Biosynthesis of Microbial Metabolites

Principles of Microbial Metabolic Pathways

To successfully manipulate microorganisms for the efficient production of economically valuable substances at minimal cost, a deep understanding of their physiological and metabolic characteristics is essential. Comprehensive knowledge of microbial metabolism allows for improved productivity, better process control, and enhanced biotechnological applications.

A Metabolic Pathway is a series of chemical reactions that occur inside a living cell, where one molecule is converted step-by-step into another molecule. Each step is controlled by a specific enzyme, and the reactions work together to maintain life.

Anabolism (or an anabolic pathway) is a type of metabolic process in which small, simple molecules are built into larger, more complex molecules. These reactions require energy, usually in the form of ATP.

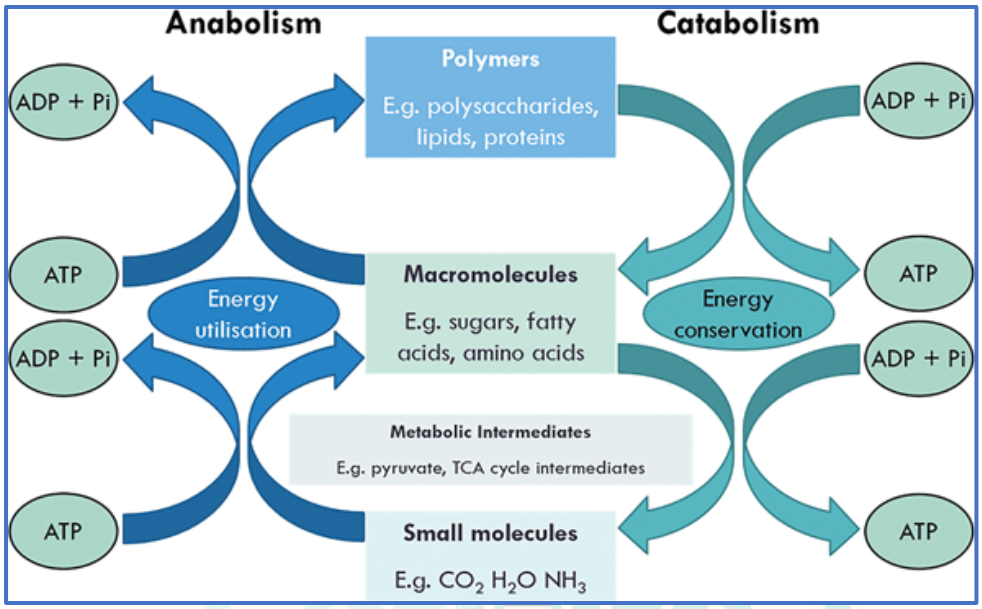
Catabolism (or a catabolic pathway) is a type of metabolism in which large, complex molecules are broken down into smaller molecules, and energy is released.

In a Metabolic Pathway, intermediates are the molecules formed between the starting molecule (substrate) and the final product during a series of reactions.

Intermediates are temporary compounds produced in the middle steps of a metabolic pathway that are then converted into other molecules in the next step.

General sequence:

Substrate → **Intermediate 1** → **Intermediate 2** → **Intermediate 3** → Final Product



Catabolic Reaction refers to chemical reactions in cells that break down large, complex molecules into smaller, simpler molecules and release energy**.**

Examples of Catabolic Reactions

1. Cellular Respiration

Glucose is broken down to produce **ATP energy**.

2. Glycolysis

Glucose → Pyruvate + energy.

3. Digestion

Food molecules are broken down:

- Proteins → Amino acids
- Fats → Fatty acids
- Carbohydrates → Simple sugars

1-Catabolic Reaction not only releases energy but also **provides carbon skeletons for biosynthesis**.

Example

In **Amino Acid** metabolism:

When the **amino group (-NH_2)** is removed from an amino acid, the remaining carbon structure is called the **carbon skeleton**.
This skeleton can then enter pathways like **Citric Acid Cycle** to produce energy or be used in **Biosynthesis**.

2-Anabolic reaction is a reaction that uses energy to form complex molecules from simpler ones.

Examples of Anabolic Reactions

1. Protein Synthesis

Joining **amino acids** to form **proteins**.

