ABDUR REHMAN BIOLOGY

18 Biotechnology and genetic modification

18.1 Biotechnology

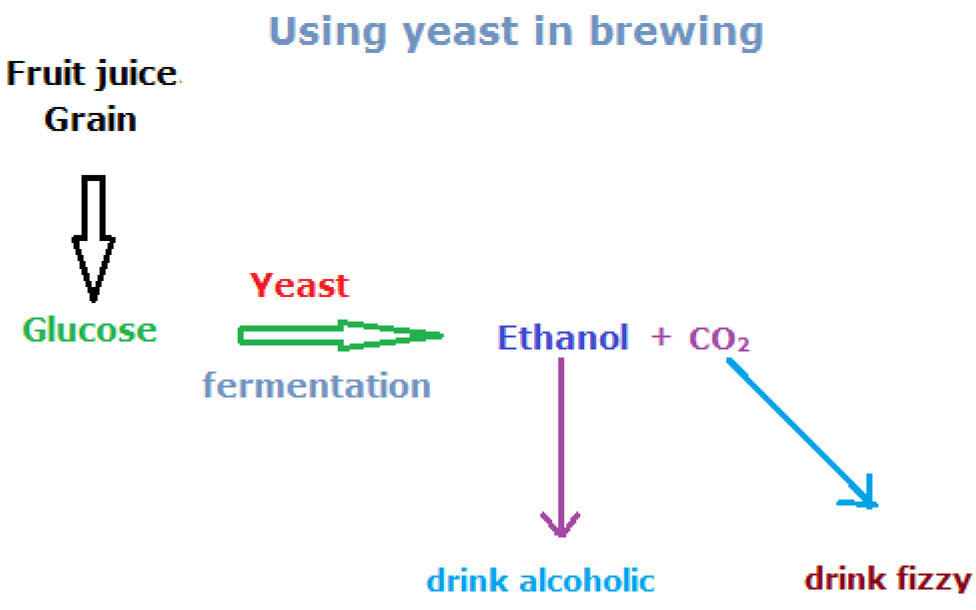
Explain the role of yeast in the production of bread and ethanol.

Biotechnology
Biotechnology is defined as the use of living organisms in process for the manufacture of useful products or for services.

Yeast plays a crucial role in both the production of bread and ethanol through fermentation processes. Fermentation is a metabolic process that occurs in the absence of oxygen and involves the conversion of organic compounds, such as sugars or carbohydrates, into simpler molecules, typically producing energy and metabolic byproducts.

Ethanol Production.
Ethanol can be produced from fermented sugar or spare grain by yeast. This could the place correctly supplement petrol. This fermentation is carried out by many types of yeast such as Saccharomyces cerevisiae. In this process, yeast metabolizes sugars, such as glucose and sucrose, and converts them into ethanol and carbon dioxide. The ethanol produced is separated from the fermentation mixture through distillation, resulting in a concentrated ethanol solution.

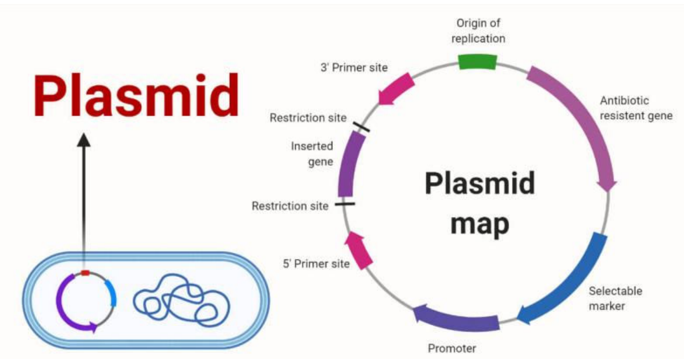
Bread production.
In bread making, yeast serves as a leavening agent, facilitating the rise of the dough and imparting lightness and texture to the final product. During fermentation, yeast metabolizes sugars present in the dough, primarily glucose and fructose, and converts them into carbon dioxide (CO2) and ethanol through anaerobic respiration. The CO2 produced by yeast creates bubbles in the dough, causing it to expand and rise. This process, known as alcoholic fermentation, gives bread its characteristic airy texture and helps it to rise during baking. Additionally, the ethanol produced by yeast evaporates during baking, leaving behind the distinctive flavor associated with yeast-leavened bread.



