BIO 311C
Spring 2010

Lecture 27 – Monday 5 Apr.

Metabolic Pathways and Processes that Participate in Respiration

- Glycolysis ..... Occurs in the cytoplasmic matrix

- Pyruvate dehydrogenase
- Krebs Cycle
- Mitochondrial electron transport chain
- Oxidative phosphorylation

} Occur in mitochondria of eukaryotic cells

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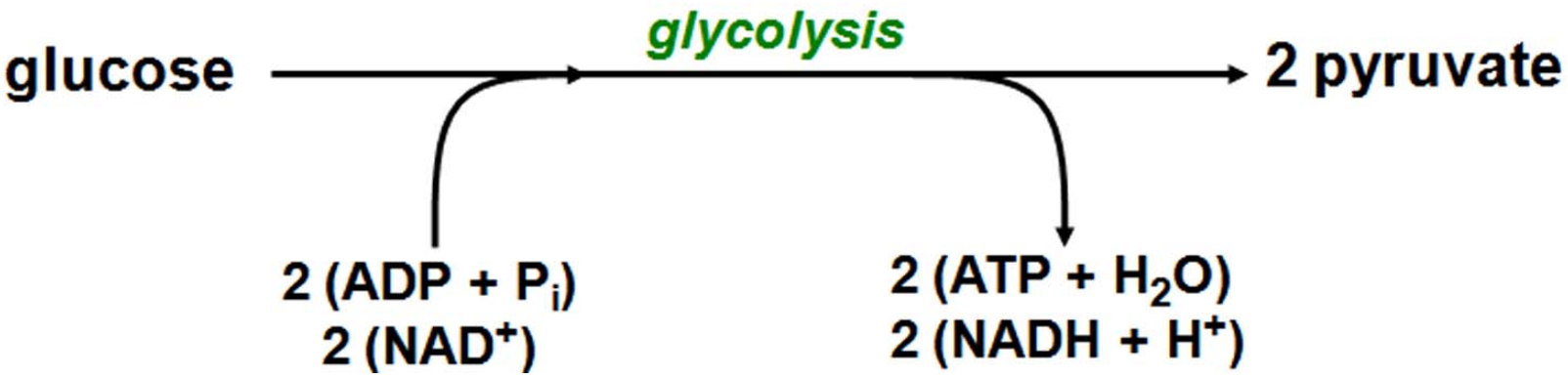
Reactants and Products of Glycolysis



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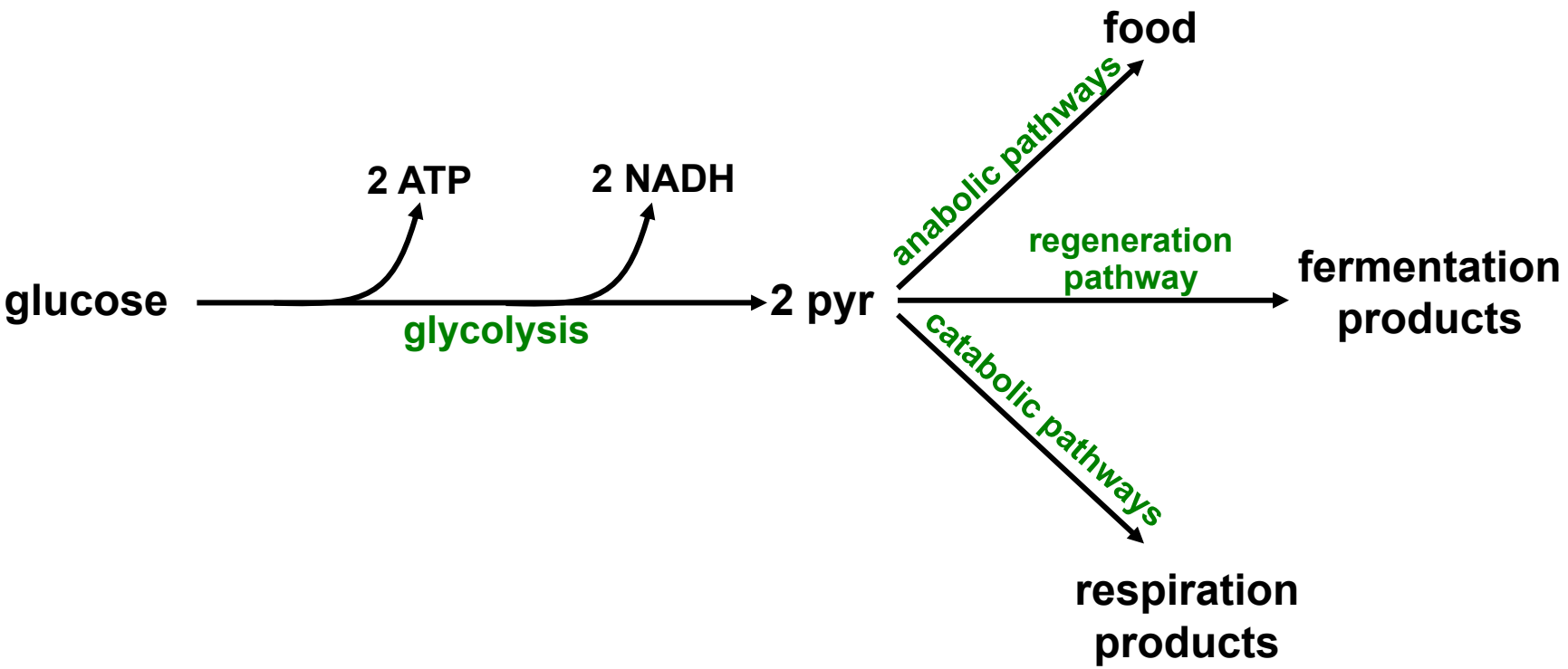
Some Alternative Possible Fates of the Pyruvate Generated During Glycolysis



- Pyruvate may serve a a food source for making bigger and more complex molecules, using anabolic pathways.

- Pyruvate may be chemically reduced by fermentation in one of more reactions that regenerate NAD^+ from NADH.

- Pyruvate may serve as a fuel by continuing respiration, using catabolic pathways.

