in the healthcare industry for medical devices, implants, drug delivery systems, surgical instruments, and packaging materials due to their biocompatibility, sterilizability, and versatility.
Textiles	Polymers are widely used in the textile industry for fibers, fabrics, clothing, upholstery, carpets, and ropes due to their softness, strength, and dyeability.

These are just a few examples of the diverse application areas of polymers, highlighting their importance and ubiquity in modern society.

4.3. Biomolecules and cellular activities

4.3.1. Definition

A **Biomolecule** is an essential molecule in living organisms that helps in carrying out biological processes of life like cell division, metabolic reactions, repairing tissues, development, and others.

Biomolecules are referred to as biological molecules as they are produced in living organisms. Biomolecules are produced through different biochemical processes in living organisms that involve combining small molecules to form a large molecule. For example, proteins are synthesized from amino acids in ribosomes with the help of genetic information from deoxyribonucleic acid (DNA), and carbohydrates are produced in plants through the process of photosynthesis. Photosynthesis is a biochemical reaction in plants that converts light energy into chemical energy using water and carbon dioxide.

4.3.2. The four major types of biomolecules

Biomolecules can be classified into four major categories: carbohydrates, lipids, proteins, and nucleic acids. Each of these biomolecule types plays a unique role in the functioning of living organisms.

a) Carbohydrates: the energy currency

Carbohydrates, often referred to as sugars or saccharides, are a fundamental source of energy for living cells. They are composed of carbon, hydrogen, and oxygen atoms, typically in a 1:2:1 ratio. Carbohydrates can be simple sugars, such as glucose and fructose, or complex molecules like starch and cellulose. Simple sugars are easily broken down during cellular respiration to release energy, while complex carbohydrates serve as storage molecules in plants and form the structural framework of cell walls.

b) Lipids: the insulators and energy reservoirs

Lipids, including fats, oils,andphospholipids, arehydrophobic molecules that serve as energy reservoirs and insulators. Fats and oils are composed of fatty acids and glycerol. They are important for long-term energy storage in organisms. Phospholipids are essential components of cell membranes, forming a protective barrier that surrounds cells and separates them from their environment. Cholesterol, a type of lipid, plays a vital role in maintaining membrane fluidity.

c) Proteins: the workhorses of cells

Proteins are the most diverse and versatile biomolecules, performing an astonishing array of functions within cells. They are composed of amino acids, linked together in specific sequences, and their three-dimensional structure determines their function. Enzymes, which catalyze chemical reactions, are a critical type of protein. Other proteins may serve as structural components, antibodies, receptors, or transporters. Hemoglobin, for example, is a protein responsible for carrying oxygen in the blood.

d) Nucleic acids: the genetic code

Nucleic acids, including DNA (deoxyribonucleic acid) and RNA (ribonucleic acid), are the carriers of genetic information. DNA, a double-stranded molecule, contains the instructions for building and maintaining an organism. It provides the blueprint for the synthesis of proteins, which govern the structure and function of cells. RNA is involved in various cellular processes, including protein synthesis.

CHAPTER V: Microbial biotechnologies and infectiology

Introduction:

The realm of biotechnology encompasses a set of methodologies centered around the utilization of microorganisms, animal and plant cells, along with their constituents. Its origins trace back to early human history, with initial applications emerging notably in the healthcare sector, notably through the pioneering work of Louis Pasteur towards the end of the previous century.

Concurrently with advancements in microbiology and immunology, the first half of the century witnessed the emergence of various vaccines targeting viral and bacterial diseases. These vaccines were developed from microorganisms or their inactivated toxins, often combined with immune-enhancing agents, or derived from attenuated pathogenic microorganisms.

The progress in vaccine production was facilitated by the simultaneous advancement of tissue and animal cell culture techniques. However, it's only in recent times that numerous breakthroughs, largely propelled by advancements in biochemistry, molecular biology, and immunology, have played a pivotal role in diagnosing, preventing, and combatting major infectious or parasitic diseases. Among these breakthroughs, significant strides include the elucidation of deoxyribonucleic acid (DNA) structure and its hereditary role, the understanding of protein structure and synthesis, genetic DNA recombination, and cell fusion culminating in the creation of monoclonal antibodies.

