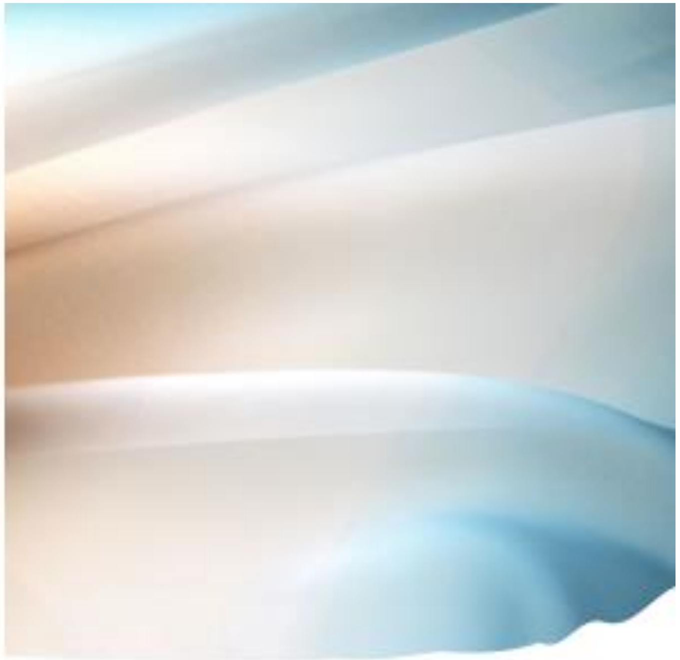
Introduction to Biotechnology

(2^{nd} Biotechnology 2023)



Introduction to Biotechnology

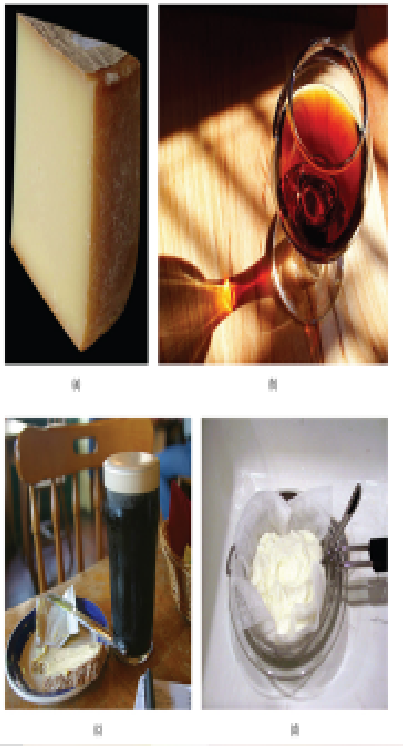
DR\ ASMAA SAYED ABDELGELIEL EL GAFARI

1 | THE STUDY OF LIFE

• According to the United Nations Convention on Biological Diversity, biotechnology is "**any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use**."

• The concept of "specific use" typically involves a commercial application or benefit to humanity. Genetic engineering, artificial selection, antibiotic production, and cell culture are current topics of study in biotechnology.

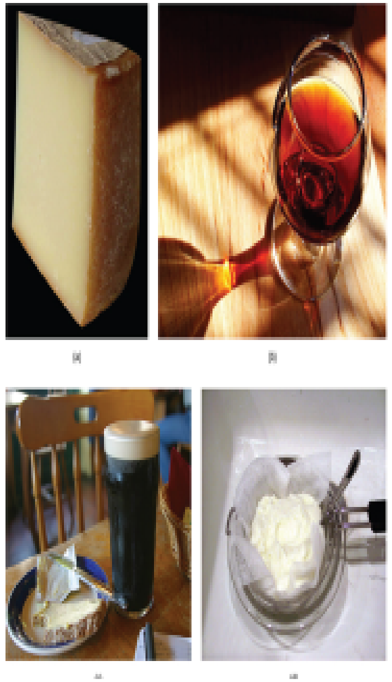
• Some of the products of this early biotechnology are as familiar as cheese, bread, wine, beer, and yogurt, which employ both bacteria and other microbes, such as yeast, a fungus (Figure).

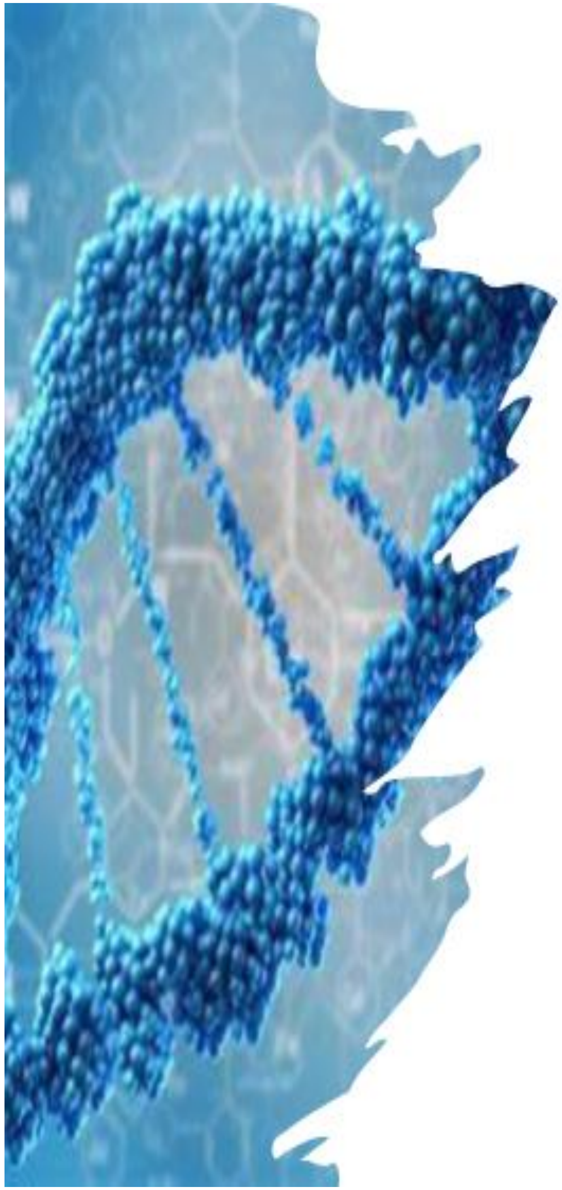


- Early Biotechnology: Cheese, Bread, Wine, Beer, and Yogurt Cheese production began around 4,000 to 7,000 years ago when humans began to breed animals and process their milk.
- Fermentation, in this case, preserves nutrients: Milk will spoil relatively quickly, but when processed as cheese, it is more stable. As for beer, the oldest records of brewing are about 6,000 years old and were an integral part of the Sumerian culture.
- Evidence indicates that the fermentation discovered by chance. Wine has been produced for about 4,500 years, and evidence suggests that cultured milk products, like yogurt, have existed for at least 4,000 years.

• In the early twentieth century, scientists gained a greater understanding of microbiology and explored ways of manufacturing specific products.

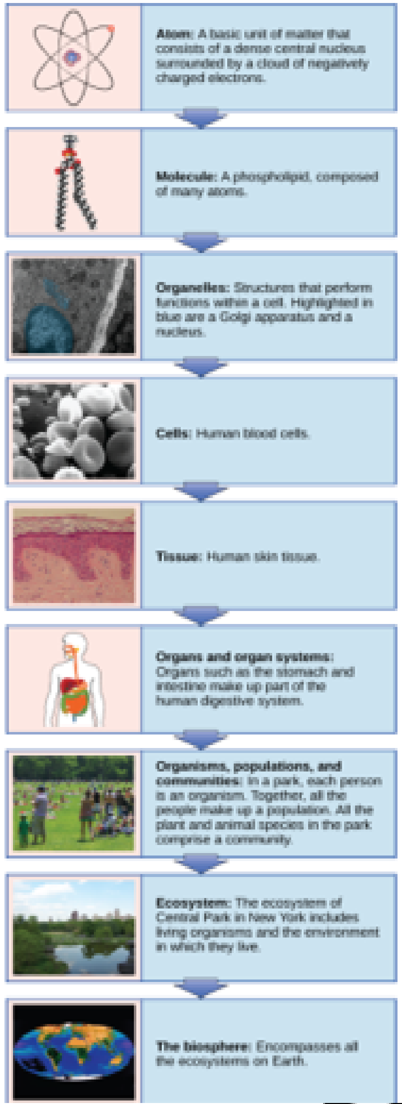
• In 1917, Chaim Weizmann first used a pure microbiological culture in an industrial process that of manufacturing corn starch using *Clostridium acetobutylicum*, to produce acetone, which was used to manufacture explosives during World War I. Shortly, in 1928, Alexander Fleming discovered the mold *Penicillium*. His work led to the purification of the antibiotic compound formed by the mold by Howard Florey, to form what we today know as penicillin. In 1940, penicillin became available for medicinal use to treat bacterial infections in humans.





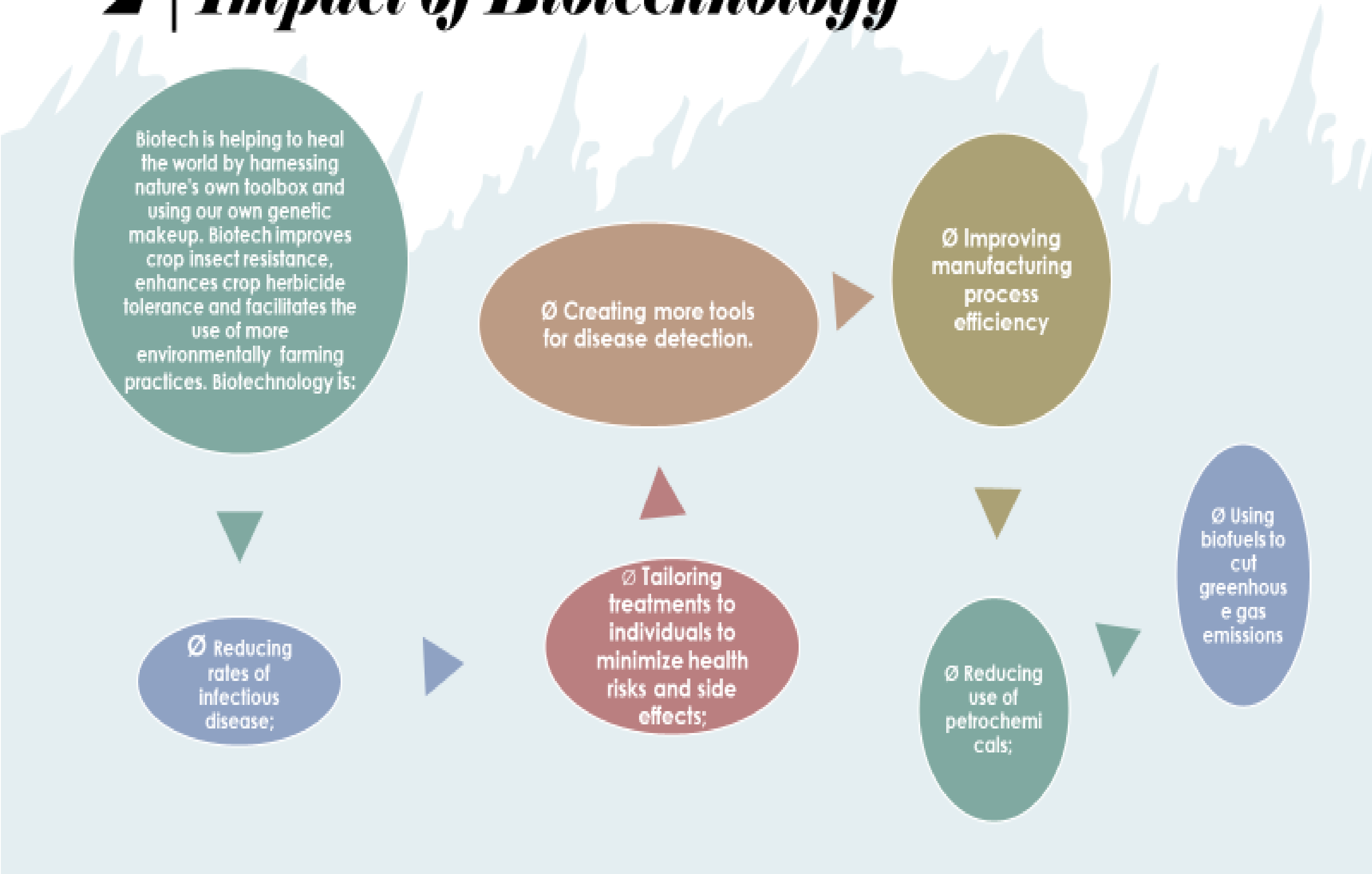
The New Biotechnology

- The field of modern biotechnology is generally thought of as having been born in 1971 when Paul Berg's (Stanford) experiments in gene splicing had early success.
- and (Stanford) significantly advanced the new technology in 1972 by transferring genetic material into a bacterium, such that the imported material would be reproduced, giving birth to the field of recombinant DNA technology.
- The commercial viability of a biotechnology industry was significantly expanded on June 16, 1980, when the United States Supreme Court ruled that a genetically modified microorganism could be patented.