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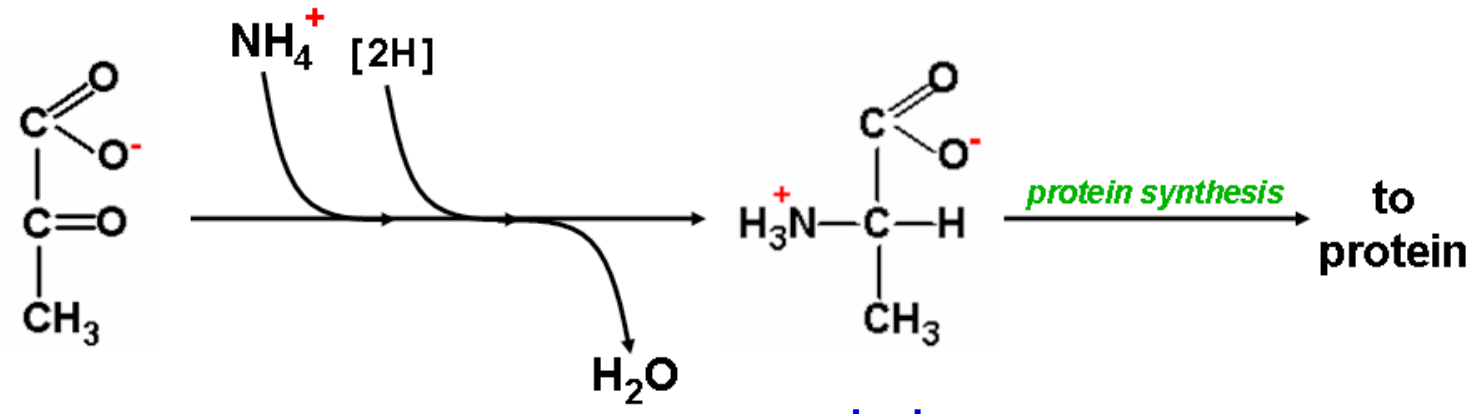
An Example of Pyruvate Used as a Food (Building Material)



pyruvate

alanine
(an amino acid)

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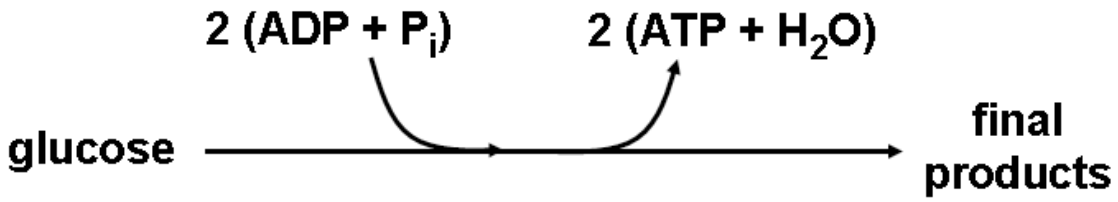
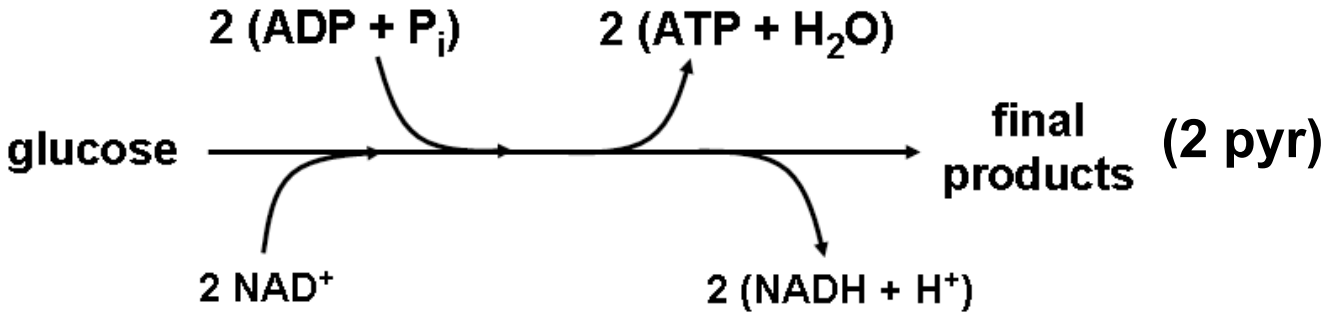
Comparison of Chemical Equations for Fermentation and Glycolysis

Fermentation written as a single equation



Glycolysis written as a single equation



The equations for fermentation and glycolysis look similar, except that in fermentation no hydrogen atoms are released (i.e. there is no net oxidation of substrate).

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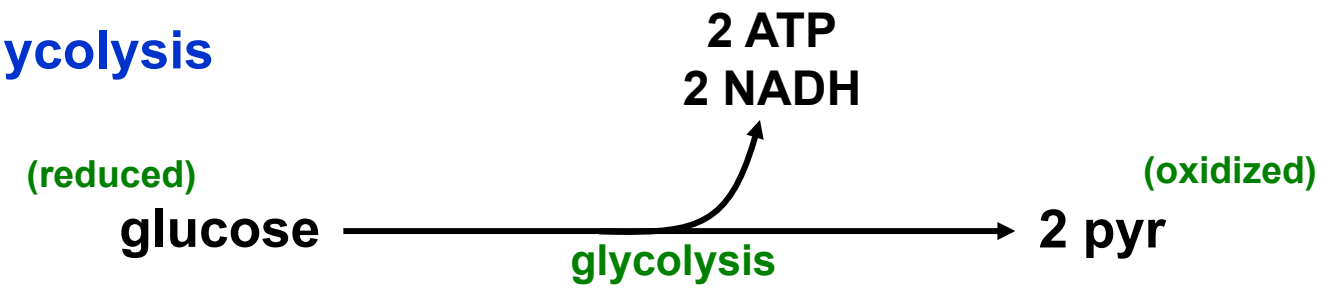
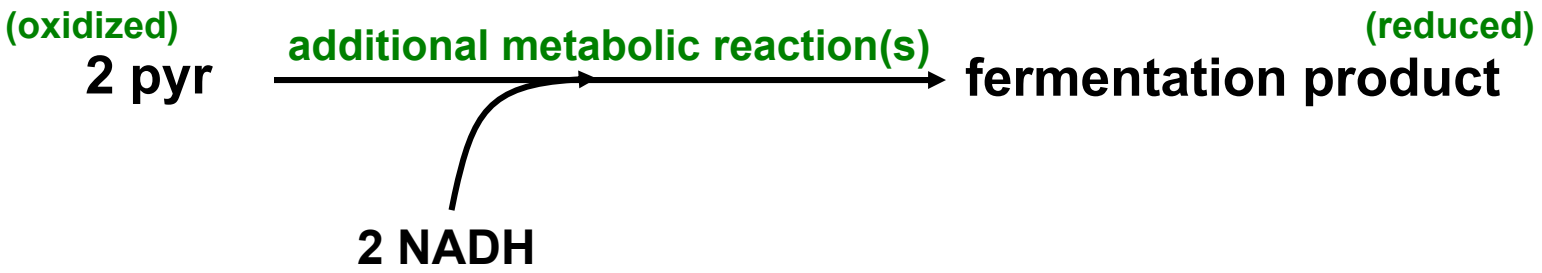
Definition: Fermentation -

An extended metabolic pathway that includes glycolysis plus one or more additional metabolic reaction that results in the chemical reduction of pyruvate or a substrate derived from it.

