CELLULAR RESPIRATION

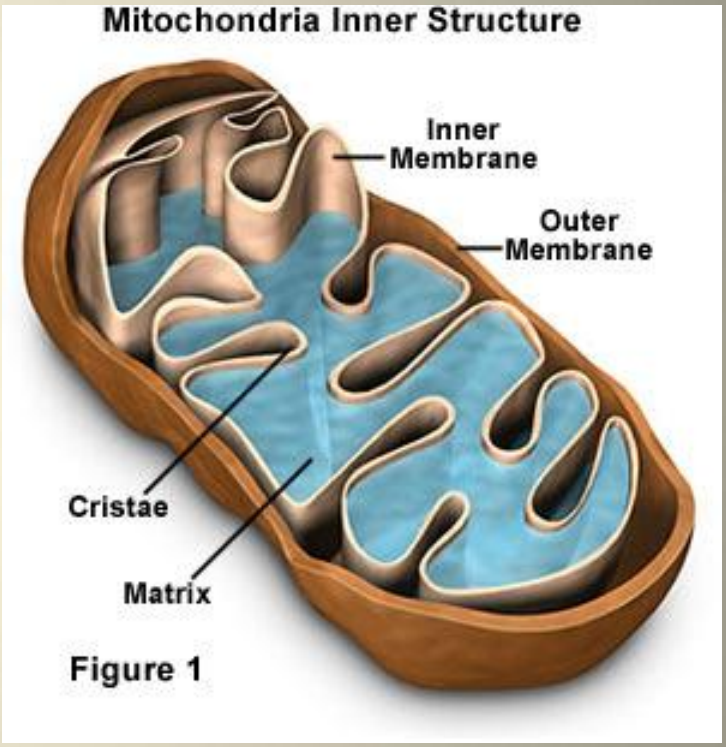
Part 2:

