

D. Cellular Respiration (pp. 107 fwd) [Amoeba Sisters : Cellular Respiration https://www.youtube.com/watch?v=4Eo7JtRA7Jg](https://www.youtube.com/watch?v=4Eo7JtRA7Jg)

- 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:



- 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 Krebs'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.

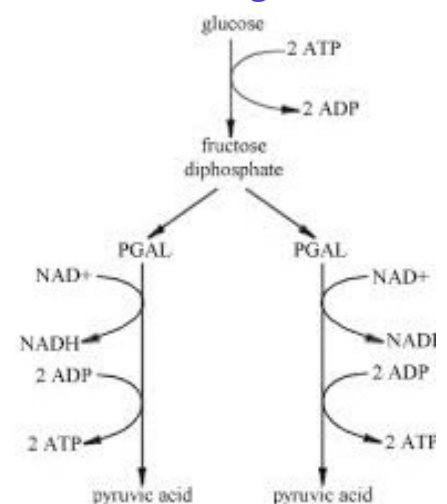
Net Results:

1 $\text{C}_6\text{H}_{12}\text{O}_6$ produces:

2 pyruvate

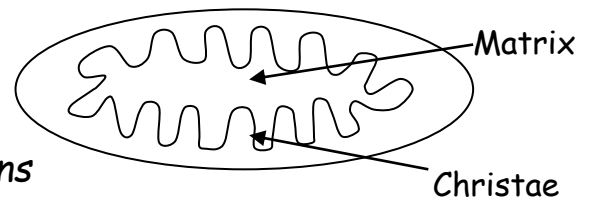
2 NADH

4 ATP (-2 invested) = 2 ATP



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

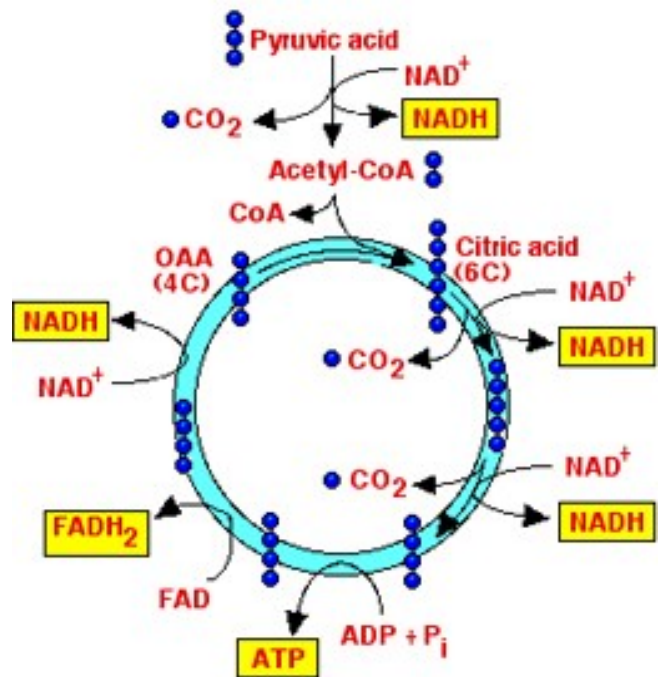
- **Site:** occurs in **matrix (inner compartment)** of the mitochondrion in cell
- **Purpose:** break down pyruvate to harvest H^+ ions & e^- 's to put through the ETC
- requires **oxygen**



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 converted into **Acetyl CoA** and then broken apart
 - H^+ ions & e^- 's = picked up by the carrier molecules NAD & FAD producing **NADH** & **FADH₂** 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 **CO₂** (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 Pyruvic Acid)

