Sawa University

Biochemistry I

Introduction of Biochemistry, Metabolism (Anabolism & Catabolism), Production of Energy

Sawa University — جامعـــــة ســـــــاوة الاهلية

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Stage : 2nd — المرحلـــــــــــــة : الثانية

الجانب النظري محاضرة رقم 1

Theoretical Lecture No. 1

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Topics

- Introduction to Biochemistry.
- Metabolism (Anabolism & Catabolism).
- Production of Energy.

Introduction: What is Biochemistry?

- **Definition of Biochemistry**: Biochemistry is the study of the chemical processes and substances that occur within living organisms. It combines the principles of **chemistry** and **biology** to understand life at a molecular level.
- **Importance of Biochemistry in Medicine**: Understanding chemical processes in the body is crucial for diagnosing diseases, developing treatments, and understanding how drugs work.
- **Basic Components**:
  - **Biomolecules**: The four main classes are **proteins**, **carbohydrates**, **lipids**, and **nucleic acids**.
  - **Enzymes**: Catalysts that speed up chemical reactions in the body, essential for all biological processes.

Metabolism: The Cellular Energy

❑ Metabolism

- **Metabolism** is a biochemical process that allows an organism to live, grow, reproduce, heal, and adapt to its environment.
- A **metabolic pathway** constitutes a series of enzymatic reactions to produce specific products.
- The term **metabolite** is applied to a substrate or an intermediate or a product in the metabolic reactions.

- **Metabolism**, the sum of all the chemical transformations taking place in a cell or organism, occurs through a **series of enzyme-catalyzed reactions** that constitute metabolic pathways.

Types of metabolic reactions

- The biochemical reactions are mainly of four types:

1) **Oxidation-reduction reactions.**
2) **Group transfer reactions.**
3) **Eliminations, isomerization and rearrangement reactions.**
4) **Formation or degradation of C-C bonds**.

These reactions are catalyzed by specific enzymes—more than 2,000 are known so far.

❑ Metabolism is divided into two types:-

1. Catabolism

- **Catabolism** is the degradative phase of metabolism in which organic nutrient molecules (**carbohydrates, fats, and proteins**) are converted into **smaller**, simpler end products (such as **lactic acid, CO_2, NH_3**).
- **Catabolic pathways release energy**, some of which is conserved in the formation of **ATP** and reduced electron carriers (**NADH, NADPH, and FADH2**); the rest is lost as heat.

