Brief content on discipline “Bioprocesses Engineering”

Lecture 1. BASIC INTRODUCTION OFBIOPROCESS

- **DEFINITION:** BIOPROCESS is a specific process that uses complete living cells, or their components [e.g. bacteria , enzymes , chloroplasts] to obtain desired products .
- BIOPROCESS ENGINEERING is the alteration or significance of renewable thing to create value-added products.
- BIOPROCESS ENGINEERING IS SPECILIZATION OF :

i. *BIOLOGICAL ENGINEERING*
ii. *BIOTECHNOLOGY*
iii. *CHEMICAL ENGINEERING*
iv. *AGRICULTURAL ENGINEERING*

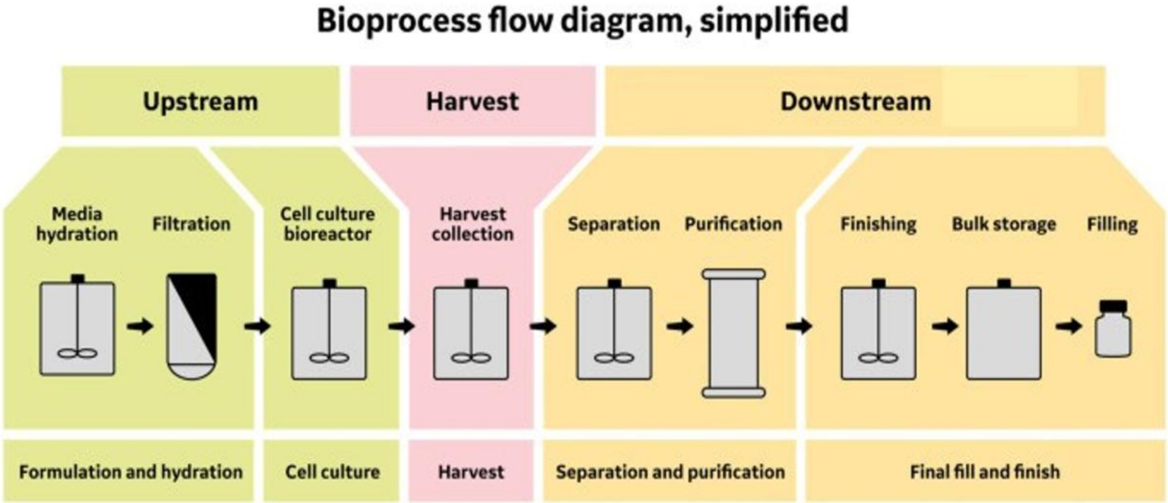
Terms related to Bioprocess development:

Bioprocess technology- A technique that produces a biological material

Industrial microbiology/ biotechnology- deals with all forms of microbiology and biotechnology which have an economic aspect.

Fermentation technology- deals with process and techniques involved in fermentation, in which a substance breaks down to simpler ones.

Biochemical engineering- is a field of study which involves both chemical engineering and biological engineering.



- Principles of mechanics applied to understand biological systems.
- Biomechanics – is the application of mechanical principles in the study of living organisms including their kinematics and kinetics, it views human body as a collection of levers, made of bones which are moved by its muscles. In sport, used to analyze the performance level of athletes. Focuses on body segments and its interaction with the surrounding environment.
- Understanding Pharmacokinetics and Pharmacodynamics of medicines.

Why do engineers need to study the principles of biology?

Shinkansen Sonic Boom

Many man-made things have significant scope for optimising their design. For example, Shinkansen, Japan’s high-speed bullet train, plays an important role in Japan with a coverage of close to 3000 km.