- All the individuals of a species living within a specific area are collectively called ***a population***. For example, a forest may include many white pine trees. All of these pine trees represent the population of white pine trees in this forest.
- Different populations may live in the same specific area. For example, the forest with the pine trees includes populations of flowering plants and insects and microbial populations.
- ***A community*** is the set of populations inhabiting a particular area. For instance, all of the trees, flowers, insects, and other populations in a forest form the forest's community.
- The forest itself is ***an ecosystem***. An ecosystem consists of all the living things in a particular area together with the abiotic, or non-living, parts of that environment such as nitrogen in the soil or rainwater.
- At the highest level of organization, ***the biosphere*** is the collection of all ecosystems, and it represents the zones of life on Earth. It includes land, water, and portions of the atmosphere.

2 | Impact of Biotechnology



- Ø Decreasing water usage and waste generation
- Ø Generating higher crop yields with fewer inputs;
- Ø Lowering volumes of agricultural chemicals required by crops-limiting the run-off of these products into the environment;
- Ø Using biotech crops that need fewer applications of pesticides
- Ø Developing crops with enhanced nutrition profiles that solve vitamin and nutrient deficiencies;
- Ø Producing foods free of allergens and toxins
- Ø Improving food and crop oil content to help improve cardiovascula r health.

So, we can say that Biotechnologists have a broad scope. They can:-

- Ø Help in increasing productivity and in improving energy production and conservation by conducting research and development work.
- Ø Work with chemical processes, genetic engineering, textile development cosmetic development etc...
- potential of micro-organisms and living systems for the benefit of mankind as by using micro-organisms in the production of drinks, bread, cheese and
- Ø Find new ways to design and use antibiotics and pesticides
- Ø Use genetic modification and genome mapping to improve crop production or crop resistance to pests and diseases.
- Ø Combating environmental pollution by developing the use of biosensors for early detection of pollutants.
- Ø Find new ways to treat industrial waste for recycling of sewage sludge.
- Ø Carry out their work in the laboratories, as it is a scientific research oriented field.
- Ø Help medical professionals in improving in the methods of diagnosis, medicines and vaccinations for diseases

3 | Drawbacks of biotechnology

- Ethics

Ethics-related concerns include:

- cloning, xenotransplantation, stem cell research, fetal tissue use, and genetic modification of organisms.
- Riskiness
- The biggest concern over biotechnology is the its long term effects. The immediate advantages are clear in many circumstances, but they may directly or indirectly impact the future in unforeseen ways.
- Cost
- Balancing benefits of biotechnology with cost, especially in the field of medicine, can be one tricky aspect. In terms of investment, the value of biotech products is often miscalculated with failure to include the factors of risk and product development periods, which can ultimately lower the return on profit.
- Thus far, biotech products are often more expensive and less practical than alternatives.
- Too much altering of crops is destroying tha soul of natural farming
- Genetically modified species can damage the natural ecosystem.

Biotechnology & plants

Yeast responsible for bread & curd formation

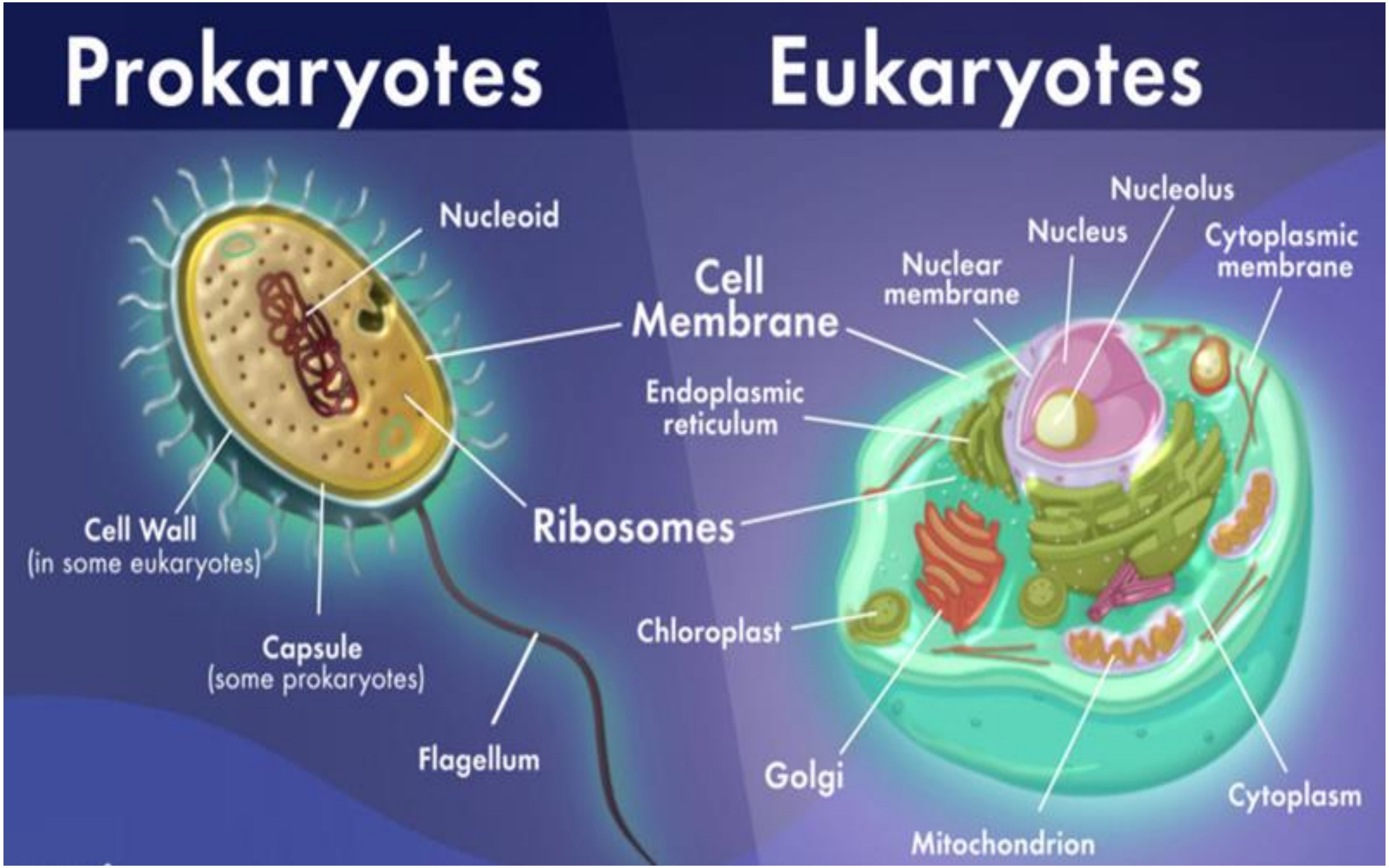
Product of biotechnology, The DOLLY sheep

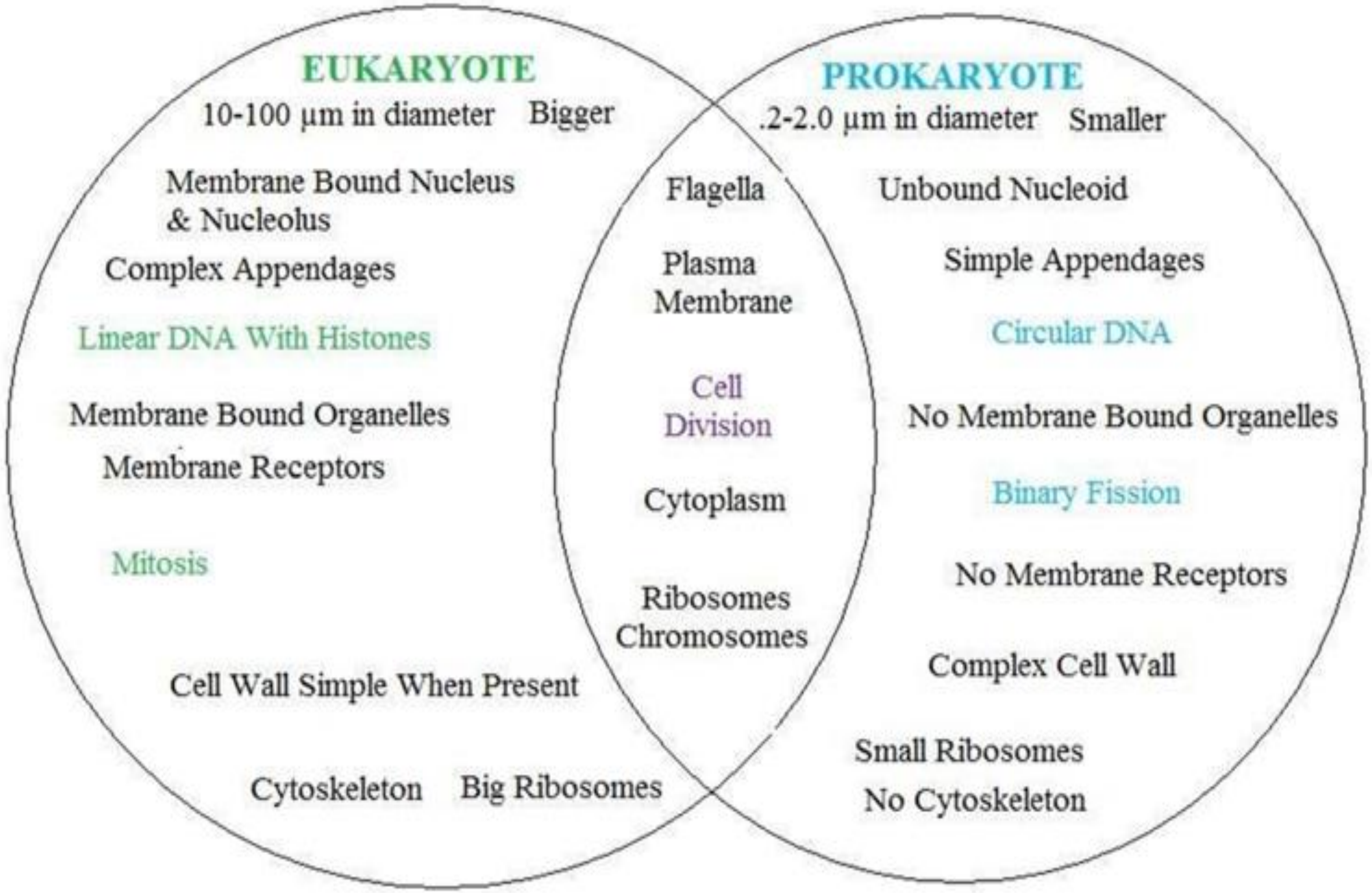
- In short, Today's biotechnology is continuing to help improve the way we live, and it helps us do so more responsibly.
- The result of biotechnology is a diverse and nearly endless set of practical biotechnology products helping us live longer and healthier lives, have a more abundant and sustainable food supply.
- Biotechnology has brought humanity to this level of comfort; the next question is, where will it take us? Biotechnology has both beneficial and destructive potentials.
- It is, WE who should decide how to use this technology to help humanity rather than to destroy it.