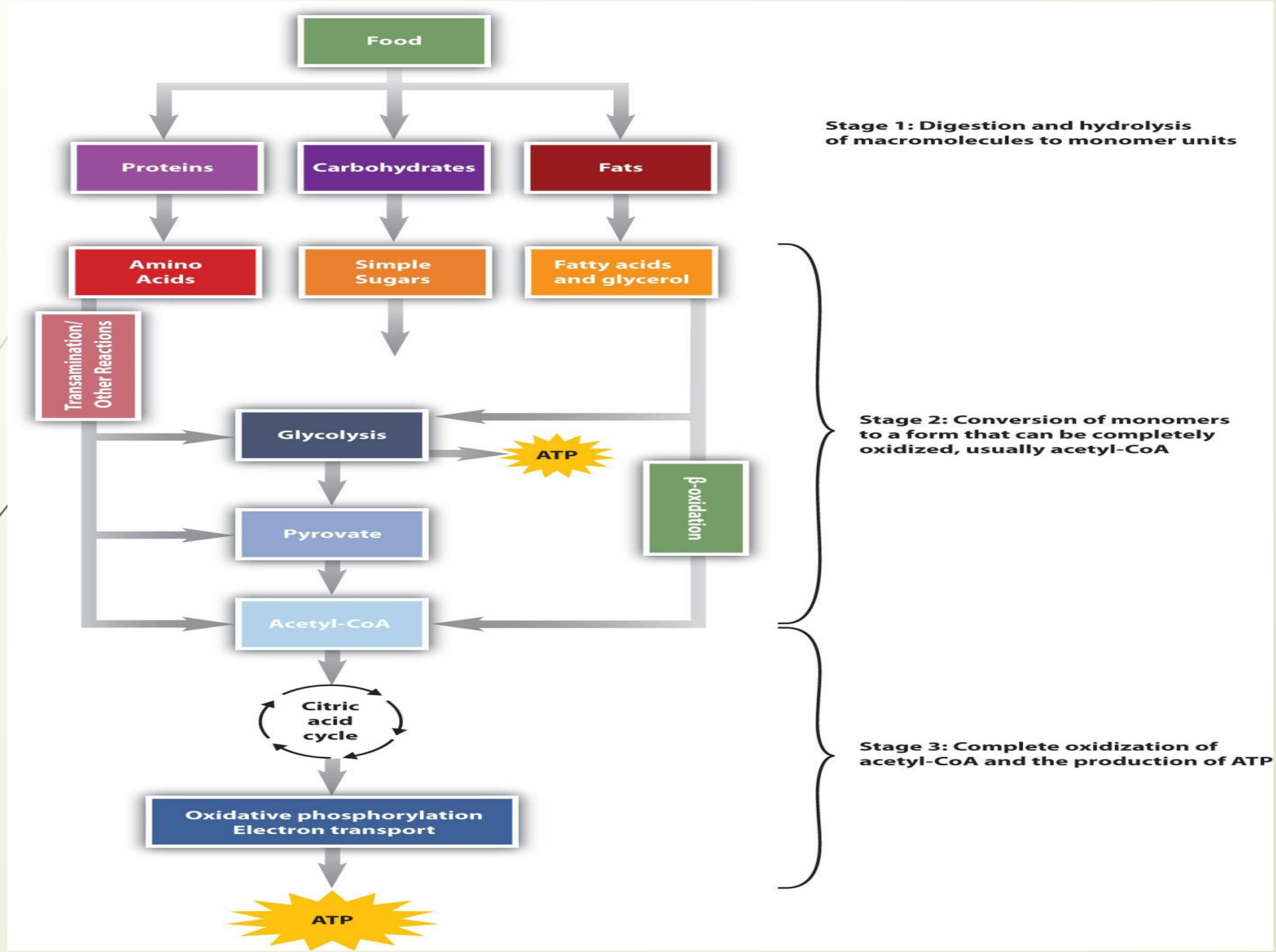
Purpose	Breaking down complex molecules into simpler ones
Energetics	Releases energy when bonds are broken *(exergonic)*
Mechanism	Typically involves oxidation reactions
Examples	Glycolysis

❖ Catabolism occurs in three stages:-

1) **Hydrolysis of complex molecules:** **In the first stage**, complex molecules are broken down into their component building blocks. For example, **proteins** are degraded to **amino acids**, **polysaccharides** to **monosaccharides**, and **fats** (**triacylglycerols**) to **free fatty acids** and **glycerol**.

2) **Conversion of building blocks to simple intermediates:** **In the second stage**, these diverse building blocks are further degraded to **acetyl co-enzyme A (CoA)** and a few other simple molecules. Some energy is captured as **ATP**, but the amount is small compared with the energy produced during the third stage of **catabolism**.

3) **Oxidation of acetyl co-enzyme A:** **The tricarboxylic acid cycle (TCA)** is the final common pathway in the oxidation of fuel molecules that produce **acetyl CoA**. Oxidation of **acetyl CoA** generates large amounts of **ATP** via **oxidative phosphorylation** as electrons flow from **NADH** and **flavin adenine dinucleotide ($FADH_2$)** to **oxygen**.


Food
Proteins
Carbohydrates
Fats
Amino Acids
Simple Sugars
Fatty acids and glycerol
Transamination/ Other Reactions
Glycolysis
ATP
β-oxidation
Pyrovate
Acetyl-CoA
Citric acid cycle
Oxidative phosphorylation Electron transport
ATP
Stage 1: Digestion and hydrolysis of macromolecules to monomer units
Stage 2: Conversion of monomers to a form that can be completely oxidized, usually acetyl-CoA
Stage 3: Complete oxidization of acetyl-CoA and the production of ATP

