



الأيض (١)

Metabolism (1)

BCH 340

Lecture 1: Introduction to metabolism

Prepared by Dr. Atekah Alshammari

Course information

Course code:	BCH 340
Course title:	Metabolism (1)
Credit hours:	3(3+0)
Prerequisites	BCH 303
Class schedule:	Every Sunday – Tuesday – Thursday 11:00 to 11:50 am
Class location:	Building 5, Second floor, Class No. 2B19
Mark distribution:	First CAT (25 marks), 15/09/2024, 11:00-12:00 Second CAT (25 marks), 20/10/2024, 11:00-12:00 Activities (10 marks) Final Exam (40 marks)

CAT refers to Continuous Assessment Tests

Intended learning outcomes (ILOs)

By the end of this lecture, students will be able to:

- Define and differentiate between catabolic, anabolic, and amphibolic pathways.
- Describe the key characteristics of metabolic pathways.
- Explain the structure of ATP and understand its role as the primary energy currency in cells.

Introduction to metabolism

- Metabolism refers to the sum of all chemical reactions that occur within a living organism to sustain life.
- These processes involve the conversion of nutrients (obtained from the organism's environment) into energy and building blocks necessary for the cells.

Metabolic pathways:

- It is a series of chemical reactions that occur within a cell to regulate and control the flow of **metabolites**, which are the intermediate molecules involved in various metabolic processes.

Introduction to metabolism (cont.)

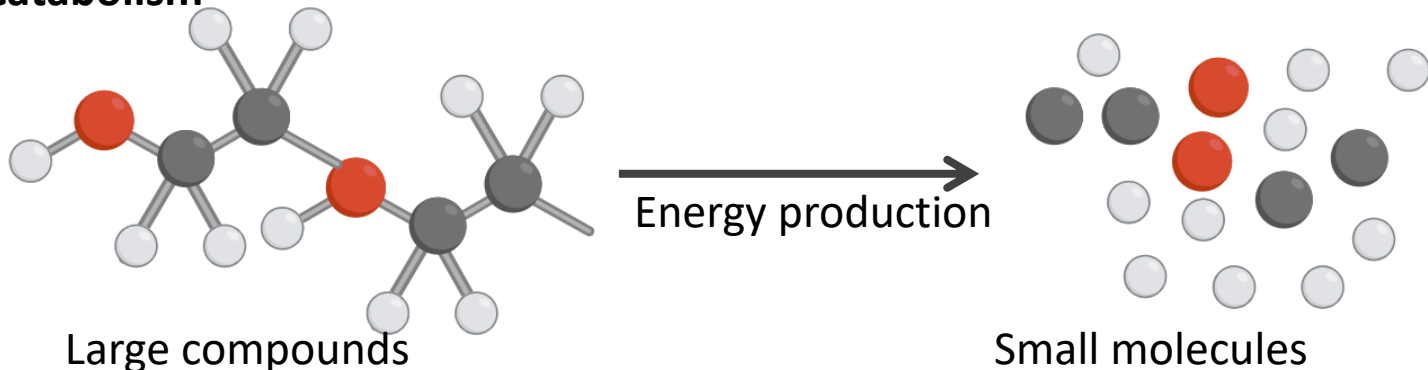
- Metabolic pathways are crucial for the synthesis, breakdown, and transformation of biomolecules that cells need for energy, growth, and maintenance of cellular functions.
- They can be broadly categorized into two main types of biochemical pathways:
 - Catabolic pathway
 - Anabolic pathway

Metabolic pathways

I. Catabolic pathways:

- A catabolic pathway is a series of biochemical reactions that involve:
 - The breakdown of complex molecules into simpler ones (i.e. it provides the building blocks necessary for the synthesis of new compounds).
 - The **release of energy** (usually in the form of ATP, which can then be used for various cellular activities).