Understand that bacteria are useful in biotechnology and genetic modification due to their rapid reproduction rate and their ability to make complex molecules.
Discuss why bacteria are useful in biotechnology and genetic modification, limited to:
(a) no ethical concerns over their manipulation and growth.
(b) presence of plasmids.

Bacteria play a pivotal role in the realms of biotechnology and genetic modification owing to their rapid reproductive rates and intricate biochemical machinery. Their swift reproduction enables the scalable production of target molecules or proteins within relatively short timeframes. Bacteria doubles its amount in twenty minutes. Moreover, bacteria exhibit a diverse array of metabolic pathways, allowing them to synthesize complex molecules, including enzymes, hormones, antibiotics, and various organic compounds. In biotechnology applications, bacteria serve as workhorses for various tasks, such as pharmaceutical production, enzyme synthesis, biofuel generation, and chemical manufacturing. Engineered bacterial strains are tailored to produce essential medical compounds like insulin, industrial enzymes for detergent formulation, and antibiotics to combat bacterial infections. Additionally, bacteria contribute to environmental efforts through applications such as bioremediation, wherein they degrade pollutants in contaminated sites or wastewater treatment facilities.
In genetic modification, bacteria serve as efficient hosts for the introduction and expression of foreign genetic material. Utilizing techniques like genetic engineering, researchers can manipulate bacterial genomes to confer novel traits or functionalities. Well-studied bacterial species such as Escherichia coli (E. coli) and Bacillus subtilis are favoured choices for genetic experimentation and industrial applications due to their well-characterized genetic makeup and amenability to genetic manipulation.

Bacteria are immensely valuable in biotechnology and genetic modification for several reasons, including their lack of ethical concerns regarding manipulation and growth, as well as the presence of plasmids.
(a) No ethical concerns over their manipulation and growth:
Unlike higher organisms such as animals or plants, bacteria are generally regarded as having minimal ethical concerns associated with their manipulation and growth in laboratory settings. This is primarily due to their microscopic size, rapid reproduction rates, and relatively simple genetic makeup. Manipulating bacterial genomes for various biotechnological applications, such as producing pharmaceuticals or enzymes, does not raise the same ethical dilemmas as altering the genomes of higher organisms. Therefore, researchers have greater freedom to conduct experiments and genetic modifications using bacteria without significant ethical constraints.
(b) Presence of plasmids:
Plasmids are small, circular DNA molecules found in bacteria that exist independently of the bacterial chromosome. They often carry genes that confer advantageous traits such as antibiotic resistance, toxin production, or the ability to metabolize specific compounds. Plasmids play a crucial role in genetic modification and biotechnology because they can be easily manipulated and transferred between bacterial cells. Scientists can introduce foreign DNA sequences into plasmids, creating recombinant DNA molecules that are then inserted into bacterial hosts. This process allows for the expression of desired traits encoded by the inserted genes, such as the production of therapeutic proteins or the enhancement of metabolic pathways for industrial applications.

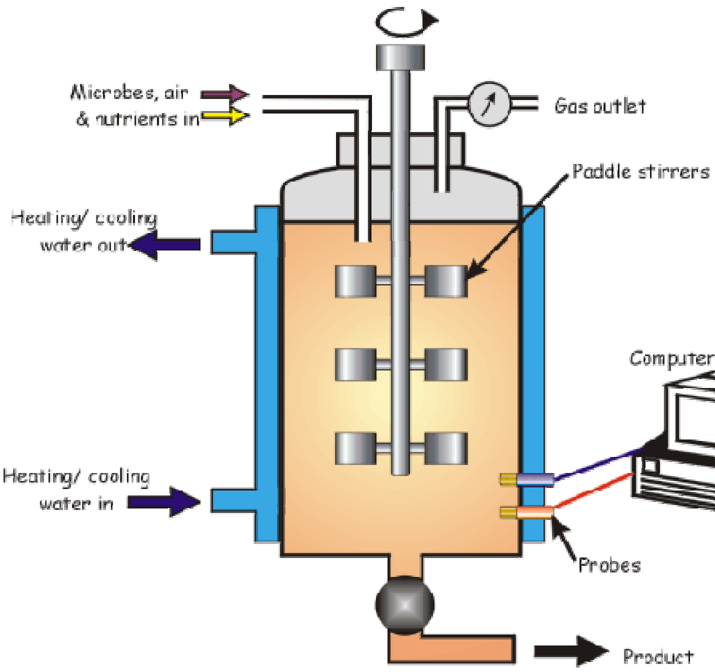


Describe how fermenters can be used for the large-scale production of useful products by bacteria and fungi, including the conditions that need to be controlled, limited to: temperature, pH, oxygen, nutrient supply and waste products.