2. Anabolism

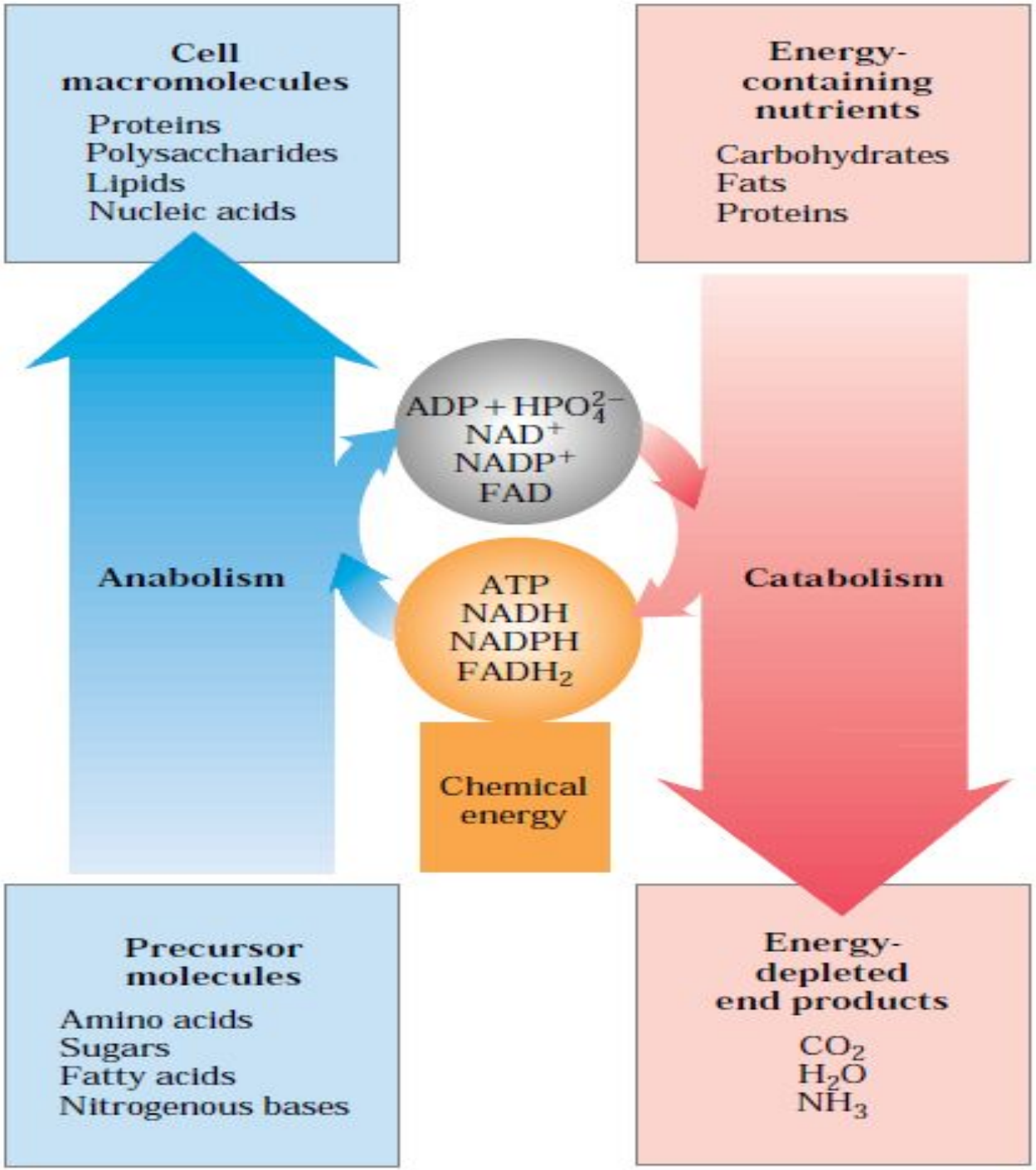
- In **anabolism**, also called **biosynthesis**, small, simple precursors are built up into larger and more complex molecules, including **lipids, polysaccharides, proteins,** and **nucleic acids**.
- **Anabolic reactions require an input of energy,** generally in the form of the **phosphoryl group** transfer potential of **ATP** and the reducing power of **NADH, NADPH,** and **$FADH_2$**.