Introduction to Biomanufacturing

CELL STRUCTURE AND FUNCTION

- Cells fall into one of two broad categories: prokaryotic and eukaryotic.
- The predominantly single-celled organisms of the domains Bacteria and Archaea are classified as prokaryotes (pro- = before; -karyon- =nucleus).
- Animal cells, plant cells, fungi, and protists are eukaryotes (eu- = true).


Prokaryotes
Eukaryotes
Nucleoid
Cell
Membrane
Cell Wall
(in some eukaryotes)
Capsule
(some prokaryotes)
Flagellum
Ribosomes
Endoplasmic
reticulum
Chloroplast
Golgi
Mitochondrion
Nucleolus
Nucleus
Nuclear
membrane
Cytoplasmic
membrane
Cytoplasm

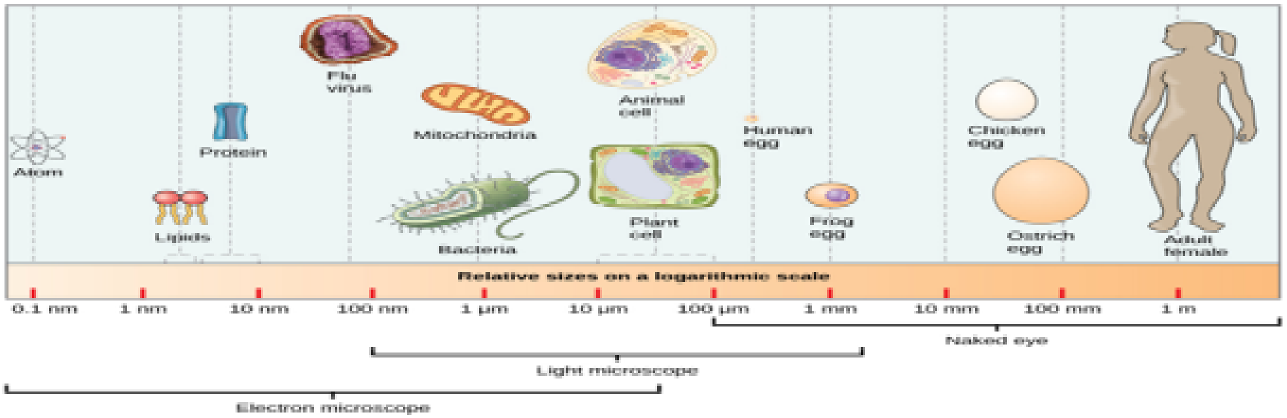

EUKARYOTE
10-100 µm in diameter Bigger
Membrane Bound Nucleus & Nucleolus
Complex Appendages
Linear DNA With Histones
Membrane Bound Organelles
Membrane Receptors
Mitosis
Cell Wall Simple When Present
Cytoskeleton Big Ribosomes
Flagella
Plasma Membrane
Cell Division
Cytoplasm
Ribosomes
Chromosomes
PROKARYOTE
.2-2.0 µm in diameter Smaller
Unbound Nucleoid
Simple Appendages
Circular DNA
No Membrane Bound Organelles
Binary Fission
No Membrane Receptors
Complex Cell Wall
Small Ribosomes
No Cytoskeleton

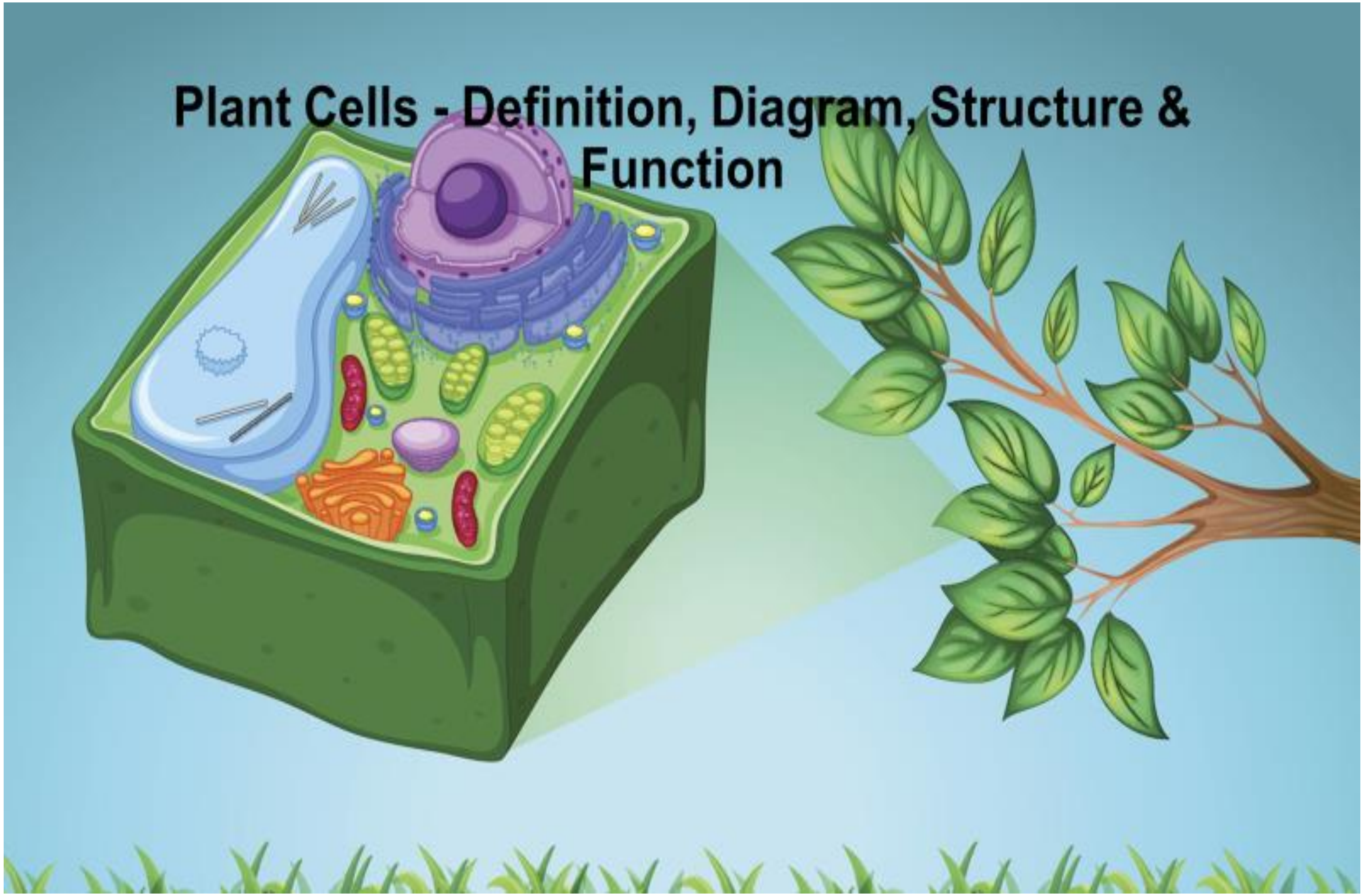
Cell Size

At 0.1–5.0 μm in diameter, prokaryotic cells are significantly smaller than eukaryotic cells, which have diameters ranging from 10–100 μm.

The small size of prokaryotes allows ions and organic molecules that enter them to quickly spread to other parts of the cell. Similarly, any wastes produced within a prokaryotic cell can quickly move out.

However, larger eukaryotic cells have evolved different structural adaptations to enhance cellular transport. Indeed, the large size of these cells would not be possible without these adaptations. In general, cell size is limited because volume increases much more quickly than does cell surface area. As a cell becomes larger, it becomes more and more difficult for the cell to acquire sufficient materials to support the processes inside the cell, because the relative size of the surface area across which materials must be transported declines.




Plant Cells - Definition, Diagram, Structure & Function

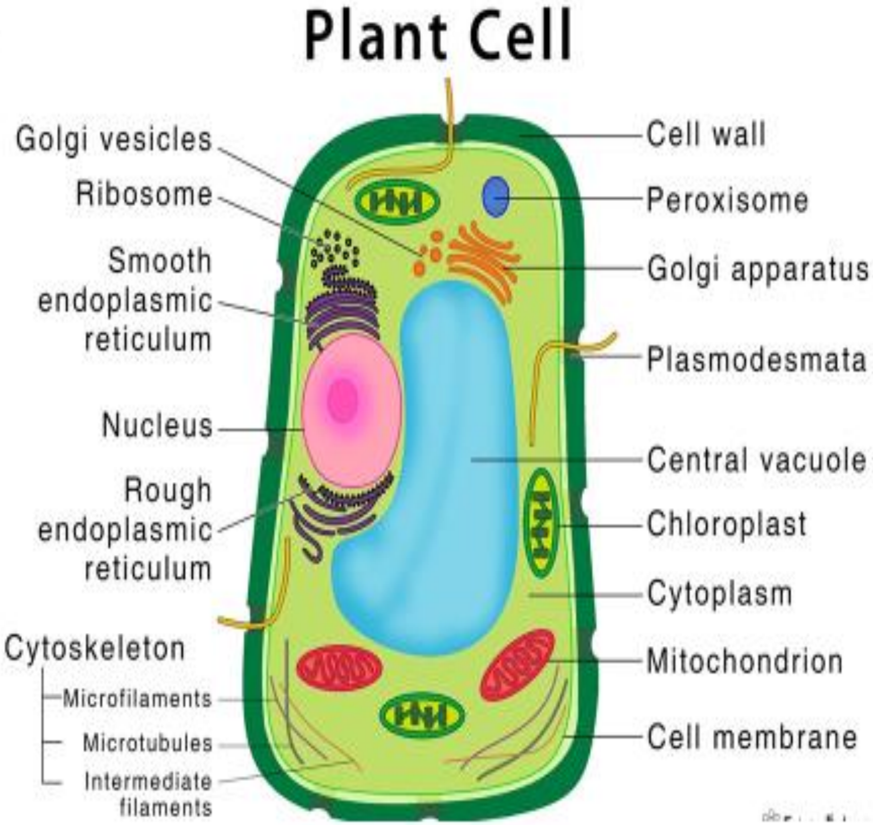
- **Plant Cell Definition**

- **What is a Plant Cell?**

- Plant cells are eukaryotic cells with a true nucleus that vary in several fundamental factors from other eukaryotic organisms. Both plant and animal cells contain nucleus along with similar organelles. One of the distinctive aspects of a plant cell is the presence of a cell wall outside the cell membrane.

- **Plant Cell Diagram**

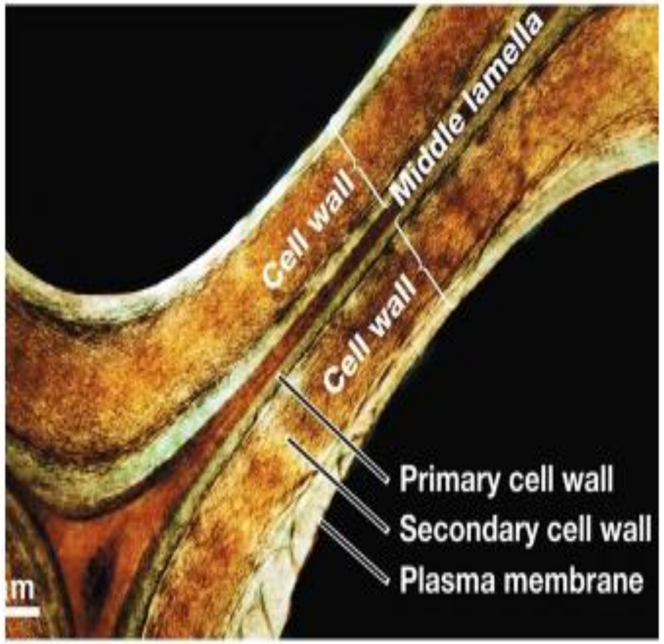
The plant cell is larger than the animal cell. Even though plant and animal cells are eukaryotic and share a few cell organelles, plant cells are quite distinct when compared to animal cells as they perform different functions. Some of these differences can be clearly understood when the cells are examined under an electron microscope.


