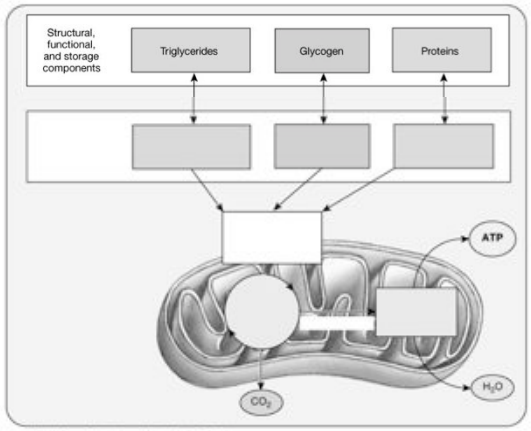
Topics

- Cellular Respiration
  - Glycolysis
  - Transition Reaction
  - Krebs/Citric Acid cycle

Cellular Metabolism



Cellular Respiration

Chemical energy is released and partially captured in the form of ATP.

Carbohydrates, fats, and proteins can all be used as fuel
glucose is most commonly used

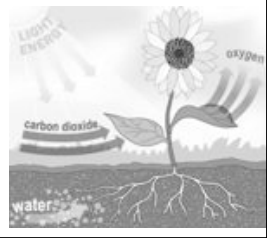
Loss of hydrogen atoms

$C_6H_{12}O_6$ + 6 O_2 → 6 CO_2 + 6 H_2O + energy (ATP)
glucose

Gain of hydrogen atoms

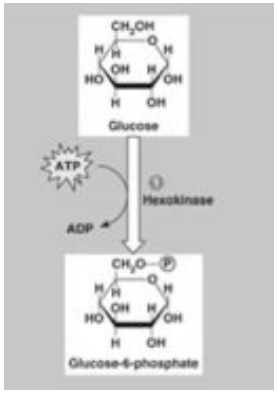
Photosynthesis

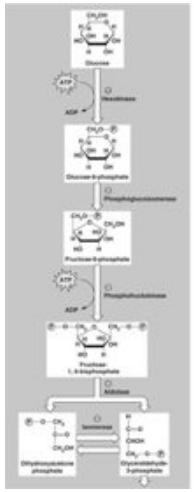
6 CO_2 + 6 H_2O (+ light energy) → $C_6H_{12}O_6$ + 6 O_2

