Basic Concept on Biotechnology

Objective Learning:

After completing this lecture, you should be able to:

1. Define biotechnology and understand the many scientific disciplines that contribute to biotechnology.
2. Provide examples of historic and current applications of biotechnology and its products.
3. List and describe different types of biotechnology and their applications.
4. Provide examples of potential advances in biotechnology.

What Is Biotechnology?

- If you have ever eaten a corn chip, you may have been affected by biotechnology. How about sour cream, yogurt, cheese, or milk?
- In this century, more and more of the foods we eat will be produced by **organisms that have been genetically altered** through biotechnology.
- Such **genetically modified (GM) foods** have become a controversial topic over the last few years, as have **human embryos** such as the one shown in the opening photo (**Figure 1**).
- **Biotechnology** is a multidisciplinary science with many powerful applications and great potential for future discoveries.

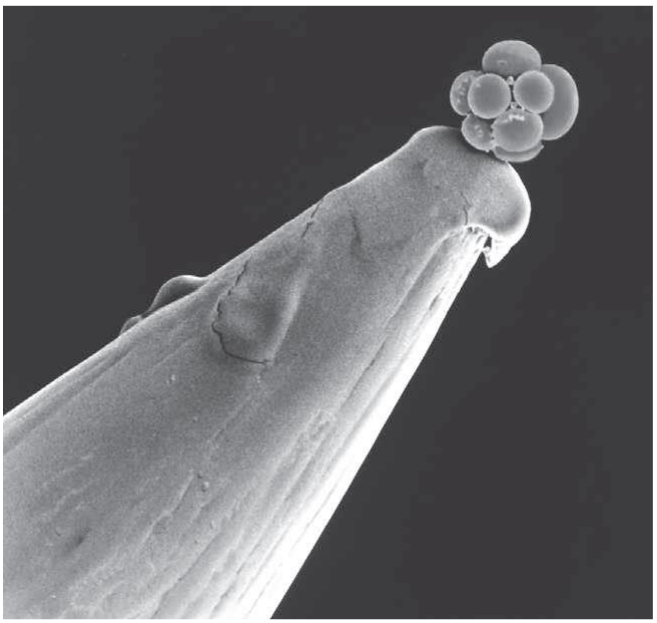


Figure 1: Miracle cells? This tiny cluster on the tip of a pin is a human embryo approximately three days after fertilization. Some scientists believe that **stem cells** contained within embryos may have the potential for **treating and curing a range of diseases** in humans through **biotechnology**. Use of these cells is also one of the most controversial topics in **biotechnology**.

Biotechnology is broadly defined as the science of using living organisms, or the products of living organisms, for human benefit (or to benefit human surroundings)—that is, to make a product or solve a problem. So, the biotechnology is a broad area of biology, involving the use of living systems and organisms to develop or make products.

- The term biotechnology was first used by **Karl Ereky** in 1919, **meaning** "the production of products from raw materials with the aid of living organisms".

A Brief History of Biotechnology

- In fact, many applications represent old practices with new methodologies.
- Humans have been using other biological organisms for their benefit in many processes for several thousand years.
- Historical accounts have shown that the **Chinese, Greeks, Romans, Babylonians, and Egyptians,** among many others, have been involved in biotechnology since about 2000 b.c.
- **Biotechnology** does not mean hunting and gathering animals and plants for food; however, the **domestication** of animals such as **sheep** and **cattle** for use as **livestock** is a **classic example of biotechnology**.

- Our early ancestors also took advantage of **microorganisms** used **fermentation** to make **breads, cheeses, yogurts, and alcoholic beverages** such as beer and wine.

- During fermentation, some strains of yeast decompose sugars to derive energy, and in the process they produce ethanol (alcohol) as a waste product.

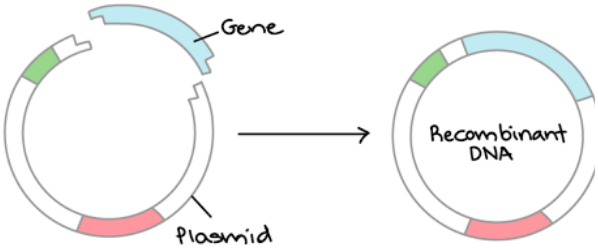
- When bread dough is being made, yeast (***Saccharomyces cerevisiae***, commonly called baker's yeast) is added to make the dough rise. This occurs because the yeast ferments sugar-releasing carbon dioxide, which causes the dough to rise and creates holes in the bread.

