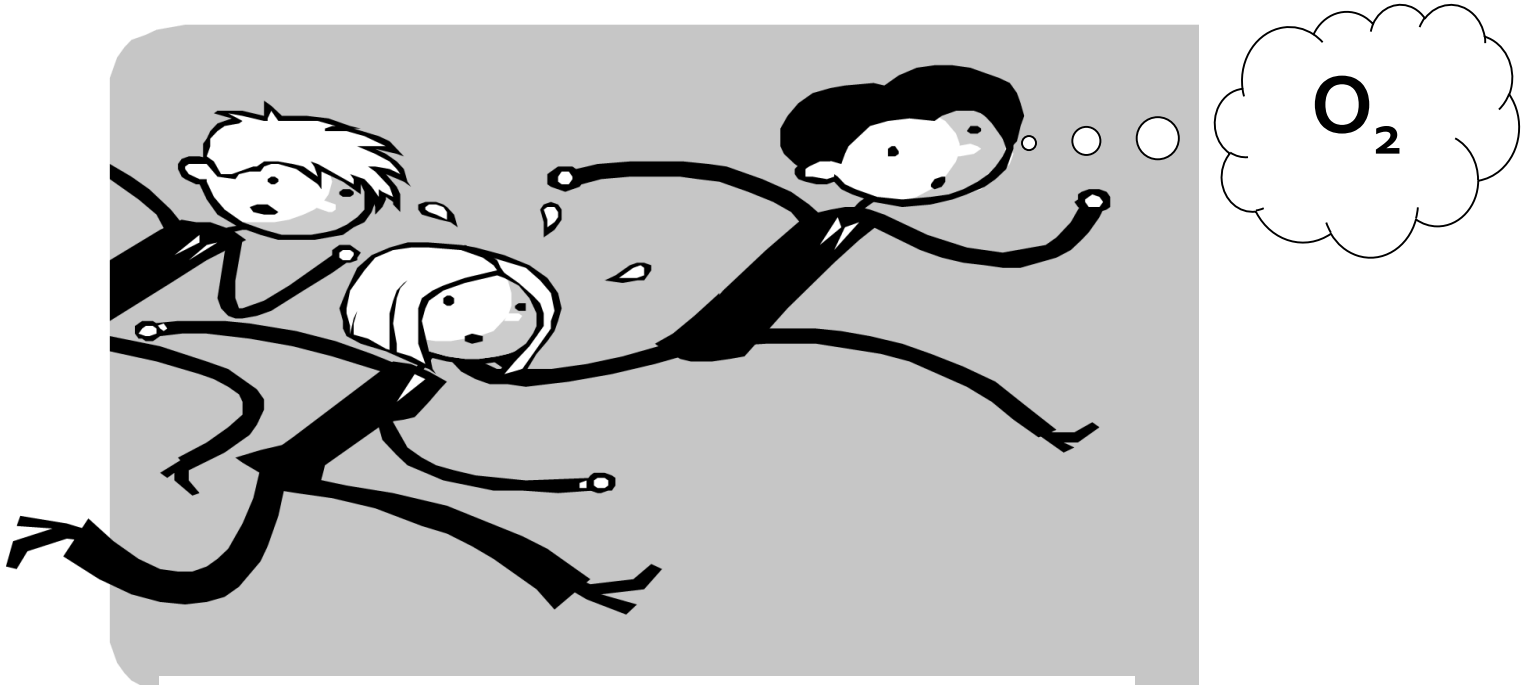
Cellular Respiration
View from your perspective