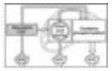


Glycolysis

Energy Investment Phase

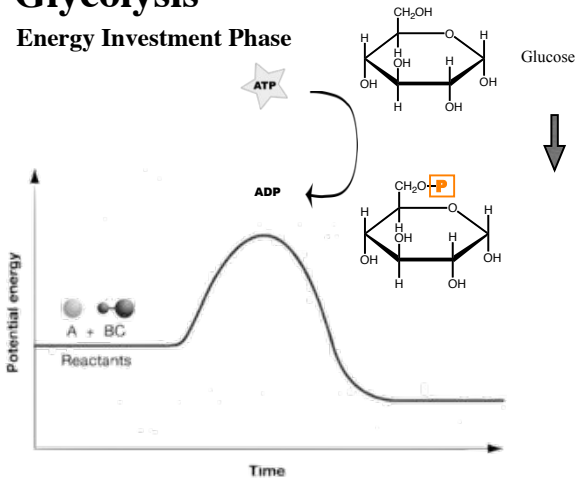






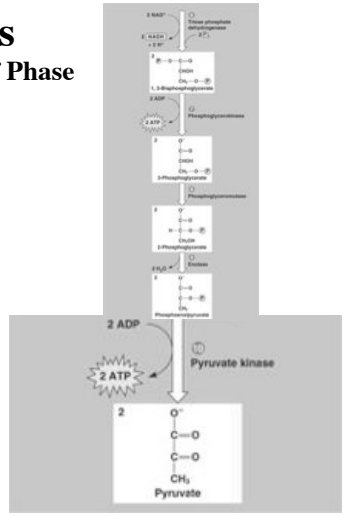
Glycolysis

Energy Investment Phase



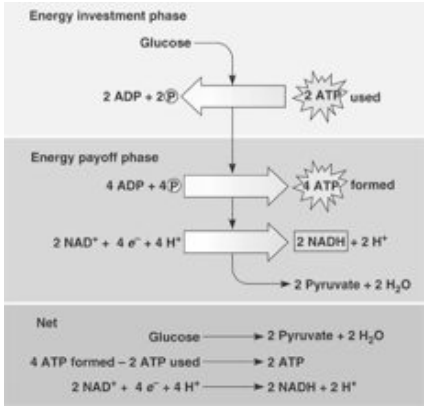
Glycolysis

Energy Payoff Phase

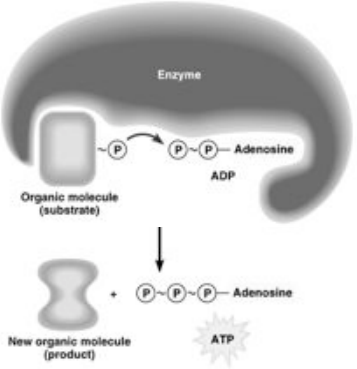


Glycolysis

Energy Investment Phase



Substrate-level Phosphorylation



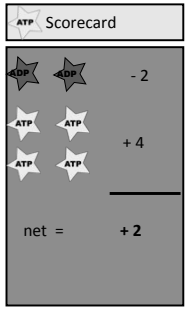
- **Substrate-level phosphorylation** is the direct transfer of a high-energy phosphate from one molecule to another.

How does this relate to the glycolysis pathway just discussed?

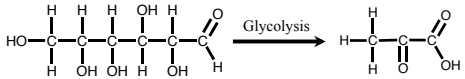
Is this an exergonic or endergonic reaction?

Glycolysis

Energy PAYOFF Phase

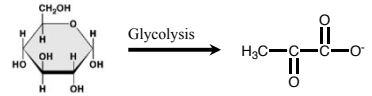


Even though 2 ATP molecules were needed to start glycolysis, 4 more were created, leaving a net gain of 2 ATP molecules per glucose



Glucose (x1) Pyruvic acid (x2)

Glycolysis-Review



Glucose Pyruvate (x2)