Fermenter

Fermenter is a device that provides optimum environment to microorganisms to grow into a biomass so that they can interact with a substrate forming the product. They are also known as bioreactors.

For each biotechnological process, the environment provided to the organisms must be monitored and controlled. Such a controlled environment is provided by fermenters. A fermenter optimizes the growth of the organisms by controlling many factors like nutrients, oxygen, growth inhibitors, pH and temperature. Temperature must be maintained within optimal ranges for microbial growth, while pH levels are adjusted using sensors and controllers to support specific organisms' requirements. Oxygen levels are regulated through agitation and aeration systems, vital for aerobic microorganisms but minimized for anaerobic ones. Nutrient supply, including carbon and nitrogen sources, vitamins, and minerals, is carefully controlled to support robust microbial growth and product formation. Waste product accumulation is managed through filtration, centrifugation, or continuous harvesting methods, ensuring optimal fermentation conditions. By controlling these factors, fermenters enable the efficient production of enzymes, antibiotics, biofuels, and pharmaceuticals, among other valuable products, contributing to various industries, including healthcare, food and beverage, agriculture, and environmental sustainability. A fermenter may hold several thousand litres of the growth medium. So, fermenters allow the production of materials in bulk quantities.



Describe the use of:
(a) enzymes in biological washing powders (b) pectinase for fruit juice production (c) lactase for lactose-free milk.

Enzymes in biological washing powder.
Most modern washing powders contain protein digesting enzymes (proteases) and lipid digesting enzymes (lipases). Protease enzymes target protein-based stains like blood or grass, amylase enzymes tackle starch-based stains like pasta or rice, and lipase enzymes work on fatty stains like oil or grease. These enzymes accelerate the breakdown of complex molecules into smaller, soluble fragments, which can then be easily washed away. This enzymatic action increases the cleansing power of detergents. Biological washing powders save energy because they are used at low temperatures and do not require boiling water.

Pectinase for fruit juice production.
Pectinases, derived from fungi such as Aspergillus niger, are enzymes employed in the extraction of fruit juices, particularly from fruits like apples. Their primary function is to catalyze the breakdown of pectin, a complex polysaccharide that acts as a gel-like adhesive between plant cell walls. By cleaving the bonds within pectin molecules, pectinases facilitate the separation of juice from fruit tissues, aiding in the extraction process.
Furthermore, pectinases play a role in improving the clarity of fruit juice. When fruit cells are disrupted during juicing, various polysaccharides are released into the juice, causing cloudiness. Pectinases target these polysaccharides, breaking them down into smaller, soluble fragments, thereby enhancing juice transparency. This enzymatic action contributes to the aesthetic appeal of the juice by reducing cloudiness and enhancing visual clarity. Additionally, the breakdown of pectin by pectinases releases sugars from the fruit cells, leading to an increase in sweetness in the resulting juice. This enzymatic process not only improves the texture and appearance of the juice but also enhances its flavor profile, making it more appealing to consumers.

Lactase for lactose-free milk.
Lactase enzyme is used in the production of lactose-free milk to hydrolyze lactose, a disaccharide sugar found in milk, into its component monosaccharides, glucose, and galactose. Individuals with lactose intolerance lack sufficient levels of the enzyme lactase required to digest lactose properly. By adding lactase enzyme to milk, lactose is broken down into its absorbable forms, allowing lactose-intolerant individuals to consume milk without experiencing gastrointestinal discomfort. Lactase-treated milk retains the nutritional qualities of regular milk while providing a lactose-free alternative for those with lactose intolerance. This enzymatic process enables the production of lactose-free milk products that are more easily digested and suitable for individuals with lactose intolerance.

18.2 Genetic modification

Describe genetic modification as changing the genetic material of an organism by removing, changing or inserting individual genes.