Catabolism

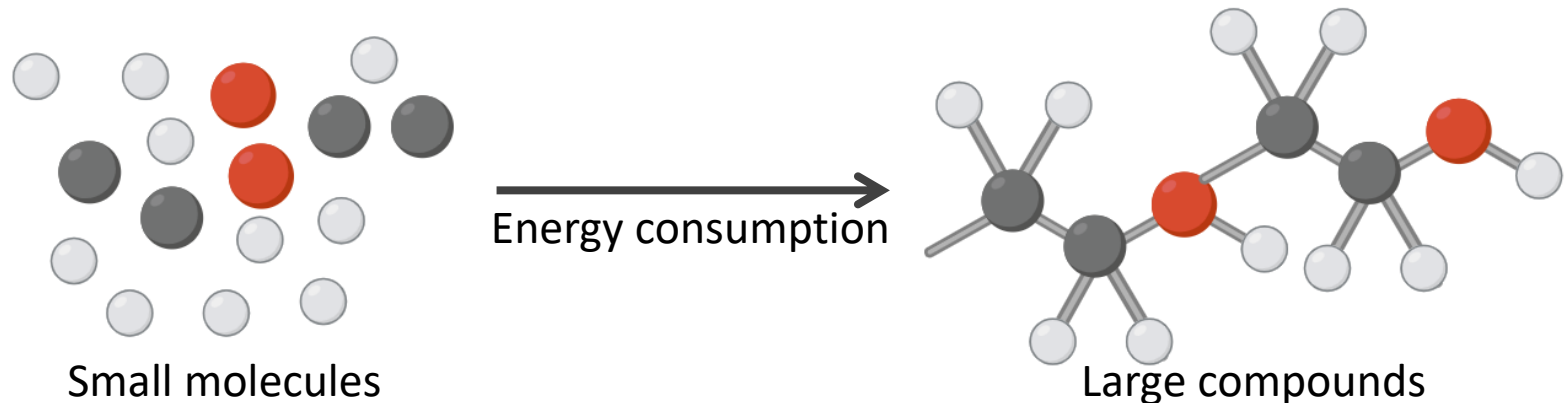


Metabolic pathways (cont.)

II. Anabolic pathways:

- Anabolic pathways are series of biochemical reactions that build complex molecules from simpler ones, requiring an **input of energy** (from ATP breakdown into ADP and Pi).
- These pathways are essential for the synthesis of biomolecules that cells need for growth, maintenance, and specialized functions.

Anabolism



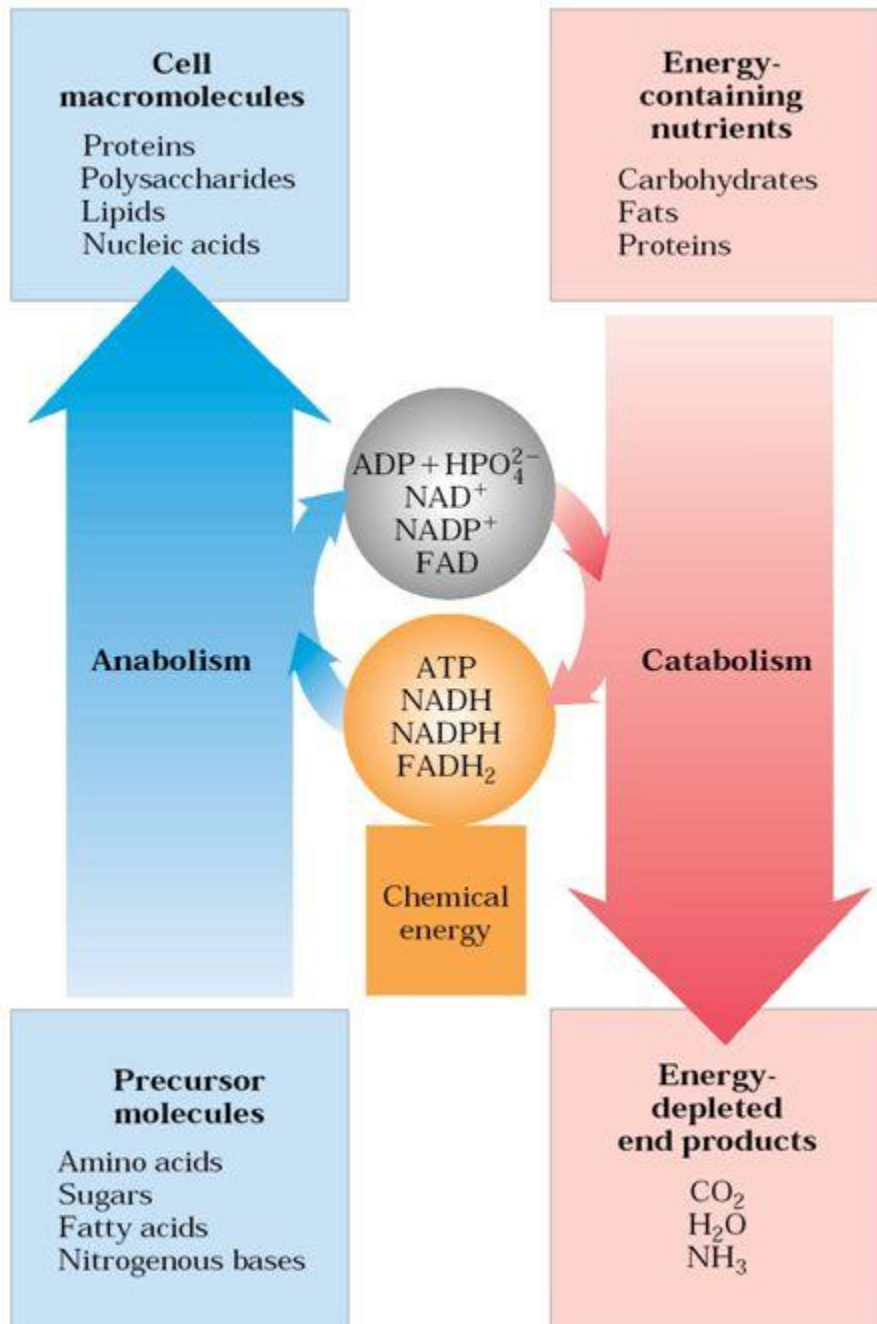
Metabolic pathways (cont.)