- Takes place in the cytosol

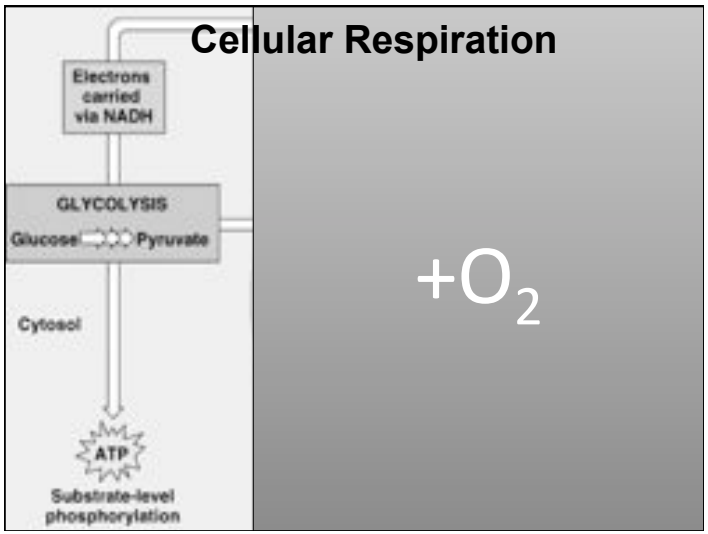
Glycolysis
glucose ---» pyruvate

- Produces 2 ATP (net)
- Produces 2 reduced NADH molecules

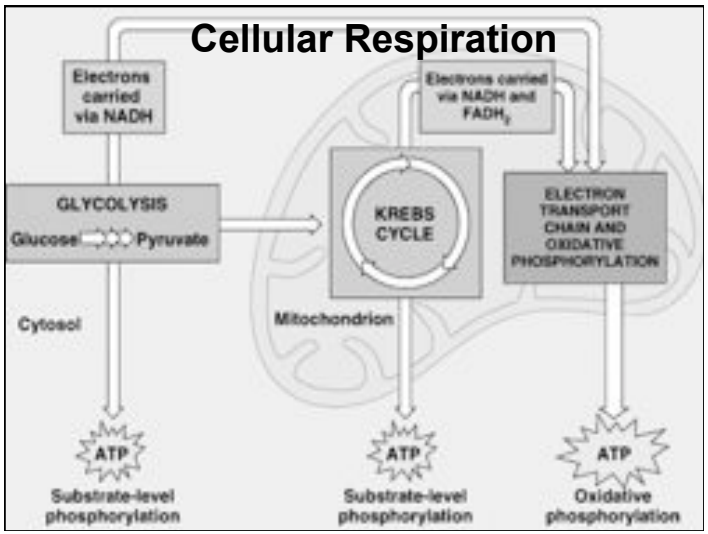
NADH
NADH

No role for mitochondria... yet

Cellular Respiration



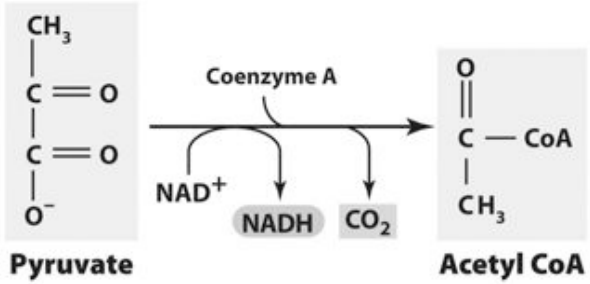
Cellular Respiration



Before The Citric Acid Cycle

(The "transition" or "preparatory reaction)

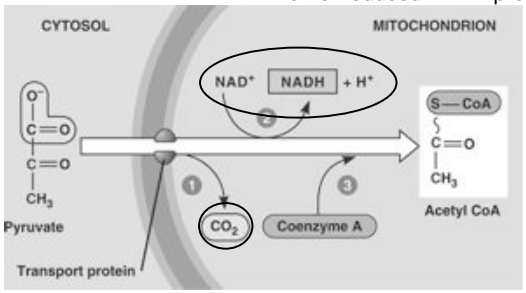
- Pyruvate is shuttled into the mitochondria (active transport)
- Pyruvate itself does not go into the Kreb's cycle; it must be "primed" first by converting to **Acetyl-CoA**



Transition Reaction- Pyruvate oxidation

Oxidation of pyruvate to acetate and CO2 within the mitochondrial matrix.
Acetate is then bound to coenzyme A.
Complex process involving 60 individual proteins.
Exergonic reaction, and 1 molecule of NAD+ is reduced.

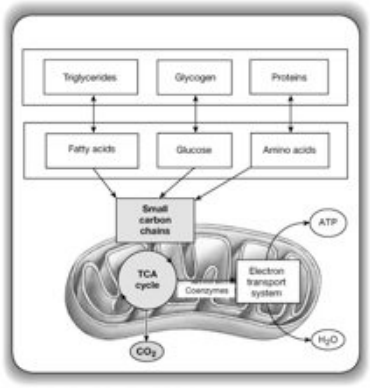
Another reduced NADH produced



1 carbon lost as CO_2

The Citric Acid Cycle

(AKA The Krebs, TCA cycle)