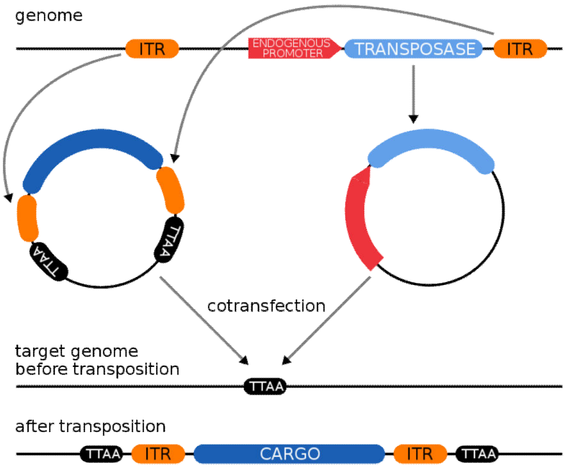
Understand that the gene that controls the production of human insulin has been inserted into bacterial DNA, for commercial production of insulin.

Genetic modification.

Genetic modification also known as genetic engineering or genetic manipulation, refers to the deliberate alteration of an organism's genetic material using biotechnological techniques. This can include removing genes, altering their sequences or inserting entirely new ones.

In agriculture, genetically modified organisms (GMOs) are developed to enhance traits like pest resistance, drought tolerance, or nutritional content. For example, crops can be engineered to produce their own insecticides, reducing the need for chemical pesticides.

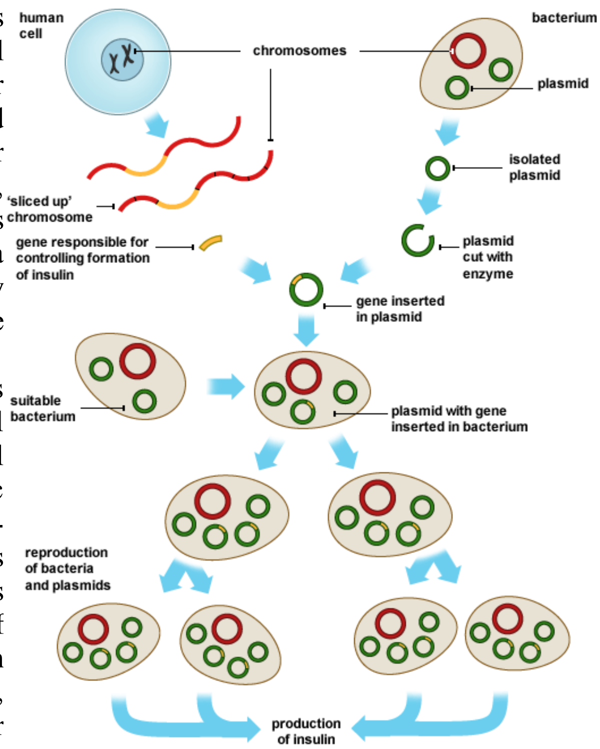
In medicine, genetic modification holds promise for treating genetic disorders by correcting defective genes. It can also be used to create genetically modified animals for research purposes or to produce valuable pharmaceuticals.



However, concerns about the safety and environmental impact of GMOs remain, leading to ongoing debates and regulatory scrutiny. Despite this, genetic modification continues to advance, offering both opportunities and challenges in various fields.

In this process, the gene encoding human insulin is integrated into the bacterial genome. Bacterial species like Escherichia coli are chosen due to their amenability to genetic manipulation and rapid growth rates. Initially, the gene responsible for human insulin synthesis is isolated. Subsequently, through recombinant DNA technology, this gene is introduced into the bacterial genome. The bacteria then commence insulin production, facilitated by the transcription and translation machinery of the host cell, guided by the inserted gene sequence.

This genetic engineering approach revolutionizes insulin production, supplanting conventional methods reliant on extraction from animal pancreatic tissue. By harnessing the biosynthetic capabilities of genetically modified bacteria, large-scale, cost-effective production of human insulin is achieved. The modified bacteria function as bioreactors, synthesizing substantial quantities of human insulin. Following purification, the insulin is rendered suitable for medical applications, providing a dependable and sustainable supply for individuals managing diabetes.



Outline the use of genetic modification in crop plants by inserting genes:
(a) to confer resistance to herbicides.
(b) to confer resistance to insect pests.
(c) to provide additional vitamins.