Plant Cell
Golgi vesicles
Ribosome
Smooth endoplasmic reticulum
Nucleus
Rough endoplasmic reticulum
Cytoskeleton
Microfilaments
Microtubules
Intermediate filaments
Cell wall
Peroxisome
Golgi apparatus
Plasmodesmata
Central vacuole
Chloroplast
Cytoplasm
Mitochondrion
Cell membrane

Cell Wall:

It is a layer which is composed of cellulose, glycoproteins, lignin and pectin. It is located outside the cell membrane.

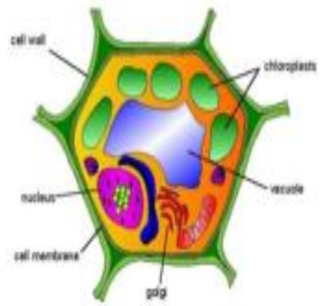
The primary function of the cell wall is to protect and provide structural support to the cell. The plant cell wall is also involved in protecting the cell against mechanical stress. It also filters the molecules passing in and out of the cell.



- The formation of the cell wall is guided by microtubules. It consists of three layers, namely, primary, secondary and the middle lamella.
- **Cell membrane:**
- It is the semi-permeable membrane that is present within the cell wall. It is composed of a thin layer of protein and fat.
- The cell membrane plays an important role in regulating the entry and exit of specific substances within the cell.
- For instance, cell membrane keeps toxins from entering inside, while nutrients and essential minerals are transported across.

PROTOPLASM

- the living component of a cell.
- Protoplasm = cytoplasm + nucleus
- surrounded by the **plasma membrane**.
- Plant cells have an outer boundary called the **cell wall**.



- **Protoplasm is the living part of the cell, which comprises of different cellular organelles. It is a jelly-like, colourless, transparent and viscous living substances present within the cell wall. The term protoplasm was proposed in the year 1835 and is known as the primary substance, as it is responsible for various living processes.**

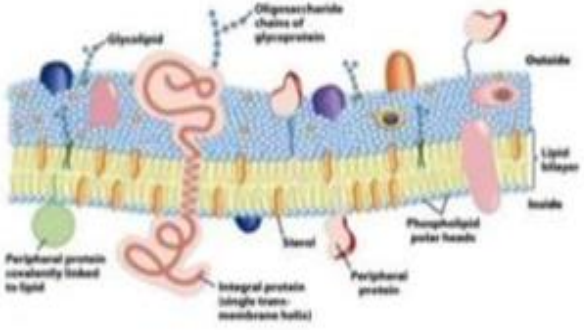
Plasma Membrane

Membrane is composed of:

A. *Lipids*
- ✓ Phospholipids
- ✓ Sterols

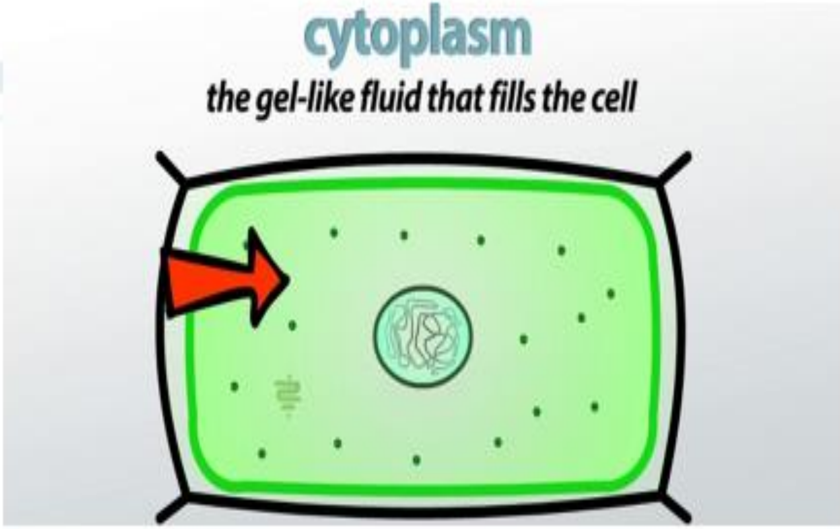
B. *Proteins*
- ✓ Integral
- ✓ Peripheral

C. *Carbohydrates*
- ✓ Glycolipids
- ✓ Glycoproteins



• Plasma Membrane:

- All living cells, both eukaryotic and prokaryotic, have a plasma membrane that surrounds the cells contents.
- The primary plasma membrane function is to protect, contain and provide unit structure to cells. It is composed of thinly structured phospholipid bilayer and protein molecules and it found as a major component of every biological cell, while serving to divide the inner environment of the cell from the outer environment such as the animal skin.



- **Cytoplasm:**

works in plant cells much like it does in animal cells. It provides support to the internal structures, is the suspension medium for the organelles and maintains the shape of a cell. It stores chemicals that are vital to plants for life and provides metabolic reactions such as synthesis of proteins and glycolysis.

Plastids:

They are necessary to store starch, to carry out the process of photosynthesis. It is also used in the synthesis of many molecules, which form the building blocks of the cell.

Leucoplasts

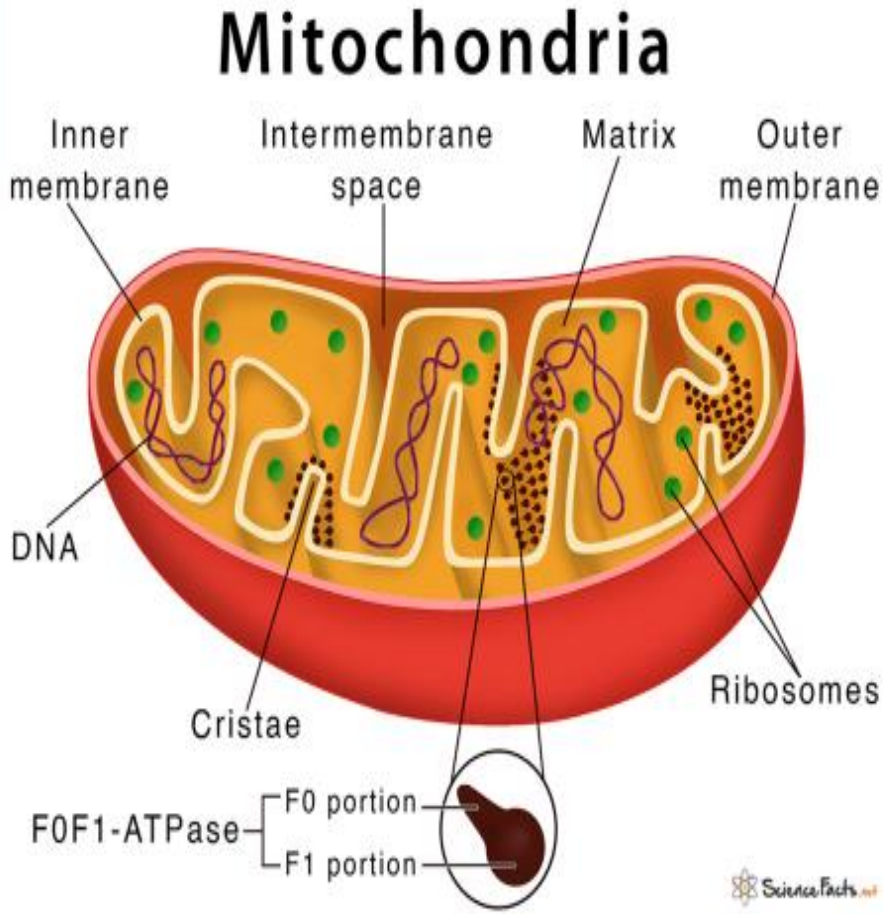
They are used for the storage of protein, lipid and starch.

Chloroplasts

The chloroplast is shaped like a disc. Each chloroplast contains a green coloured pigment called chlorophyll required for the process of photosynthesis.

Chromoplasts

Coloured plastid which is responsible for pigment synthesis and for storage in photosynthetic eukaryotic organisms. Chromoplasts have red, orange and yellow coloured pigments which provide colour to all ripe fruits and flowers.



• Mitochondria:

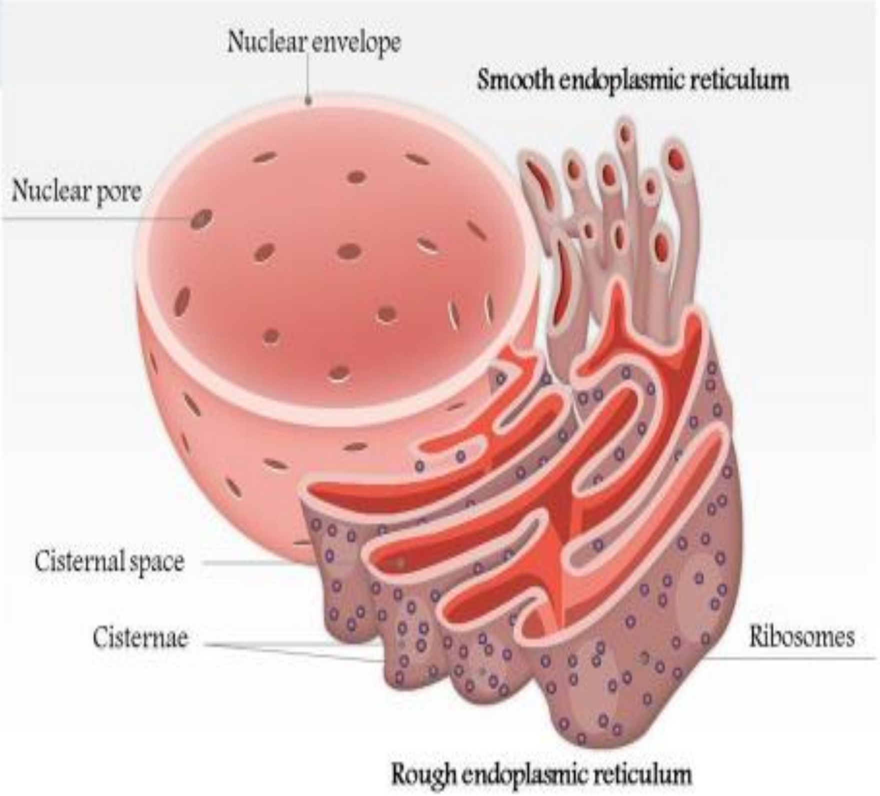
Mitochondria are membrane-bound organelles present in the cytoplasm of all eukaryotic cells, that produces (ATP), the main energy molecule used by the cell."

Popularly known as the "Powerhouse of the cell," mitochondria (singular: mitochondrion) are a double membrane-bound organ found in most eukaryotic organisms. They are found inside the cytoplasm and essentially functions as the cell's "digestive system."