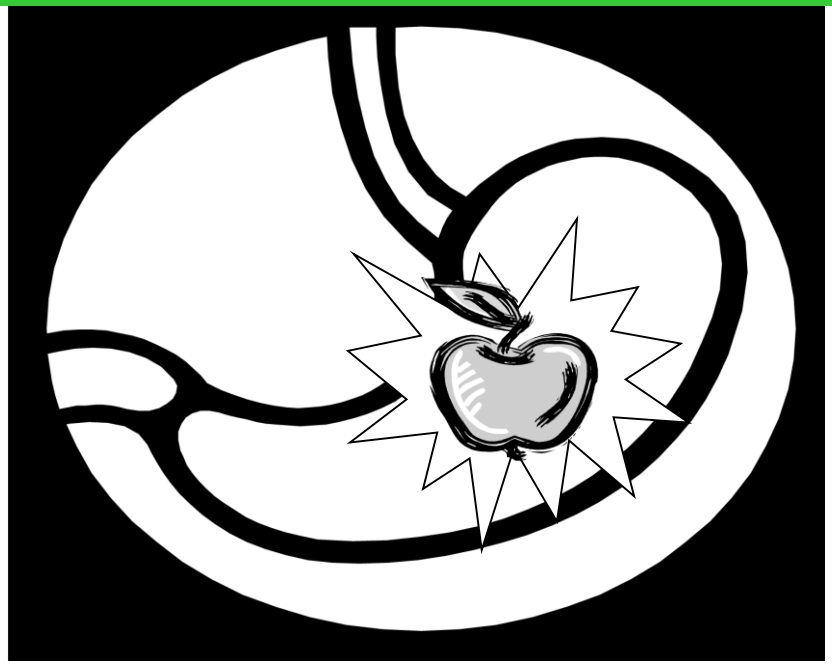


You have been running around all day and are low on energy

Cellular Respiration
View from your perspective

You decide eating an apple might help you feel more energized.

Cellular Respiration
View from your perspective



Inside your stomach the apple is broken down into simple sugars.

Cellular Respiration
View from your perspective

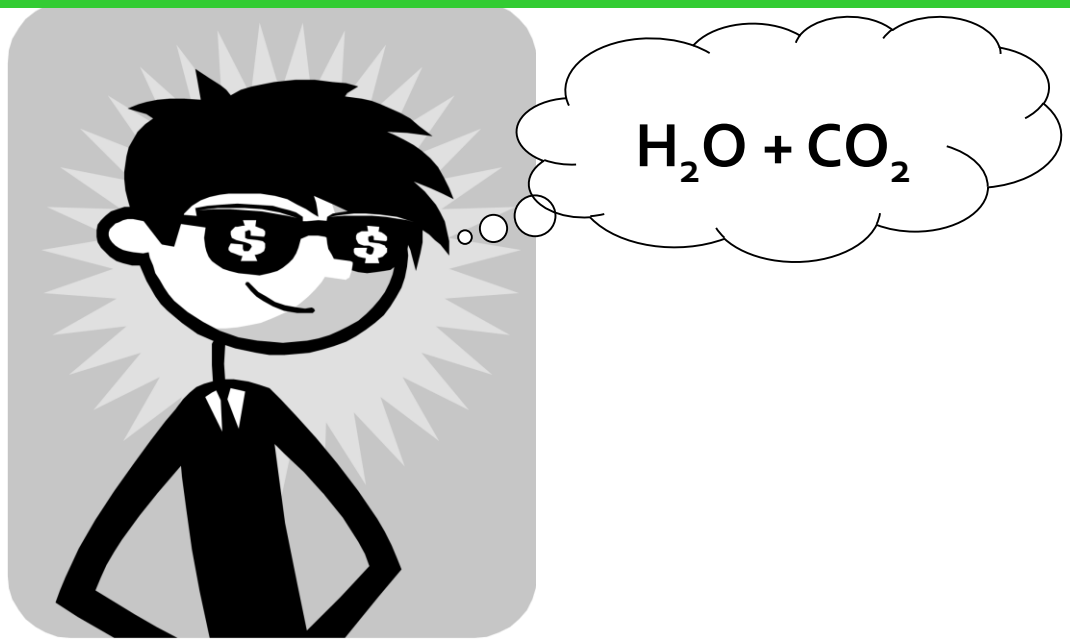
Sugars from the apple are split by chemical processes:

1. **Glycolysis**
2. **Kreb's Cycle**
3. **Electron Transport Chain**

Cellular Respiration
View from your perspective

Your body gets energy in the form of ATP from these processes. ATP = cell energy.

Cellular Respiration
View from your perspective



As a waste product from these processes, you release carbon dioxide and water.

I. Overview of Cellular Respiration (Know sequence of events)

Definition – The process that releases energy (ATP) by breaking down glucose and other food molecules in the presence of **oxygen** (aerobic). This is an oxidation reaction.

- NAD^+ acts as the electron carrier (NAD – Nicotinamide adenine dinucleotide)
- Occurs in **ALL** eukaryotic cells, plants included!