- For thousands of years, humans have used **selective breeding** as a **biotechnology application** to improve production of crops and livestock used for food purposes.
- In **selective breeding**, organisms with desirable features are purposely mated to produce offspring with the same desirable characteristics. For example, **crossbreeding plants** (including: Corn and cabbage) and **crossbreeding of farm animals** (including cows and chickens).
- One of the most widespread and commonly understood **applications of biotechnology** is the use of **antibiotics**.
- In 1928, **Alexander Fleming** discovered that the mold ***Penicillium*** inhibited the growth of a bacterium called ***Staphylococcus aureus***, which causes skin disease in humans. Subsequent work by Fleming led to the discovery and purification of the antibiotic penicillin.



- **Antibiotics** are substances produced by microorganisms that will inhibit the growth of other microorganisms.
- Since the 1960s, rapid development of our understanding of **genetics** and **molecular biology** has led to exciting new innovations and applications in **biotechnology.**
- **New technologies** have led to **gene cloning**, the ability to identify and reproduce a gene of interest, and genetic engineering, manipulating the DNA of an organism.
- Through **genetic engineering**, scientists are able to combine DNA from different sources. This process, called **recombinant DNA technology**, is used to produce many proteins of medical importance, including insulin, human growth hormone, and blood-clotting factors.

From its inception, **recombinant DNA technology** has dominated many important areas of **biotechnology**, and as you will soon learn, many credit **recombinant DNA technologies** with starting **modern biotechnology** applications including the development of **disease-resistant plants**, food crops that produce greater yields, **"golden rice"** engineered to be more nutritious, and **genetically engineered bacteria** capable of degrading *environmental pollutants*.



Biotechnology: A Science of Many Disciplines

- It is impossible to talk about biotechnology without considering the important contributions of the different fields of science.
- Although a major focus of biotechnology involves **molecular biology techniques**, biotechnology is not a single, narrow discipline of study.
- **Figure 2**, on the next page, provides a diagrammatic view of the many disciplines that contribute to biotechnology.
- Notice that the **"roots"** are primarily formed by work in the basic sciences—research into fundamental processes of living organisms at the biochemical, molecular, and genetic levels.