- **Ribosomes:**

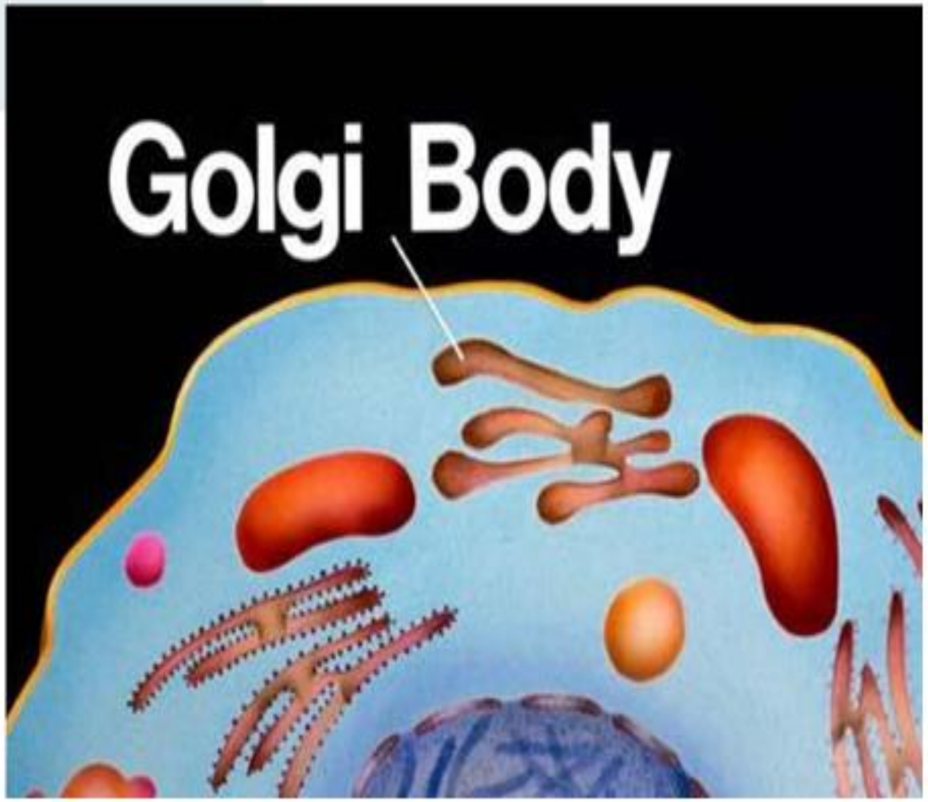
The functions of ribosomes in plant cells are: They take part in protein synthesis. Two or more ribosomes engaged in protein synthesis on the same m-RNA strand form polyribosomes

Endoplasmic Reticulum



- **Endoplasmic reticulum:**

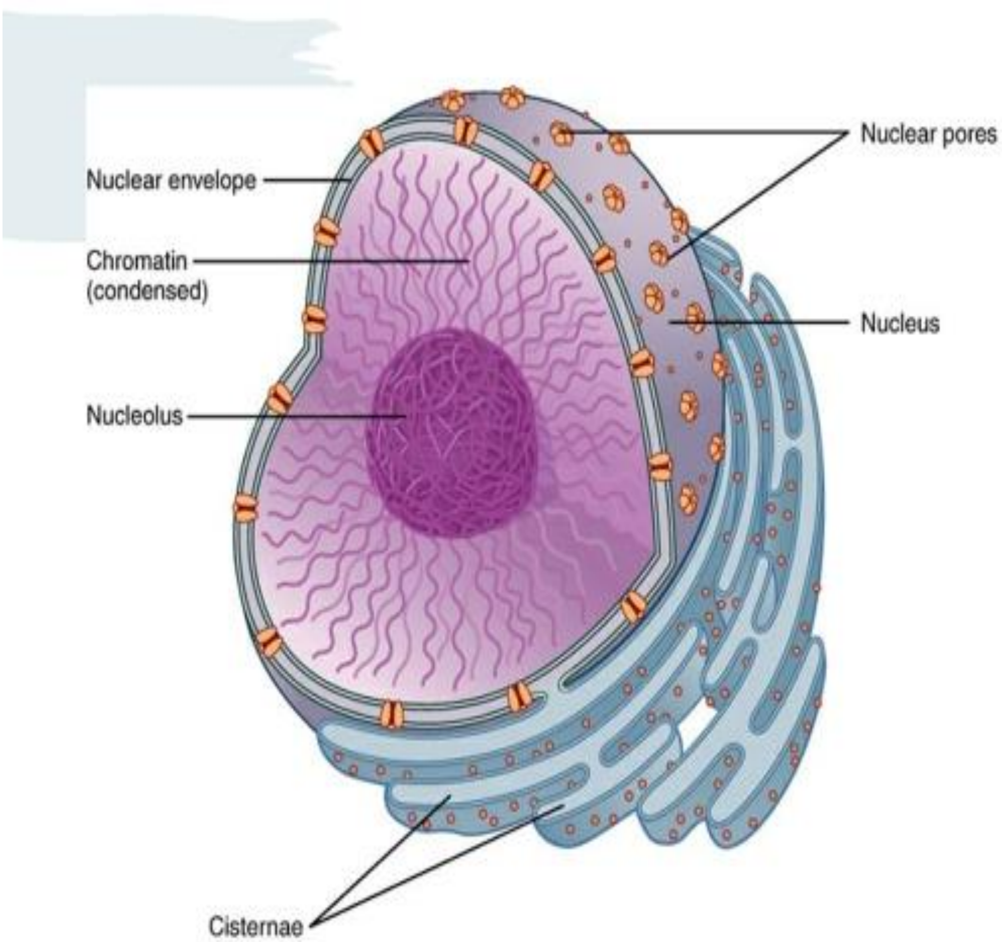
The endoplasmic reticulum is a network of tubules and flattened sacs that serve a variety of functions in plant and animal cells. The two regions of the ER differ in both structure and function. Rough ER has ribosomes attached to the cytoplasmic side of the membrane. Smooth ER lacks attached ribosomes.



- **Golgi bodies:**

In plant cells, Golgi bodies process and pack enzymes and carbohydrates into the same vesicles or different vesicles for the synthesis of cell walls.

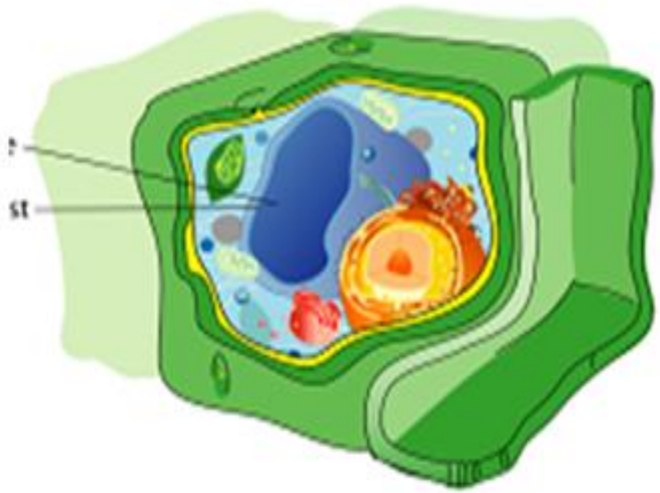
Its main function is the packaging and secretion of proteins.



- **Nucleus**
- The nucleus is a membrane-bound structure that is present only in eukaryotic cells. The vital function of a nucleus is to store DNA or genetic information required for cell division, metabolism and growth.
- Nucleolus: It manufactures cell's protein-producing structures and ribosomes.
- Nucleopore: Nuclear membrane is perforated with holes called nucleopore that allows proteins and nucleic acids to pass through.

Vacuoles:

Vacuoles are membrane-bound cell organelles. They are present in both plant and animal cells. Vacuoles are sack-like flexible structures filled with water. Vacuoles play an important role in the functioning of every cell.



Isolating harmful materials from other cell organelles.

Separate and store the waste products after consumption.

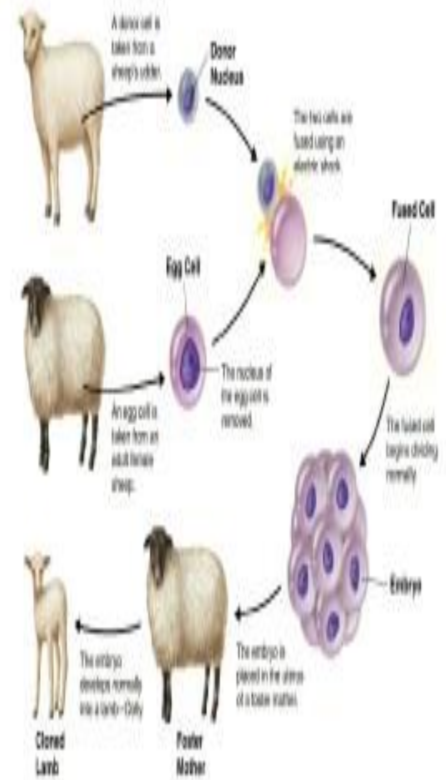
Store extra water in plant cells. Vacuoles also help in maintaining osmotic pressure inside the cell.

Maintaining an acidic internal pH.

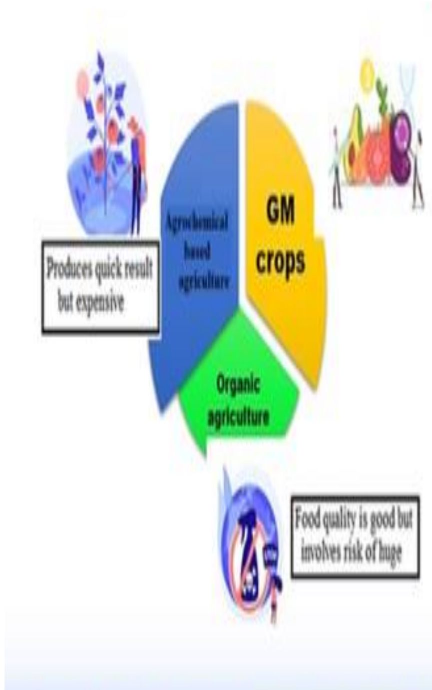
Agricultural biotechnology

- Agricultural biotechnology, also known as agritech, is an area of agricultural science involving the use of scientific tools and techniques, including genetic engineering, molecular markers, molecular diagnostics, vaccines, and tissue culture, to modify living organisms: plants, animals, and microorganisms.
- Crop biotechnology is one aspect of agricultural biotechnology which has been greatly developed upon in recent times. Desired trait are exported from a particular species of Crop to an entirely different species. These transgene crops possess desirable characteristics in terms of flavor, color of flowers, growth rate, size of harvested products and resistance to diseases and pests.

- Farmers have manipulated plants and animals through selective breeding for decades of thousands of years in order to create desired traits. In the 20th century, a surge in technology resulted in an increase in agricultural biotechnology through the selection of traits like the increased yield, pest resistance, and herbicide resistance.
- The first food product produced through biotechnology was sold in 1990, and by 2003, 7 million farmers were utilizing biotech crops. More than 85% of these farmers were located in developing countries.



- Human beings learned agriculture around 10,000 B.C.
- Selective breeding led to the development of a new modified variety of plants. We learned to improve our productivity with the help of agrochemicals like fertilizers and pesticides around the 1930s. In the 1960s, the green revolution was brought about worldwide.
- At present, there are three main approaches to enhance crop yield: Agrochemical based, organic, and GM crops.



Application and Important Role of Biotechnology in Agriculture

- One can define agricultural biotechnology as a set of scientific techniques which can improve plants, micro-organisms, and animals based on DNA and its concepts.

- The use of biotechnology in agriculture is deemed to be more effective than that of agrochemicals. The latter is believed to be responsible for causing environmental distress and is also somewhat unfeasible for farmers.

The following highlight the few ways in which biotechnology has found its way in agriculture :

- Genetic engineering / rDNA technology

It is a technology in which one or more genes are modified in the lab. This is achieved by the process of using recombinant DNA (rDNA) technology, thereby altering the genetic makeup of an organism.

- Tissue culture

Tissue culture involves nurturing fragments of plant or animal tissue in a controlled environment where they survive and continue to grow. For this tissue has to be isolated first.

- Embryo rescue

It is a form of in-vitro culture technique for plants. Here an immature embryo is nurtured in a controlled environment to ensure its survival. This can help in the preservation of species of seeds that are nearing extinction. This can include heritage seeds, local grains.

- Somatic hybridisation

It is a process through which the cellular genome is manipulated through the process of protoplast fusion.

- Molecular-gene markers

In genetic engineering, Molecular-gene markers are specific segments of DNA that are associated with a particular location within the genome.

- Molecular diagnostics

Molecular diagnostics is a set of techniques used toanalyze biological markers in the genome and proteome. It helps in determining how their cells express their genes as proteins

- Vaccine

It is a formulation that is injected into a host body to stimulate a desired immune response. It helps in preventing various diseases such as polio. Its production is carried out widely currently to fight against covid.

- Micropropagation

It is a clonal propagation of plants in a closed vessel under aseptic and controlled conditions.