Bio-robotics

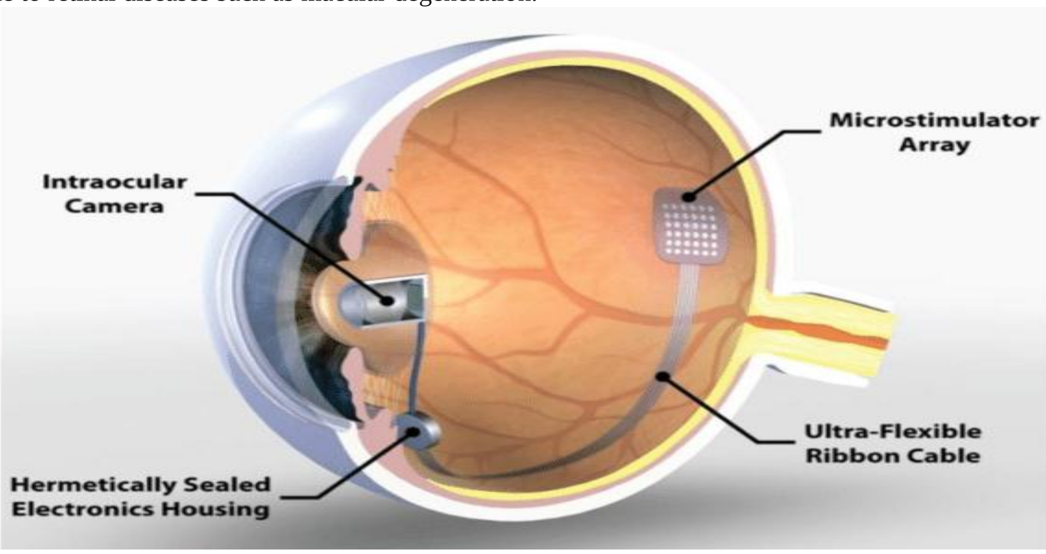
- It refers to robots that are inspired by biological entities or the use of biological components in robots.
- We are possibly familiar with the concept of bio-robotics from many sci-fi movies and TV shows, which show robots with human like features.

Biological process engineering deals with biological mass transformation. The following agents carry out this mass transformation: • complete living organisms with one or a few cells, such as bacteria, fungi or algae • biologically active, isolated components of organisms, such as animal or plant cells • biologically active, isolated components of cells, such as enzyme

Biological process engineering has to create optimal conditions for these organisms, cells and cell components. The scientific findings from the areas of biology, biochemistry, etc. are implemented in industrial-scale processes. Examples of typical processes are: • production of drugs • production of chemicals • production of food • decontamination of soil, air and wastewater • production of biomass energy source

Retinal Prosthetic

- It is a device that purportedly replaces lost photoreceptor function by transmitting computer-processed video images to an array of electrodes or via light sensors placed in the epiretinal or subretinal space.
- Many engineering fields were effectively harnessed along with biology to provide eye-sight to people who could see due to retinal diseases such as macular degeneration.



***Lecture** 2. Fermentation. Biological role. Types of fermentation*

Fermentation is a type of metabolism carried out in the absence of oxygen.

During fermentation, organic molecules (e.g., glucose) are catabolized and donate electrons to other organic molecules.

In the process, ATP and organic end products (e.g., lactate) are formed.

EXAMPLES: Yeast perform fermentation to obtain energy by converting **sugar** into **alcohol.**

HISTORY OF FERMENTATION:

Louis Pasteur was the first scientist to study fermentation.

He showed that lactic acid fermentation is caused by living organisms.

Because oxygen is not required, it is an alternative to aerobic respiration.

Over 25% of bacteria and archaea carry out fermentation.

