Metabolism: Anabolism and Catabolism

By
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Objectives

- Understand the concept of metabolic pathway
- Identify types & characters of metabolic pathways- anabolic and catabolic
- Identify ATP as the energy currency of cells

Metabolism

- All the chemical reactions taking place inside a cell are collectively known as METABOLISM

- Metabolism consists of:
  energy consuming (anabolic) pathways

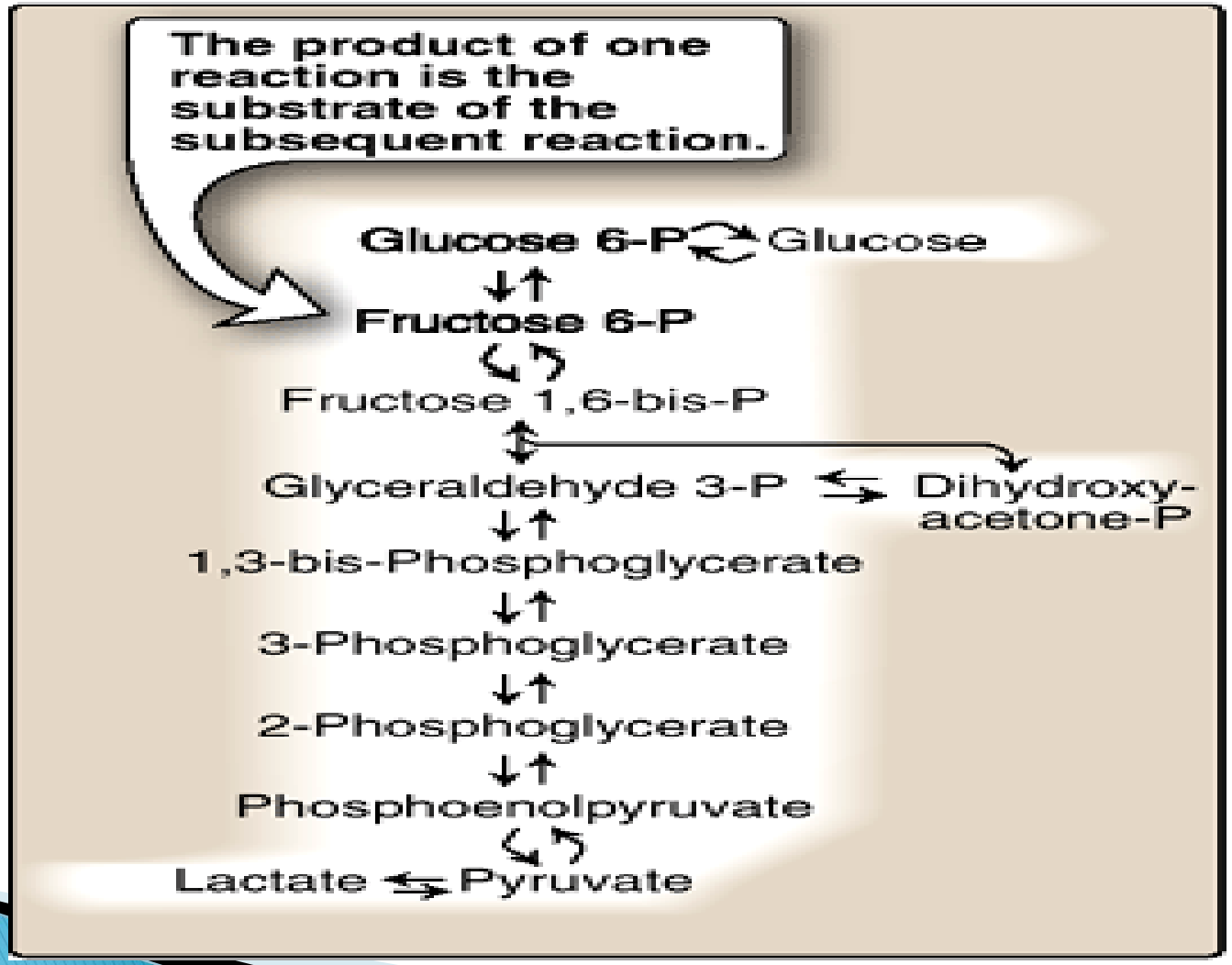
  energy producing (catabolic) pathways

Pathway Vs Chemical Reaction

Metabolic Pathway:

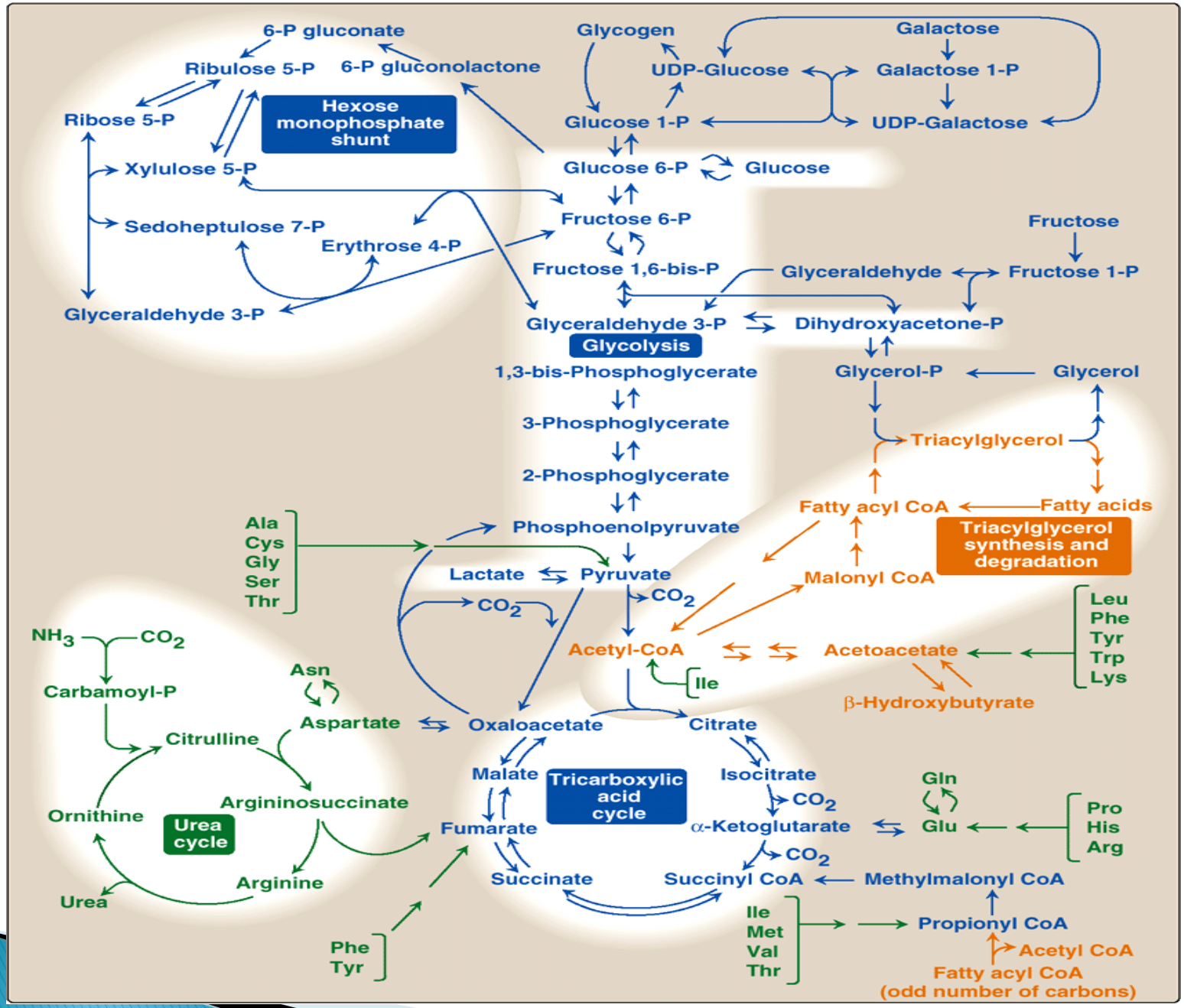
- **A multi-step sequence of chemical reactions**
- **A product of first reaction becomes a substrate for second reaction**
- **Integrated pathways: Metabolism**