Glycolysis



Extending Reaction(s)



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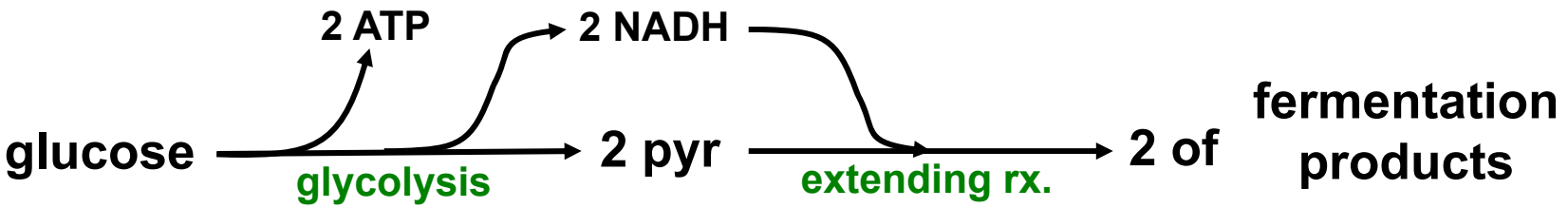
Fermentation, shown as a single metabolic pathway



The final fermentation product is often excreted from cells as waste.

Question: Is fermentation a catabolic process or is it an anabolic process?

Fermentation may be considered as two metabolic pathways, glycolysis and the extending reactions.

It may also be considered as a single metabolic pathway from glucose to the final fermentation products.

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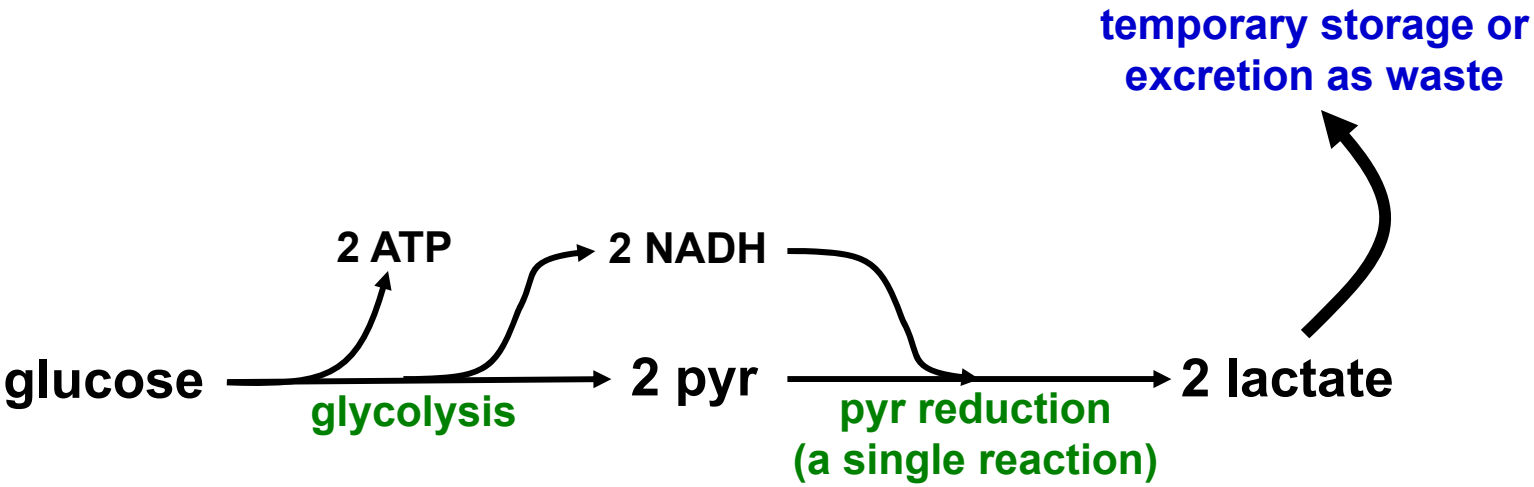
Lactate Fermentation



Lactate fermentation occurs in muscle cells when they cannot get enough oxygen to do complete respiration.

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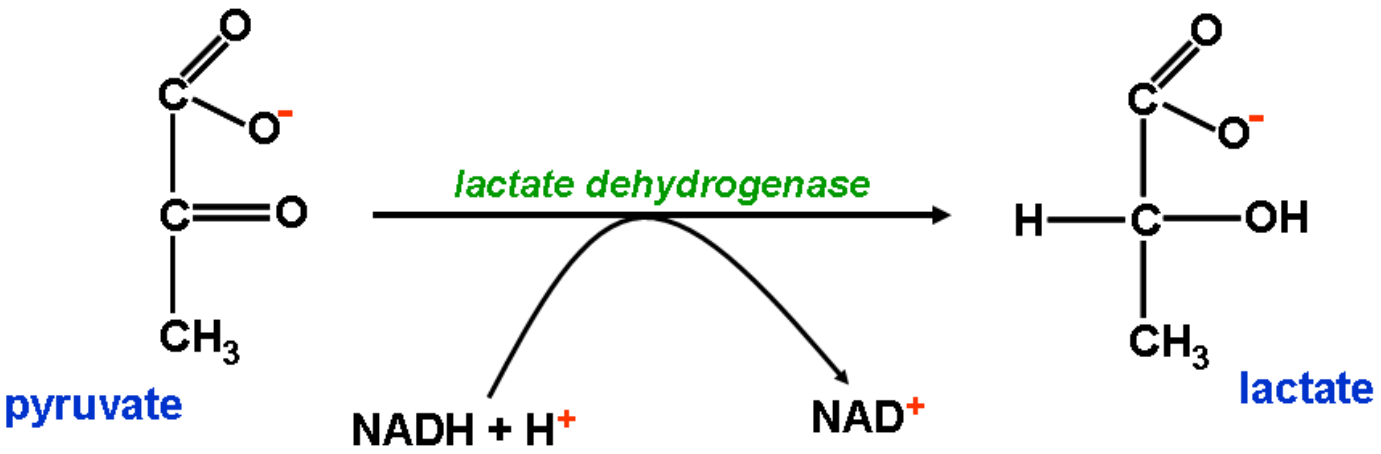
The Final Reaction in Lactate Fermentation



Note: we would multiply this chemical equation by two in order to show the number of lactate molecules generated from one molecule of glucose.