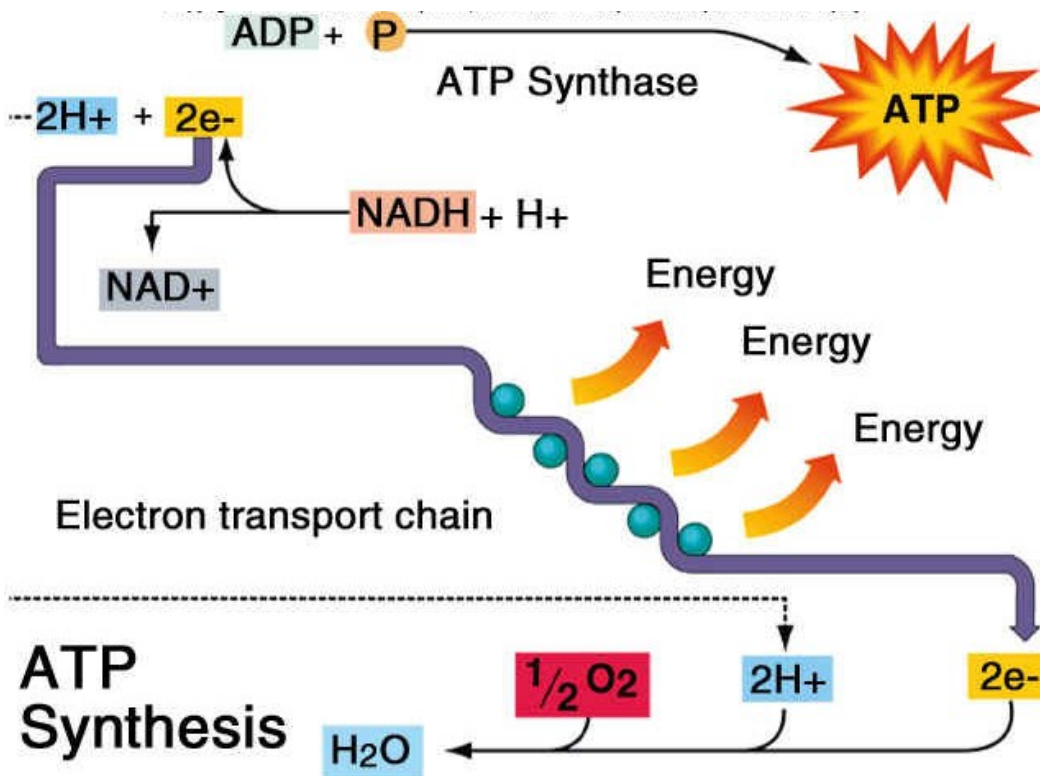
- : 1 ATP
- : 4 NADH and 1 FADH₂
- : 3 CO₂



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 FADH₂ 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 H₂O(g) which is exhaled.



Net Results:

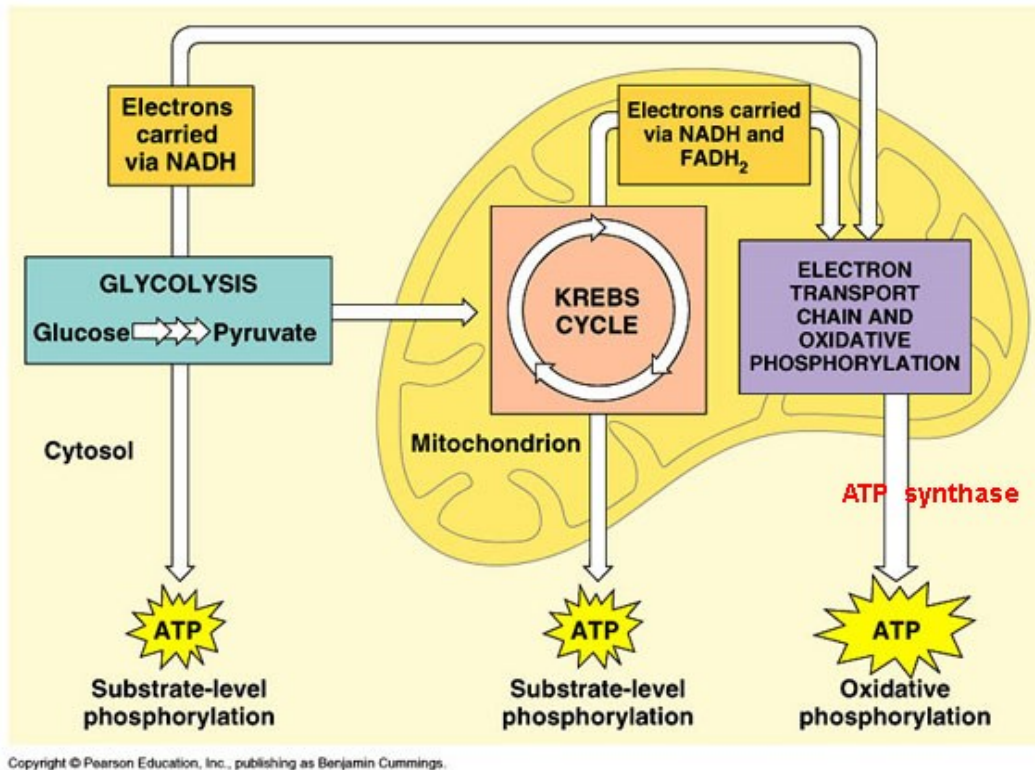
6 H₂O (exhaled)