$6O_2 + C_6H_{12}O_6 \longrightarrow 6\ CO_2 + 6\ H_2O + Energy\ (36\ ATP)$

$$6O_2 + C_6H_{12}O_6 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{Energy (36 ATP)}$$

Reactants **Products**

ATP – Adenosine Triphosphate

Supplies energy for all cellular processes

Adenine | Ribose | 3 Phosphate groups

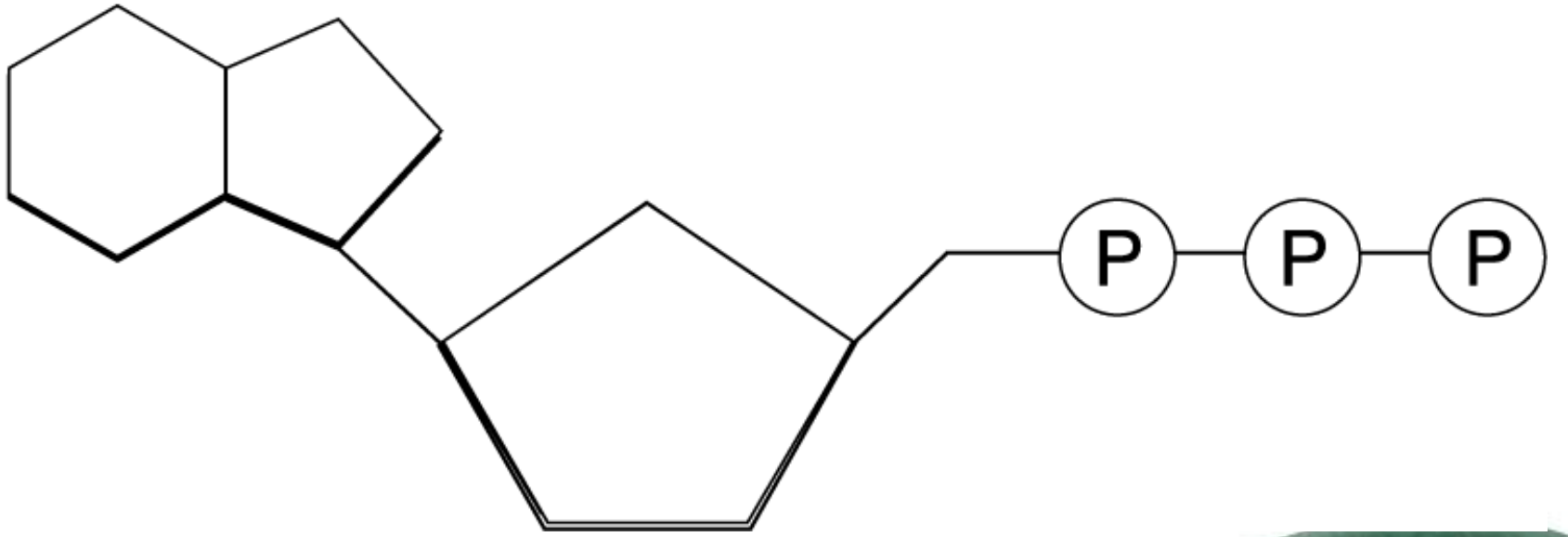


Figure 8-3 Comparison of ADP and ATP to a Battery

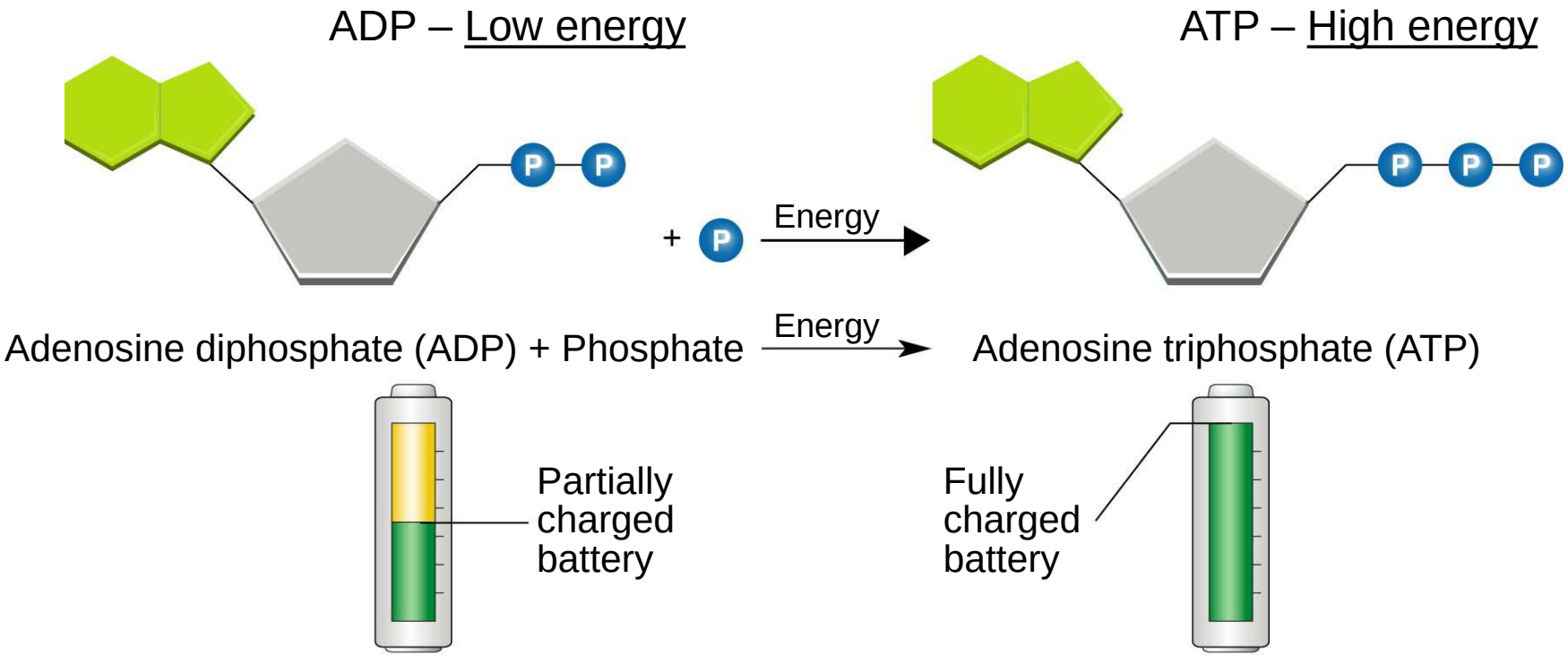
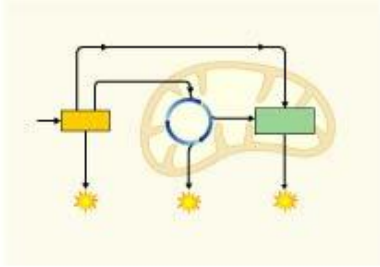
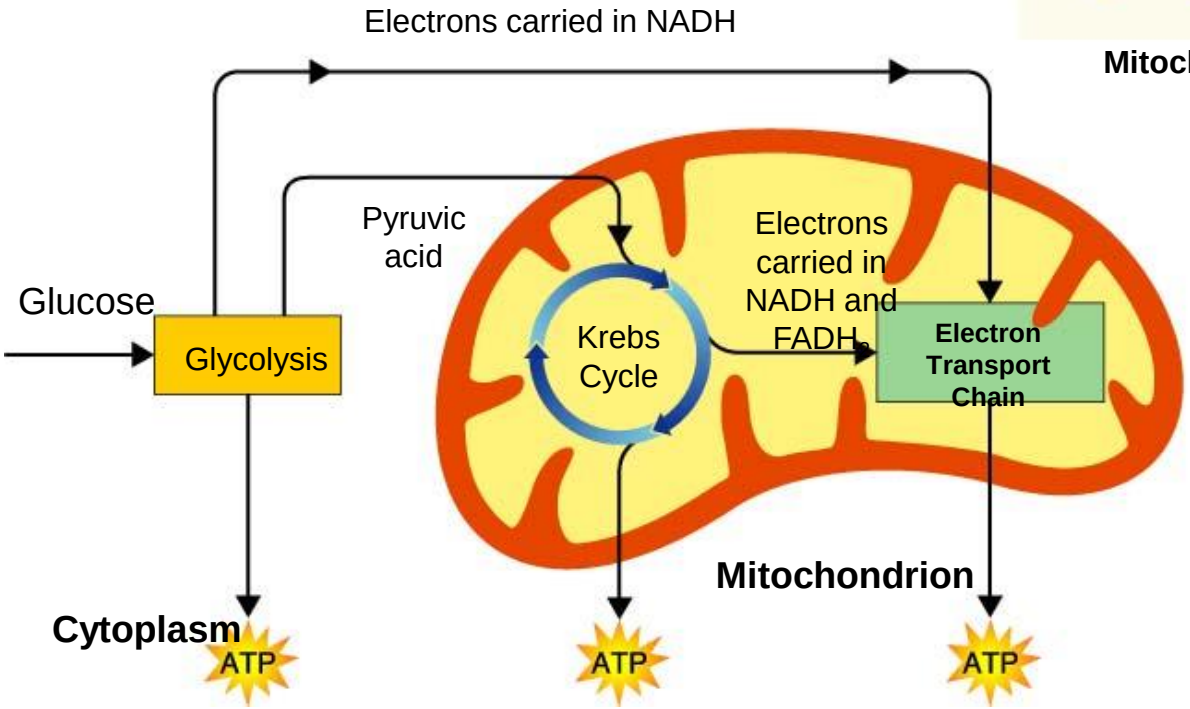