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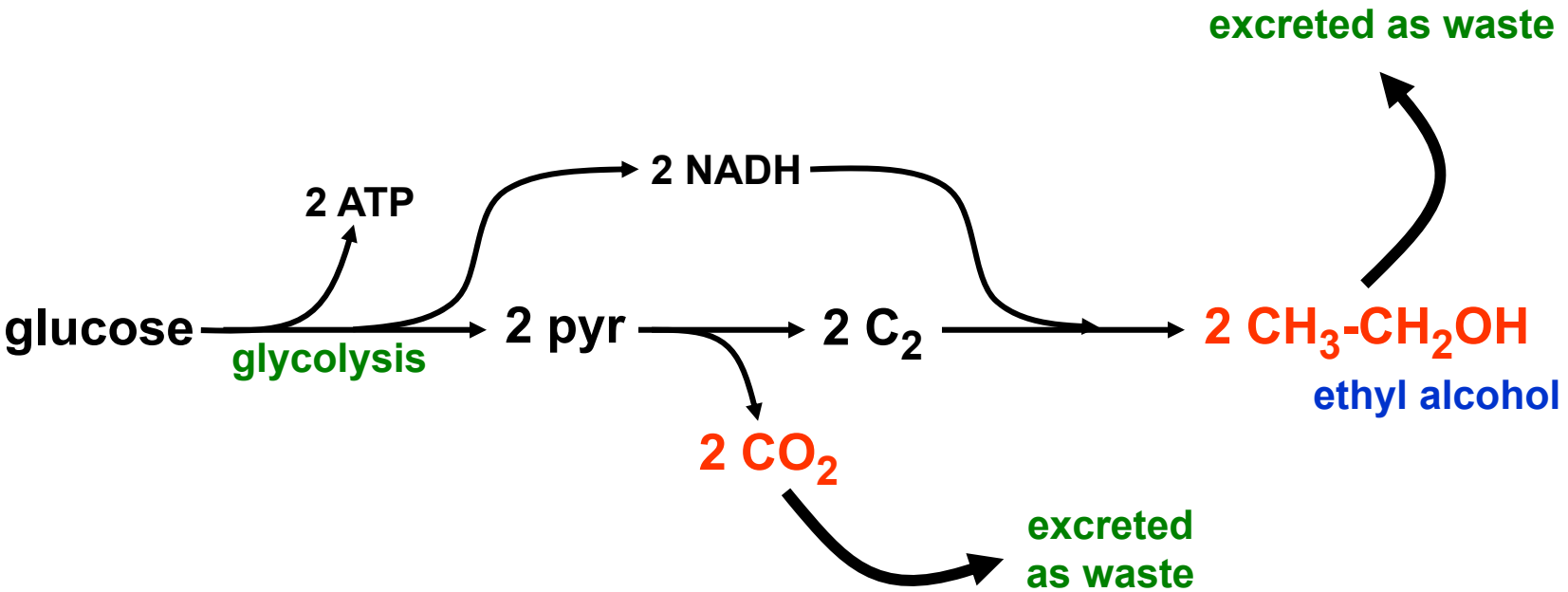
Some Details of Ethanolic Fermentation



Ethanolic fermentation includes two metabolic reactions in addition to glycolysis.

Balanced equation of ethanolic fermentation:

$$\text{glucose} + 2\,(\text{ADP} + P_i) \longrightarrow 2\ \text{ethanol} + 2\ CO_2 + 2\,(\text{ATP} + H_2O)$$

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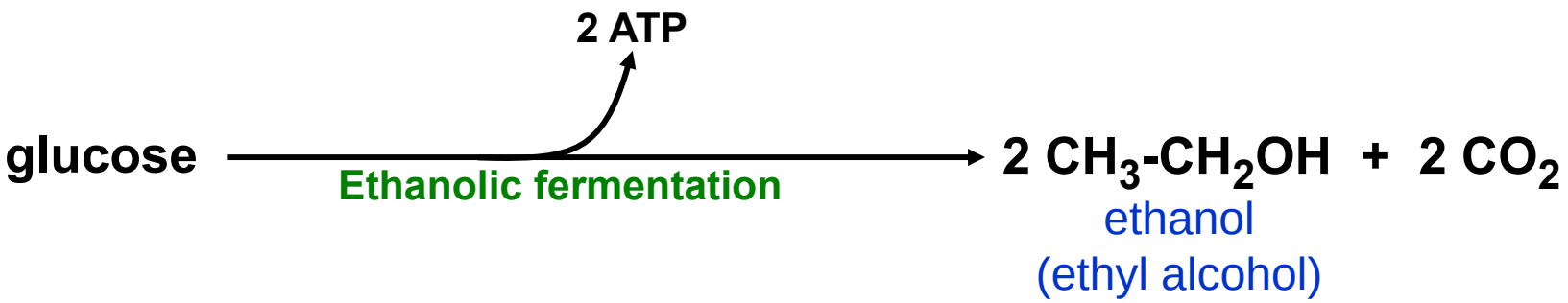
Abbreviated Equation of Ethanolic Fermentation



Ethanolic fermentation occurs in many kinds of cells during times that they are deprived of oxygen. It occurs in some kinds of yeast even in the presence of oxygen.

Note: In fermentation all products of glucose metabolism may be discarded except ATP.