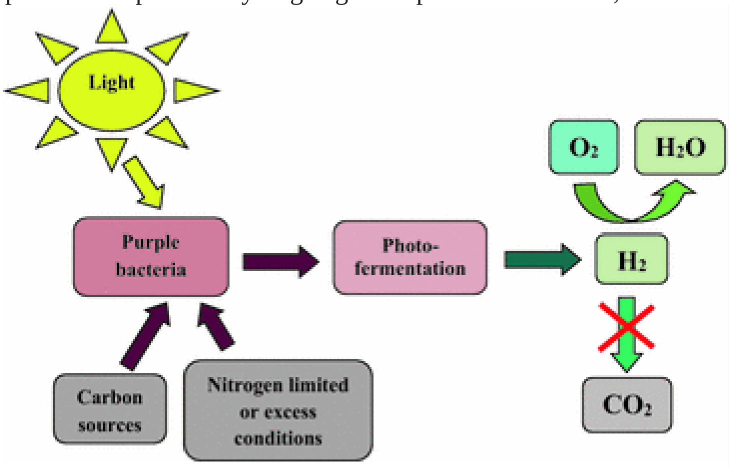
They live in the gut, sediments, food, and other environments.
Eukaryotes, including humans and other animals, also carry out fermentation.
Fermentation is important in several areas of human society.
Humans have used fermentation in production of food for 13,000 years.
Humans and their livestock have microbes in the gut that carry out fermentation, releasing products used by the host for energy.
Fermentation is used at an industrial level to produce commodity chemicals, such as ethanol and lactate.
In total, fermentation forms more than 50 metabolic end products with a wide range of uses.
Fermentation is used by organisms to generate ATP energy for metabolism. One advantage is that it requires no oxygen or other external electron acceptors, and thus it can be carried when those electron acceptors are absent. A disadvantage is that it produces relatively little ATP, yielding only between 2 to 4.5 per glucose[1] compared to 32 for aerobic respiration

System biology

- Systems biology is the computational and mathematical analysis and modelling of complex biological systems.
- It is a biology-based interdisciplinary field of study that focuses on complex interactions within biological systems.
- Systems biology is a holistic approach in biomedical research to better understanding of complex picture of biology.

Lecture 3. *Theme Phytofermentation. Modern "fermentation. Dark Fermentation*.

Photofermentation is the fermentative conversion of organic substrate to biohydrogen manifested by a diverse group of photosynthetic bacteria by a series of biochemical reactions involving three steps similar to anaerobic conversion. Photofermentation differs from dark fermentation because it only proceeds in the presence of light.
For example, photo-fermentation with *Rhodobacter sphaeroides* SH2C (or many other purple non-sulfur bacteria) can be employed to convert small molecular fatty acids into hydrogen[2] and other products.
Phototropic bacteria produce hydrogen gas via photofermentation, where the hydrogen is sourced from organic compounds.



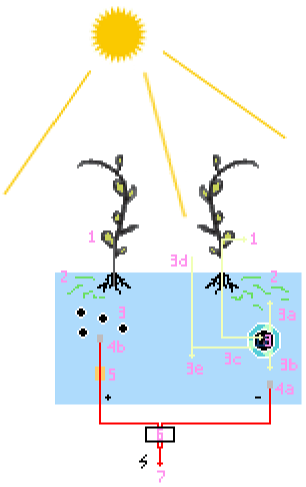
eneral process of photofermentation.

Dark fermentation is the fermentative conversion of organic substrate to biohydrogen. It is a complex process manifested by diverse groups of bacteria, involving a series of biochemical reactions using three steps similar to anaerobic conversion. Dark fermentation differs from photofermentation in that it proceeds without the presence of light.

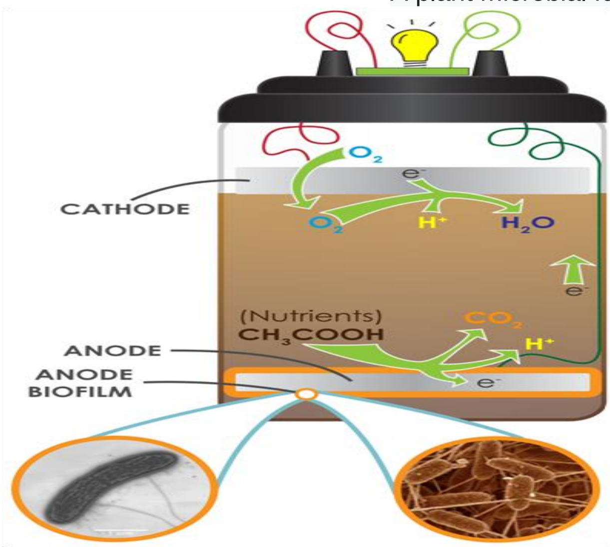
Lecture 4 Microbial fuel cell (MFC)

