D. Cellular Respiration (pp. 107 fwd)

- The process by which mitochondria in the cells of all living organisms break down glucose to make ATP
  = convert the NRG stored in glucose to a form the cell can use
- Chemical equation for cellular respiration:

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

- complementary to photosynthesis
  = products of photosynthesis used in cellular respiration
- Two types:
  - Aerobic respiration: requires O_2; results in complete breakdown of glucose
  - Anaerobic respiration: requires no O_2, incomplete decomposition of glucose

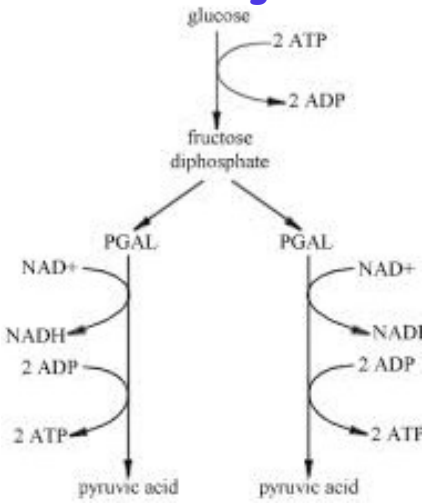
i) Aerobic Respiration

- Involves 3 stages: Glycolysis, the Kreb's Cycle, & the Electron Transport System

a) Glycolysis

- ***Site:*** *occurs in the cytoplasm of the cell*
- ***Purpose:*** *Split sugar into 3 C molecules to be processed in the mitochondria*
- *does* ***not*** *require the presence of oxygen*

1. A molecule of glucose is split into two 3 carbon molecules of PGAL using two molecules of ATP.
2. Each PGAL molecule is converted into Pyruvate by removing a H^+ ion & e^-'s. Energy is released in this process (creates 2 ATP per pyruvate).
3. The H^+ ions & e^-'s are picked up by the carrier molecule NAD which becomes NADH.
4. The pyruvate and NADH molecules are carried over to the next **stages**.

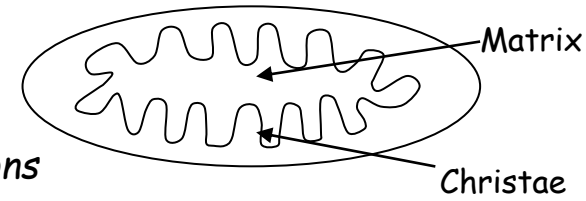


Net Results:

1 $C_6H_{12}O_6$ produces:

2 pyruvate
2 NADH
4 ATP (-2 invested) = 2 ATP

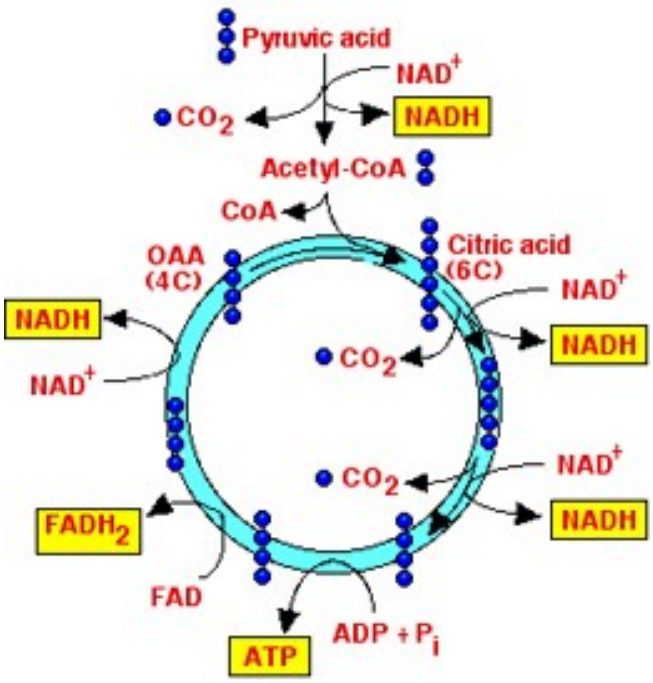
b) ***Krebs Cycle (a.k.a. Citric Acid Cycle)***



- ***Site:*** *occurs in matrix (inner compartment) of the mitochondrion in cell*
- ***Purpose:*** *break down pyruvate to harvest H^+ ions & e^-'s to put through the ETC*
- *requires oxygen*

1. The Krebs Cycle is like a big circular assembly line which requires the NRG 2 ATP to run.
2. Through a complex set of chemical reactions each pyruvate is broken apart
   → H^+ ions & e^-'s = picked up by the carrier molecules NAD & FAD producing NADH & $FADH_2$ which will be used in the production of ATP
   → Carbon = is joined with atmospheric oxygen and given off as a byproduct in the form of CO_2 (exhaled)
   = nothing is left of the original glucose molecule (taking apart Leggo)
3. The energy released from this process produces ATP.