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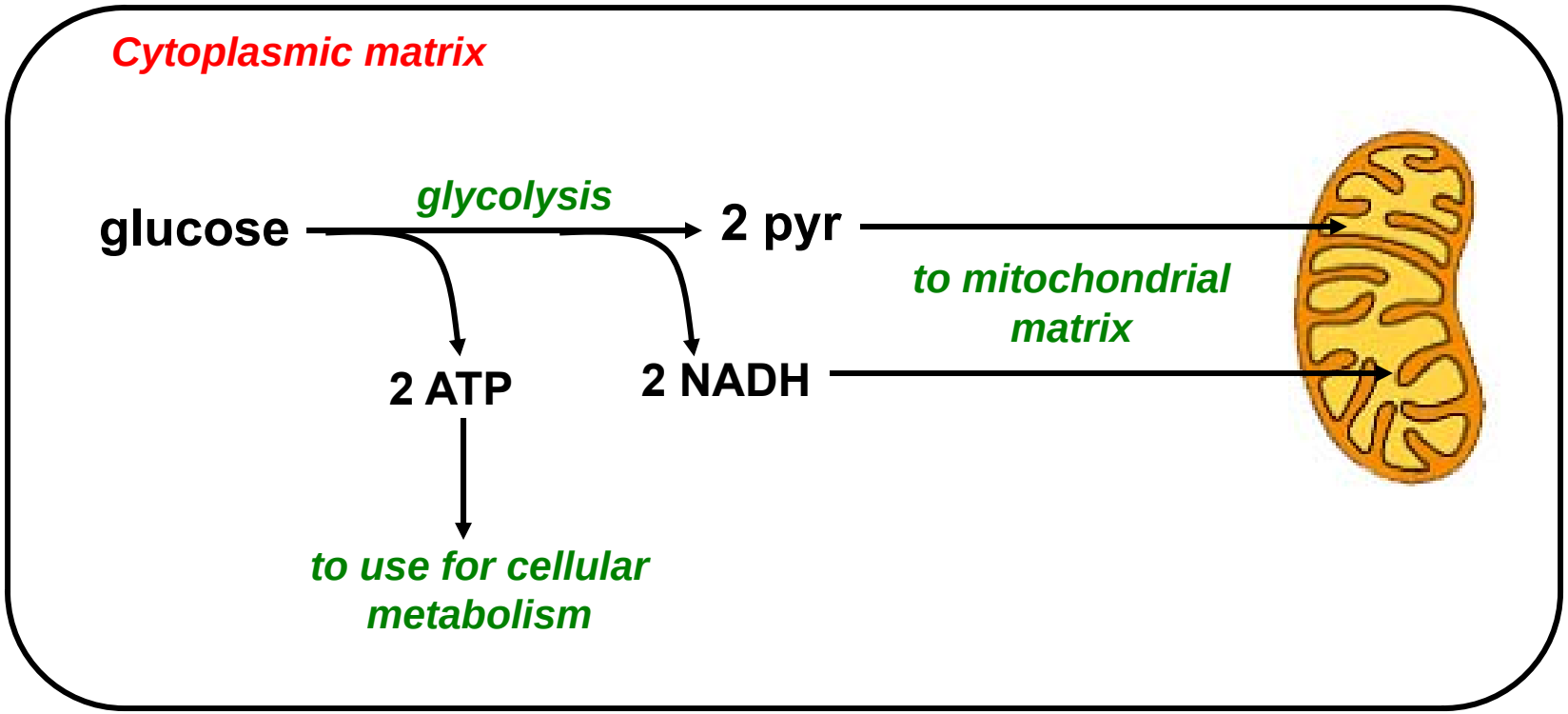
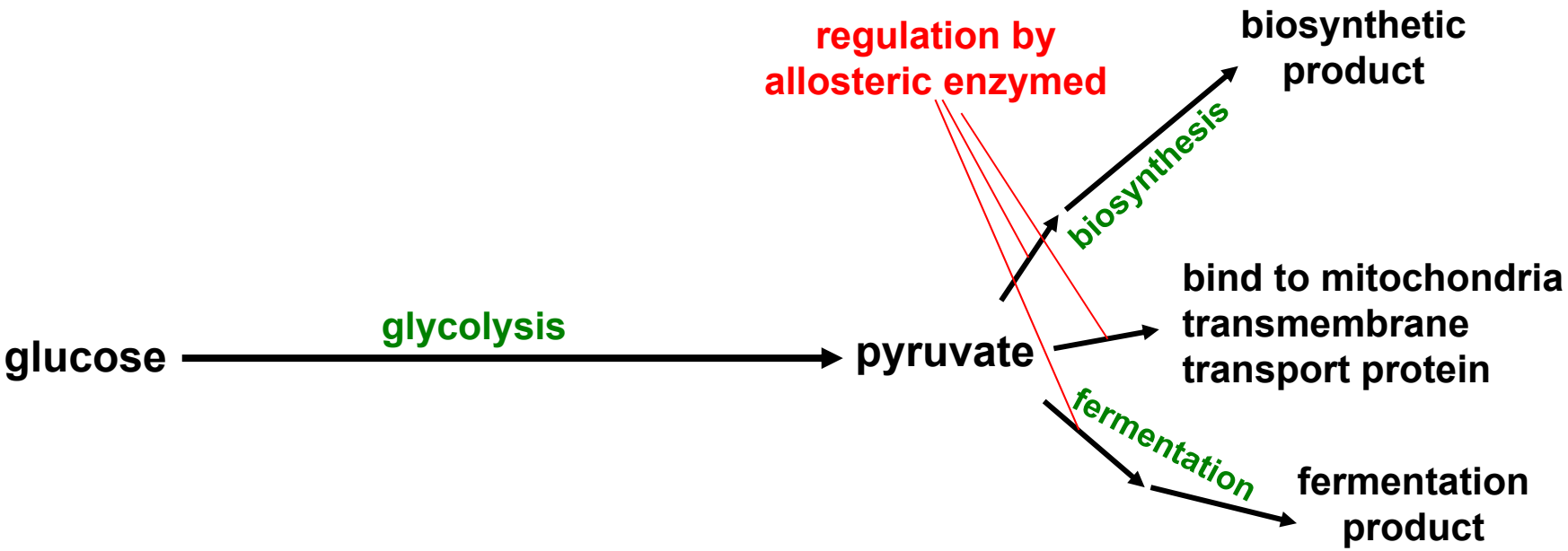
By far the most common fate of products of glycolysis in most kinds of cells is to proceed through respiration. In eukaryotic cells the remainder of respiration takes place in mitochondria.



Both pyruvate and NADH bind to mitochondrial transmembrane proteins and are moved across the envelope by active transport. *

The fate of the pyruvate produced during glycolysis is determined by the relative activities of various allosteric proteins that can act on pyruvate.