- **The role of biotechnology in agriculture is multifaceted. Some of the most prevalent benefits of biotechnology in agriculture include :**

i. Increase in Crop Production

With better disease control and increased tolerance, biotechnology leads to a significant increase in crop production. This does not just match the ever-growing demand for food but also helps farmers to lower losses.

ii. Better Crop Protection

The techniques of biotechnology serve as cost-effective solutions to problems about pests. Farmers have been able to transform crops like cotton, corn, and potato to synthesize a protein that tackles issues of pests effectively.

iii. Increase in Nutrition Value

It has also enabled farmers to produce crops with a higher nutritional value and enhanced flavour and texture. For instance, the technology has made it possible to cultivate soybeans with high protein content, beans with more amino acids, and potatoes with starch.

iv. Fresher Produce and Better Taste

It further helps to improve the taste and flavor of crops by enhancing the activity of enzymes present in plants. Also, it helps in keeping the yield fresh for longer.

V. Chemical Tolerance

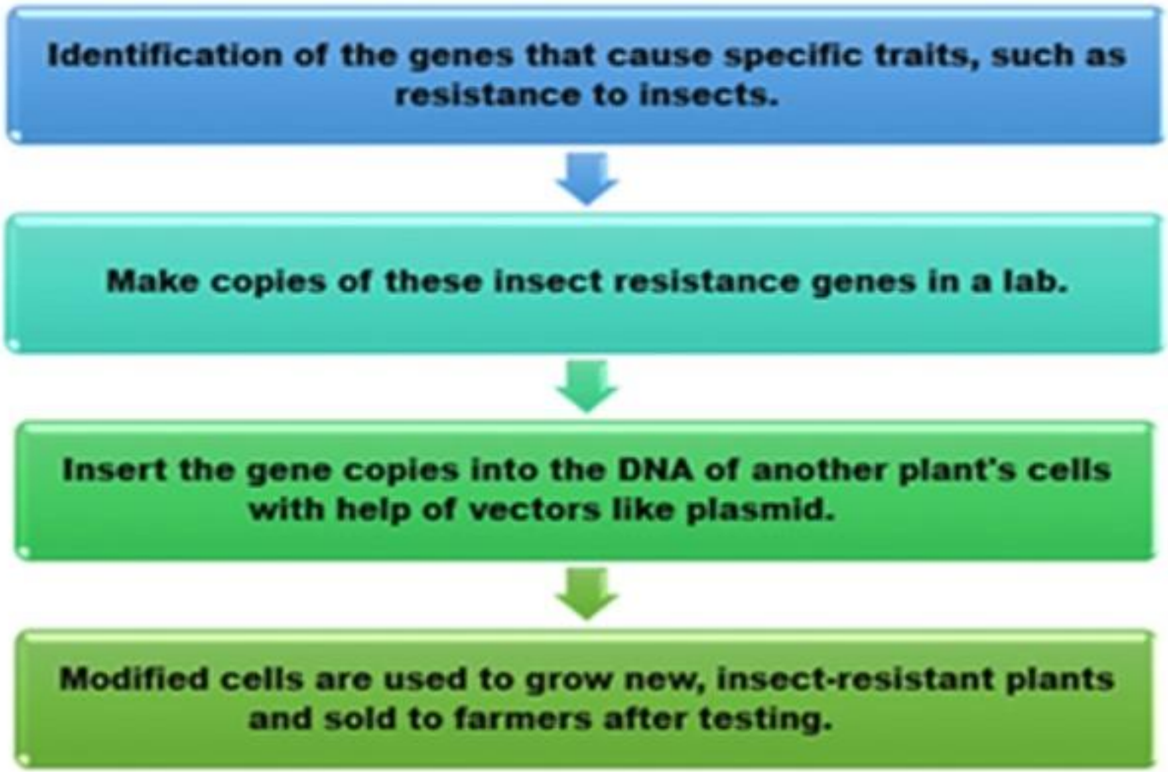
Most farmers rely on herbicides to control the growth of weeds which often leads to soil erosion. However, genetically engineered food is resistant to a variety of chemicals, including herbicides; as a result, the scale of soil erosion is significantly low.

Vi. Disease Resistance

Viral infections spread by insects are often difficult to contain, and also the use of insecticides tends to pose a threat to both soil and the quality of produce. Nonetheless, genetically modified plants are less susceptible to viral infection and make it easier for farmers to contain crop damage.

How are Genetically Modified Plants Produced?

- Genetic modification of crops involves inserting DNA into the genome of an organism.
- Production of a GM plant involves adding a specific DNA into the plant's genome, giving it new or different characteristics, and the cells are then grown in tissue culture where they develop into plants.
- The seeds produced by these plants will inherit the new DNA with the required set of characteristics. Production of genetically modified plants takes long-time research, continuous hard work, and lots of knowledge and funds.


Identification of the genes that cause specific traits, such as resistance to insects.
Make copies of these insect resistance genes in a lab.
Insert the gene copies into the DNA of another plant's cells with help of vectors like plasmid.
Modified cells are used to grow new, insect-resistant plants and sold to farmers after testing.

- Some examples of Transgenic crops or GM crops are discussed below:

Pest Resistant Bt cotton: Worms and pests have always been one of the biggest enemies of farmers. A group of scientists decided to develop a plant that is resistant to the pest. Examples of pest-resistant plants are Bt cotton, Bt corn, rice, tomato, potato, soybean, etc. It was possible after bacteria *Bacillus thuringiensis* (Bt for short) was found. This bacterium affects certain insects.

How does Bt kill worms:

- 1. Some strains of these bacteria possess a gene called cry and its variants like cryIAb, cryIAc, and cryIIAb.
- 2. These genes code for a protein crystal that enters the gut cells.
- 3. These protein crystals are protoxins or inactive toxins and require alkaline pH for activation.
- 4. Once the bacteria enter the gut epithelial cells, where the alkaline medium is readily available, the toxin becomes active and causes swellings in gut cells, ultimately destroying it.

Crop modification techniques

- **Traditional breeding**

Traditional crossbreeding[3] has been used for centuries to improve crop quality and quantity. Crossbreeding mates two sexually compatible species to create a new and special variety with the desired traits of the parents. For example, the honeycrisp apple exhibits a specific texture and flavor due to the crossbreeding of its parents. In traditional practices, pollen from one plant is placed on the female part of another, which leads to a hybrid that contains genetic information from both parent plants. Plant breeders select the plants with the traits they're looking to pass on and continue to breed those plants. Note that crossbreeding can only be utilized within the same or closely related species.

- **Mutagenesis**

Mutations can occur randomly in the DNA of any organism. In order to create variety within crops, scientists can randomly induce mutations within plants. Mutagenesis uses radioactivity to induce random mutations in the hopes of stumbling upon the desired trait. Scientists can use mutating chemicals such as ethyl methanesulfonate, or radioactivity to create random mutations within the DNA. Atomic gardens are used to mutate crops. A radioactive core is located in the center of a circular garden and raised out of the ground to radiate the surrounding crops, generating mutations within a certain radius. Mutagenesis through radiation was the process used to produce ruby red grapefruits.

• Polyploidy

Polyploidy can be induced to modify the number of chromosomes in a crop in order to influence its fertility or size. Usually, organisms have two sets of chromosomes, otherwise known as a diploidy. However, either naturally or through the use of chemicals, that number of chromosomes can change, resulting in fertility changes or size modification within the crop. Seedless watermelons are created in this manner; a 4-set chromosome watermelon is crossed with a 2-set chromosome watermelon to create a sterile (seedless) watermelon with three sets of chromosomes.

• Protoplast fusion

Protoplast fusion is the joining of cells or cell components to transfer traits between species. For example, the trait of male sterility is transferred from radishes to red cabbages by protoplast fusion. This male sterility helps plant breeders make hybrid crops.

• RNA interference

RNA interference (RNAIi) is the process in which a cell's RNA to protein mechanism is turned down or off in order to suppress genes. This method of genetic modification works by interfering with messenger RNA to stop the synthesis of proteins, effectively silencing a gene.

- **Transgenics**

Transgenics involves the insertion of one piece of DNA into another organism's DNA in order to introduce new genes into the original organism. This addition of genes into an organism's genetic material creates a new variety with desired traits. The DNA must be prepared and packaged in a test tube and then inserted into the new organism. New genetic information can be inserted with gene guns/biolistics. An example of a gene gun transgenic is the rainbow papaya, which is modified with a gene that gives it resistance to the papaya ringspot virus.[5]

- **Genome editing**

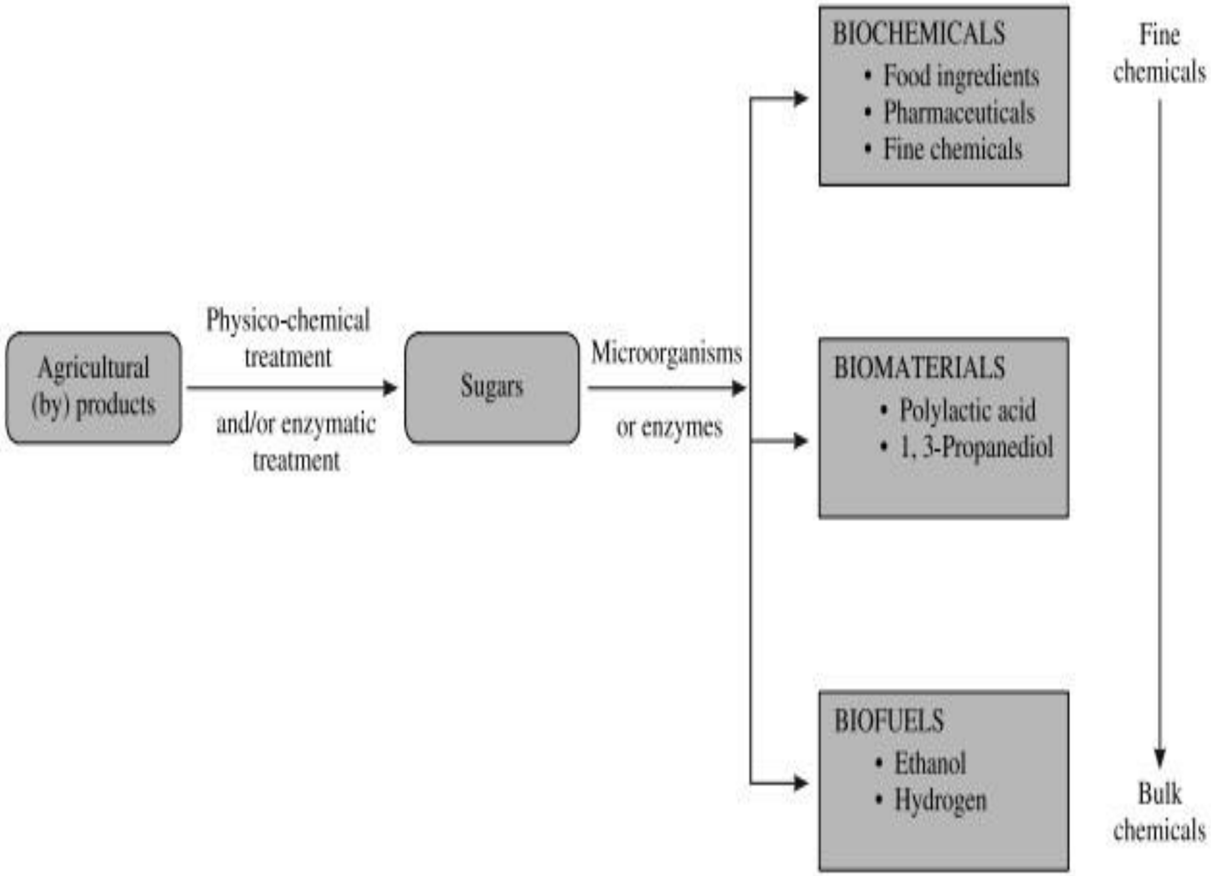
Genome editing is the use of an enzyme system to modify the DNA directly within the cell. Genome editing is used to develop herbicide resistant canola to help farmers control weeds.

- **Improved nutritional content**
- Agricultural biotechnology has been used to improve the nutritional content of a variety of crops in an effort to meet the needs of an increasing population. Genetic engineering can produce crops with a higher concentration of vitamins. For example, golden rice contains three genes that allow plants to produce compounds that are converted to vitamin A in the human body. This nutritionally improved rice is designed to combat the world's leading cause of blindness —vitamin A deficiency. Similarly, the Banana 21 project has worked to improve the nutrition in bananas to combat micronutrient deficiencies in Uganda. By genetically modifying bananas to contain vitamin A and iron, Banana 21 has helped foster a solution to micronutrient deficiencies through the vessel of a staple food and major starch source in Africa. Additionally, crops can be engineered to reduce toxicity or to produce varieties with removed allergens.