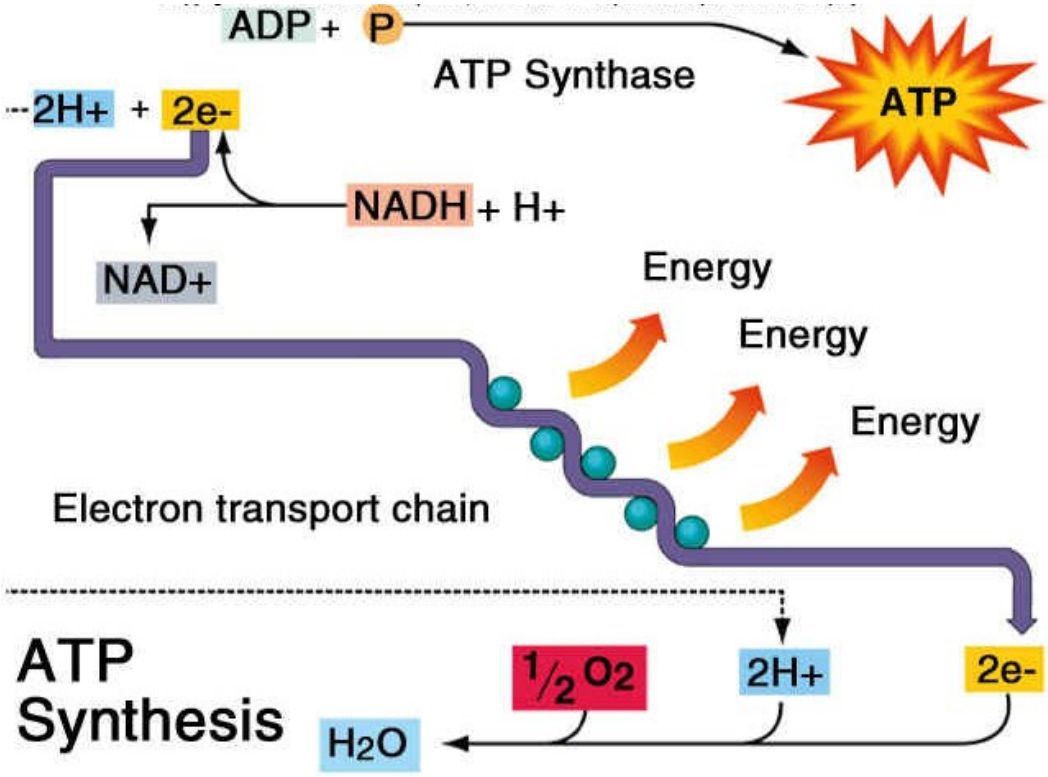
Net Results:(for each acetyl CoA)
: 1 ATP
: 3 NADH and 1 $FADH_2$
: 2 CO_2



c) *Electron Transport System (a.k.a. Electron Transport Chain)*

- *Site: occurs in the cristae (inner folded membranes) of the mitochondrion*
- *Purpose: produce ATP*
- *requires oxygen*

1. All of the NADH and $FADH_2$ from Glycolysis and the Krebs Cycle are stripped of H^+ ions & e^-'s which are put into the Electron Transport System requires 2 ATP
2. These ions and electrons are sent down the ETC releasing NRG to create ATP
3. The hydrogen ions and e-'s join with oxygen to form $H_2O(g)$ which is exhaled.