is a type of bioelectrochemical fuel cell system also known as micro fuel cell that generates electric current by diverting electrons produced from the microbial oxidation of reduced compounds (also known as fuel or electron donor) on the anode to oxidized compounds such as oxygen (also known as oxidizing agent or electron acceptor) on the cathode through an external electrical circuit. MFCs produce electricity by using the electrons derived from biochemical reactions catalyzed by bacteria. MFCs can be grouped into two general categories: mediated and unmediated. The first MFCs, demonstrated in the early 20th century, used a mediator: a chemical that transfers electrons from the bacteria in the cell to the anode. Unmediated MFCs emerged in the 1970s; in this type of MFC the bacteria typically have electrochemically active redox proteins such as cytochromes on their outer membrane that can transfer electrons directly to the anode.In the 21st century MFCs have started to find commercial use in wastewater treatment

Microbial fuel cell (MFC) is a device that converts chemical energy to electrical energy by the action of microorganisms.These electrochemical cells are constructed using either a bioanode and/or a biocathode.



A plant microbial fuel cell (PMFC)



A soil-based MFC

Lecture. 5 Theme Industrial important microbes

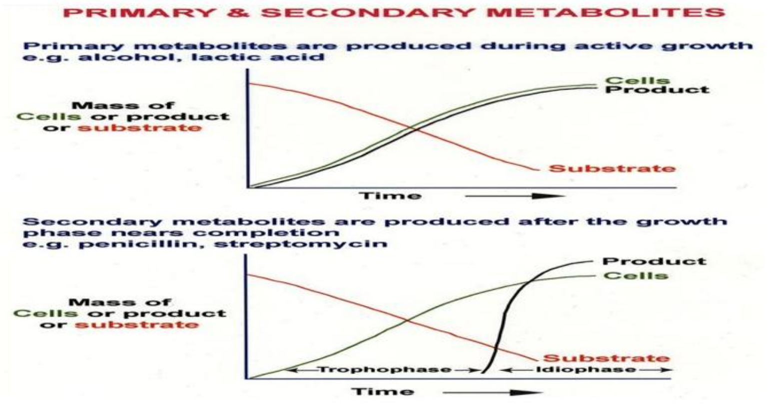
- **Industrial microorganism** is the branch of biotechnology that applies in industry for creating industrial products in mass quantities.
- **Industrial biotechnology** uses microorganisms to make bio based products such as:
- **chemicals, food and feed, detergents, paper and pulp, textile and bioenergy with less waste generation & reduce energy consumption.**

Properties of Industrial important microorganisms:

- Produces spores can be easily inoculated
- Grows rapidly on a large scale in inexpensive medium
- Produces desired product quickly
- Should not be pathogenic

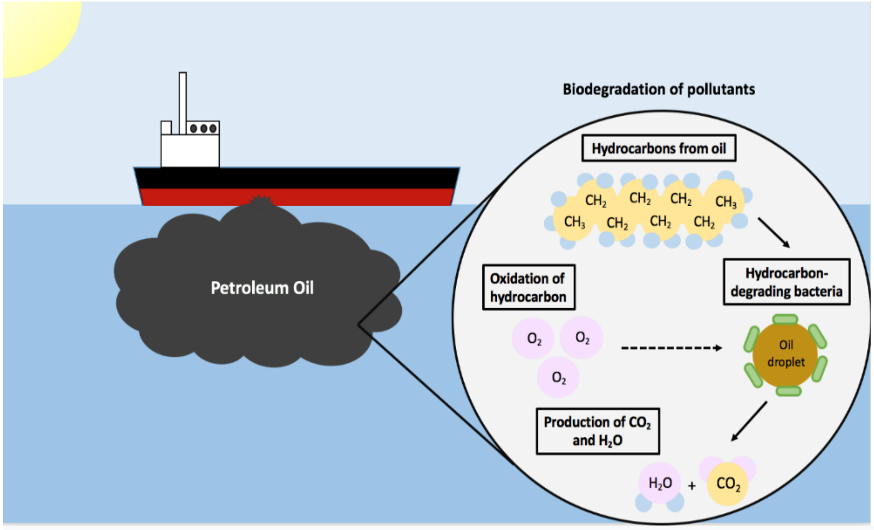
Amenable to genetic manipulation

The products of an industrial microbial process are divided into two broad classes:



Lecture 6. *Theme. Microbial degradation of xenobiotics*

Microbial biodegradation is the use of bioremediation and biotransformation methods to harness the naturally occurring ability of microbial xenobiotic metabolism to degrade, transform or accumulate environmental pollutants, including hydrocarbons (e.g. oil), polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), heterocyclic compounds (such as pyridine or quinoline), pharmaceutical substances, radionuclides and metals.



General overview of microbial biodegradation of petroleum oil by microbial communities. Some microorganisms, such as *A. borkumensis*, are able to use hydrocarbons as their source for carbon in metabolism. They are able to oxidize the environmentally harmful hydrocarbons while producing harmless products, following the general equation $C_nH_n + O_2 \rightarrow H_2O + CO_2$. In the figure, carbon is represented as yellow circles, oxygen as pink circles, and hydrogen as blue circles. This type of special metabolism allows these microbes to thrive in areas affected by oil spills and are important in the elimination of environmental pollutants.

Lecture 7 Biological importance of a mold, mould (UK) ***- one of the structures that certain fungi form.***

M**mold** or **mould** is one of the structures that certain fungi can form. The dust-like, colored appearance of molds is due to the formation of spores containing fungal secondary metabolites. The spores are the dispersal units of the fungi Not all fungi form molds. Some fungi form mushrooms; others grow as single cells and are called microfungi (for example yeasts).

A large and taxonomically diverse number of fungal species form molds. The growth of hyphae results in discoloration and a fuzzy appearance, especially on food. The network of these tubular branching hyphae, called a mycelium, is considered a single organism. The hyphae are generally transparent, so the mycelium appears like very fine, fluffy white threads over the surface. Cross-walls (septa) may delimit connected compartments along the hyphae, each containing one or multiple, genetically identical nuclei. The dusty texture of many molds is caused by profuse production of asexual spores (conidia) formed by differentiation at the ends of hyphae. The mode of formation and shape of these spores is traditionally used to classify molds. Many of these spores are colored, making the fungus much more obvious to the human eye at this stage in its life-cycle.

Lecture 8. *Theme.* ***Genetic Engineering***

Genetic modification can include the introduction of new genes or enhancing, altering, o knocking out endogenous genes. In some genetic modifications, genes are transferred within the same species, across species (creating transgenic organisms), and even across kingdoms. Creating a genetically modified organism is a multi-step process

Recombinant DNA: the altered DNA is called recombinant DNA (recombines after small section of DNA inserted into it).

Genetically Modified Organism (GMO): is the organism with the altered DNA. A wide variety of organisms have been genetically modified (GM), including animals, plants, and microorganisms

Genetic engineering allows DNA from different species to be joined together.

Genetic engineering breaks the species barrier

Tools Used in Genetic Engineering

Restriction Enzymes: are special enzymes used to cut the DNA at specific places.

different enzymes cut DNA at specific base sequences known as a **recognition site.**

DNA Ligase: enzyme which acts like a glue sticking foreign DNA to DNA of the cloning vector.

Process of Genetic Engineering

Five steps involved in this process:

1. *Isolation*
2. *Cutting*
3. *Insertion (Ligation)*
4. *Transformation*
5. *Expression*

2. **Applications of Genetic Engineering**
3.

Lecture 9 *Theme.* ***Omics driven bioengineering. Metabolic Engineering***

Metabolic engineering, as first defined by Baily in 1981, is “the improvement of cellular activities by manipulating enzymatic, regulatory, and transport functions of the cell with the use of recombinant DNA technology.”

