RESPIRATION AND FERMENTATION

Objectives

1. List the stages of cellular respiration.
2. Describe the main steps in glycolysis and the Krebs cycle.
3. Describe the electron transport chain and chemiosmosis and how poisons disrupt them.
4. Contrast fermentation and respiration.

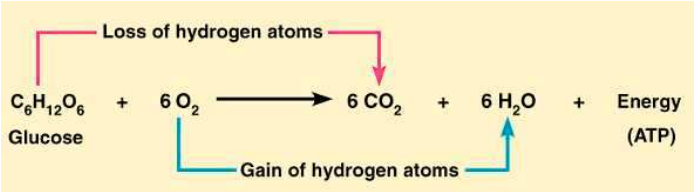
Outline

A. Cellular Respiration
   1. Glycolysis
   2. Production of Acetyl~CoA
   3. Krebs Cycle
   4. Electron Transport System
      a. Chemiosmosis

B. Fermentation

A. Cellular Respiration

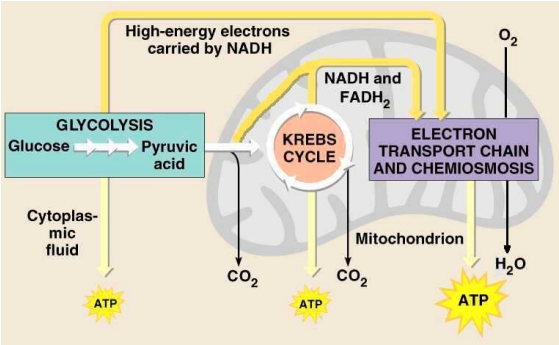
- Catabolism of organic molecules
  - Oxidation of glucose to CO_2



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

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

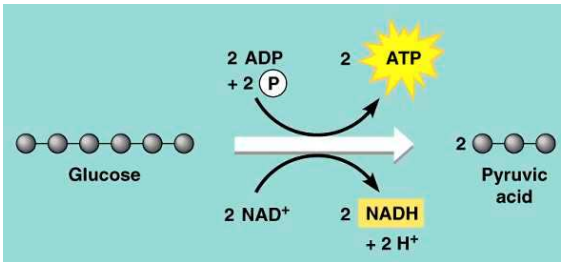
- Stages
  - Glycolysis
  - Production of Acetyl~CoA
  - Krebs Cycle
  - Electron Transport Chain



1. Glycolysis

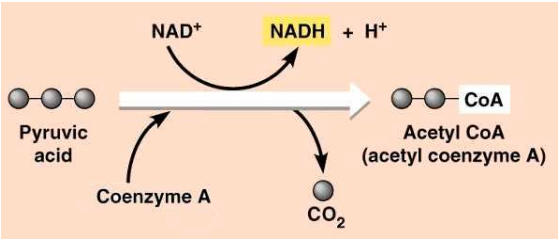
- In cytoplasm
- Oxidation of glucose to pyruvic acid

glucose + 2 NAD^+ + 2 (ADP + Ⓟ) $\rightarrow \rightarrow \rightarrow$
2 pyruvic acid + 2 NADH + 2 ATP



- Glucose destabilized by adding Ⓟ
    - Broken into two G3P
        - glyceraldehyde-3-phosphate
- Net 2 ATP made via SLP
- High energy e^- reduce 2 NAD^+
- Pyruvic acid is left

2. Production of Acetyl~CoA



- In matrix of mitochondria
- Oxidation of pyruvic acid to acetyl~CoA

(2 pyruvic acid + 2 CoA) + 2 NAD^+ $\rightarrow$
(2 acetyl~CoA + 2 CO_2) + 2 NADH

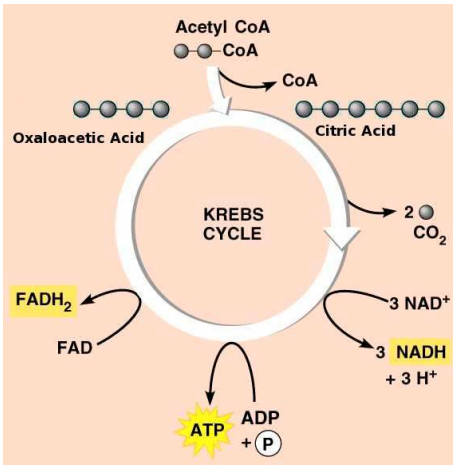
- Occurs 2x per glucose molecule

3. Krebs Cycle

- Circular series of reactions

- In matrix of mitochondria

- Oxidation of acetyl~CoA to CO_2



- Entering step

(2 acetyl~CoA + 2 oxaloacetic acid) →
(2 citric acid + 2 CoA)