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Metabolic Pathways and Processes that Participate in Respiration

- Glycolysis
- Pyruvate dehydrogenase → occurs in the matrix of mitochondria in eukaryotes
- Krebs Cycle
- Mitochondrial electron transport chain
- Chemiosmosis

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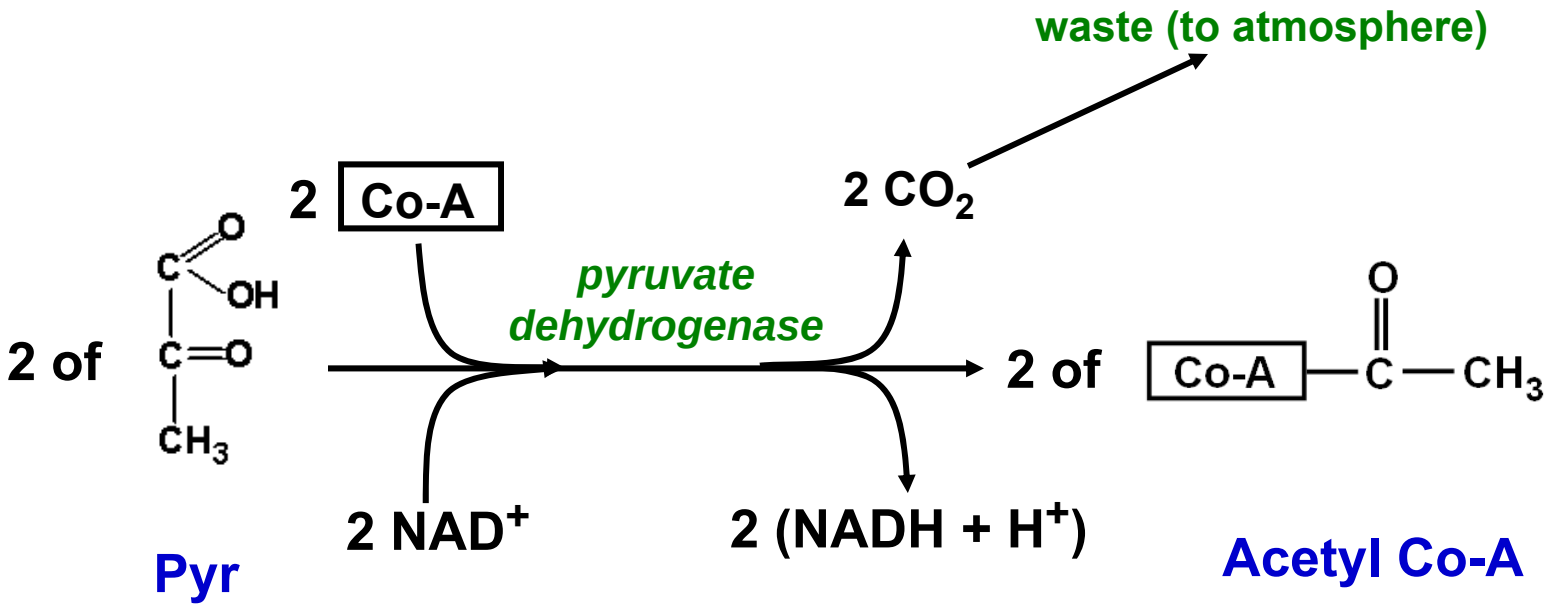
Pyruvate is metabolized in a metabolic pathway called pyruvate dehydrogenase.



Pyruvate dehydrogenase is a cluster of several enzymes bound together and acting as a unit in the mitochondrial matrix. It is often considered as a single enzyme, but it actually involves several different reactions with a product of one reaction serving as a reactant of the next reaction. Thus, it may be thought of as a metabolic pathway rather than a single metabolic reaction.

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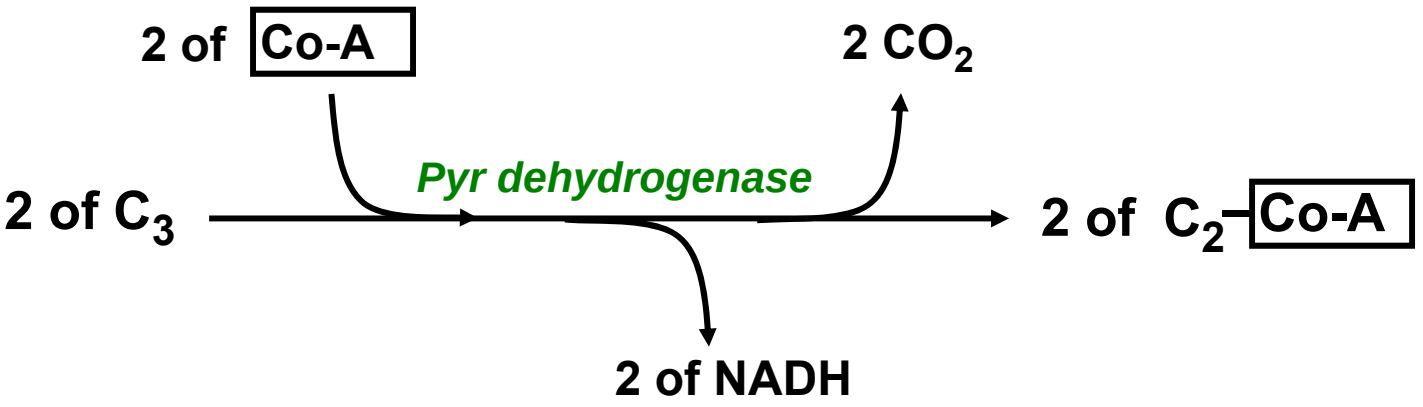
Abbreviated illustration of the Pyr dehydrogenase pathway*:



Co-A can be described as a C_2 carrier molecule. Its full name is Coenzyme A.

Would the pyruvate dehydrogenase pathway best be described as anabolic or catabolic?

Balanced equation of pyr dehydrogenase

$$2\,(\,Pyr + CoA + NAD^+) \longrightarrow 2\,(C_2\text{-}CoA + CO_2 + NADH + H^+)$$

*All substrates are shown here multiplied by 2 in order to consider the number of substrates generated from one glucose molecule, since during glycolysis each glucose produces two pyruvates.

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Metabolic Pathways and Processes that Participate in Respiration