Figure 9–2 Cellular Respiration: An Overview

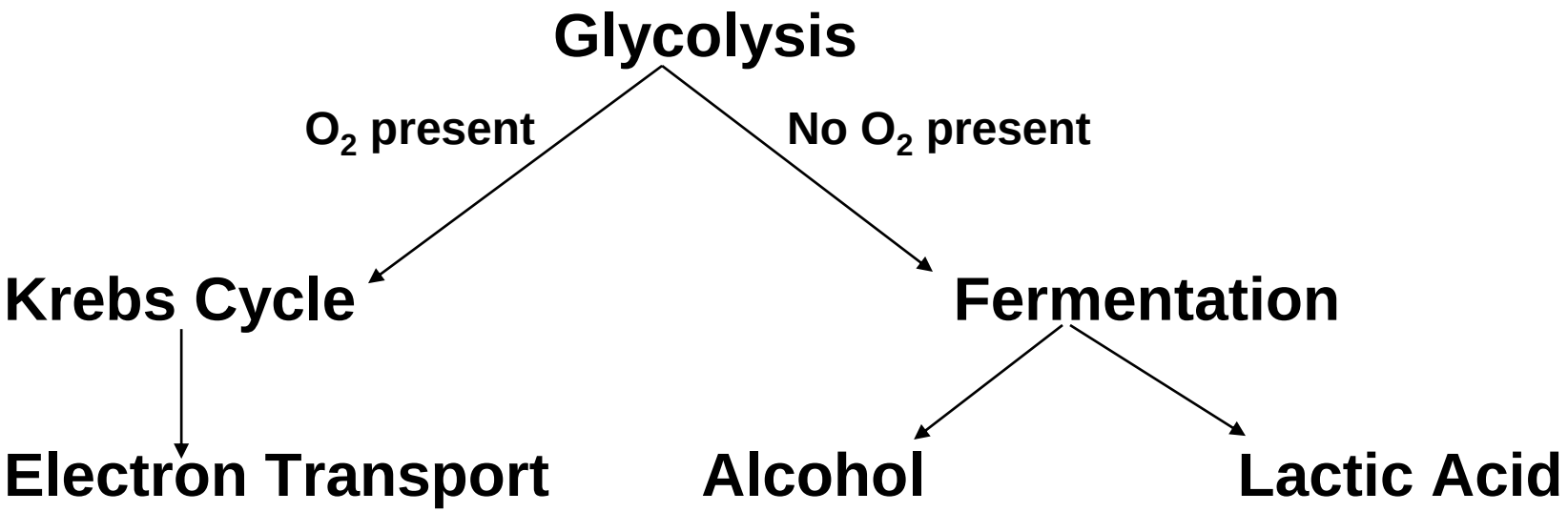


Mitochondrion



1st step – Glycolysis is when one molecule of glucose is broken in half, producing two molecules of pyruvic acid, a 3-C compound.