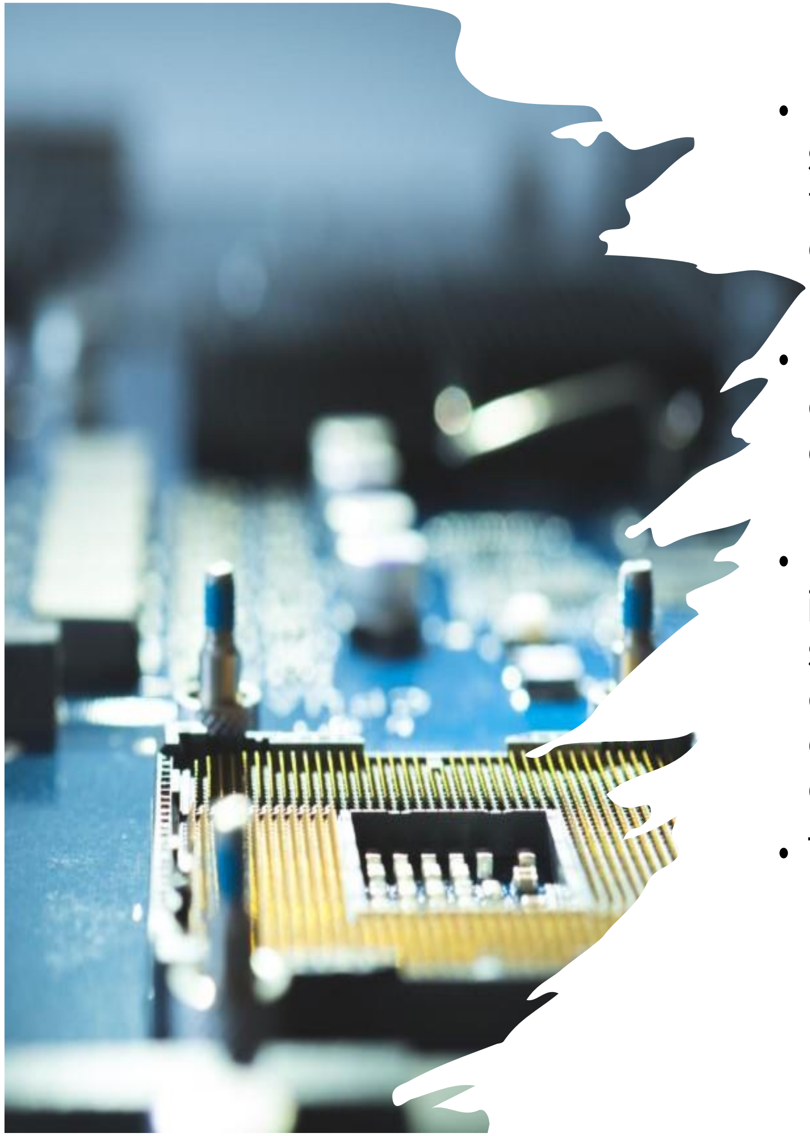
Industrial Biotechnology

1. INTRODUCTION

- Industrial biotechnology, also known as white biotechnology.
- Is the modern use and application of biotechnology for the processing and production of chemicals, materials and fuels from renewable sources, using living cells and/or their enzymes.
- This field is widely regarded as the third wave of biotechnology, distinct from the first two waves (medical or red biotechnology and agricultural or green biotechnology).
- Biotechnological processing uses enzymes and microorganisms or plant/animal cells to make products in a wide range of industrial sectors including chemicals, pharmaceuticals, food & feed, detergents, paper, textiles, energy, materials and polymers.
- Moreover, much interest has been generated in industrial biotechnology mainly because of this field is associated with reduced energy consumption, greenhouse gas emissions and waste generation.


Agricultural (by) products
Physico-chemical treatment
and/or enzymatic treatment
Sugars
Microorganisms
or enzymes
BIOCHEMICALS
• Food ingredients
• Pharmaceuticals
• Fine chemicals
BIOMATERIALS
• Polylactic acid
• 1, 3-Propanediol
BIOFUELS
• Ethanol
• Hydrogen
Fine chemicals
Bulk chemicals

- Figure shows the industrial biotechnology value chain.
- Raw materials, including crops and organic by-products from agricultural sources and households are converted into sugars, which can be readily converted by microorganisms or enzymes into the desired product.
- Traditionally, the Netherlands has a strong foothold in this value chain, given the presence of many important and international players in the agribusiness, food and chemical industry.



- Biochemical engineering is another important side of industrial biotechnology. It deals with the design & development of bioprocesses and equipment for the manufacturing of bioproducts.
- Biotechnological processes can be complex and difficult to control. Therefore, bioprocess engineering is the fusion of biological knowledge and engineering skills.
- Engineering aspects required in bioprocessing include design & operation of bioreactors, sterilizers and product recovery equipment's; development of systems for process automation & control and lay out of efficient as well as safe biotech industries.
- The study on the optimization of yield of final product at industrial scale as well as maintenance of its quality also comes in the preview of bioprocess engineering.

2. BIOPROCESS DEVELOPMENT

- The developments in the field of genetics and molecular biology in the 21st century has brought world-wide interest in biotechnology.
- Coupled with scientific breakthroughs in gene expression, protein engineering and cell fusion are transforming biotechnology industry to deliver new products and services.
- The ultimate goal of biotechnology is to use knowledge of molecular biology and cell manipulation for the large scale processing of biological materials. This goal is fulfilled by pairing biotechnology with bioprocess development.
- Bioprocess development is an essential part of many food, chemical and pharmaceutical industries.
- Bioprocess operation make use of microbial, animal and plant cells, and components of cells such as enzymes to manufacture new products and waste management.

- The use of microorganisms to transfer biological material for production of fermented foods has its origins in biotechnology.
- Since then, bioprocesses have been developed for an enormous range of commercial products, from relatively cheap materials such as industrial alcohol and organic solvents to expensive specialty chemicals such as antibiotics, therapeutic proteins and vaccines.
- As techniques and instrumentation are refined, bioprocesses may have applications in other areas where chemical processes are now used.
- Because bioprocesses use living cells or enzymes, they offer several advantages over chemical methods of production:

(i) they usually require lower temperature, pressure and pH (the measure of acidity).

(ii) they can use renewable resources as raw material,

(iii) greater quantities can be produced with less energy consumption.

- Enzymes can produce specific products rapidly and in high yield, but developments are often needed to make them suitable for use in industrial processes.
- Techniques such as protein engineering, gene engineering,. make enzymes better suitable for use in industrial processes.
- These tools also allow the synthesis of new biocatalysts for completely novel applications.
- Optimal biocatalytic process design will increase the efficiency of production processes.
- Therefore, there is a strong need for systematic design technology which can devise new high-performance processes quickly and reliably.
- The focus areas of research in biocatalytic process design are mentioned in **Table 1**

Table 1: Focus areas of research in biocatalytic process design.

- Expansion of the range of enzymes for industrial applications.
- Use of newly generated information on the biochemical pathways and enzymes to search for catalysts capable of novel chemical conversions.
- Expanded applicability of high-throughput screening methods for activity and (stereo) selectivity of enzyme and mutant libraries.
- Optimisation of biocatalysts by directed evolution and/or rational design.
- In depth understanding of catalytic enzyme-substrate interactions to enable new enzyme applications or synthesis of new bioproducts.
- Integration of bio- (and chemo-) catalysts into industrial processes, as well as development of robust biocatalysts for industrial processes to ensure successful scale-up.
- Direct integration of enzyme production and enzyme transformation including downstream processing of target compounds.
- Development of modular and multiphase bioreactors.
- Reduction of the number of unit operations in biocatalytic processes by using multi-step bioreactions without isolation of intermediates, via design of both enzymes and bioreactors.
- Use of cascades of enzymes in a single unit process and whole cell bioconversion system.
- Development of micro- and nano-devices for chemical and biochemical analysis, including biochips for molecular and cellular detection and (automated on-line) monitoring.

2.1 Upstream Processing (USP)

- Upstream processing involves all the factors and processes leading to fermentation as well as including the fermentation.
- It consists of three main areas:

1. The first relates to the aspects associated with the producer microorganism. It includes the strategy, initially obtaining a suitable microorganism, strain improvement to enhance productivity and yield, maintenance of strain purity, preparation of a suitable inoculum and the continuing development of selected strains to increase the economic efficiency of the process.

Strain development begins with identification or isolation of an organism capable of producing the molecule of interest. the isolated strain is improved by mutagenesis, screening, selection, and genetic engineering to meet the production process and economic requirements.

2. The second aspect of USP involves fermentation medium, especially the selection of suitable cost-effective carbon and energy source along with other essential nutrients.

Thus media optimization is a vital aspect of process development to ensure maximization of yield and profit. Detailed investigations are needed to establish the most suitable medium for an individual bioprocess, but certain basic requirements must be met by any such medium.

All microorganisms require water, sources of energy, carbon, nitrogen, mineral elements, etc. and oxygen is also required if the process is aerobic.

- On a small scale it is relatively simple to device a medium containing pure compounds, but the resulting medium, although supporting satisfactory growth may be unsuitable for use in a large scale process.
- On a large scale one must normally use sources of nutrient to create a medium which will meet the as many as possible criteria mentioned in **Table 2**.

The use of cane molasses, beet molasses, cereal grains, starch, glucose, sucrose and lactose as carbon sources, and ammonium salts, urea, nitrates, corn steep liquor, soya bean meal, slaughter house waste and fermentation residues as nitrogen sources have tended to meet most of the above criteria for production media, because they are cheap substrates.

However, other more expensive pure substrates may be chosen if the overall cost of the complete process can be reduced, because it is possible to use simpler procedures.

Table 2: Criteria for the selection of a medium at industrial scale.

- It will produce the maximum yield of product or biomass per gram of substrate used.
- It will produce the maximum concentration of product or biomass.
- It will permit the maximum rate of product formation.
- There will be the minimum yield of undesired products.
- It will be of consistent quality and be readily available throughout year.
- It will cause minimal problems during media making and sterilization.
- It will cause minimal problems in other aspects of the production process particularly aeration & agitation, extraction, purification and waste treatment.

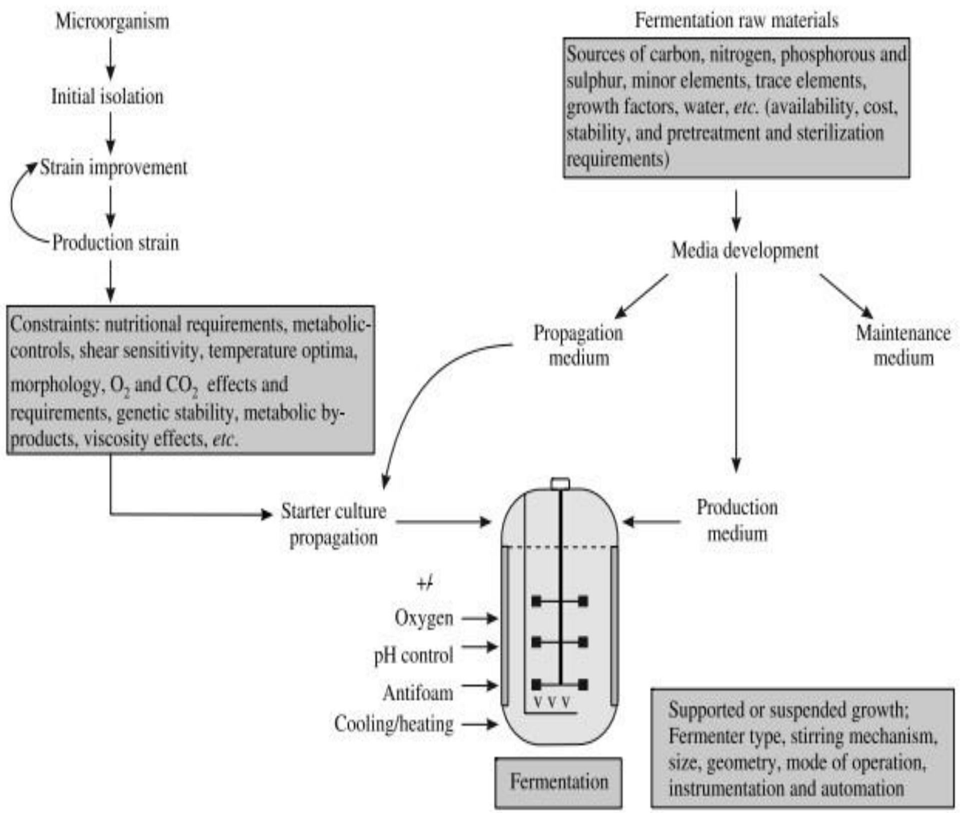


Fig. 3: Outline of upstream processing.