10 NADH produce **30 ATP**

2 FADH₂ 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 ₂ O

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

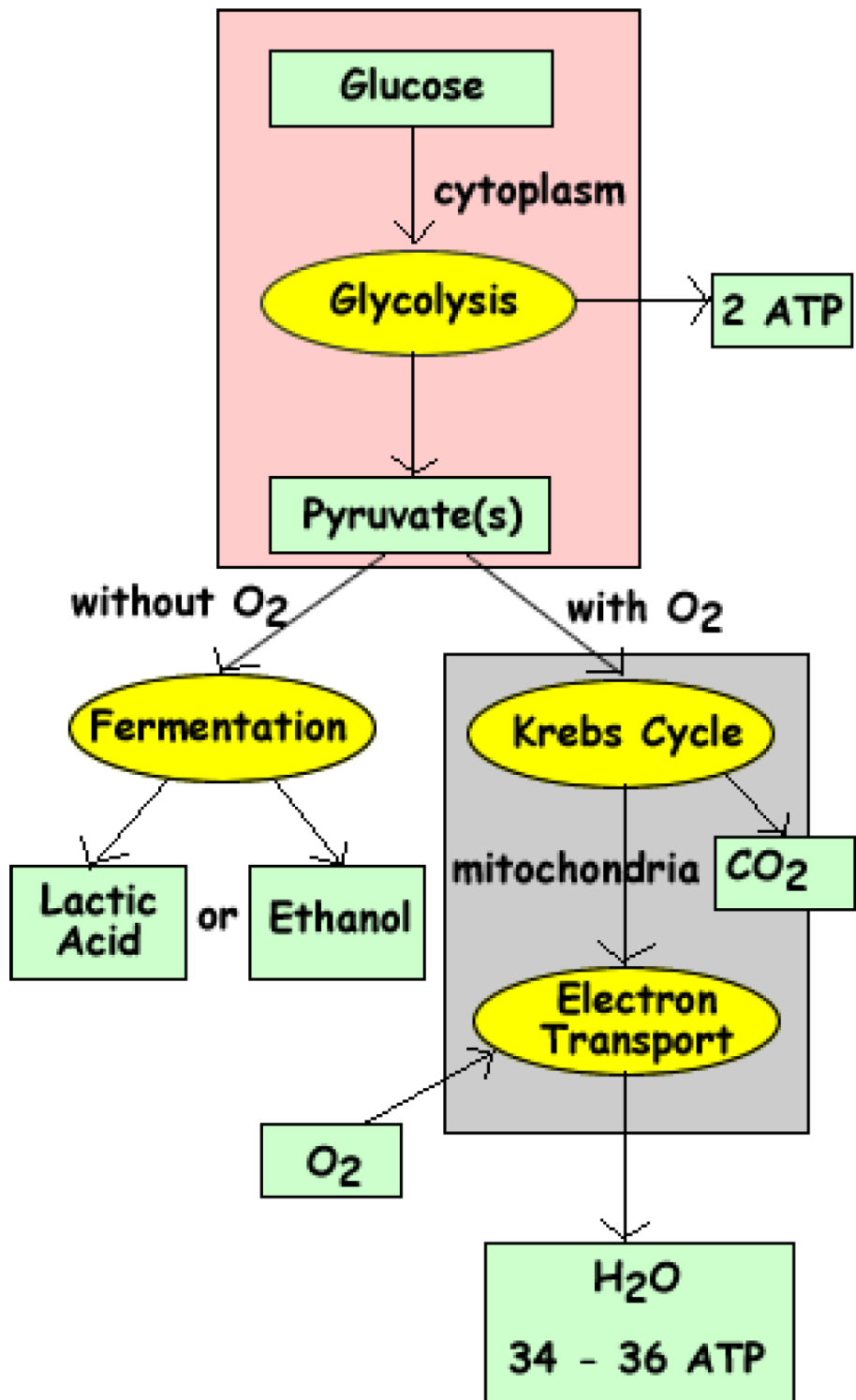
Comparing Aerobic and Anaerobic Respiration

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**



	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 ₂ O