- If oxygen is present then pyruvic acid enters Krebs Cycle
- If **no** oxygen then pyruvic acid enters fermentation process



Glycolysis - Occurs in the cytoplasm

A. Starting molecule is glucose

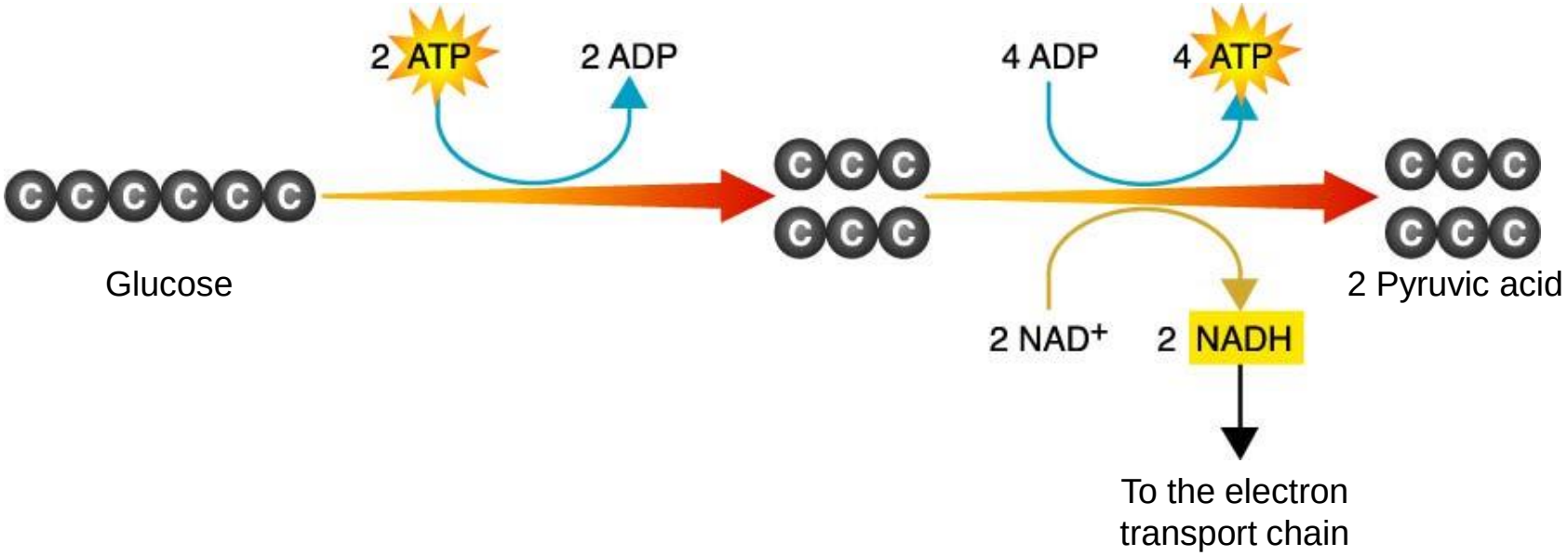
B. ATP Production – 2 ATPs are needed at beginning, but 4 are produced, total of 2 net gain for the cell.

C. NADH is a carrier for electrons to the electron transport chain (ETC).

D. 1 glucose = 2 pyruvic acid + 2 ATP + 2 NADH

E. Total ATP = 2

Figure 9–3 Glycolysis



Glycolysis Movie

Fermentation

A. Anaerobic – no oxygen present

B. Types

1. Alcoholic fermentation by yeast and some bacteria

Pyruvic acid + NADH $\longrightarrow$ alcohol + CO_2 + NAD^+

- Carbon dioxide causes bread to rise, heat in baking evaporates any alcohol.
- Used to produce beer and wine