Purpose	Synthesizing complex molecules from simpler ones
Energetics	Uses energy to construct new bonds *(endergonic)*
Mechanism	Typically involves reduction reactions
Examples	Gluconeogenesis

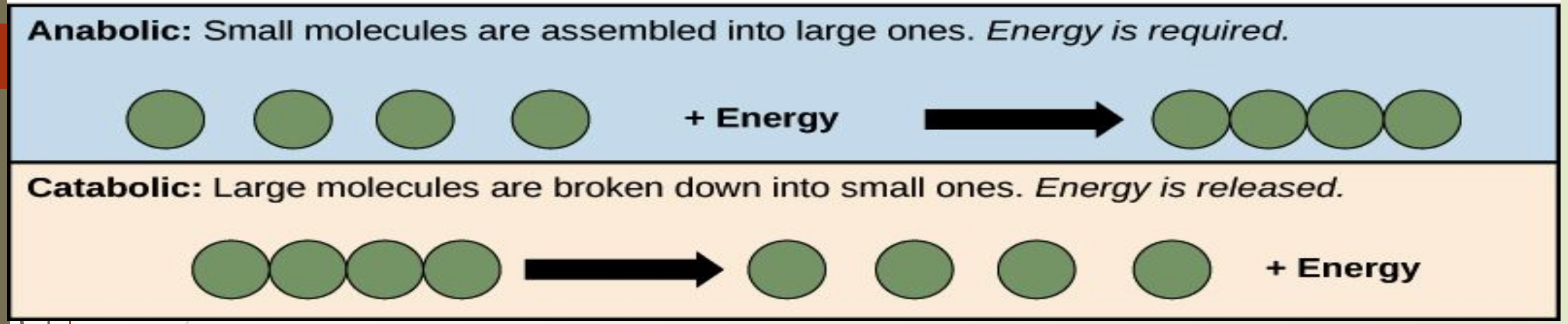
Stages of anabolism

- **There are three basic stages of anabolism :-**

1) **Production of precursors** such as **amino acids**, **monosaccharides**, and **nucleotides**.
2) **Activation of precursors**: energy from **ATP** (and other high-energy molecules) is used to convert these precursors into their **activated** or **reactive forms**.
3) **Assembly of complex macromolecules**: the activated precursors are joined together to form complex molecules such as **proteins**, **polysaccharides**, **lipids**, and **nucleic acids**.


Cell macromolecules
Proteins
Polysaccharides
Lipids
Nucleic acids
Energy-containing nutrients
Carbohydrates
Fats
Proteins
Anabolism
ADP + HPO4 2−
NAD+
NADP+
FAD
ATP
NADH
NADPH
FADH2
Catabolism
Chemical energy
Precursor molecules
Amino acids
Sugars
Fatty acids
Nitrogenous bases
Energy-depleted end products
CO2
H2O
NH3

Metabolic pathways



Examples

✔ Catabolism: Cellular respiration

- Cellular respiration is a catabolic process during which **glucose** is broken down to release usable energy for a cell.
- The overall reaction for cellular respiration is:

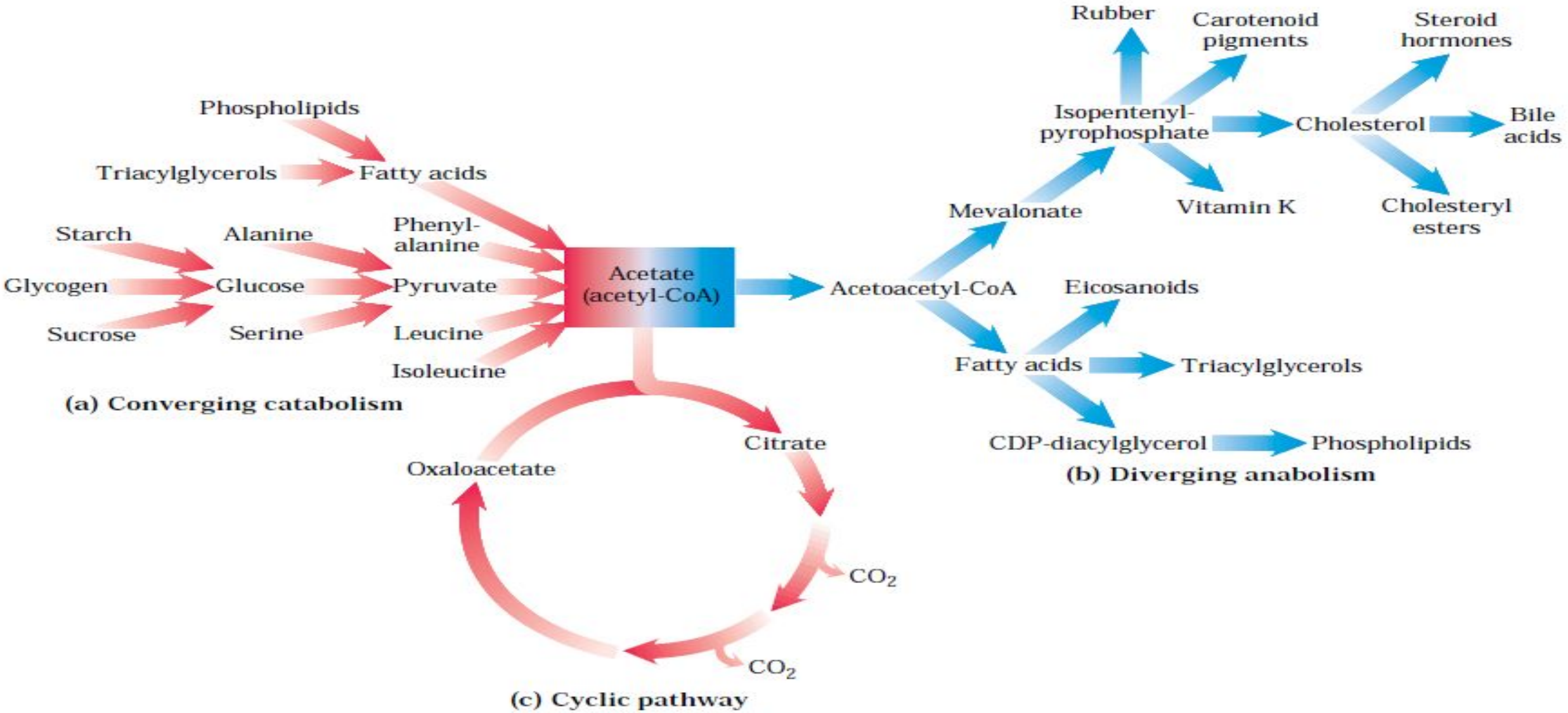
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

✔ Anabolism: Photosynthesis

- Photosynthesis is an anabolic process during which plants use energy from sunlight to convert carbon dioxide gas and water into sugar molecules.
- The overall reaction for photosynthesis is:

$$6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

- Some metabolic pathways are **linear**, and some are **branched**, yielding multiple useful end products from a single precursor or converting several starting materials into a single product.
- In general, **catabolic pathways** are convergent and **anabolic pathways** are divergent.
- Some pathways are **cyclic**: one starting component of the pathway is regenerated in a series of reactions that convert another starting component into a product.



Three types of nonlinear metabolic pathways. **(a)** Converging, catabolic; **(b)** diverging, anabolic; and **(c)** cyclic

❑ Energy Production in the Body:

- **ATP-The Energy Currency of the Cell**: **Adenosine triphosphate (ATP)** is the molecule that stores and transfers energy within cells. It releases energy when it is converted to **ADP** (**adenosine diphosphate**).
- **How ATP is Produced**:
  - **Glycolysis**: Occurs in the cytoplasm and breaks down **glucose** into **pyruvate**, generating a small amount of **ATP**.
  - **Krebs Cycle (Citric Acid Cycle)**: Occurs in the **mitochondria**, where **pyruvate** is fully broken down, releasing more energy.
  - **Electron Transport Chain (ETC)**: Also in the **mitochondria**, the **ETC** generates the majority of **ATP** through electron transfer and the creation of a proton gradient.
- **Importance of Oxygen**: Both **the Krebs cycle** and **the electron transport chain** require oxygen, making respiration essential for energy production.

❑ Clinical Applications of Metabolism and Energy Production.

- **Diabetes**: How imbalances in glucose metabolism affect blood sugar levels and lead to diabetes.
- **Obesity**: The relationship between fat storage, metabolism, and how lifestyle changes can influence metabolic rate.
- **Mitochondrial Diseases**: Disorders that affect energy production and their impact on overall health.

Questions

Q1/ Briefly discuss the relationship between an imbalance of catabolism and anabolism and the development of metabolic diseases such as obesity or diabetes.

Q2/ Briefly explain what happens if the formation of Acetyl-CoA is impaired during the second stage of catabolism.

Q3/ Explain: Why do anabolic reactions require energy, while catabolic reactions produce energy?

Any questions?