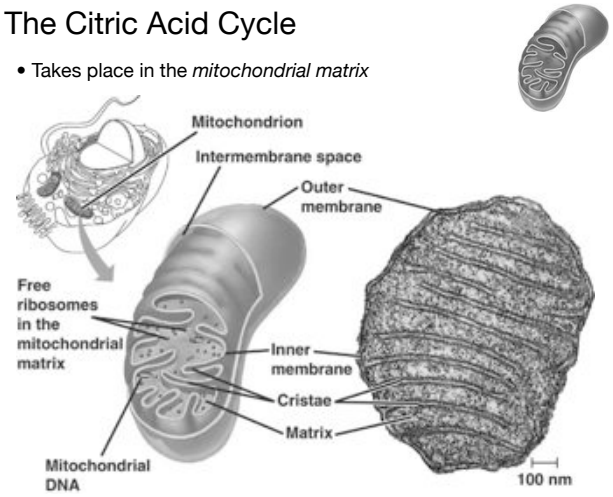


A Little Krebs Cycle History

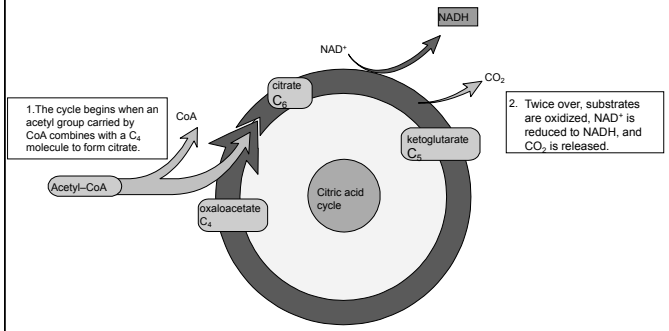
- **Discovered by Hans Krebs in 1937**
- **He received the Nobel Prize in physiology or medicine in 1953 for his discovery**
- **Forced to leave Germany prior to WWII because he was Jewish**

The Citric Acid Cycle

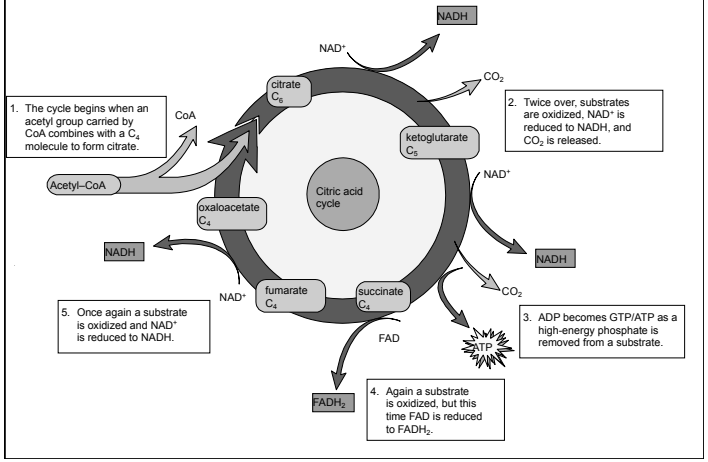
- Takes place in the *mitochondrial matrix*