Glycolysis, an example of a metabolic pathway



Metabolic Map

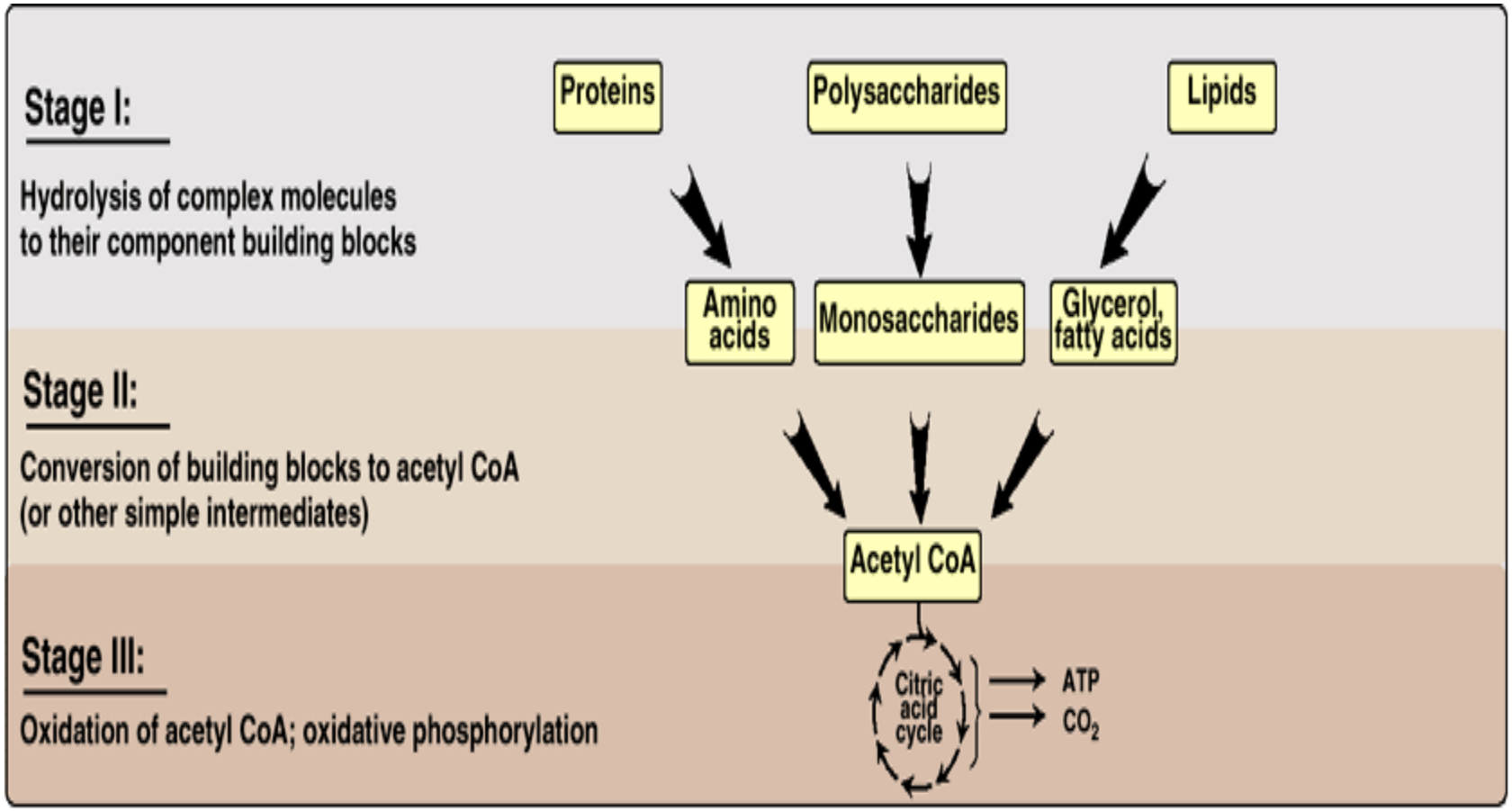
- Different pathways can intersect, forming an integrated and purposeful network of chemical reactions "The Metabolic Map"


6-P gluconate
Ribulose 5-P
6-P gluconolactone
Ribose 5-P
Hexose monophosphate shunt
Xylulose 5-P
Sedoheptulose 7-P
Erythrose 4-P
Glyceraldehyde 3-P
Glycogen
UDP-Glucose
Galactose
Galactose 1-P
UDP-Galactose
Glucose 1-P
Glucose 6-P
Glucose
Fructose 6-P
Fructose
Fructose 1-P
Fructose 1,6-bis-P
Glyceraldehyde
Glyceraldehyde 3-P
Dihydroxyacetone-P
Glycolysis
1,3-bis-Phosphoglycerate
Glycerol-P
Glycerol
3-Phosphoglycerate
Triacylglycerol
2-Phosphoglycerate
Fatty acyl CoA
Fatty acids
Triacylglycerol synthesis and degradation
Ala
Cys
Gly
Ser
Thr
Phosphoenolpyruvate
Lactate
Pyruvate
Malonyl CoA
CO_2
CO_2
Leu
Phe
Tyr
Trp
Lys
NH_3
CO_2
Acetyl-CoA
Acetoacetate
Ile
Asn
Carbamoyl-P
β-Hydroxybutyrate
Aspartate
Oxaloacetate
Citrate
Citrulline
Malate
Tricarboxylic acid cycle
Isocitrate
Gln
CO_2
Argininosuccinate
Ornithine
Urea cycle
Fumarate
α-Ketoglutarate
Glu
Pro
His
Arg
CO_2
Arginine
Urea
Succinate
Succinyl CoA
Methylmalonyl CoA
Phe
Tyr
Ile
Met
Val
Thr
Propionyl CoA
Acetyl CoA
Fatty acyl CoA
(odd number of carbons)

Classification

- Most pathways can be classified
  - catabolic
  - anabolic
- Note: Pathways that regenerate a component are called cycles