Metabolic engineering is a process for modulating the metabolism of the organisms so as to produce the required amounts of the desired metabolite through genetic manipulations.

Metabolic engineering is not only widely applied in industrial fermentation for strain improvement and metabolite overproduction, but has also found many important applications in functional genomics, biological research (e.g., signal transduction),and medical research (e.g., drug discovery and gene therapy)

Ways to engineer metabolic pathways

Fundamental requirements for metabolic engineering

Different approaches of metabolic engineering: Engineering biosynthetic pathways

Transport engineering

Plant Metabolic Engineering

Lecture 10. *Theme.* ***Biochemical Engineering***

: Biochemical engineering is branch of chemical or biological engineeing mainly deals with design and construction of unit processes that involves biological organisms or molecules (bioreactor). OR Biochemical Engineering involves all the designing and engineering aspects related to production of useful products from microorganisms like pharmaceuticals, enzymes, chemicals, food technology etc. and we deal with stuff like reactor designing , process designing. OR Biochemical engineering, also known as bioprocess engineering, is a field of study with roots stemming from chemical engineering and biological engineering. It mainly deals with the design, construction, and advancement of unit processes that involve biological organisms or organic molecules and has various applications in areas of interest such as biofuels, food, pharmaceuticals, biotechnology, and water treatment processes

Biochemical engineers often specialize in certain areas, such as:

● Enzyme engineering: The production of chemicals and chemical reactions through enzymes

● Metabolic engineering: The production of metabolites through molecular genetics ● Tissue engineering: Treating disease or damaged tissue using living cells.

Lecture 11. Theme. Biomolecular engineering

Biomolecular engineering is the application of engineering principles and practices to the purposeful manipulation of molecules of biological origin.

Biomolecular engineers integrate knowledge of biological processes with the core knowledge of chemical engineering to focus on molecular level solutions to issues and problems in the life sciences related to the environment, agriculture, energy, industry, food production, biotechnology and medicine.

History of Biomolecular engineering

Future of Biomolecular engineering.

Main biomoleculs for manipulation by bioengineering - carbohydrates, proteins, nucleic acids and lipids. g

Lecture *12* Theme. ***Immobilization of enzymes and cells.***

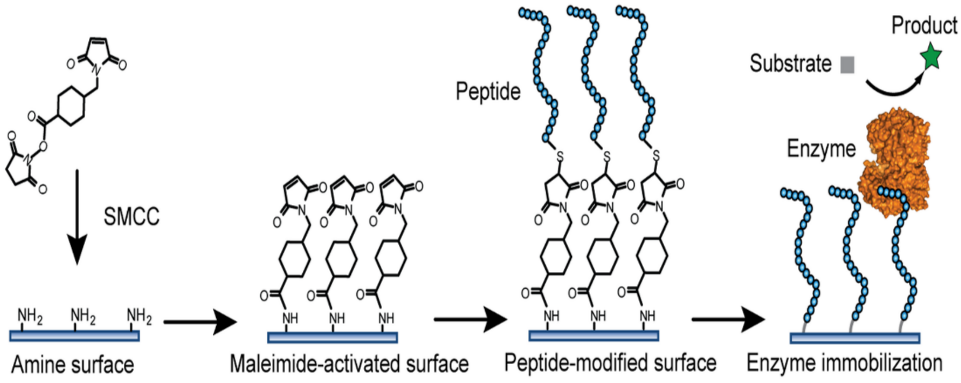
An immobilized enzyme is an enzyme, with restricted mobility, attached to an inert, insoluble material—such as calcium alginate (produced by reacting a mixture of sodium alginate solution and enzyme solution with calcium chloride).

This can provide increased resistance to changes in conditions such as pH or temperature. It also lets enzymes be held in place throughout the reaction, following which they are easily separated from the products and may be used again - a far more efficient process and so is widely used in industry for enzyme catalysed reactions. An alternative to enzyme immobilization is whole cell immobilization.Immobilized enzymes are easily to be handled, simply separated from their products, and can be reused.