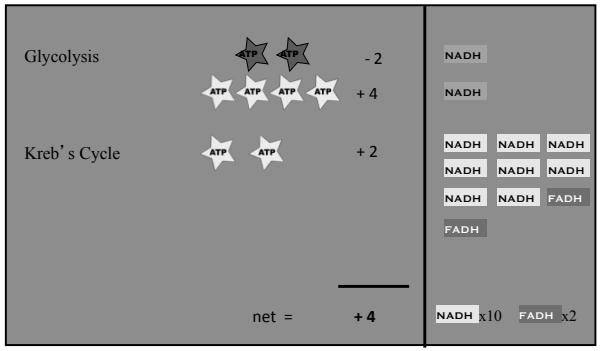
The Citric Acid Cycle



The Citric Acid Cycle



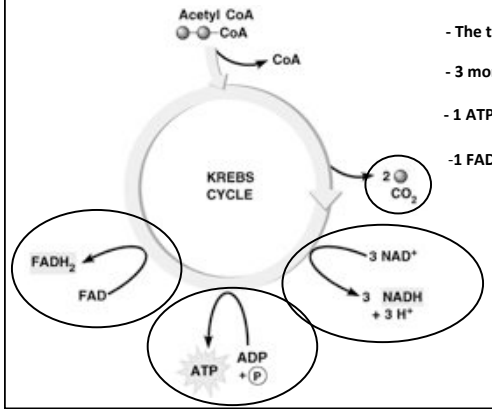
The ATP Scorecard



Kreb's/TCA Cycle Overview

1 glucose = 2 pyruvate = 2 Acetyl-CoA = 2 turns of the Kreb's Cycle

Involves 8 steps to fully oxidize acetyl CoA to CO2



- **The two carbons are lost as CO_2**
- **3 more NADH *per Acetyl-CoA***
- **1 ATP created per Acetyl-CoA**
- **1 FAD reduced to $FADH_2$ (coenzyme)**

Citric Acid Cycle Summary

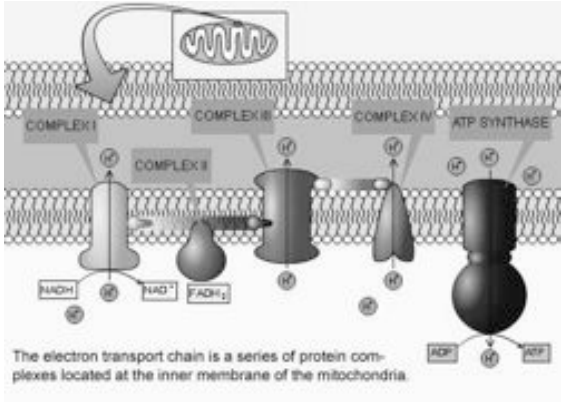
- Takes place in the *mitochondrial matrix*
- Kreb's cycle, Tricarboxylic Acid Cycle or Citric Acid Cycle
- Produces **2 ATP** ATP ATP
- Is the precursor to **the Electron Transport Chain** and **Oxidative Phosphorylation (Chemiosmosis)**

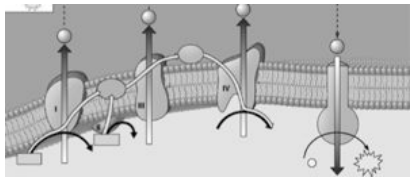
Citric Acid Cycle Summary

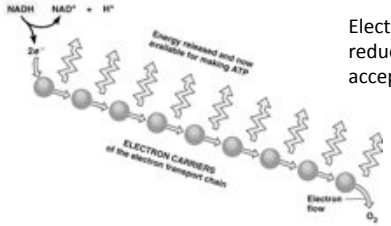
- **Requires Oxygen (Aerobic)**
- **Cyclical series of oxidation reactions that give off CO_2 and produce one ATP per cycle**
- **Turns twice per glucose molecule**
- **Each turn of the Krebs Cycle also produces 3NADH, 1$FADH_2$, and 2CO_2**
- **Therefore, For each Glucose molecule, the Krebs Cycle produces 6NADH, 2$FADH_2$, 4CO_2, and 2ATP**

Last stage…

Electron transport chain coupled to oxidative phosphorylation



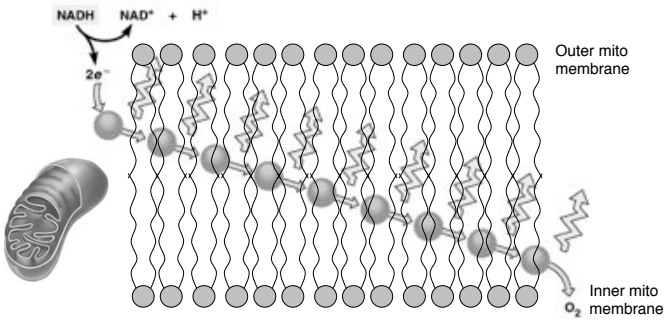




Electron carriers alternate between reduced and oxidized states, accepting and donating electrons

There is a drop in free energy as the electrons travel down the chain.