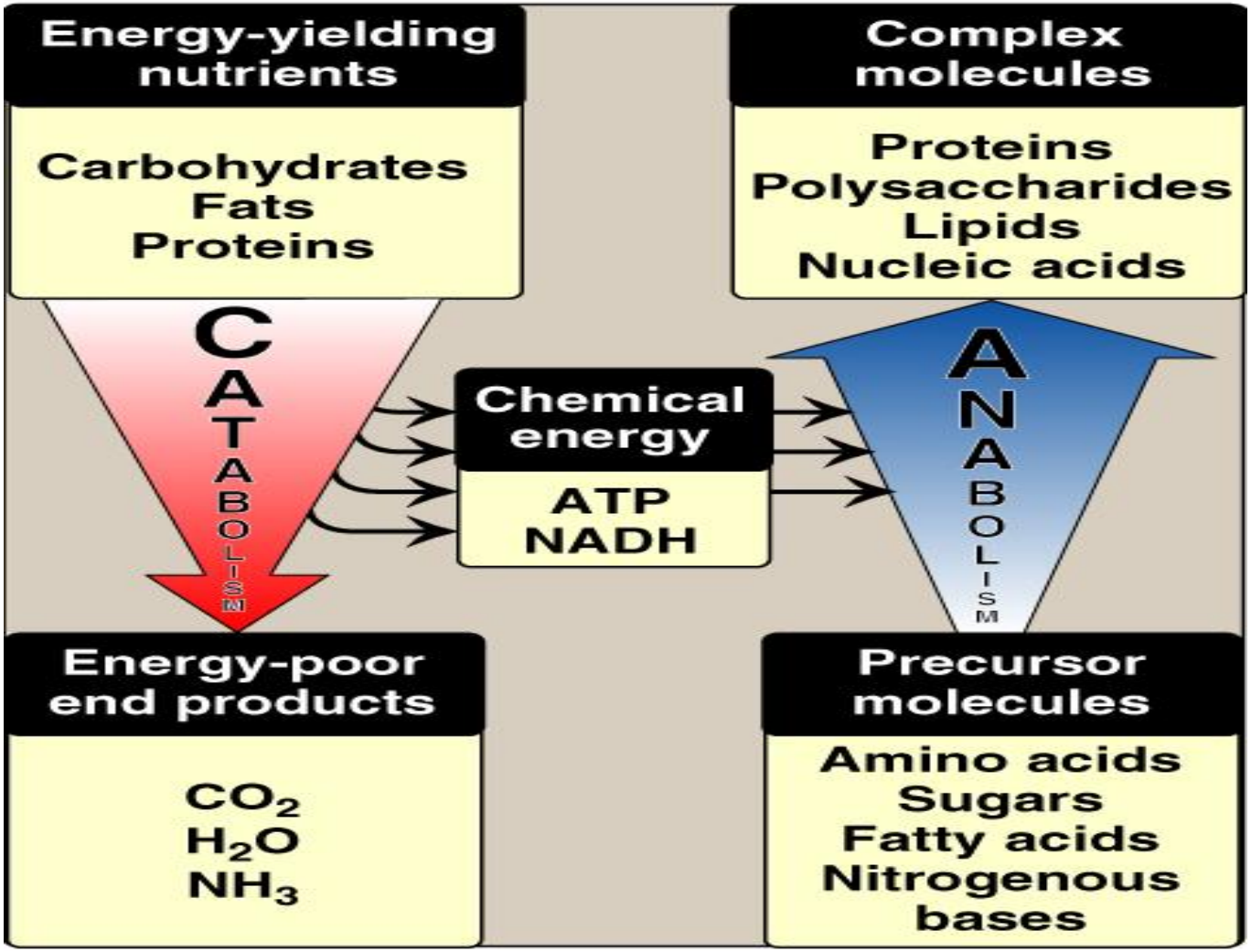
Catabolic Pathways



Anabolic Pathways

- Precursor molecules into complex molecules
- Endergonic reactions require ATP
- Divergent process

Catabolism Vs Anabolism



Comparison of catabolic and anabolic pathways

Anabolic	Catabolic
Simple to complex molecules	Complex to simple molecules
Endergonic	Exergonic
Involves reductions	Involves oxidations
Requires NADPH	Requires NAD^+
Divergent process	Convergent process