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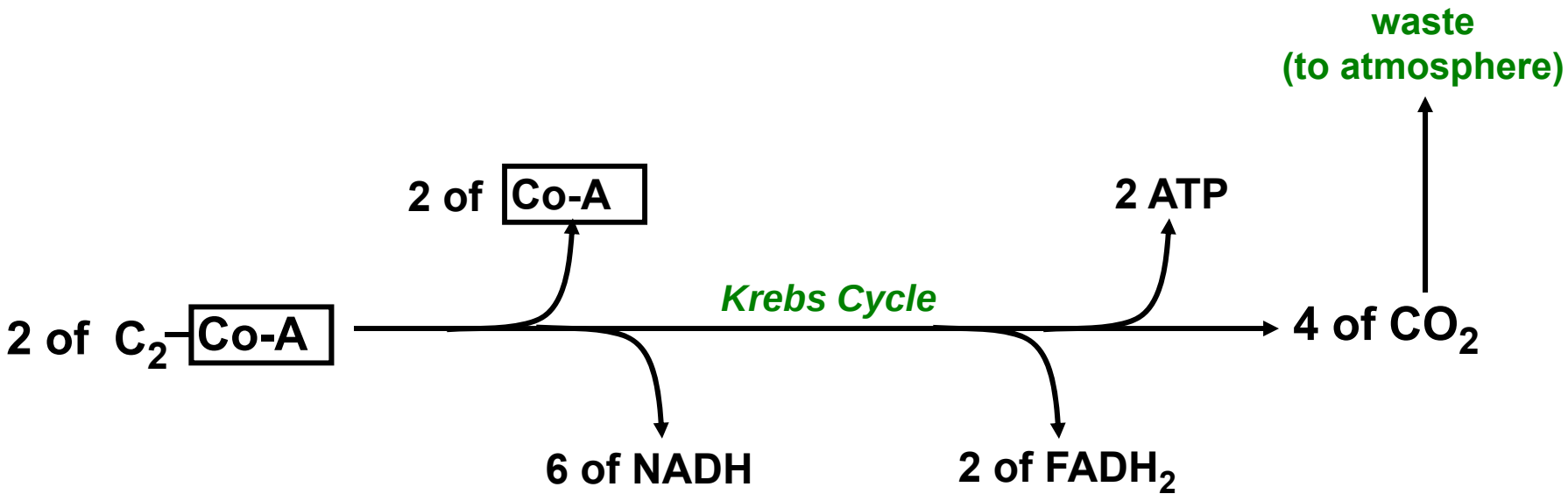
The Citric Acid Cycle (also called the TCA Cycle and the Krebs Cycle), Showing Important Products



Is the Krebs cycle a catabolic pathway or is it an anabolic pathway?

Balanced equation of the TCA cycle:

$$2\left\{C_2\text{-CoA} + 3\ NAD^+ + \ FAD + (ADP + P_i)\right\} \xrightarrow{\textit{Krebs Cycle}}$$

$$2\left\{CoA + 2\ CO_2 + 3\ (NADH + H^+ + FADH_2 + (ATP + H_2O)\right\}$$

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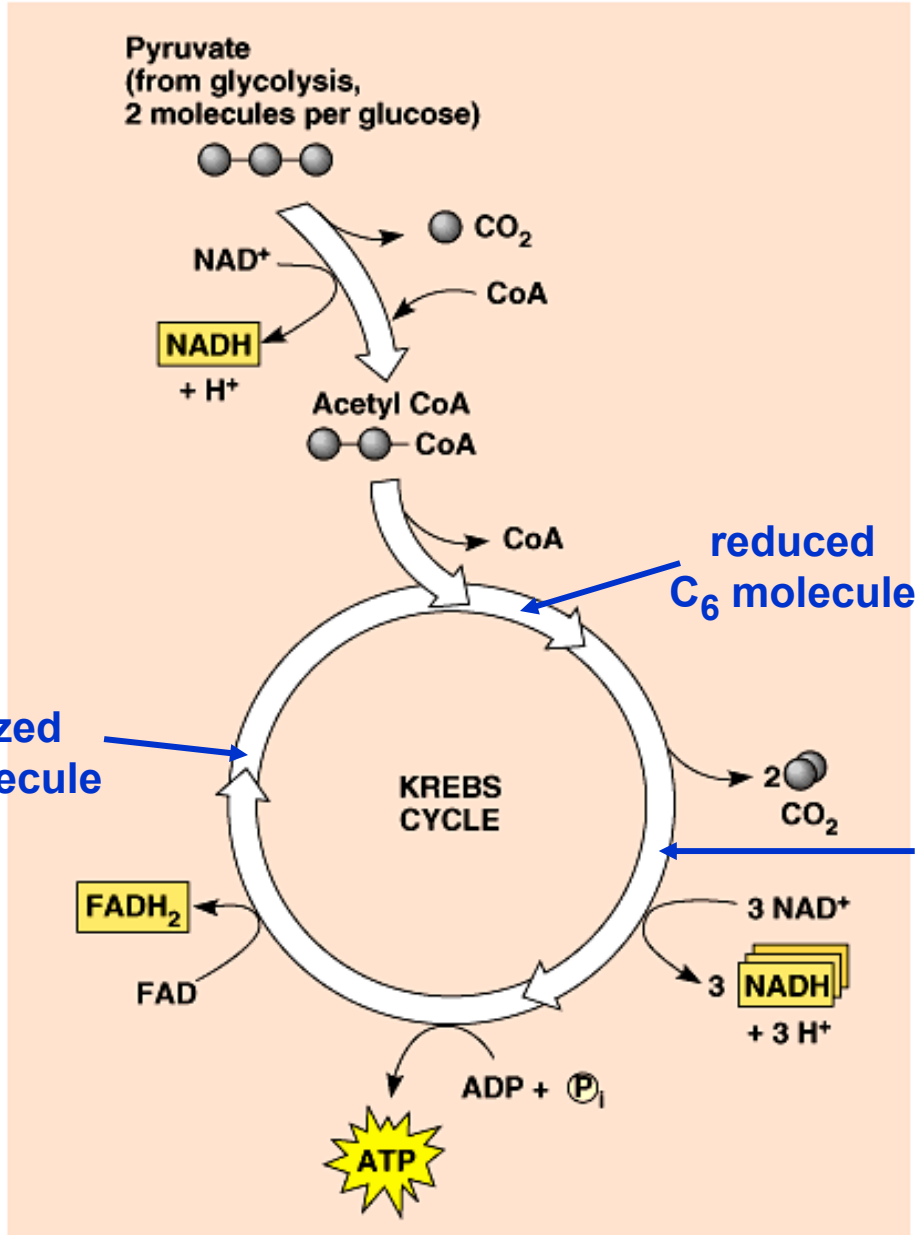
An Overview of pyr dehydrogenase and the TCA Cycle



Textbook Fig. 9.11, p. 170

The number of each substrate shown must be multiplied by 2 in order to account for the total number produced from each molecule of glucose.