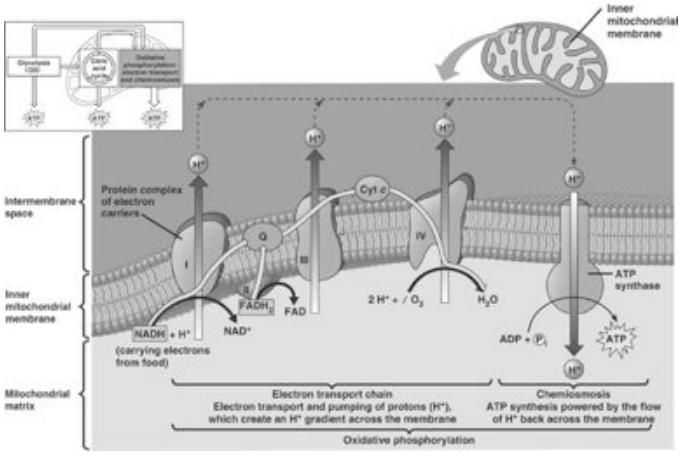
Electron Transport Chain



- electrons continue being passed down the "chain", releasing energy

- Energy drives the pumping of H+ (protons) **outside** the inner mitochondrial membrane (intermembrane space)

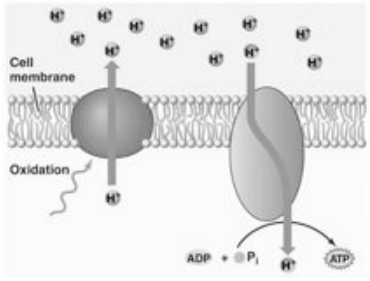
ETC is "coupled" to oxidative phosphorylation



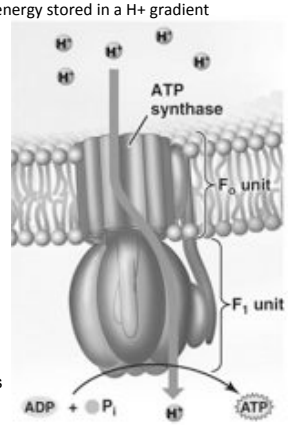
Chemiosmosis and Oxidative Phosphorylation

Proton motive force: measurement of the potential energy the H+ gradient contains

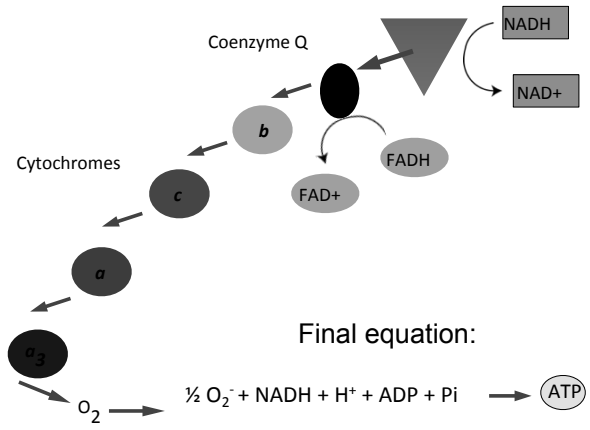
Chemiosmosis: energy-coupling mechanism, uses energy stored in a H+ gradient across a membrane to do cellular work.