Oxidation of Pyruvate

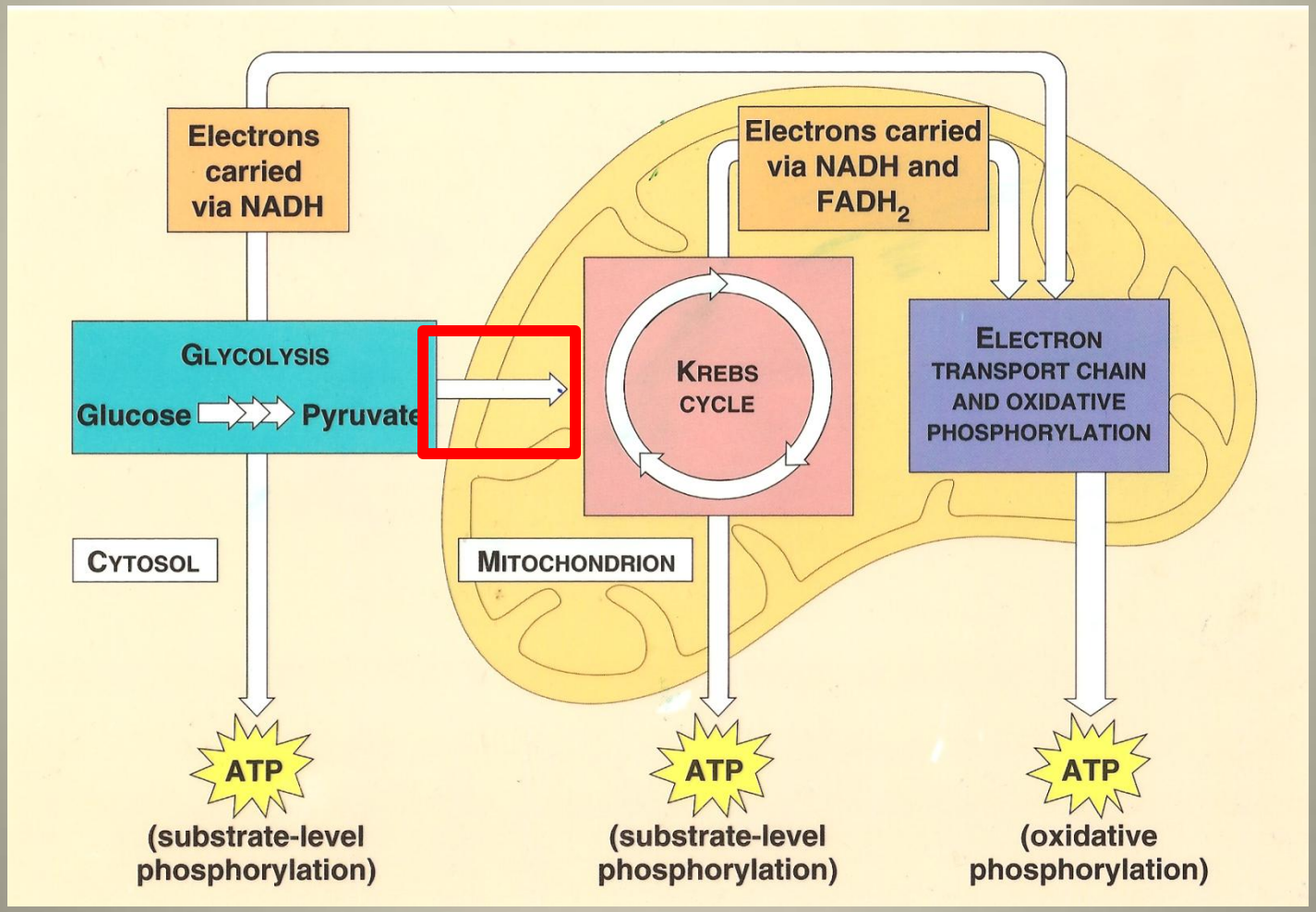
Krebs Cycle

Recall: Location

- Glycolysis occurs in the cytoplasm
- Krebs cycle occurs in the matrix
- The end product of glycolysis (pyruvate) must make its way into the mitochondria