2. Photosynthesis

Plants convert **carbon dioxide and water** into **glucose** using sunlight.

3. Glycogenesis

Converting **glucose** into **glycogen** for energy storage.

Primary and Secondary Metabolites

Products of Primary Metabolism

- **Primary metabolism** refers to the interconnected set of chemical reactions that occur within a microorganism.
- It is common to all living organisms and involves both the release of energy and the synthesis of essential macromolecules such as proteins, nucleic acids, and other cellular components.
- If primary metabolism ceases, the organism cannot survive**.**

- The products of primary metabolism are closely linked to growth, and their production reaches its peak during the logarithmic (exponential) phase of a batch culture.
- Primary catabolic products include compounds such as ethanol, lactic acid**,** and butanol**,** whereas primary anabolic products include amino acids, enzymes, and nucleic acids**.**

Products of Secondary Metabolism

Secondary Metabolism

1. **Non-essential for survival:**
   - Secondary metabolism does **not have a vital function** for the organism.
   - The organism can **survive without it**, but stopping **primary metabolism** would be fatal.
2. **Timing of production:**
   - Secondary metabolites are usually produced **after nutrient limitation**, **at the end of the logarithmic phase** and during the **stationary phase** of growth.
3. **Species-specific:**
   - Only some species of plants and microorganisms produce secondary metabolites.
4. **Controlled by plasmids:**
   - The ability to make secondary metabolites can be **lost easily**, especially under stress such as **high temperature or exposure to certain dyes**.
   - This suggests that **plasmids control** secondary metabolite production.
5. **Chemical diversity:**
   - Secondary metabolites often have unusual or complex chemical structures.
   - A single organism can produce several closely related metabolites**.**
6. **Strain degeneration:**
   - Some organisms can lose the ability to produce certain secondary metabolites over time.
   - This phenomenon is called **strain degeneration**.
7. **Inducers and morphogenesis:**
   - Factors that trigger secondary metabolism (**inducers**) can also cause **morphological changes** in the organism.
   - Secondary metabolites are often **characteristic of a particular species**.

Microbial Secondary Metabolites

Microbial secondary metabolites LIKE

1.Antibiotics**, 2.**Pigment**s, 3.**Toxins**, 4.** Pheromones**, 5.**Enzyme**, 7.**Immunomodulating agents**, 8.** pesticides**, 9.**Antitumor agents **.**

Trophophase-Idiophase Relationships in the Production of Secondary Products:

Microbial growth and metabolite production are often divided into two phases:

1. Trophophase (Growth Phase)

- This is the **active growth period** of microorganisms.
- The cells are **metabolically active**, dividing rapidly, and producing **primary metabolites** (essential for growth, like amino acids, nucleic acids, and enzymes).
- The nutrients are abundant, and the **focus is on cell multiplication**, not on secondary metabolite production.

2. Idiophase (Secondary Metabolism Phase)

- This occurs **after the growth slows down**, usually in the **stationary phase**.
- Cells stop dividing actively due to **nutrient limitation or accumulation of waste products**.
- During idiophase, microorganisms start producing **secondary metabolites** like antibiotics, pigments, toxins, or other bioactive compounds.
- Secondary metabolites are **not essential for growth** but often provide ecological advantages (e.g., inhibiting competitors).

Trophophase → Idiophase Transition

Microorganisms go through different metabolic phases as they grow:

1. Trophophase (Growth Phase)

- Cells are actively dividing and consuming nutrients.
- Focus is on cell growth and multiplication.
- Primary metabolites are produced here. These include compounds essential for growth**,** such as:
  - Amino acids
  - Nucleotides
  - Enzymes
- Secondary metabolites like **antibiotics** are **not produced** during this phase.

2. Transition to Idiophase

- As nutrients become limited or waste products accumulate, growth slows down.
- This triggers the shift from trophophase to **idiophase**.
- The organism switches from growth-focused metabolism to secondary metabolism.

3. Idiophase (Secondary Metabolism Phase)

- Cells stop dividing actively (stationary phase).
- Secondary metabolites are produced, including:
  - Antibiotics
  - Pigments
  - Toxins
  - Other bioactive compounds
- These compounds often help the microorganism **compete or survive under stress**.