Generates **ATP** by the movement of hydrogen ions



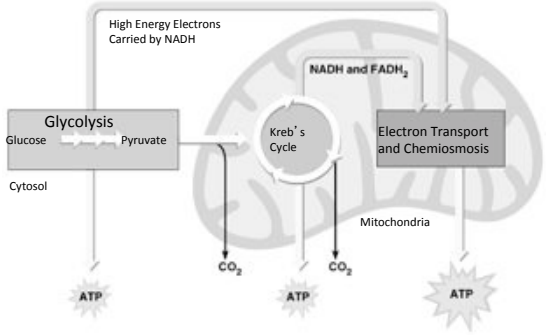
Electron Transport System



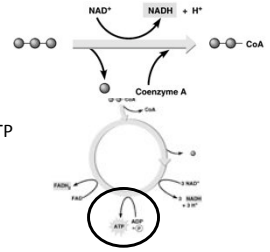
Electron Transport Chain

- Electron carriers loaded with electrons and protons from the Kreb's cycle move to this chain-like through a series of steps (staircase).
- Occurs Across **Inner Mitochondrial membrane**
- As electrons drop down stairs, energy released to **form a total of 30 ATP**
- Oxygen waits at bottom of staircase, picks up electrons and protons and in doing so becomes water

Catabolism of Glucose



The Energy of Glucose



cytosol

NADH = 2.5 ATP

2 NADH/FADH2 = 5 ATP

2 ATP = 2 ATP

mitochondria

2 ATP = 2 ATP

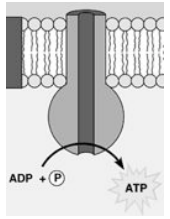
NADH = 2.5 ATP

8 NADH = 20 ATP

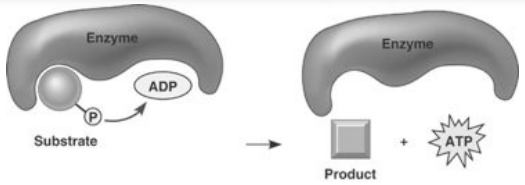
FADH = 1.5 ATP

2 FADH = 3 ATP

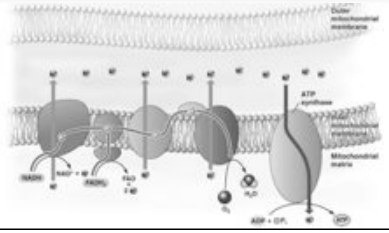
~32 ATP per Glucose!



Substrate-level Phosphorylation

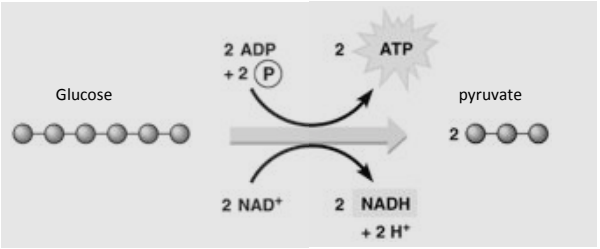


Oxidative Phosphorylation



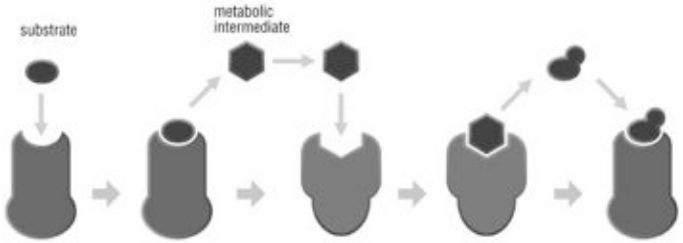
Glycolysis Overview

For a reaction to proceed you must remove excess product.

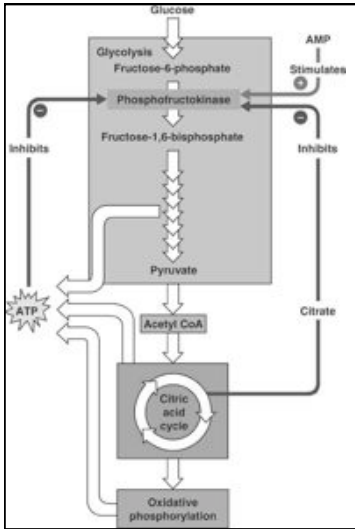


Substrates Products

Feedback Signaling



Enzyme 1 Enzyme 2 Enzyme 1



Feedback control of ATP production