Net Results:

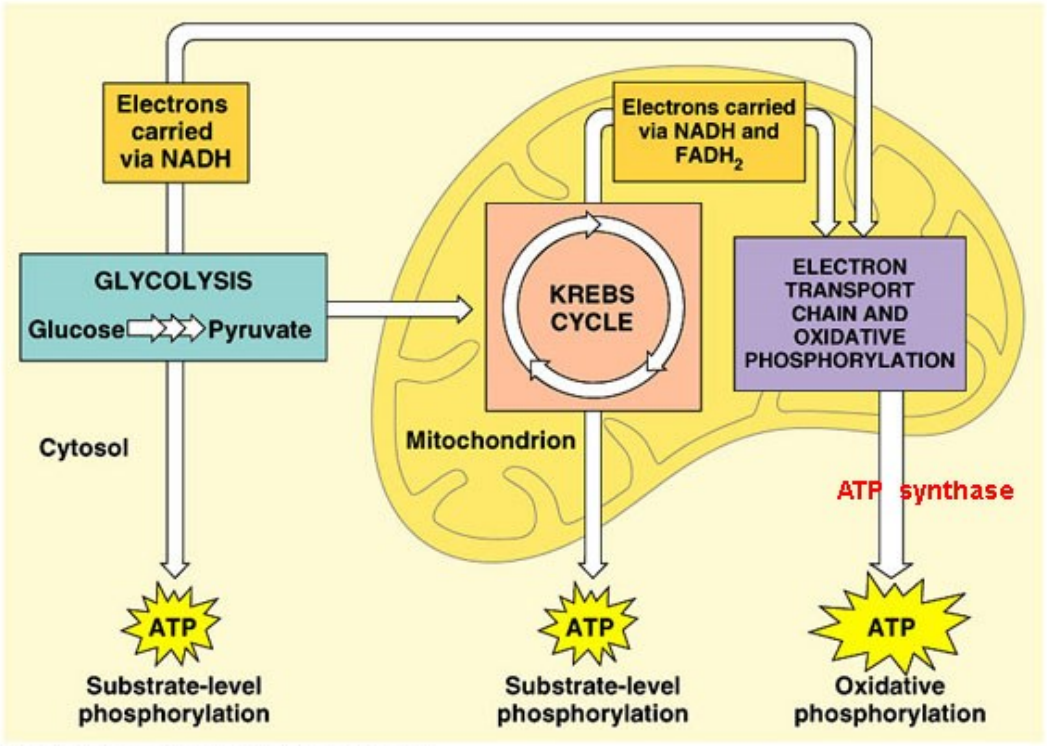
6 H_2O (exhaled)

10 NADH produce 30 ATP

2 $FADH_2$ produce 4 ATP

34 ATP (but 2 invested) = 32 ATP

**Most of the ATP for aerobic respiration is produced in this stage



**ATP Totals for aerobic respiration:

Glycolysis – 2 ATP

Citric Acid Cycle – 2 ATP

Electron Transport Chain – 32 ATP

1 Glucose = ~36 ATP in all for aerobic respiration

	GLYCOLYSIS	KREBS CYCLE	E⁻ TRANSPORT CHAIN
INPUT	Glucose 2ATP NAD	2 Pyruvate Citric Acid NAD FAD Oxygen	NADH $FADH_2$ 2 ATP Oxygen
OUTPUT	2 Pyruvate 4 ATP (2 net) NADH	6 NADH 2 $FADH_2$ 2 ATP 4 CO_2	32 ATP 6 H_2O

ii) Anaerobic Respiration (a.k.a. Fermentation)

- Also called incomplete cellular respiration
- Does not require oxygen to make ATP
- Is Glycolysis but in the absence of O_2 pyruvate is converted into more stable products
- 2 types:

a) Alcohol Fermentation

- used by yeast
- as there is no O_2 the pyruvate is rearranged forming ethanol & releasing CO_2

Net Results:

2 ATP
CO_2 (make bread rise)
Ethanol (produce beer, wine)

b) Lactate Fermentation

- used by anaerobic bacteria and muscles
- lack of O_2 causes pyruvate to be converted to lactic acid & CO_2 is released.
- bacteria (ie. milk turns sour)
- muscle cells: a lack of sufficient oxygen during strenuous exercise causes lactic acid build up in muscles resulting in muscle cramps and fatigue

Net Results:

2 ATP
CO_2
Lactic Acid

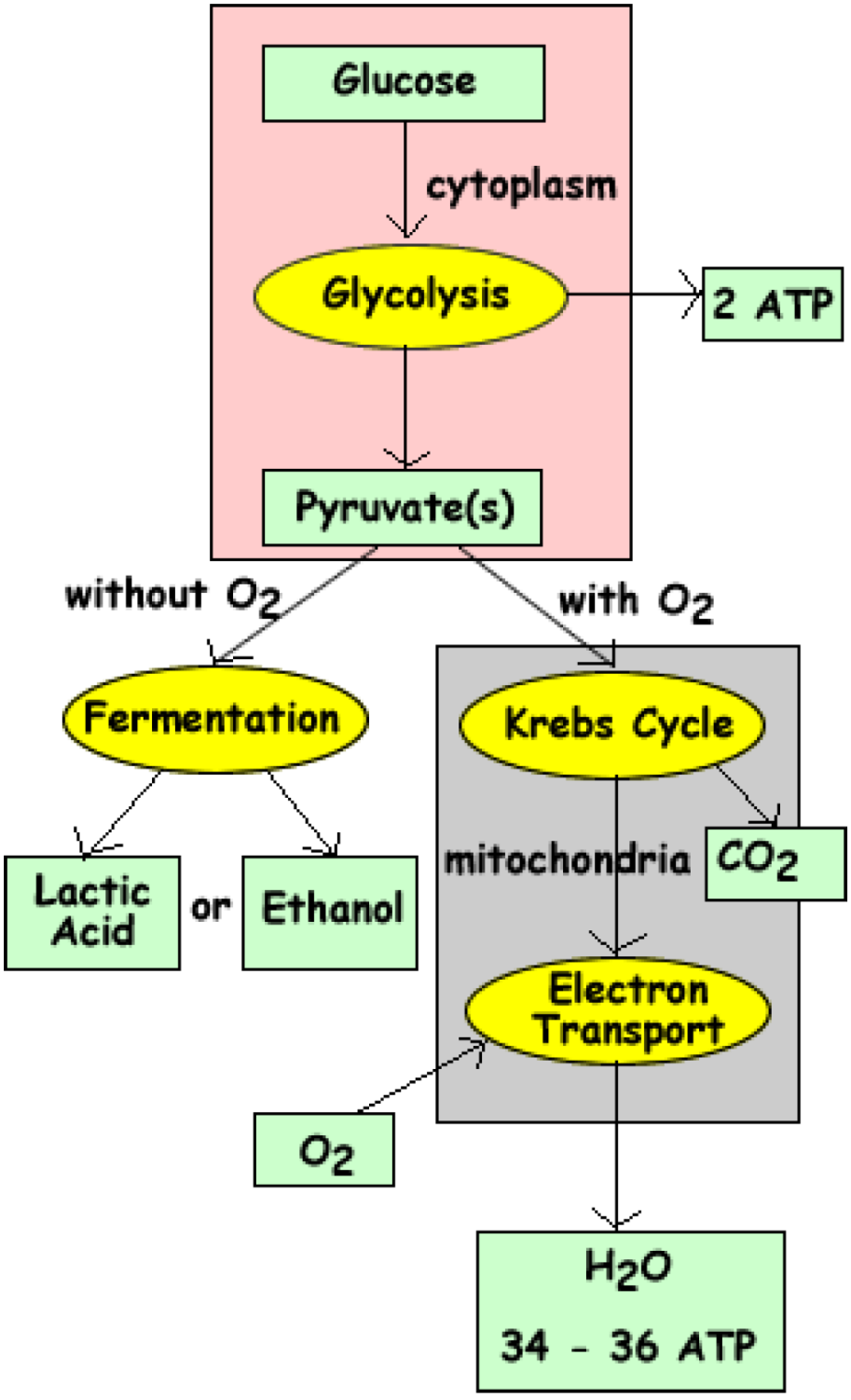
Comparing Aerobic and Anaerobic Respiration

ATP production : Aerobic = 36 vs Anaerobic = 2

**Aerobic Respiration is more efficient due to the Electron Transport Chain

= is where most ATP is formed

- like complete combustion of fuel in a car


Glucose
cytoplasm
Glycolysis
2 ATP
Pyruvate(s)
without O_2
with O_2
Fermentation
Krebs Cycle
mitochondria
CO_2
Lactic Acid
or
Ethanol
Electron Transport
O_2
H_2O
34 - 36 ATP

	GLYCOLYSIS	PREP FOR KREBS CYCLE	KREBS CYCLE	E^- TRANSPORT CHAIN
INPUT	Glucose 2 ATP NAD	2 Pyruvate Co-Enzyme A NAD Oxygen	Acetyl Co- A Citric Acid NAD FAD Oxygen	NADH $FADH_2$ 2 ATP Oxygen
OUTPUT	2 Pyruvate 4 ATP (2 net) 2 NADH	2 Acetyl Co-A 2 NADH 2 CO_2	6 NADH 2 $FADH_2$ 2 ATP 4 CO_2	32 ATP 6 H_2O