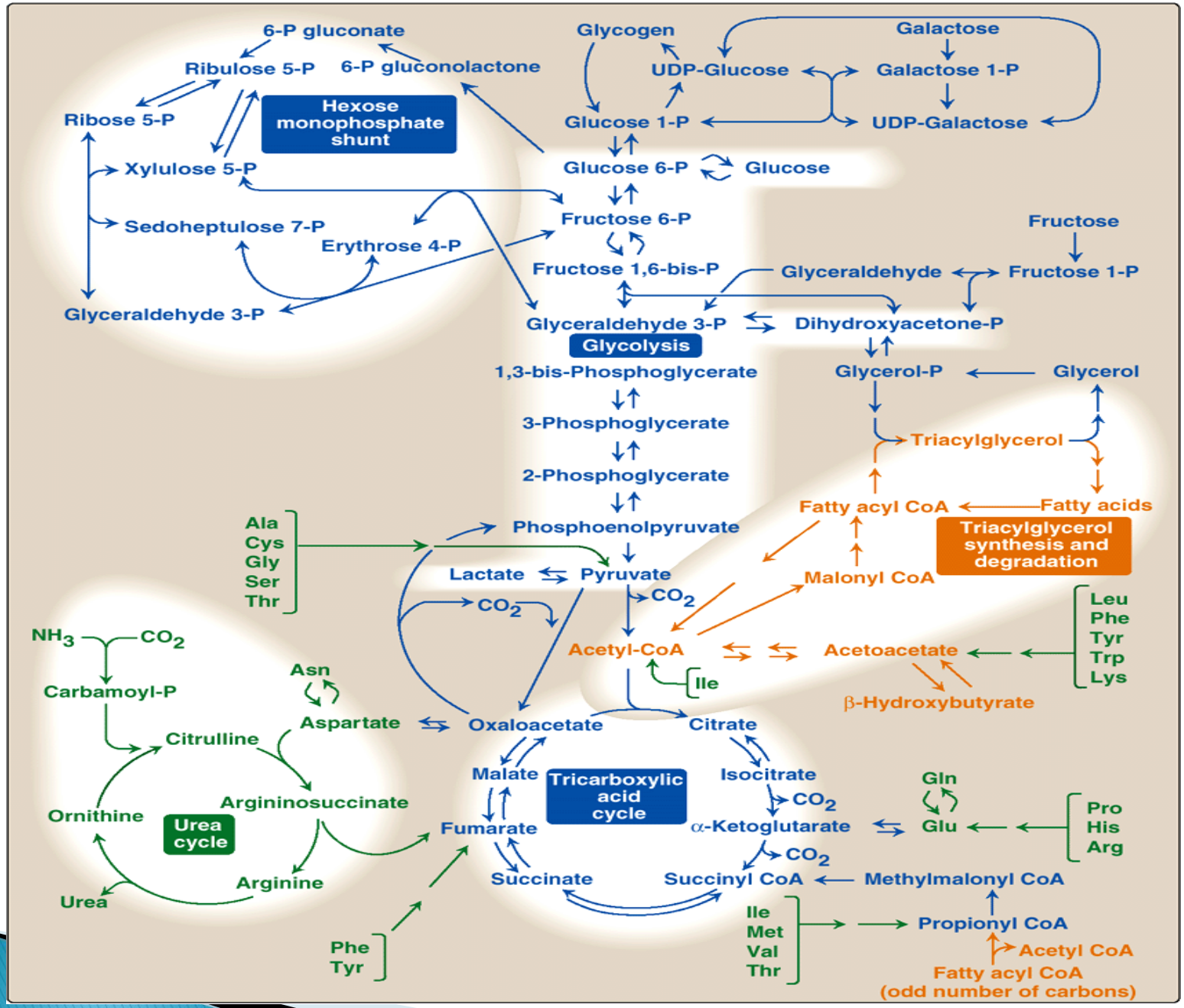
Amphibolic Pathways

- Amphi = Dual, amphibolic: dual pathway

- For example,
  Krebs cycle is mainly a catabolic cycle, but with some anabolic features,

  e.g., part of Krebs cycle is used for the synthesis of glucose from amino acids

  Therefore, Krebs cycle is amphibolic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Fructose
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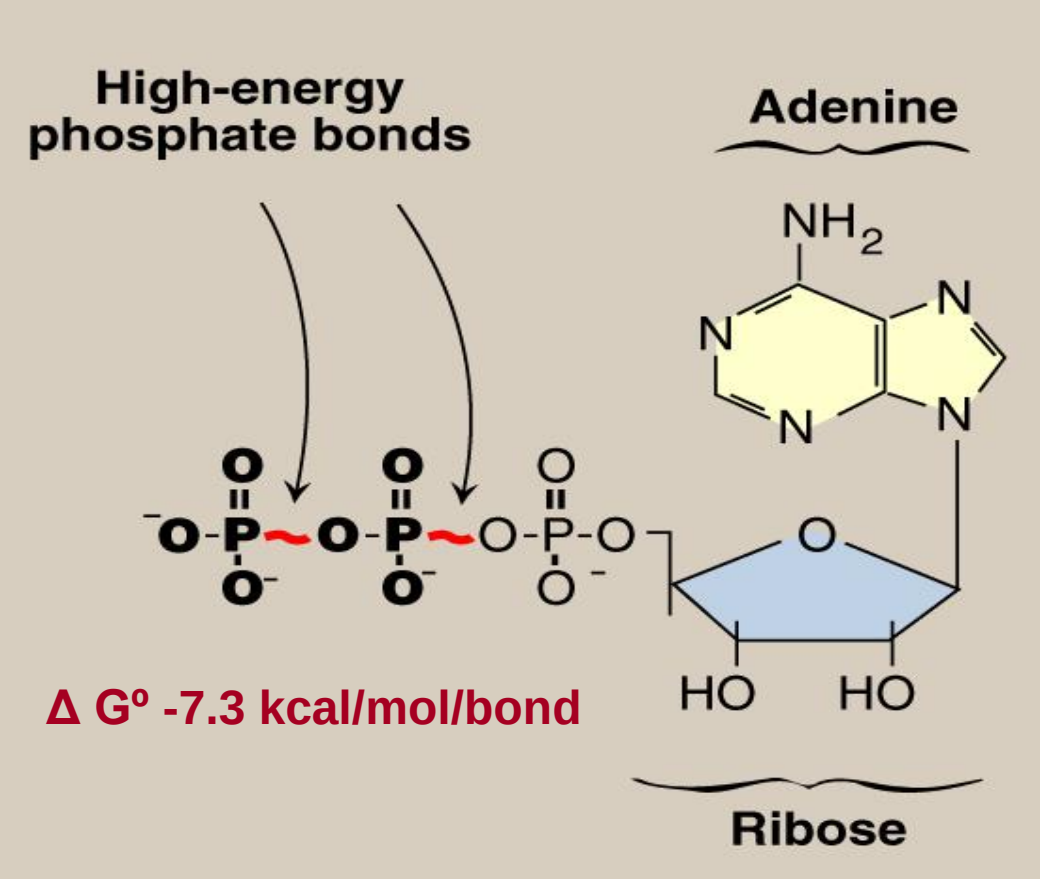
Fructose 1,6-bis-P
Glyceraldehyde
Glyceraldehyde 3-P
Dihydroxyacetone-P
Glycolysis
1,3-bis-Phosphoglycerate
Glycerol-P
Glycerol
3-Phosphoglycerate
Triacylglycerol
2-Phosphoglycerate
Fatty acyl CoA
Fatty acids
Triacylglycerol synthesis and degradation
Ala
Cys
Gly
Ser
Thr
Phosphoenolpyruvate
Lactate
Pyruvate
Malonyl CoA
CO_2
CO_2
Leu
Phe
Tyr
Trp
Lys
NH_3
CO_2
Acetyl-CoA
Acetoacetate
Ile
Asn
Carbamoyl-P
β-Hydroxybutyrate
Aspartate
Oxaloacetate
Citrate
Citrulline
Malate
Tricarboxylic acid cycle
Isocitrate
Gln
CO_2
Argininosuccinate
Ornithine
Urea cycle
Fumarate
α-Ketoglutarate
Glu
Pro
His
Arg
CO_2
Arginine
Urea
Succinate
Succinyl CoA
Methylmalonyl CoA
Phe
Tyr
Ile
Met
Val
Thr
Propionyl CoA
Acetyl CoA
Fatty acyl CoA
(odd number of carbons)