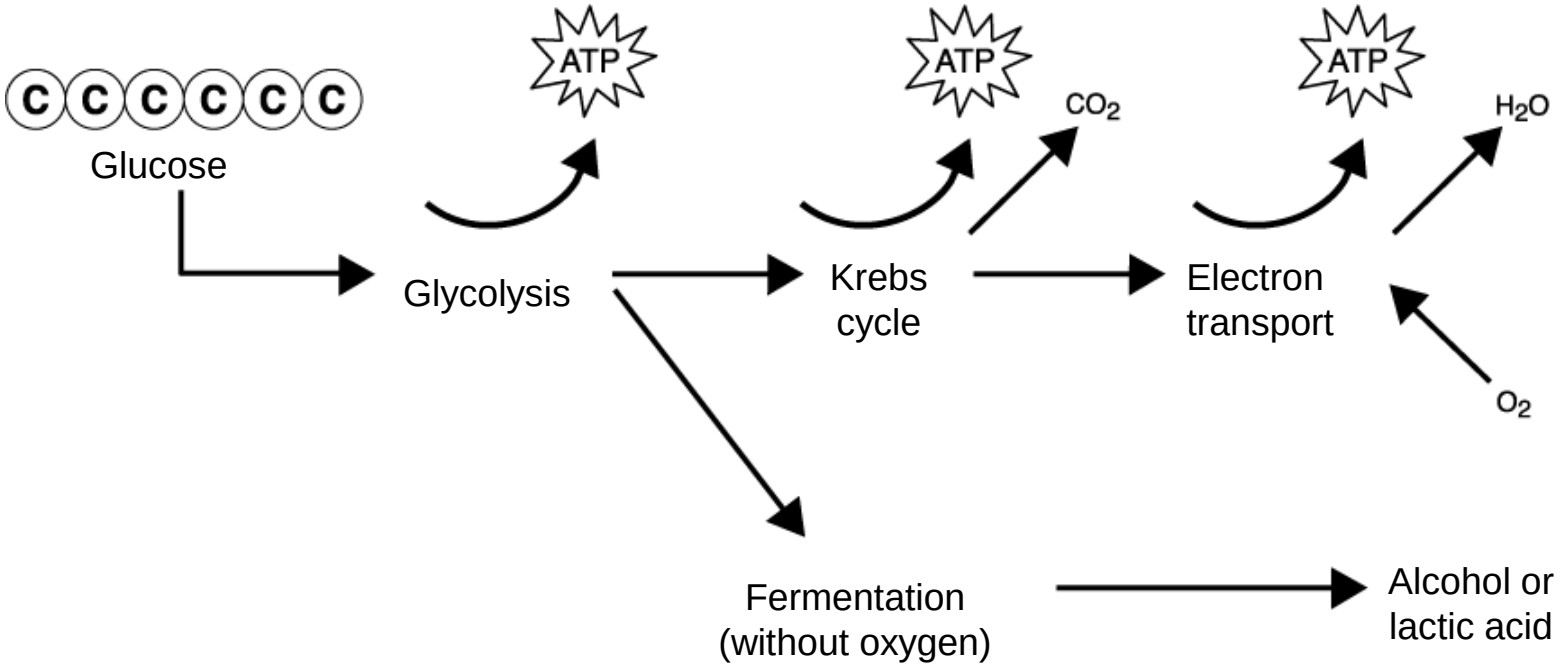
2. Lactic acid fermentation

Pyruvic acid + NADH $\longrightarrow$ Lactic acid + NAD^+

- Produced in muscles during vigorous exercise when the body cannot supply enough oxygen. Leads to soreness.
- Unicellular organisms ferment food and beverages.