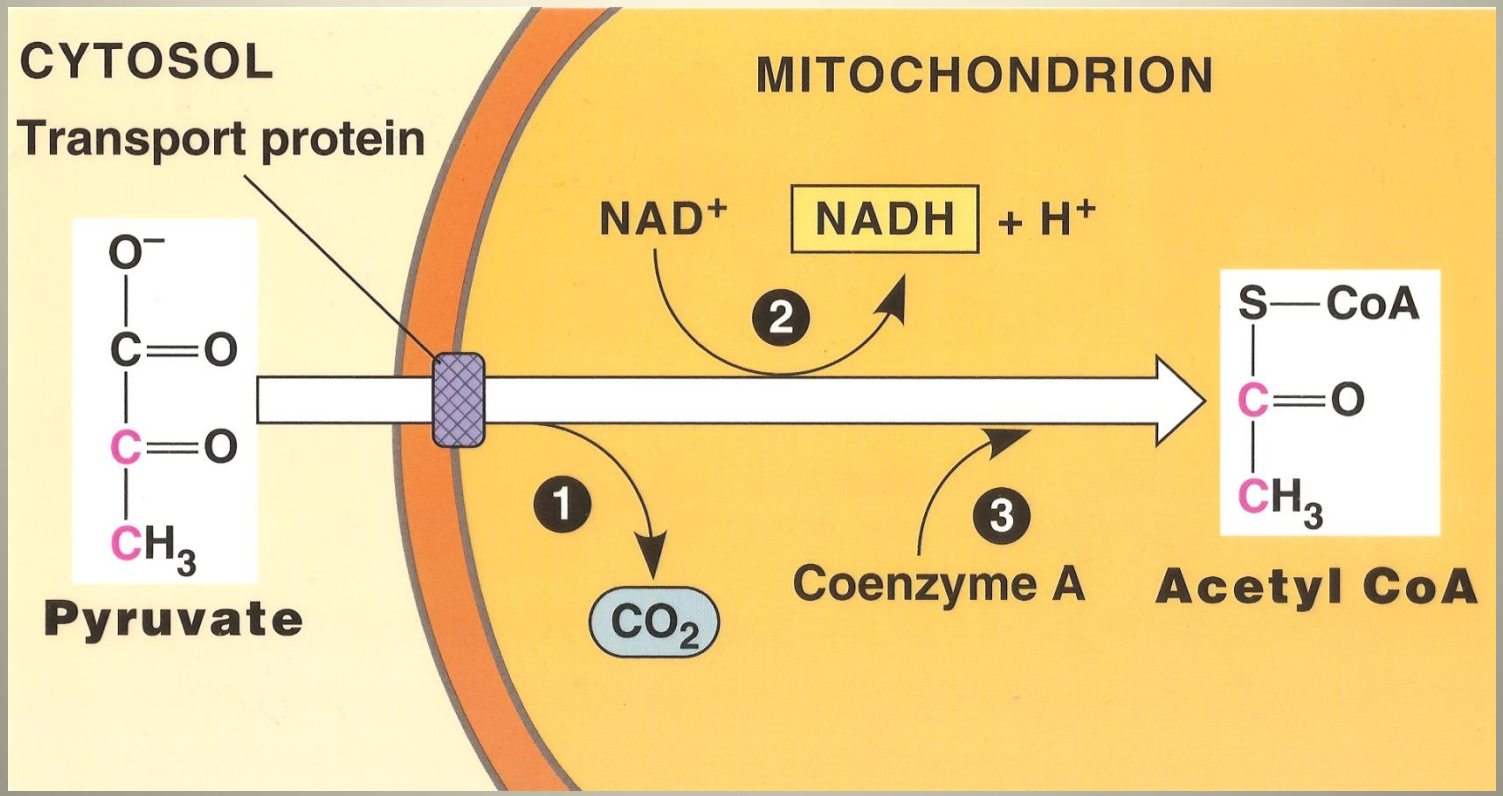


Oxidative Decarboxylation



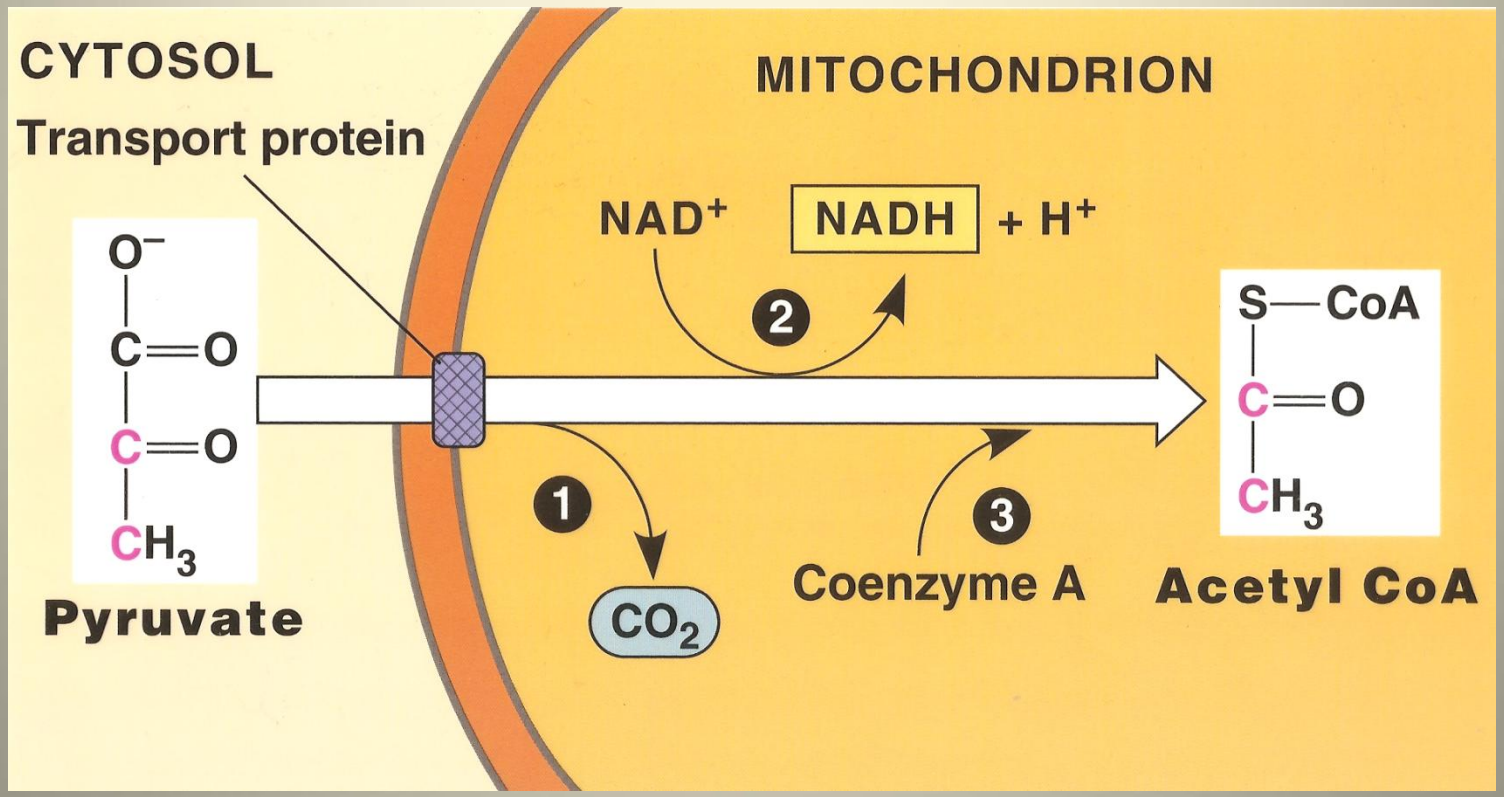
Pyruvate Oxidation / Oxidative Decarboxylation

- Decarboxylation
- Redox reaction
- Coenzyme A addition



Pyruvate Oxidation / Oxidative Decarboxylation

- Pyruvate (3C) is converted into acetyl-CoA (2C) in order to be brought into the Kreb's cycle



Pyruvate Oxidation / Oxidative Decarboxylation

Reaction type:

- decarboxylation
- redox
- synthesis

Enzyme:

- decarboxylase
- dehydrogenase
- synthase

Energy: released

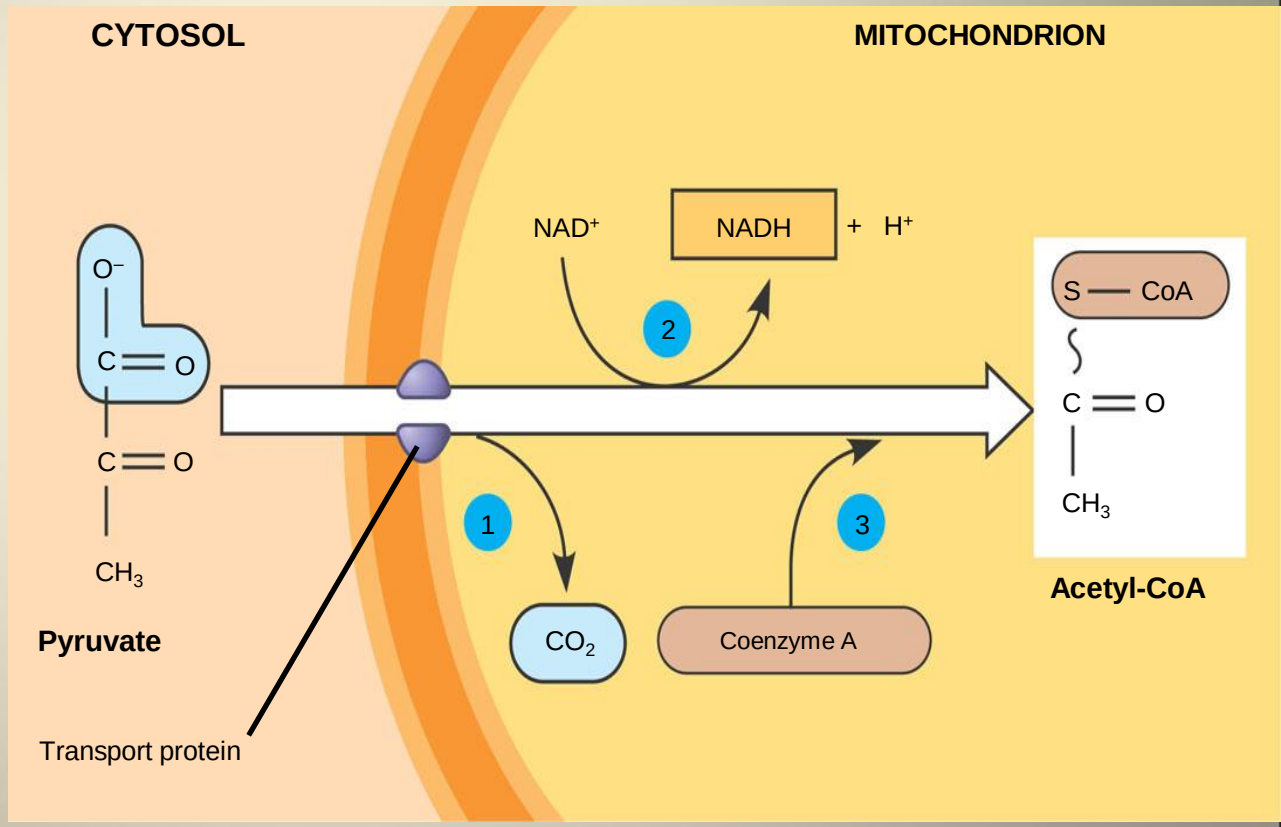
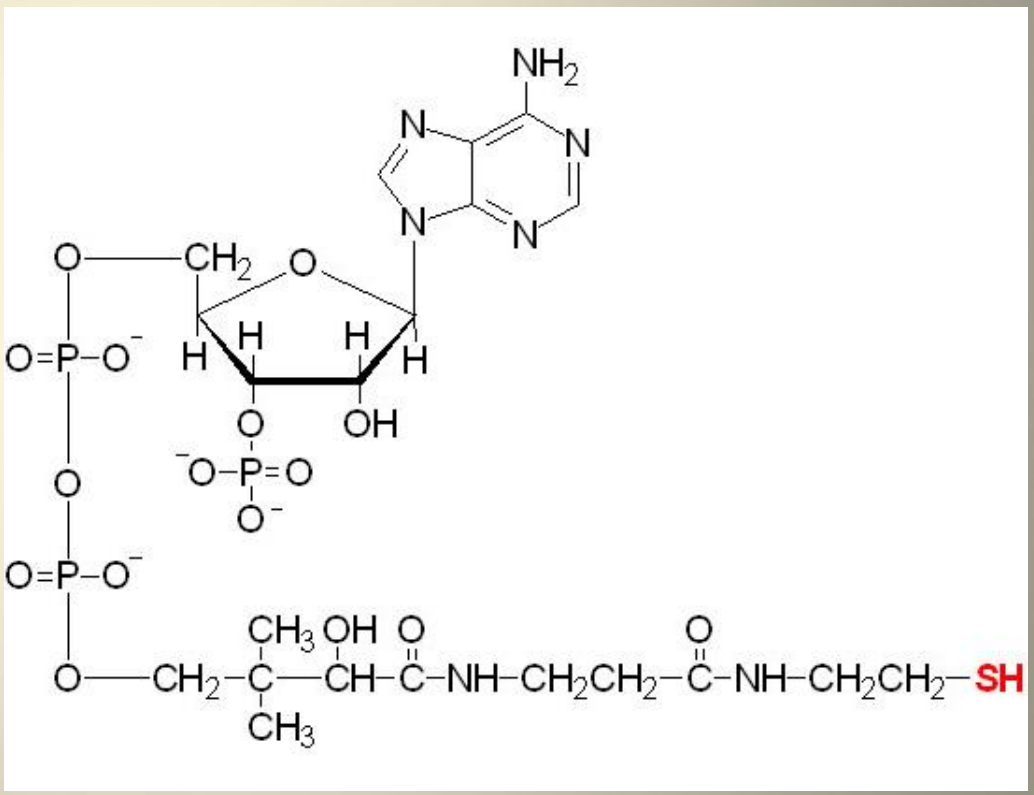