Energy Currency: ATP

$$ATP + H_2O \longrightarrow ADP + P_i$$

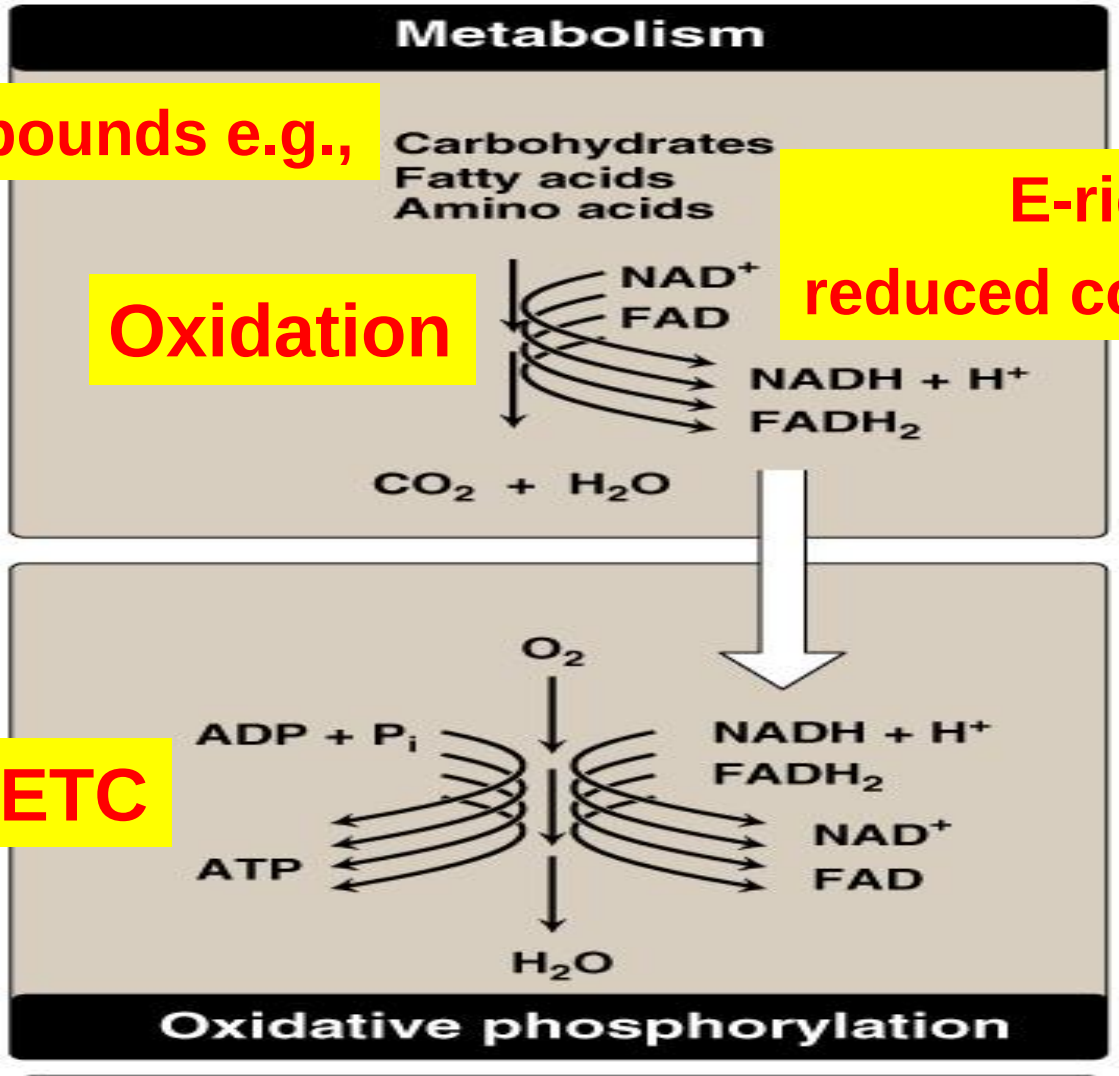
- **The free energy liberated in the hydrolysis of ATP is used to drive the endergonic reactions**
- **ATP is formed from ADP and P_i when fuel molecules are oxidized**
- **This ATP-ADP cycle is the fundamental mode of energy exchange in biological systems**

