Metabolic Energy
**Metabolic Energy**

**Anabolic Versus Catabolic Processes**

- **Nutrients and products of catabolism**
  - Requires reducing agents and energy
  - Energy-requiring
  - Products of anabolism include proteins, nucleic acids, fats, and carbohydrates
  - Excretion
  - To catabolism

- **Anabolism**
  - Reductive

- **Catabolism**
  - Oxidative
  - Energy-releasing
  - Fats
  - Polysaccharides
  - Proteins
  - Smaller molecules
  - Excretion
  - To anabolism
  - To synthesis of amino acids
Metabolic Energy

Macromolecules (DNA/RNA/Proteins/Fats/-) → Building blocks

Anabolism (Reductive, requires energy)

ADP + P → ATP

Catabolism (Oxidative, releases energy)

Nutrients (From Food) → Catabolic Products
Metabolic Energy

Photosynthesis

Sunlight
ATP, NADPH
Light
Dark
Glucose

CO₂
NADH, ATP

Anabolism
DNA/RNA, Carbohydrates, Proteins, Fats

Catabolism
Metabolic Energy

For \( aA \rightleftharpoons bB \)

\[
\Delta G = \Delta G^\circ' + RT \ln \left( \frac{[B]^b}{[A]^a} \right)
\]

For \( aA + cC \rightleftharpoons bB + dD \)

\[
\Delta G = \Delta G^\circ' + RT \ln \left\{ \frac{([B]^b[D]^d)}{([A]^a[C]^c)} \right\}
\]

\[
\Delta G = \Delta G^\circ' + RT \ln \left( \frac{\{\text{Products}\}}{\{\text{Reactants}\}} \right)
\]
For A <=> B

if ΔG is negative, A→B is favored
if ΔG is positive, B→A is favored
if ΔG is 0, B→A and A→B are equally favored
At ΔG = 0, the system is at equilibrium
Muscle Energy
Creatine Kinase

Creatine + ATP ⇌ Creatine Phosphate + ADP

$\Delta G^0' = +12 \text{ kJ/mol}$
Metabolic Energy
Metabolic Energy

Free energies of oxidation in KJ/mol

\[ \begin{align*}
-196 & \quad \text{Most Reduced} \\
\text{H} & \quad \text{H} \\
\text{C} & \quad \text{C} \\
\text{H} & \quad \text{H} \\
\text{OH} & \quad \text{O} \\
-168 & \quad \text{O} \\
\text{O} & \quad \text{O} \\
-125 & \quad \text{O} \\
\text{C} & \quad \text{C} \\
-68 & \quad \text{C} \\
0 & \quad \text{C} \\
\end{align*} \]
Metabolic Energy
Nicotinamide Adenine Dinucleotide

Metabolic Energy

NADH (reduced)

NAD+ (oxidized)
Metabolic Energy

Coupled Reactions

Glucose + Pi $\leftrightarrow$ Glucose-6-Phosphate $\Delta G^\circ' = +14$ kJ/mol

Glucose + ATP $\leftrightarrow$ Glucose-6-Phosphate $\Delta G^\circ' = -16.5$ kJ/mol
Metabolic Pathways

- Glycogen
  - Glycogen$_{n-1}$
    - Glycogen Phosphorylase
  - Glucose-1-Phosphate
    - Phosphoglucomutase
  - Glucose-6-Phosphate
    - Glycolysis
    - Pyruvate
      - Fermentation
        - Lactate
        - Citric Acid Cycle
          - CO$_2$ + H$_2$O
      - Gluconeogenesis
        - Acetyl CoA
        - Glucose
          - Blood
    - Pentose Phosphate Pathway
      - Ribose + NADPH
      - Glucose-6-Phosphatase
Metabolic Pathways

- Glucose:
  - 2 ATP
  - 4 ATP
  - 2 NAD^+
  - 2 NADH

- 2 Pyruvate

- Aerobic Oxidation
- Anaerobic Fermentation (Yeast/Bacteria):
  - 2 NADH
  - 2 NAD^+
  - 2 CO₂ + 2 Ethanol

- Anaerobic Fermentation (Animals):
  - 2 NADH
  - 2 NAD^+
  - 2 Lactate

- Citric Acid Cycle

- Oxidative Phosphorylation:
  - 2 NADH + 6 O₂ + 30-38 ADP
  - 2 NAD^+ + 30-38 ATP
  - 6 CO₂ + 6 H₂O
ΔG°’ Values of Hydrolysis (kJ/mol)

- PEP = -61.9
- 1,3BPG = -49.4
- Creatine Phosphate = -43.1
- ATP to ADP = -30.5
- G1P = -20.9
- Pyrophosphate = -19.3