- Occurs 2x per glucose molecule

- Oxidize citric acid to oxaloacetic acid

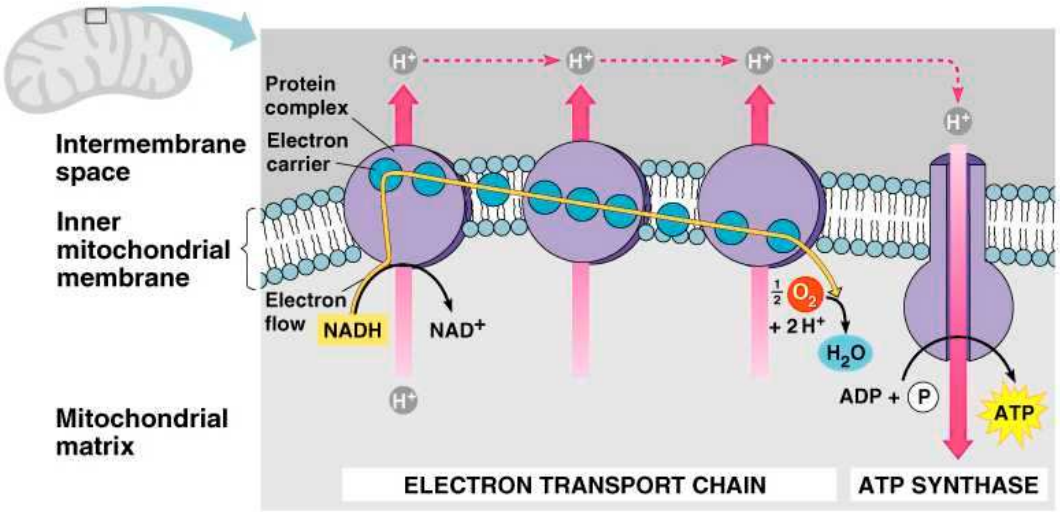
2 citric acid + $6\ NAD^+$ + $2\ FAD$ + $2\ (ADP + Ⓟ) \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow$
(2 oxaloacetic acid + $4\ CO_2$) + $6\ NADH$ + $2\ FADH_2$ + $2\ ATP$

  - two C, eight e^- are stripped
    - C excreted as CO_2
    - high energy e^- reduce NAD^+
    - lower energy e^- reduce FAD
  - 2 ATP made via SLP

- Oxaloacetic acid (OAA) is left
  - Restarts cycle

4. Electron Transport Chain (ETC)

- In cristae in mitochondria



- Oxidation of NADH and $FADH_2$

- Reduction of O_2 to H_2O

$10\ NADH + 2\ FADH_2 + 6\ O_2 + 34\ (ADP + Ⓟ) \rightarrow \rightarrow \rightarrow$
$10\ NAD^+ + 2\ FAD + 12\ H_2O + 34\ ATP$

- High-energy e^- produce $[H^+]$ gradient

    - Passed to e^- carriers in membrane

    - As e^- passed, H^+ are pumped out
        - e^- from NADH pump 3 pairs of H^+
        - e^- from $FADH_2$ pump 2 pairs of H^+