Adenosine Triphosphate (ATP)



Oxidation-Reduction in Metabolism

E-rich compounds e.g.,



Oxidation

E-rich reduced coenzymes

ETC

Oxidation/Reduction

Oxidation:

Loss of hydrogen

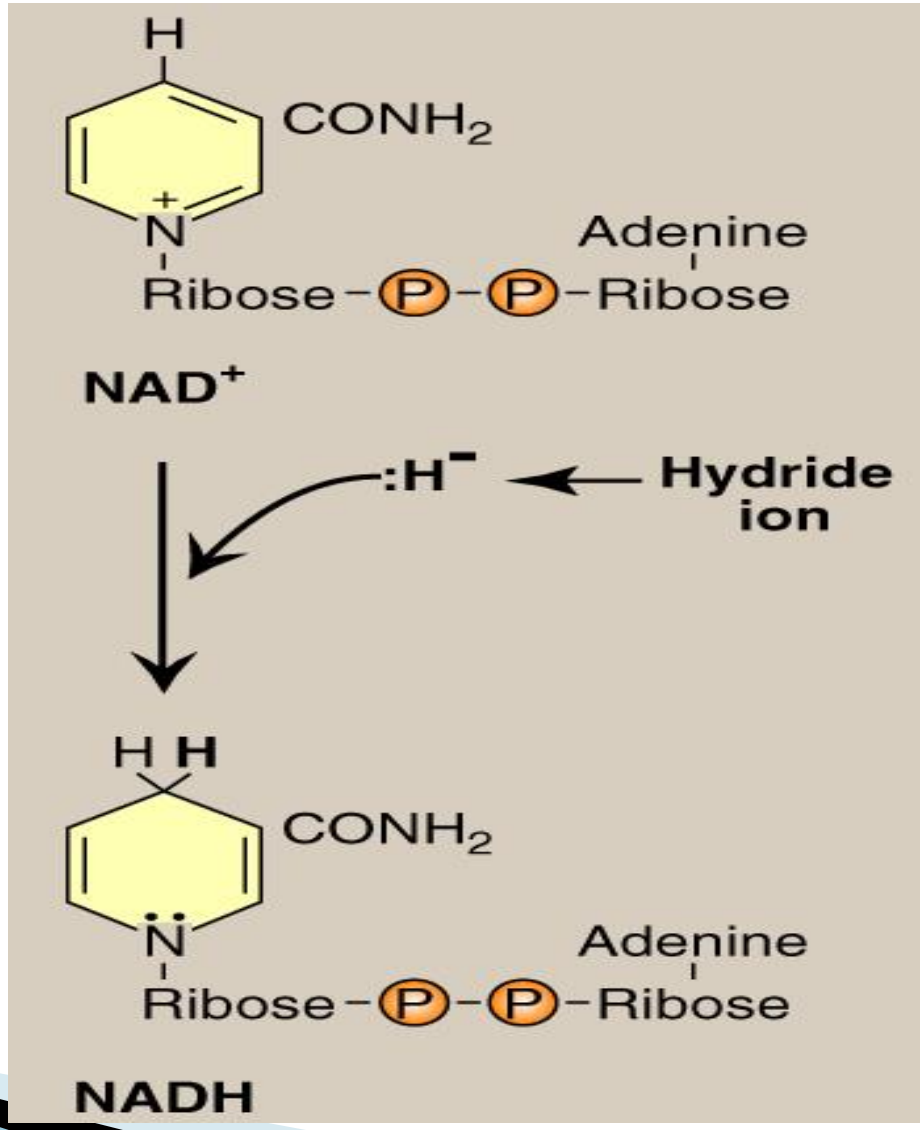
Loss of electrons

Reduction:

Gain of hydrogen

Gain of electrons

NAD^+/ NADH


H
CONH2
+
N
Adenine
Ribose – P – P – Ribose
NAD+
:H−
Hydride ion
H H
CONH2
N
Adenine
Ribose – P – P – Ribose
NADH

Regulation of Metabolism

Intracellular signals:

- **Substrate availability**
- **Product inhibition**
- **Allosteric activators**

Intercellular communications:

- **Chemical signaling (hormones):**
  - **Second messenger**
    - **cAMP, cGMP**
    - **Ca/phosphatidylinositol**

Metabolic Fuel

- Carbohydrates & lipids (mainly) and proteins (little extent) are used for energy production
- These are– glucose, fatty acids and amino acids
- Glucose is the major metabolic fuel of most tissues

Take Home Message-1

- Metabolism is the sum of all biochemical pathways that occur inside the cells.
- A metabolic pathway is a multistep sequences of enzyme-catalyzed reactions.