5.1. Diagnostics:

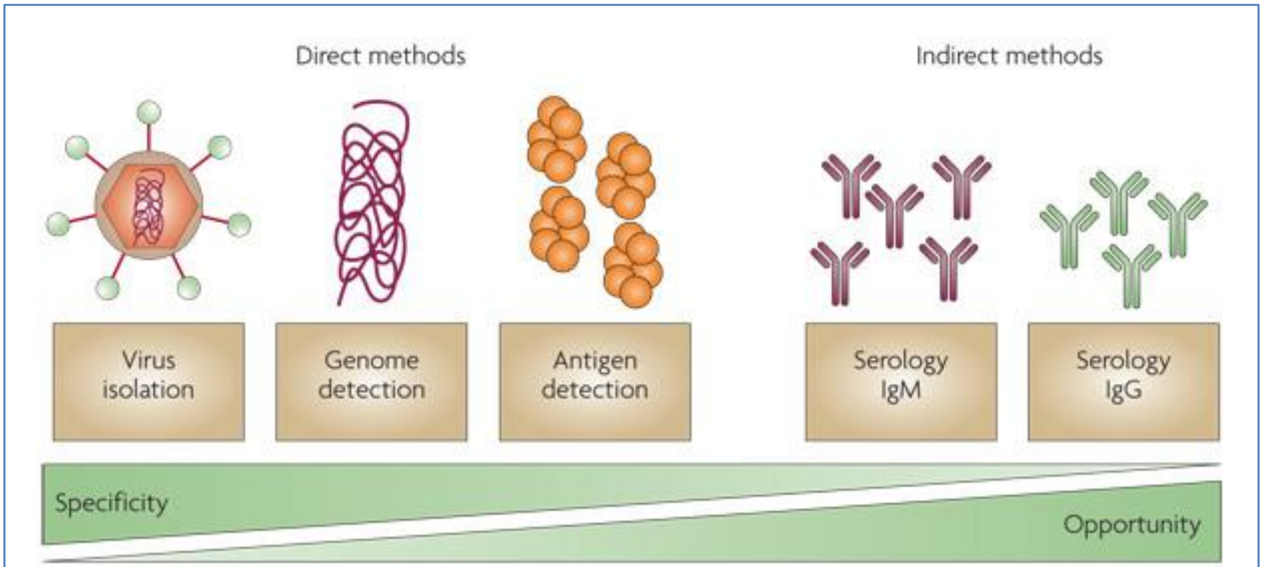
Refers to the process or techniques used to identify, diagnose, or detect a disease, medical condition, or health problem in an individual. This may include medical examinations, laboratory tests, medical imaging analyses, physical evaluations, and other methods used to determine the nature and severity of a disease or medical condition.

5.1.1. Direct Diagnosis:

Involve directly detecting the presence of a pathogen or a disease-causing agent in a sample taken from the patient. This can include methods such as polymerase chain reaction (PCR), enzyme-linked immunosorbent assay (ELISA), or culture-based techniques where the pathogen is grown and identified (figure 5).

5.1.2. Indirect Diagnosis:

Involve detecting the body's response to an infection or disease rather than the pathogen itself. This can include measuring antibodies produced by the immune system in response to the pathogen, looking for specific antigens or markers in the body, or assessing changes in physiological parameters that occur as a result of the infection or disease (figure 5).



***Nature Reviews Microbiology* 8, S30–S37**

Direct diagnostic methods such as dengue virus isolation, genome detection, and antigen detection are more specific ways to diagnose dengue than indirect methods that detect IgM and IgG antibodies against dengue. There is a greater opportunity for diagnosis with the indirect tests because these diagnostic methods are typically the most practical options available.

Figure 5. Direct and indirect diagnostic **(Nature Reviews Microbiology 8, S30–S37 (2010).**

5.2. New therapeutic approaches

Firstly, advancements in biotechnology have enabled the production of drugs that were previously unavailable or obtained through traditional industrial methods, such as extraction from living organisms (often animals), which posed challenges in purification and risked contamination, particularly viral contamination.

For instance, growth hormone, interferons, and monoclonal antibodies are now produced more efficiently using genetic engineering, cloning, and protein synthesis techniques for therapeutic purposes. Additionally, the accessibility of large quantities of pure proteins has opened up avenues for novel therapeutic strategies.

Clinicians have witnessed an evolution from sulfasalazine and hydrocortisone to alternative aminosalicylates and steroids. Revolutionary changes beyond these, however, and other “nonspecific” anti-immunoinflammatory compounds require clarification of the primary events either activating inflammatory cascades or preventing the down-regulation of homeopathic inflammation.51 The authors remain encouraged by advances in basic research pertaining to IBD and optimistic that novel empiric observations and therapeutic trials will focus bench-side investigation as clinicians strive to improve the quality of life for patients.

5.3. Combatting doping and drug use

5.3.1. What’s doping?

The International Olympic Committee (IOC) says that doping is a substance that uses an athlete to improve their perfermance in competition.

Doping is also a medical treatment can increase performance.

The origin of the word “doping” comes from the british word “dope” (droga).

5.3.2. Doping Substances

- **Stimulants (Indications)**

These are substances that stimulate the central nervous system or inhibit some functions such as appetite. They are commonly used to maintain the individual’s stability and control your weight

- **Narcotic Analgesics (Indications)**

They are indicated for pain relief in cases such as fractures, post operative pain, myocardial infaction and cancer, where conventional analgesics are insufficient.

- **Anabolic Steroids (Indications)**

Are only indicated in cases of increased catabolism (consumption of the body) and in severe malnutrition, cancer and advanced osteoporosis.

- **Beta blockers (Indications)**

Medicines used to control hypertention.

- **Diuretics (Indications)**

Promote or enhance diuresis (urination). It is used in renal and cardiovascular disease and hypertension and renal failure.

- **Hormones (Indications)**

Substances referred to in cases where there is hormone deficiency.

5.3.3. Combatting doping

To combat doping, it is crucial to detect doping substances in the blood amidst numerous other molecules present in athletes' bodies. Advanced techniques have been developed for this purpose. This poses a significant challenge, particularly because these substances can exist in extremely low concentrations, sometimes as little as a nanogram (ng = one billionth of a gram) per milliliter (ng/ml). To put it into perspective, this is akin to finding a sugar cube in an Olympic-sized swimming pool. For smaller molecules, chromatography is one of the most commonly used methods in analysis laboratories, proving highly efficient for processing blood or urine.

Additionally, the speed of analysis is paramount, as real-time diagnostics are required during sports competitions. Highly effective techniques are also available for detecting larger doping molecules such as EPO or growth hormone.

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