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Some Intermediate and Final Products of Respiration

From Glycolysis		2 ATP/glucose
		2 NADH/glucose
From Pyr Dehydrogenase	1 NADH/pyruvate	2 NADH/glucose
	1 CO_2/pyruvate	2 CO_2/glucose
From the Krebs Cycle	3 NADH/C_2-CoA	6 NADH/glucose
	1 $FADH_2$/C_2-CoA	2 $FADH_2$/glucose
	1 ATP/C_2-CoA	2 ATP/glucose
	2 CO_2/C_2-CoA	4 CO_2/glucose

Sum - each molecule of glucose metabolized through glycolysis, pyruvate dehydrogenase and the Krebs cycle produces:

6 CO_2 diffuses out of the cell

10 NADH, 2 $FADH_2$ } remain in the mitochondrion, where they are further metabolized

4 ATP is distributed throughout the cell

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Metabolic Pathways and Processes that Participate in Respiration

- Glycolysis
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- Chemiosmosis

} Oxidative phosphorylation

Uses the matrix, intermembrane space and inner membrane of the mitochondrion

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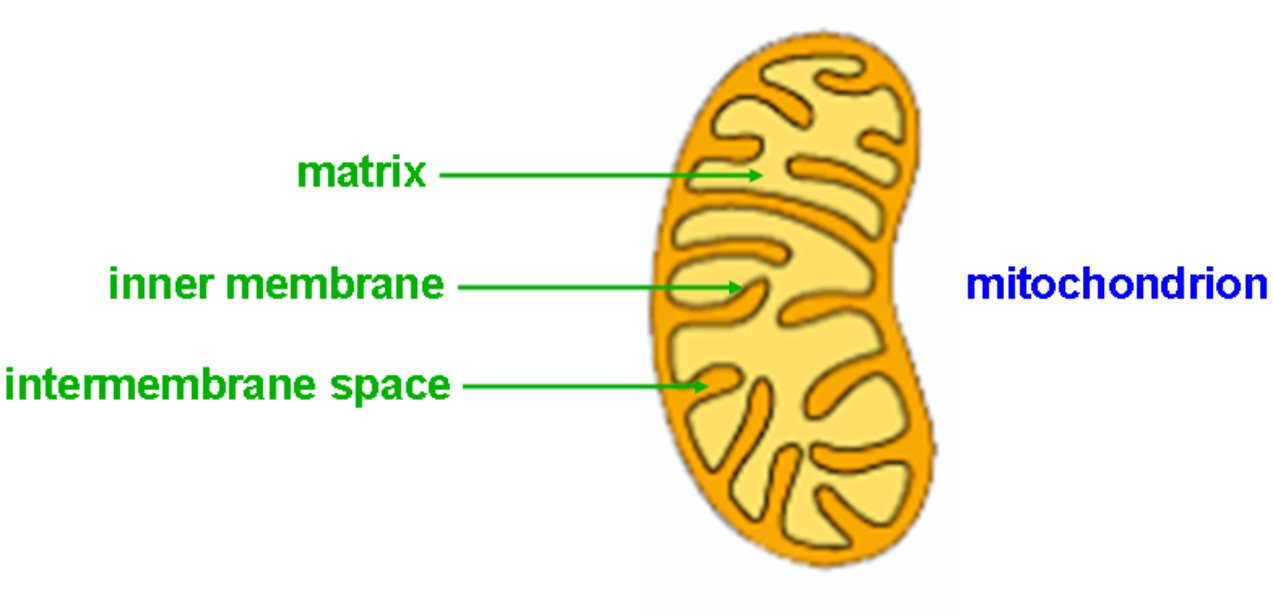
Definition - Oxidative Phosphorylation:

The production of ATP using energy derived from oxidation/reduction (redox) reactions of an electron transport chain.

Oxidative phosphorylation requires that the redox reactions occur within a membrane that separates two distinct compartments.

Compartments of the Mitochondrion Essential for Oxidative Phosphorylation



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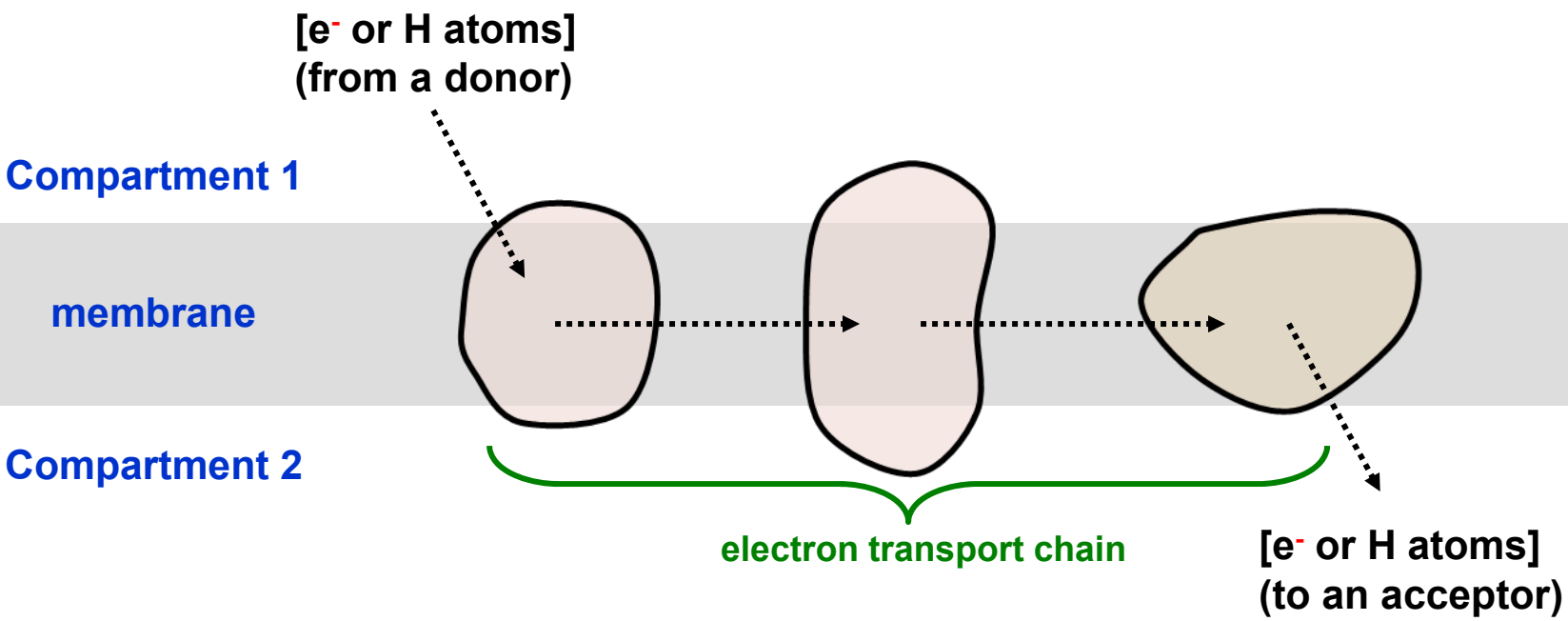
An Electron Transport Chain Within a Biological Membrane



Reducing units (hydrogen atoms or electrons) are carried sequentially from one transmembrane protein to another. The transfer is one-way only, since the ΔG value for each electron transfer reaction is negative.

The mitochondrion inner membrane contains an electron transport chain. *