

Introduction to Microbial Biotechnology

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Key concepts, tools, and applications

1. What Is Microbial Biotechnology?

Aspect	Description
Definition	Use of microorganisms (bacteria, archaea, fungi, algae, viruses) and their components to develop products, processes, or services that benefit society.
Scope	Medicine, agriculture, industry, environment, energy, and food.
Core Principle	Harness natural metabolic pathways or engineer new ones to produce desired compounds or perform specific functions.

2. Types of Microorganisms Employed

Group	Representative Species	Typical Uses
Bacteria	<i>Escherichia coli</i> , <i>Corynebacterium glutamicum</i> , <i>Clostridium acetobutylicum</i>	Recombinant protein production, amino acid synthesis, biofuel generation
Fungi	<i>Saccharomyces cerevisiae</i> , <i>Aspergillus niger</i> , <i>Trichoderma reesei</i>	Ethanol, organic acids, enzymes, antibiotics
Algae	<i>Chlorella</i> spp., <i>Nannochloropsis</i> spp.	Lipid production for biodiesel, nutraceuticals, CO ₂ sequestration
Archaea	<i>Halobacterium</i> spp., <i>Methanococcus</i> spp.	Extreme condition bioprocesses, methane production
Viruses (Bacteriophages)	T4, φx174	Phage therapy, bacterial detection, genetic tools

3. Fundamental Tools & Techniques

3.1 Genetic Engineering

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- **Plasmid vectors** – circular DNA carriers for gene insertion.
- **CRISPR/Cas systems** – precise genome editing, gene knock-in/out, base editing.
- **Synthetic biology parts** – promoters, ribosome-binding sites, terminators, operons, and modular DNA “toolkits”.

3.2 Metabolic Engineering

- **Pathway reconstruction** – introduce or re-wire metabolic routes to increase flux toward a target product.
- **Flux balance analysis (FBA)** – computational prediction of optimal gene modifications.
- **Adaptive laboratory evolution (ALE)** – select strains with improved traits under defined pressures.

3.3 Omics & Systems Biology

Omics	What It Measures	Typical Output
Genomics	DNA sequence	Gene catalog, mutations
Transcriptomics	mRNA levels	Gene expression profiles
Proteomics	Protein abundance & modifications	Enzyme inventories
Metabolomics	Small-molecule pools	Pathway activity snapshots

3.4 Bioprocess Engineering

- **Batch, fed-batch, continuous cultures** – control of growth phase and product formation.
- **Bioreactor design** – agitation, aeration, pH, temperature control.
- **Downstream processing** – cell removal, purification (chromatography, precipitation, membrane filtration).

4. Major Application Areas

Sector	Representative Products / Services	Example Microbial Platform
Healthcare	Recombinant vaccines, insulin, monoclonal antibodies, enzymes for diagnostics	<i>E. coli</i> (insulin), <i>Pichia pastoris</i> (vaccines)

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Sector	Representative Products / Services	Example Microbial Platform
Agriculture	Biofertilizers, biopesticides, nitrogen-fixing inoculants	<i>Azospirillum</i> spp., <i>Bacillus thuringiensis</i>
**Industrial		
Enzymes		