Ex: yogurt, cheese, buttermilk, sour cream, pickles, sauerkraut

Chemical Pathways



2nd step – Krebs Cycle

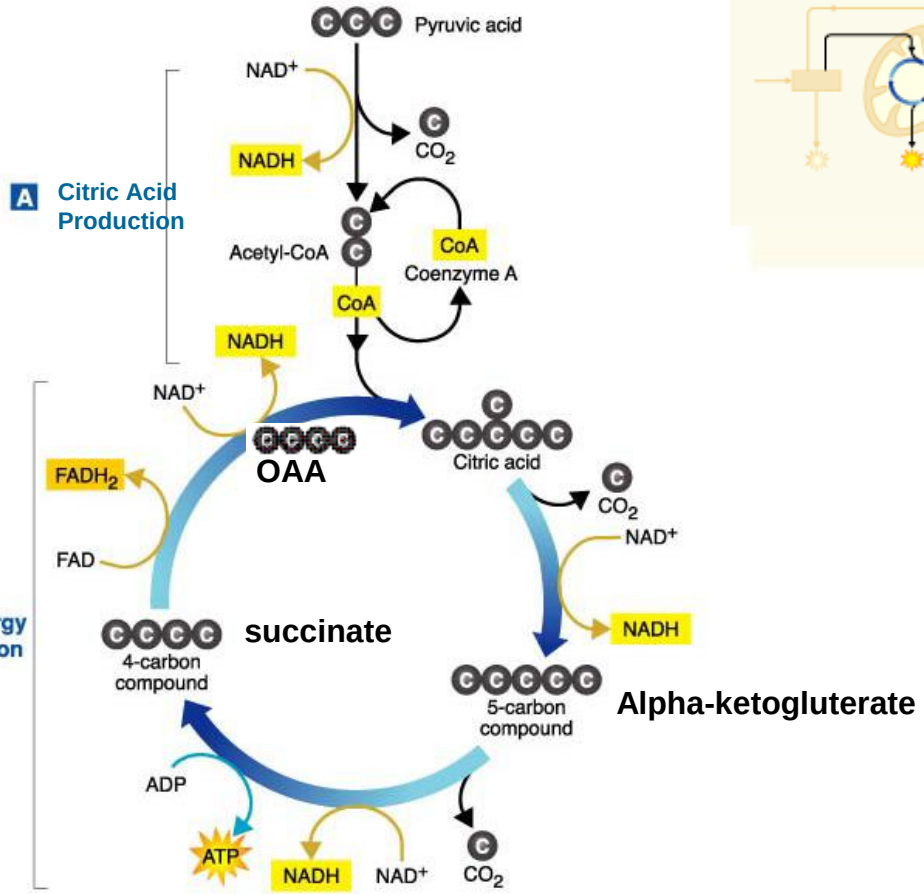
- occurs in mitochondria
- Starts with pyruvic acid and gives off carbon dioxide
- Energizes NAD+ to form NADH (electron carriers) high energy
- Results:
  - High energy carriers (NADH and $FADH_2$) take electrons to ETC
  - Carbon dioxide is breathed out
  - 2 ATP formed

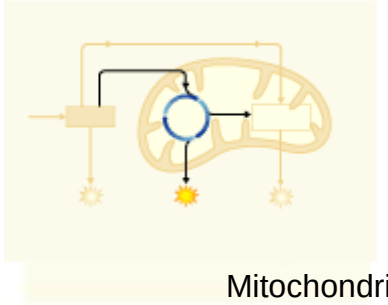
Figure 9–6 The Krebs Cycle

Krebs Cycle Movie

OAA – Oxaloacetate is a 4 Carbon molecule with low energy

$FADH_2$ – Flavin adenine dinucleotide + hydrogen





Mitochondrion

Succinate – 4 carbon compound with energy

NADH – Nicotinamide adenine dinucleotide + hydrogen

Krebs Video 1

Krebs Video 2

3rd step - Electron Transport Chain (ETC)

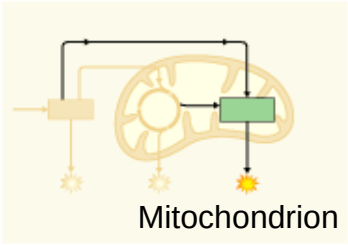
Occurs between membranes in the mitochondria in all animals, plants and prokaryotes

- Uses high energy electrons (stored in NADH and $FADH_2$) from Krebs to convert ADP to ATP.
- Carrier proteins imbedded in the mitochondrial membrane pass high-energy electrons along and force H^+ into the intermembrane space
- Oxygen is the final electron acceptor and combines with hydrogen to form water

- As the amount of H^+ builds in the intermembrane space, one H^+ rushes back across the inner membrane causes ATP synthase to spin, re-energizing ADP to ATP.
- Each pair of e^- generate enough energy to transform 3 ADP to 3 ATP.
- Total ATP = 32
- Total ATP generated in all steps of cell respiration= 36

Figure 9–7 Electron Transport Chain

ETC Movie



Energy and Exercise

- Cells normally contain enough ATP for a few seconds of intense activity.
- After 90 seconds, cellular respiration supplies ATP
- For long-term activity, glycogen stored in the muscle is burned and lasts 15-20 minutes. After that, other molecules such as fat are burned for energy (aerobics, running & swimming)
- Need to breathe heavy after exercise to repay oxygen debt and rid body of lactic acid

Comparing Photosynthesis and Cellular Respiration

- Photosynthesis does not release energy from glucose
- Photosynthesis removes CO_2 and respiration returns it.
- Products in photosynthesis are reactants in respiration.