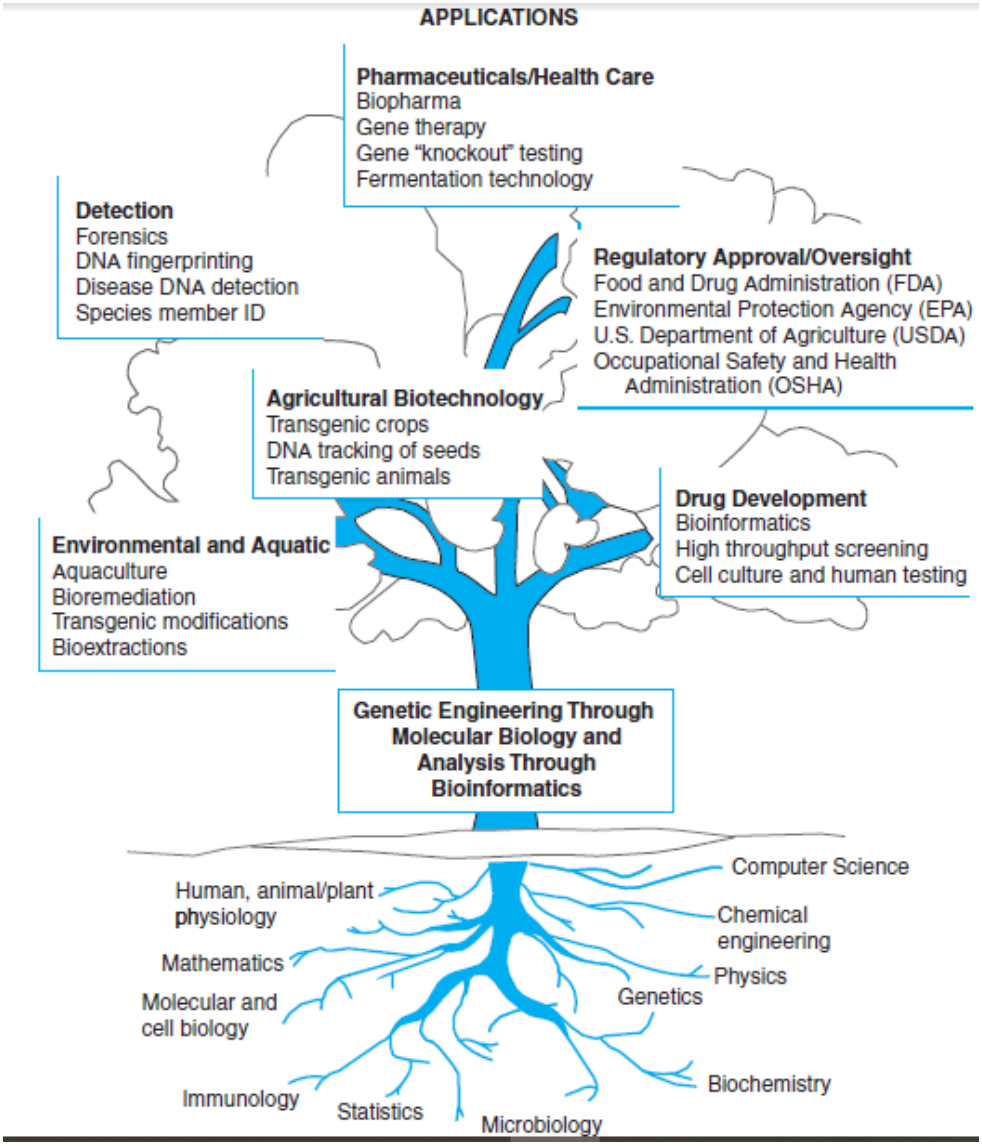


Figure 2: The Biotechnology Tree: Different Disciplines Contribute to Biotechnology The basic sciences are the foundation or **"roots"** of all aspects of biotechnology. The central focus or **"trunk"** for most biotechnological applications is genetic engineering. Branches of the tree represent different organisms, technologies, and applications that **"stem"** from **genetic engineering** and **bioinformatics**, **central aspects of most biotechnological approaches**. Regulation of biotechnology occurs through governmental agencies like the FDA, USDA, EPA, and OSHA.

Some Terms of Molecular Biological Definitions:

- ***Genomics:*** The study of the structure and function of the genome.
- ***Proteomics:*** The study of the proteome, *i.e.*, the full complement of proteins made by a cell. The term includes protein–protein and protein–small molecule interactions as well as expression profiling.
- ***Transcriptomics:*** The study of the transcriptome, *i.e.*, all the RNA molecules made by a cell, tissue or organism.
- ***Metabolomics:*** The use of genome sequence analysis to determine the capability of a cell, tissue or organism to synthesize small molecules.
- ***Bioinformatics:*** The branch of biology that deals with *in silico* processing and analysis of DNA, RNA and protein sequence data, *i.e.* The use of computer methods in studies of genomes.

- ***Lipidomics:*** is the large-scale study of pathways and networks of cellular lipids in biological systems.
- ***Cytomics:*** is the study of cell systems (cytomes) at a single cell level.
- ***Immunomics:*** is the study of immune system regulation and response to pathogens using genome-wide approaches.
- ***Epigenomics:*** is the study of the complete set of epigenetic modifications on the genetic material of a cell, known as the epigenome.
- ***Systeomics:*** it is defined as the integration of genomics, proteomics, and metabonomics.

A series of derived terms have been coined to identify several branches of biotechnology:

- Bioinformatics (also called **"gold biotechnology"**) is an interdisciplinary field that addresses biological problems using computational techniques, and makes the rapid organization as well as analysis of biological data possible.
- **Blue biotechnology** is based on the exploitation of sea resources to create products and industrial applications.
- **Green biotechnology** is biotechnology applied to agricultural processes. An example would be the selection and domestication of plants via micropropagation. transgenic plants to grow under specific environments in the presence (or absence) of chemicals.
- **Red biotechnology** is the use of biotechnology in the medical and pharmaceutical industries, and health preservation. This branch involves the production of vaccines and antibiotics, regenerative therapies, creation of artificial organs and new diagnostics of diseases. As well as the development of hormones, stem cells, antibodies, siRNA and diagnostic tests.
- **White biotechnology**, also known as industrial biotechnology, is biotechnology applied to industrial processes. An example is the designing of an organism to produce a useful chemical.
- **"Yellow biotechnology"** refers to the use of biotechnology in food production, for example in making wine, cheese, and beer by fermentation.
- **Gray biotechnology** is dedicated to environmental applications, and focused on the maintenance of biodiversity and the remotion of pollutants.
- **Brown biotechnology** is related to the management of arid lands and deserts.
- **Violet biotechnology** is related to law, ethical and philosophical issues around biotechnology.
- **Dark biotechnology** is the color associated with bioterrorism or biological weapons and biowarfare which uses microorganisms, and toxins to cause diseases and death in humans, livestock and crops.