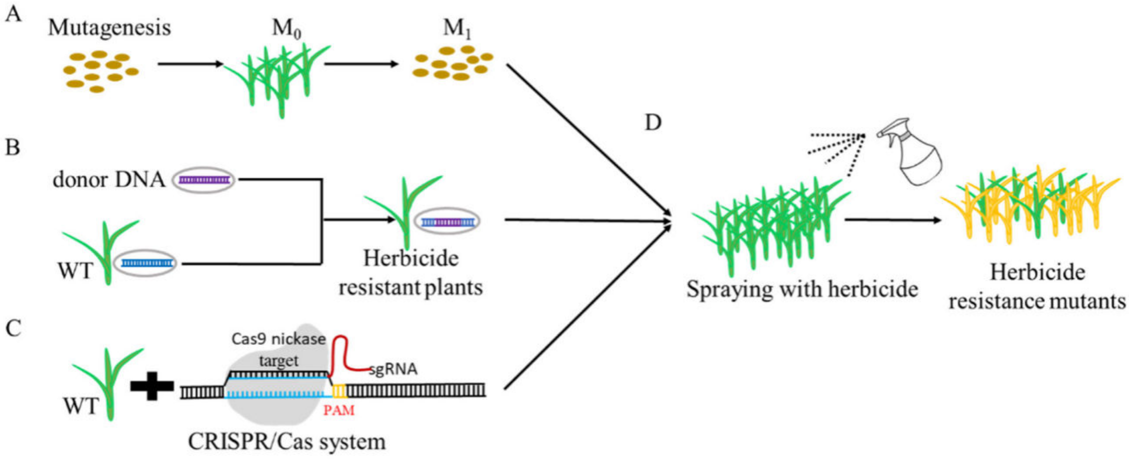
Genetic modification holds immense potential in agriculture, yet beyond a limited assortment of crop varieties, most advancements remain in experimental phases. Notably, in the United States, genetically modified (GM) soybean and maize dominate the agricultural landscape, constituting 94% and 92% of their respective crops. These modifications confer resistance to herbicides and insect pests. However, globally, the cultivation of GM crops is primarily experimental, encountering resistance due to concerns over their presence in food.

Pest resistance.

Pest resistance is achieved through the integration of genes from Bacillus thuringiensis, encoding toxins lethal to caterpillars and insect larvae, into plant species like maize, cotton, and soybean. While initially effective, signs of insect resistance to these toxins are emerging.

Herbicide resistance.

Herbicide resistance is conferred by introducing genes encoding enzymes capable of degrading herbicides like glyphosate into plant cell cultures. This genetic enhancement aims to minimize herbicide usage, albeit controversy arises due to suspected carcinogenic properties of glyphosate, leading to its prohibition in certain regions.



Additional Vitamins.

Genetic modification facilitates the fortification of crops with essential vitamins, exemplified by the creation of Golden Rice containing a gene for beta-carotene synthesis, addressing vitamin A deficiency prevalent in over 100 million children worldwide. This biotechnological approach offers a promising avenue to alleviate malnutrition-related health issues, albeit amidst ongoing debates regarding its safety and societal acceptance.

Discuss potential advantages and risks of genetic modification, limited to modifying crop plants and bacteria.

One concern regarding the use of bacteria as vectors for delivering recombinant DNA is the potential transfer of antibiotic resistance genes. These genes are employed as selection markers during the genetic engineering process. If the recombinant DNA were to transfer to harmful bacteria in the intestine, it could confer antibiotic resistance, posing a risk to public health. While no evidence suggests this occurrence in experimental animals, biotech companies are exploring alternative selection methods to eliminate the need for antibiotics. Another apprehension revolves around the possibility of GM foods containing pesticide residues or allergens. Despite rigorous testing for toxins and allergens, GM products undergo extensive scrutiny by regulatory bodies before market release. However, concerns persist, especially regarding the potential conversion of beta-carotene, present in GM golden rice, into toxic compounds post-consumption, limiting its cultivation to a few countries like the Philippines and Bangladesh.

Furthermore, worries extend to potential impacts on biodiversity and the dependence of subsistence farmers on large agricultural corporations, which may monopolize seed markets and manipulate prices. Beyond specific hazards, apprehensions arise from the fundamental alteration of genetic material across different species, a phenomenon unprecedented in nature. The long-term ecological consequences remain uncertain, fueling broader unease surrounding genetic modification practices. Specifically, concerns exist regarding the potential horizontal gene transfer of human genes carried by genetically modified bacteria to other microbial species, emphasizing the need for comprehensive risk assessment and regulatory oversight in biotechnological applications.