III. Amphibolic pathways:

- Amphibolic pathways are biochemical pathways that integrate both catabolic and anabolic processes.
- These pathways play a dual role, serving both to break down complex molecules to release energy (catabolism) and to build up complex molecules using energy (anabolism).
- Therefore, they provide flexibility and adaptability to changing cellular requirements, ensuring that the cell can respond to varying energy needs and environmental conditions.

Catabolic-anabolic balance

- Anabolic and catabolic pathways are interconnected within a cell and collectively contribute to cellular metabolism.
- The balance between anabolic and catabolic processes is crucial for maintaining cellular homeostasis.
- Cells carefully regulate these pathways to ensure that the synthesis and breakdown of molecules are coordinated and meet the cell's energy and building block requirements.



Energy relationships between catabolic and anabolic pathways.

Catabolic pathways deliver chemical energy in the form of ATP, NADH, and NADPH. These are used in anabolic pathways to convert small precursor molecules into cell macromolecules.

Characteristics of metabolic pathways

- Metabolic pathways, whether catabolic, anabolic, or amphibolic, share several common characteristics.
- These features contribute to the efficient functioning of cellular metabolism. Some of these characteristics include:

1. Specificity:

- Each metabolic pathway is specific to a particular set of reactions and substrates.
- Enzymes are highly specific as they catalyze the conversion of specific substrates into specific products.

Characteristics of metabolic pathways (cont.)

2. Interconnectedness:

- Metabolic pathways are interconnected, allowing the products of one pathway to serve as substrates for another.
- This interconnectedness enables the efficient utilization and recycling of metabolites within the cell.

3. Regulation:

- Metabolic pathways are tightly regulated to ensure that cellular processes occur in a coordinated and controlled manner.
- Regulation occurs at various levels, including enzyme activity, gene expression, and feedback mechanisms.

Characteristics of metabolic pathways (cont.)

4. Feedback Inhibition:

- Feedback inhibition is a regulatory mechanism in which the end product of a metabolic pathway acts as an inhibitor, slowing down or halting the pathway.
- This prevents the overproduction of certain molecules.

5. Compartmentalization:

- Cellular organelles, such as the mitochondria and the endoplasmic reticulum, provide distinct compartments for specific metabolic processes.
- Compartmentalization allows for the segregation of different pathways and the optimization of conditions for specific reactions.

Adenosine triphosphate (ATP)

- ATP is a molecule that serves as the primary energy currency in living cells.

ATP consists of two main components:

- **Adenosine:**

- Adenosine is a nucleoside composed of a nitrogenous base (**adenine**) and a five-carbon sugar (**ribose**).