Enzymes as bio-catalysts play an essential role in the enhancement of chemical reactions in cells without being persistently modified, wasted, nor resulting in the loss of equilibrium of chemical reactions. Although the characteristics of enzymes are extremely unique, their utility in the industry is limited due to the lack of re-usability, stability, and high-cost of production.

Methods for immobilization of enzymes

Enzymes can be immobilized by physical, or chemical methods.



I**mmobilized whole cell** system is an alternative to enzyme immobilization. Unlike enzyme immobilization, where the enzyme is attached to a solid support (such as calcium alginate or activated PVA or activated PEI), in immobilized whole cell systems, the target cell is immobilized. Such methods may be implemented when the enzymes required are difficult or expensive to extract, an example being intracellular enzymes. Also, if a series of enzymes are required in the reaction; whole cell immobilization may be used for convenience. This is only done on a commercial basis when the need for the product is more justified.

Multiple enzymes may be introduced into the reaction, thus eliminating the need for immobilization of multiple enzymes. Furthermore, intracellular enzymes need not be extracted prior to the reaction; they may be used directly. However, some enzymes may be used for the metabolic needs of the cell, leading to reduced yield of the cell.

Lecture 13. Biopreservatives. Properites. Need. Classification. Application. Classification chemical Engineering.

Biopreservation is the use of natural or controlled microbiota or antimicrobials as a way of preserving food and extending its shelf life.

Beneficial bacteria or the fermentation products produced by these bacteria are used in biopreservation to control spoilage and render pathogens inactive in food. It is a benign ecological approach which is gaining increasing attention.

Lactic acid bacteria (LAB) have antagonistic properties that make them particularly useful as biopreservatives. When LABs compete for nutrients, their metabolites often include active antimicrobials such as lactic acid, acetic acid, hydrogen peroxide, and peptide bacteriocins. Some LABs produce the antimicrobial nisin, which is a particularly effective preservative.

Biopreservatives - biologically derived antimicrobial substances which can be used to preserve food and extending shelf life. • It reduces the amount of chemical preservatives and intensity of heat treatments which can negatively effect the food quality

Microbial acids biopreservatives. Mechanism of biopreservatives action.

Lecture 14. *Theme.* ***Cell Engineering***

Improving production of natural cellular products

One general form of cell engineering involves altering natural cell production to achieve a more desirable yield or shorter production time. A possible method for changing natural cell production includes boosting or repressing genes that are involved in the metabolism of the product. For example, researchers were able to overexpress transporter genes in hamster ovary cells to increase monoclonal antibody yield. Another approach could involve incorporating biologically foreign genes into an existing cell line. For example, *E.Coli*, which synthesizes ethanol, can be modified using genes from *Zymomonas mobilis* to make ethanol fermentation the primary cell fermentation product.

Altering cell requirements

Another beneficial cell modification is the adjustment of substrate and growth requirements of a cell. By changing cell needs, the raw material cost, equipment expenses, and skill required to grow and maintain cell cultures can be significantly reduced.

Augmenting cells to produce new products

Closely tied with the field of biotechnology, this subject of cell engineering employs recombinant DNA methods to induce cells to construct a desired product such as a protein, antibody, or enzyme.

Adjustment of cell properties

Stem cell engineering

Lecture 15. *Theme.* ***Tissue engineering***

Tissue engineering is an emerging interdisciplinary field that applies the principles of biology and engineering to the development of viable substitutes that restore, maintain or improve the function of human tissues.

An interdisciplinary field that applies the principles of engineering and life sciences toward the development of biological substitutes that restore, maintain, or improve tissue function or a whole organ – Langer and Vacanti □ The use of a combination of cells, engineering and materials methods, and suitable biochemical and physico-chemical factors to improve or replace biological functions.

A History of Tissue Engineering

Need of Tissue Engineering

Important aspects of tissue engineering

¬Tissue engineered scaffold ¬Stem cell source ¬Bioreactor for making construct.