- The problem of developing the process from the laboratory to the pilot scale, and subsequently to the industrial scale, must also be considered.
- A laboratory medium may not be ideal in a large fermenter with a low gas transfer pattern.
- A medium with a high viscosity will also need higher power inputs for effective stirring.
- Besides meeting requirements for growth and product formation, the medium may also influence pH variation, foam formation, the oxidation-reduction potential, and the morphological form of the organism.
- It may also be necessary to provide precursors or metabolic inhibitors. The medium will also affect product recovery and effl uent treatment.

- In some of the microbiological bioprocesses, foaming is a problem. It may be due to a component in the medium or some factors produced by the microorganism. T
- he most common cause of foaming is due to proteins in the medium, such as corn-steep liquor, peanut meal, yeast extract or meat extract, etc. These proteins may denature at the air-broth interface and form a skin which does not rupture readily.
- Antifoam agents are added when foaming occurs during the fermentation. Because many antifoams are of low solubility, they need a carrier such as lard oil, liquid paraffin or castor oil which may be metabolized and affect the fermentation process.
- Unfortunately, the concentrations of many antifoams which are necessary to control fermentation will reduce the oxygen transfer rate by as much as 50%, therefore antifoam additions must be kept to an absolute minimum. There are also other antifoams which increase the oxygen transfer rate.
- If the oxygen transfer rate is affected by antifoam addition, then mechanical foam breakers may have to be considered as a possible alternative

3. The third component of USP relates to its fermentation which is usually performed under controlled conditions, developed to optimize the growth of the organism or the production of a target microbial product.

Analysis of the many industrial fermentation processes shows that they are common reactions from a chemical, as well as a physical.

Fermentation processes can be classified by the reaction mechanisms involved in converting the raw materials into products. These include reductions, simple and complex oxidations, substrate conversions, transformations, polymerizations, hydrolyses, complex biosyntheses, and the formation of cells.

Fermentation processes, except for sterilization, have in common many of the familiar chemical engineering unit operations. For example, aerobic fermentations involve the "mixing" of three heterogeneous phases: microorganisms, medium, and air. Other unit operations include "mass transfer" of oxygen from the air to the organisms and "heat transfer" from the fermentation medium. Analysis of fermentations by the unit operation technique has added greatly to the understanding of their behaviour.

The major research areas of upstream processing are depicted in Table 3.

Table 3: Focus areas of research of upstream processing.

- Studying the physiology of microorganisms under extreme conditions: pH and temperature, slow growth, high concentration of substrates and products to maximise product yield.
- Development of microbioreactors as a screening tool to shorten the process development time, based on realistic large scale production conditions.
- Development of engineering tools to design strategies for process intensification, such as low-cost fermenters, alternative novel reactor concepts, advanced control strategies and simulation tools for modelling fermentation processes on different scales.
- Combination of energy production and bioprocesses for chemical(s) production.

2.2 Downstream Processing (DSP)

- Isolation and purification of a biotechnological product to a form suitable for its intended use is called downstream processing.
- DSP encompasses all processes following the fermentation. Its primary aim includes efficiency, reproducibility and safely recovery of the targeted product to the required specification (biological activity, purity, etc.).
- While maximizing recovery yield and minimizing costs. The target product may be recovered by processing the cells or the spent medium depending upon whether it is an intracellular or extracellular product.
- The level of purity that must be achieved is usually determined by the specific use of the product.

- Each stage in the overall recovery procedure is strongly dependent on the protocol of the preceding fermentation.
- Fermentation factors affecting DSP include the properties of microorganisms, particularly morphology, flocculation characteristics, cell size and cell wall.
- These factors have major influences on the filterability, sedimentation and homogenization efficiency.
- The presence of fermentation by-products, media impurities and fermentation additives, such as antifoams, may interfere with DSP steps and accompanying product analysis.

- Physical process integration may be achieved by placing separation units inside the fermenter or by directly linking the two systems together.
- Where product formation is coupled with growth, i.e. primary metabolites, higher productivity may be achieved by using integrated systems that maintain high cell densities through cell retention or recycling.
- Where products are inhibitory, a wide range of methods have been employed to partition bioreactors to allow the rapid in situ removal of the products by extraction, adsorption or stripping, often increasing yield and productivity.


Medical Biotechnology

What is Medical Biotechnology?

- Medical biotechnology is a branch of medicine that uses living cells and cell materials to research and then produce pharmaceutical and diagnosing products.
- These products help treat and prevent diseases. From the Ebola vaccine to mapping human DNA to agricultural impacts, medical biotechnology is making huge advancements and helping millions of people.
- Some of the most recent uses of biological tech is work in genetic testing, drug treatments, and artificial tissue growth.

Major Medical Biotechnology Advancements

- From cancer research to agriculture advancements, medical biotechnology has many promising avenues of technological growth that have the potential to help many people.

- CRISPR
- CRISPR technology or CRISPR-Cas9 utilizes a protein called Cas9.
- CRISPRs are specialized stretches of DNA and are used in medical biotechnology as a tool to edit genomes.
- This allows scientists to alter DNA and modify gene functions, often called genetic engineering. There are many applications, like correcting genetic defects, treating diseases, preventing the spread of diseases, improving crops, and more.
- But the science of altering genomes has many ethical concerns surrounding it.

Tissue Nanotransfection

- New science may have theability to heal people with a single touch.
- Tissue nanotransfection works by injecting genetic code into skin cells, which turns those skin cells into the other types of cells required for treating diseases.
- In some lab tests, one touch of TNT completely repaired the injured legs of mice over a period of a few weeks by turning skin cells into vascular cells.
- This biotech can work on other types of tissue besides skin. The potential for this type of gene therapy is huge, from helping car crash victims to active duty soldiers.
- Medical biotechnology has made this advancement possible, and the continued research and testing will only help improve this tech and adopt it across hospitals and medicalcenters.

Recombinant DNA Technology

- Recombinant DNA technology is combining DNA molecules from two different species and then inserting that new DNA into a host organism.
- That host organism will produce new genetic combinations for medicine, agriculture, and industry.
- There are many examples of recombinant DNA technology being utilized, from biopharmaceuticals and diagnostics to energy applications like biofuel to agricultural biotechnology with modified fruits and veggies.
- The genetically modified products are able to perform better than the regular medicine or produce. Recombinant agriculture is able to be more pest resistant or weather resistant; recombinant medicine like insulin is able to better work with bodies, etc.
- Because of the many benefits that recombinant DNA holds for a variety of products, researchers are optimistic about the future it has within biosciences and in other industries as well.

Genetic Testing from 23andMe

- Genetic kits are popular these days, and they are beneficial for more than just helping people understand their genetics and heritage.
- New studies are showing that saliva kits are able to test for things like breast cancer by looking at gene mutations.
- While 23andMe test results shouldn't be a reason to make decisions about treatments, understanding your heritage and how that could impact your health is valuable. 23andMe is also authorized to analyze for a variety of diseases, including Alzheimer's.

HPV Vaccine

- You've probably heard of the Human Papilloma Virus (HPV) and how it's linked to cervical cancer —which is the second most lethal form of cancer for women, next to breast cancer.
- Statistics show that cervical cancer kills 275,000 women annually, which is why a vaccine for HPV is so important.
- The good news is there are now two vaccines on the market — Cervarix and Gardasil—that have been approved by the U.S. Food and Drug Administration for use in women from ages 9 to 26.

Stem Cell Research

- Biotechnology plays a big part in supporting stem cell research, which supports the exploration of growing stem cells in a lab setting or in vitro.
- This could help in situations where patients may be suffering from a disease or disorder where implanting stem cells could help restore their vitality and give them a new lease on life.
- How does it work? Because stem cells can repeatedly divide and transform into other types of body cells, biotechnologists can learn how to work with their unique profiles to encourage growth of specific types of cells.
- Though research is ongoing, it's reported that the results show hope for the future of this unique medical approach.

Medical and Ethical Issues of Biotechnology

- While there are great advancements and positives to medical biotechnology, anything this fast-growing and powerful is bound to come with some concerns and issues.
- Medical biotechnology is a controversial medical topic, with medical ethical issues associated.

Risk to Human Life in Clinical Trials

- A huge risk of medical biotechnology is its impact during clinical trials.
- Because it's such new tech, people can and have gotten hurt–and even died–during trials of the technology.
- Because of these risks, extensive research should be performed before even thinking of introducing tech to human subjects, and those who are participating in a trial should be extremely aware of any and all possibilities.
- Unfortunately, the paradox is that many times people who are sick are willing to try new things for the chance to get cured. This means researchers and doctors have a huge ethical responsibility to truly outline for a patient what the costs may be and respect their ultimate decision.

High Cost May Exclude the Poor

- While medical biotechnology has huge potential to make medicine more efficient and easy, what’s the cost?
- This technology is often hugely expensive compared to traditional treatments. There is an ongoing give and take about finding new medical advancements and the cost it takes to do research and then market the findings for purchase.
- There is also the concern that high costs of tech treatments can exclude an entire class of people from being able to utilize them.
- This is also a huge give and take, with science and medicine having a responsibility to help all patients —not just those who are wealthy enough to buy the best care.

Privacy Concerns

- Imagine a doctor looks at a young child's DNA and finds out they are likely to develop a heart disease or terminal issue.
- Does their employer have the right to know that? Should this information impact their ability to get a house or insurance?
- HIPAA offers some protection, but as medical biotechnology continues to advance the ability to read genes, insurance companies, doctors, and governments will have to come up with new programs and privacy tactics to match all the new needs that will arise.

Some Groups Oppose Stem Cell Research

- Medical biotechnology is kind of a hot -button political issue.
- The idea of working with fetal tissue, or other tissue, to learn about regrowth conjures images of Frankenstein's monster.
- For example, using human tissue for research can be seen as ethical, while using an embryo's tissue can be seen as unethical because it can damage the embryo.
- It is still early in the stem -cell research process, but as technology and research continue to advance in that area, scientists will have to consider ethical lines even more.

Bioterrorism is a National Concern

- Medical biotechnology has been used for security measures to help prevent a large number of people from possible bioterrorism.
- But the development of these projects takes away funding and time from curing known diseases.
- It becomes a real question of how to divide resources among projects and knowing where the resources are most needed.
- It's difficult because we don't know if people will die from bioterrorism but with so many people being concerned, it seems like a worthwhile place to spend time and money.
- Any way you look at it, there are a number of concerns when it comes to medical biotechnology, and as we continue to make advancements, these ethical considerations will have to be made.

Role of Nurses in the Biotechnology Industry

- Nurses have an ongoing role in medical biotechnology because of their direct experience with patient care.
- Nurses are able to use their knowledge and experience in hospitals and clinics to understand and demonstrate how medicines and drugs would impact large populations.
- Beyond knowing the science, they have the human element that researchers sometimes lack. They are able to understand how a patient would respond to a potential treatment and can help researchers consider new approaches to technology and adoption practices.

- Medical biotechnology is a field that is exploding and along with its potential for saving lives, it raises some ethical questions.
- As the field continues to grow, people from all types of industries are going to be required to make decisions to help regulate this field.


THE
END