- Oxygen is final electron acceptor

    - Water is waste product

- Vulnerable to poisons that bind carriers

a. Chemiosmosis

- ATP made via chemiosmosis

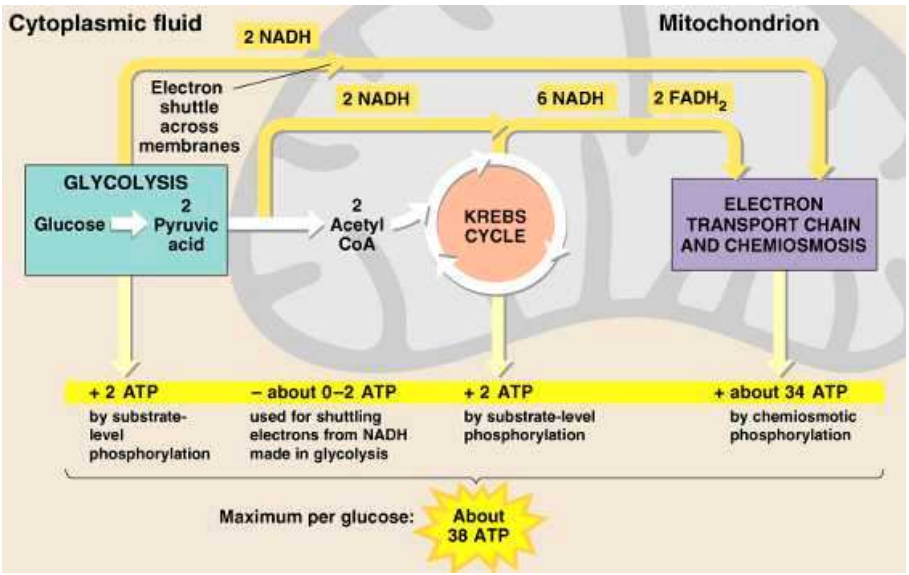
    - Oxidative phosphorylation

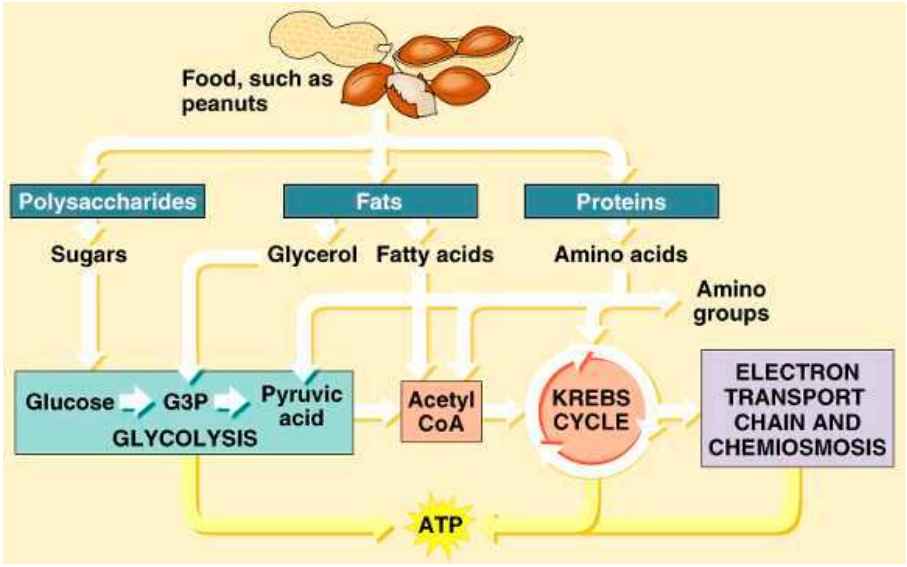
    - Diffusion of 2 H^+ makes 1 ATP

$68\ H^+ \rightarrow 34\ ATP$

- Some poisons block ATP Synthase

- Uncouplers leak H^+ through membrane
    - Not through ATP synthase
    - Produces heat, not ATP
    - Naturally occurs in brown fat


Cytoplasmic fluid
Mitochondrion
2 NADH
Electron shuttle across membranes
2 NADH
6 NADH
2 FADH2
GLYCOLYSIS
Glucose
2 Pyruvic acid
2 Acetyl CoA
KREBS CYCLE
ELECTRON TRANSPORT CHAIN AND CHEMIOSMOSIS
+ 2 ATP
by substrate-level phosphorylation
– about 0–2 ATP
used for shuttling electrons from NADH made in glycolysis
+ 2 ATP
by substrate-level phosphorylation
+ about 34 ATP
by chemiosmotic phosphorylation
Maximum per glucose:
About 38 ATP


Food, such as peanuts
Polysaccharides
Fats
Proteins
Sugars
Glycerol
Fatty acids
Amino acids
Amino groups
Glucose
G3P
Pyruvic acid
GLYCOLYSIS
Acetyl CoA
KREBS CYCLE
ELECTRON TRANSPORT CHAIN AND CHEMIOSMOSIS
ATP

B. Fermentation

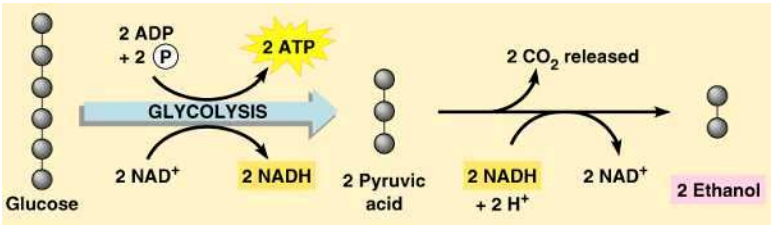
- Oxidation of NADH
  - Needed for glycolysis to continue

- e^- returned to byproduct of glycolysis
  - Frees up NAD^+

- Waste products

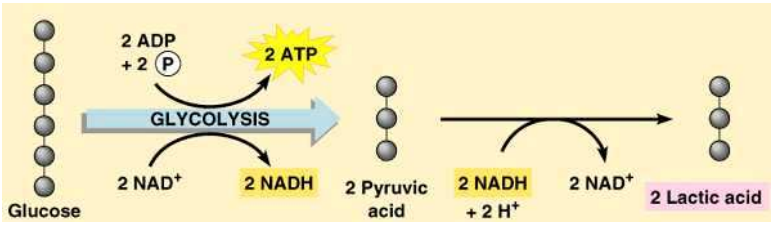
  - Alcoholic – ethanol + CO_2

2 pyruvic acid + 2 NADH $\rightarrow\rightarrow$
(2 ethanol + 2 CO_2) + 2 NAD^+



  - Lactic acid

2 pyruvic acid + 2 NADH $\rightarrow$
2 lactic acid + 2 NAD^+



- Temporary solution for some cells
  - Oxygen not available

- Only method for some anaerobes

- Produces less ATP than in respiration

  - Waste products high in energy

- Waste products also toxic