Figure 9.10

Coenzyme A

- Coenzyme A is a large organic molecule
- Active functional group is a thiol
- also written as CoA-SH



Pyruvate Oxidation / Oxidative Decarboxylation Summary

- 2 pyruvate → 2 acetyl-CoA
- 2 CO_2 released
- 2 NADH produced

Molecule Count: Per Glucose

	ATP	NADH	$FADH_2$	CO_2
Glycolysis	2	2	0	0
Pyruvate Oxidation				
Krebs				
Subtotal				
Conversion in ETC				

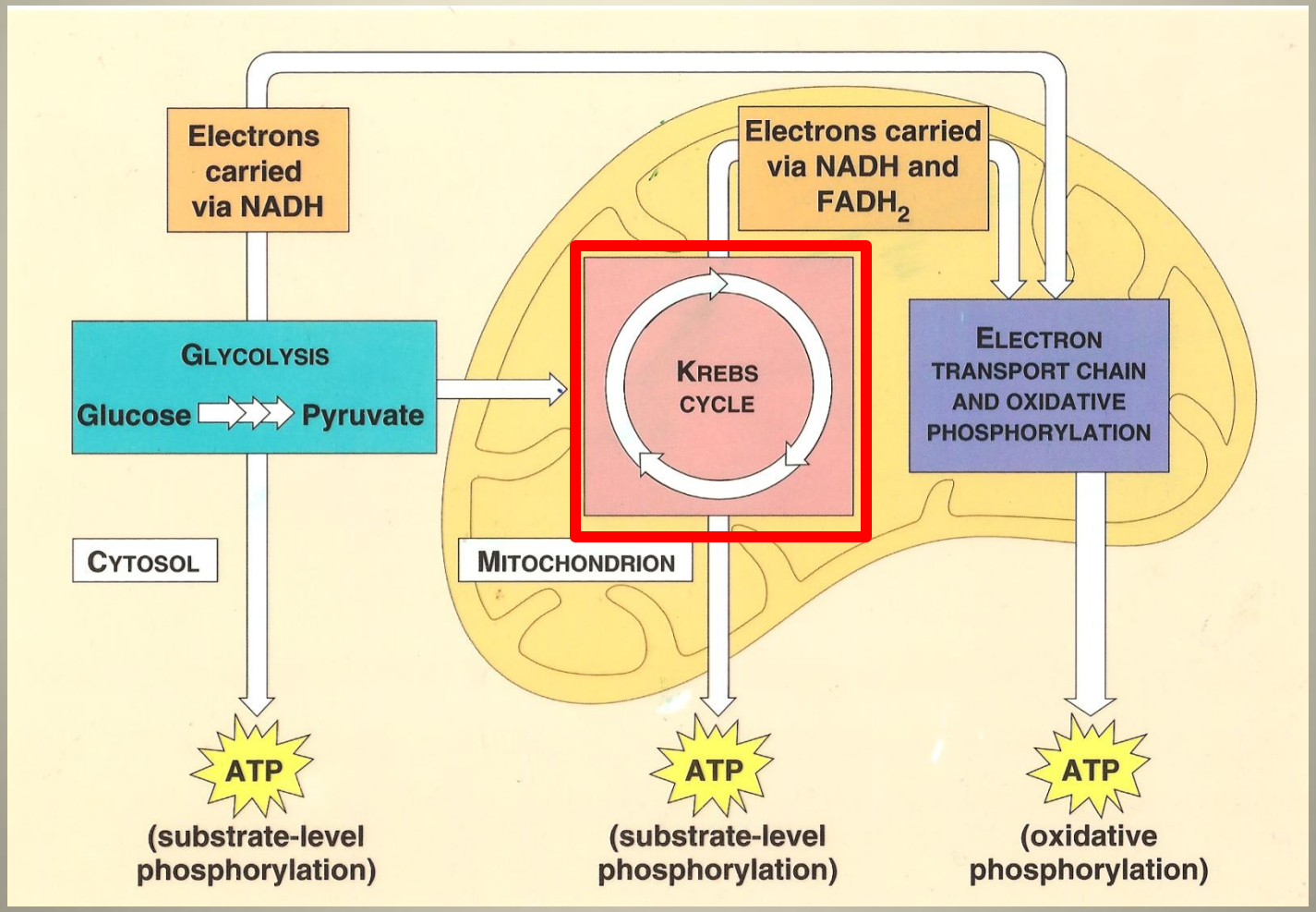
Molecule Count: Per Glucose

	ATP	NADH	$FADH_2$	CO_2
Glycolysis	2	2	0	0
Pyruvate Oxidation	0	2	0	2
Krebs				
Subtotal				
Conversion in ETC				

Important molecules in Pyruvate Oxidation and Krebs Cycle

- Pyruvate (pyruvic acid)
- Acetyl CoA
- Citrate (citric acid)
- Malate (malic acid)
- Oxaloacetate (OAA)
- CO_2
- ATP
- NADH
- $FADH_2$

Krebs Cycle


Electrons carried via NADH
Electrons carried via NADH and $FADH_2$
Glycolysis
Glucose → Pyruvate
Krebs cycle
Electron transport chain and oxidative phosphorylation
Cytosol
Mitochondrion
ATP
(substrate-level phosphorylation)
ATP
(substrate-level phosphorylation)
ATP
(oxidative phosphorylation)

Krebs Cycle

- Also known as:
  - citric acid cycle (CAC)
  - tricarboxylic acid cycle (TCA)

- Krebs cycle is a cyclical process that:
  - generates more high energy molecules (NADH, $FADH_2$ and ATP)
  - produces additional byproducts known as CO_2

Krebs Cycle Overview

- For each turn of Krebs cycle:
  - two carbons exit completely as CO2
  - three NADH and one FADH2 are formed
  - One ATP is made by substrate-level phosphorylation