Take Home Message-2

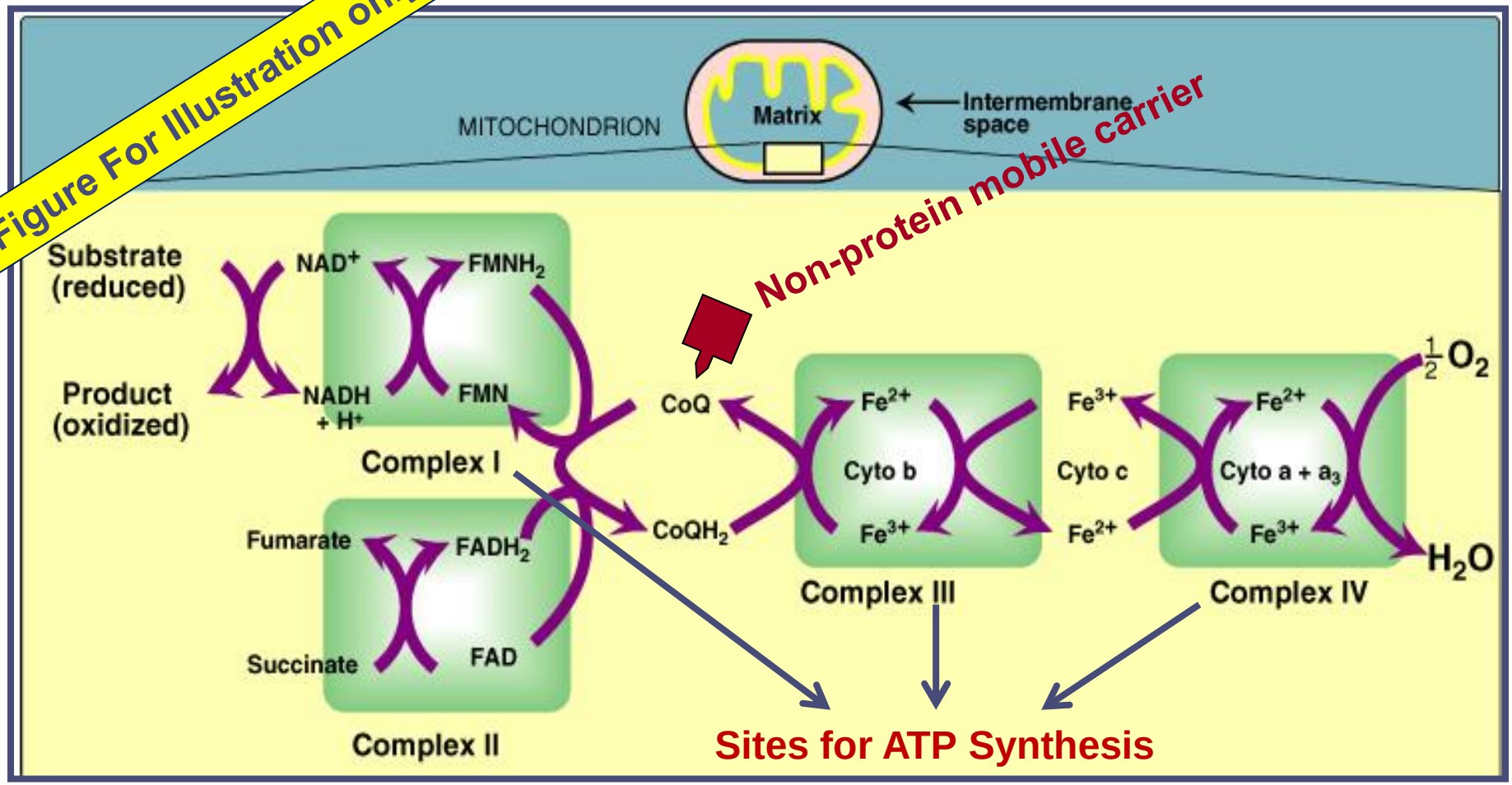
- Catabolism is a convergent process that provides energy to cells in the form of ATP.
- Anabolism is a divergent process that consumes energy for the synthesis of complex molecules.
- Metabolic pathways are tightly regulated and highly integrated.

Take Home Message-3

- ATP is the energy currency of the cells

Electron Transport Chain (ETC)

Figure For Illustration only



Electron transport and ATP synthesis are tightly coupled processes