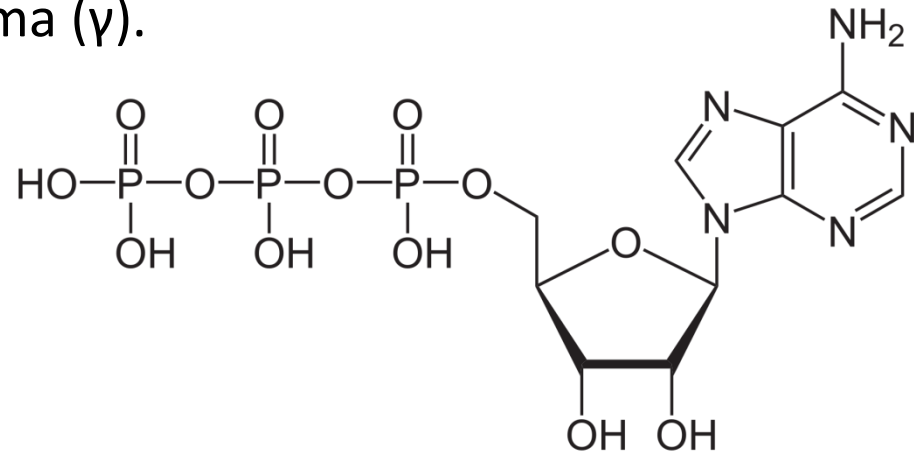
- **Triphosphate Group:**

- ATP has **three phosphate groups** attached to the ribose sugar.

These phosphate groups are crucial for the molecule's function as they store potential energy in the form of high-energy bonds.

Structure of ATP

- ATP consists of an adenine attached through its 9-nitrogen atom to the 1' carbon atom of ribose, which in turn is attached at the 5' carbon atom of the sugar to a triphosphate group.
- In its many reactions related to metabolism, the adenine and sugar groups remain unchanged, but the triphosphate is converted to di- and monophosphate, giving the derivatives ADP and AMP, respectively.
- The three phosphoryl groups are labeled as alpha (α), beta (β), and, for the terminal phosphate, gamma (γ).



Hydrolysis of ATP

- The energy stored in the high-energy bonds between the phosphate groups is released when **ATP undergoes hydrolysis**, a reaction in which water is used to break the bonds.
- This results in the formation of **Adenosine Diphosphate (ADP)** and **inorganic phosphate (Pi)**, releasing energy that can be utilized by cells.



Hydrolysis of ATP (cont.)

- The energy released during ATP hydrolysis is often used to power various cellular processes, such as:
 - **Mechanical work:** ATP is involved in muscle contraction and movement of cellular structures.
 - **Transportation:** ATP powers active transport processes across cell membranes.
 - **Biosynthetic reactions:** ATP provides energy for biosynthetic reactions, including the synthesis of macromolecules like proteins and nucleic acids.

Phosphorylation of ADP

- Phosphorylation of ADP is a process in which a phosphate group is added to ADP, converting it back into ATP.
- It commonly involves the addition of an inorganic phosphate (Pi) group.
- This process is crucial in cellular energy metabolism and occurs through various mechanisms, often in association with catabolic processes.

Phosphorylation of ADP (cont.)

Mechanisms of ADP phosphorylation:

1. Substrate-level phosphorylation:

- High-energy phosphate groups are transferred directly from substrates to ADP, resulting in the formation of ATP.
- For example, in glycolysis, the conversion of 1,3-bisphosphoglycerate to 3-phosphoglycerate leads to the direct phosphorylation of ADP.

Phosphorylation of ADP (cont.)

2. Oxidative phosphorylation:

- This occurs in the inner mitochondrial membrane during cellular respiration.
- High-energy electrons derived from the breakdown of nutrients drive proton pumping across the membrane.
- The flow of protons back through ATP synthase leads to the phosphorylation of ADP to ATP.

Phosphorylation of ADP (cont.)

3. Photophosphorylation:

- During photosynthesis (in chloroplasts), light energy is used to create a proton gradient.
- The subsequent flow of protons through ATP synthase results in the phosphorylation of ADP to ATP.

4. Nucleoside diphosphate kinases:

- Enzymes known as NDPK can transfer a phosphate group from a nucleoside triphosphate, such as GTP, to ADP, forming ATP.

Summary

- The introduction to metabolism lays the foundation for understanding the cellular processes that sustain life.
- Metabolic pathways are characterized by their specificity, interconnected nature, and finely tuned regulation to maintain cellular balance.
- Central to these processes is ATP, the energy currency of cells which holds high-energy bonds that fuel various cellular activities through controlled hydrolysis.
- This knowledge gives insights into the dynamic of metabolism, unveiling the pivotal role these pathways play in energy transfer, cellular function, and overall biological processes.