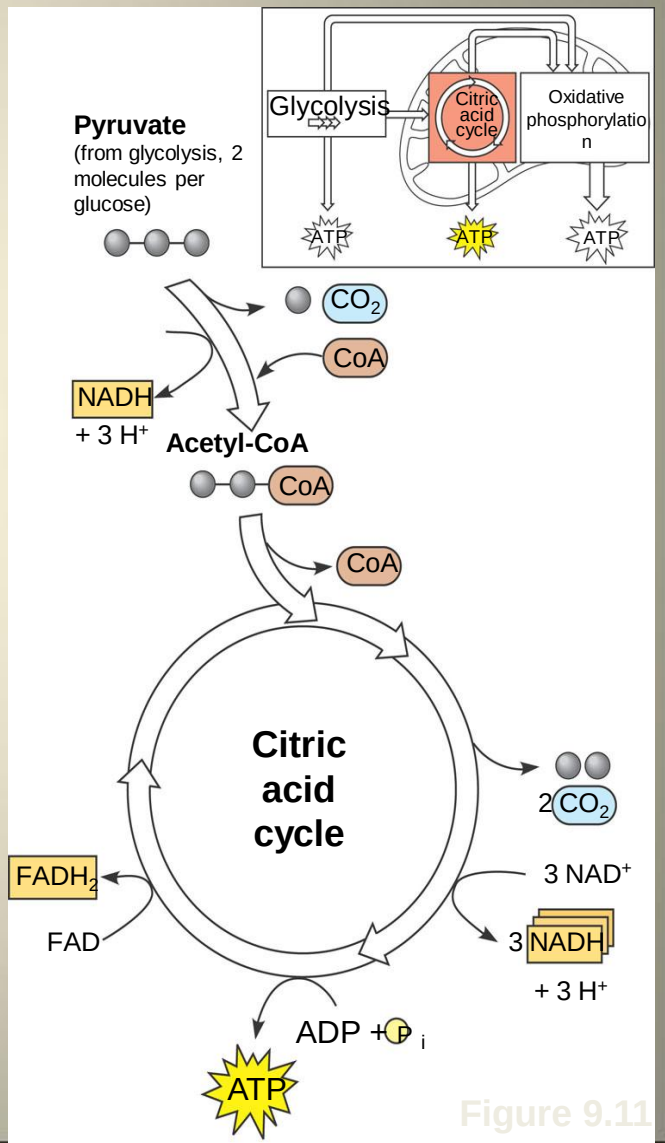
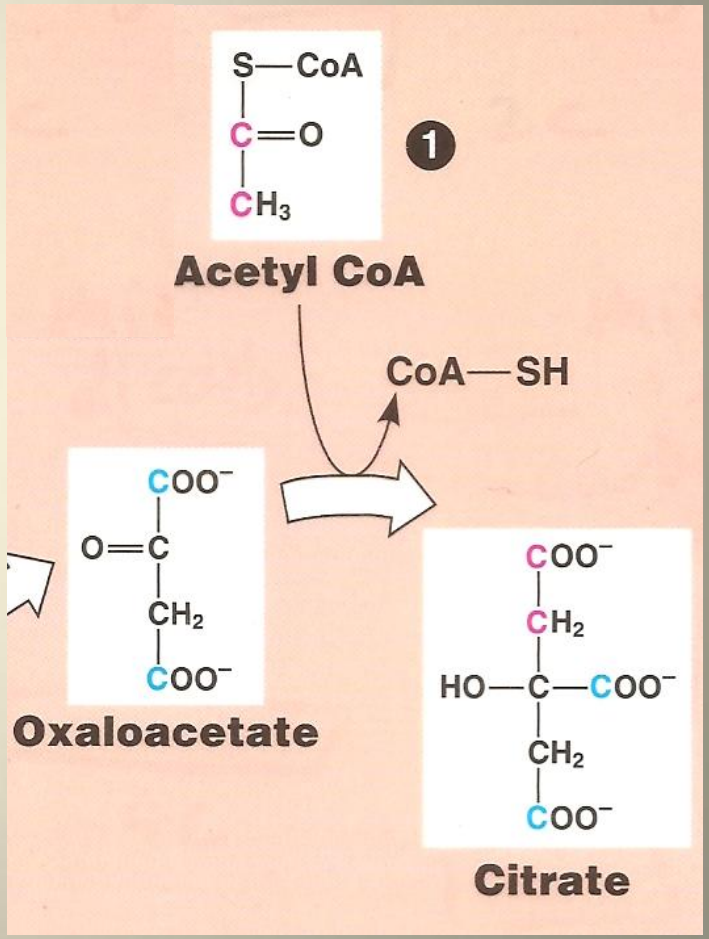


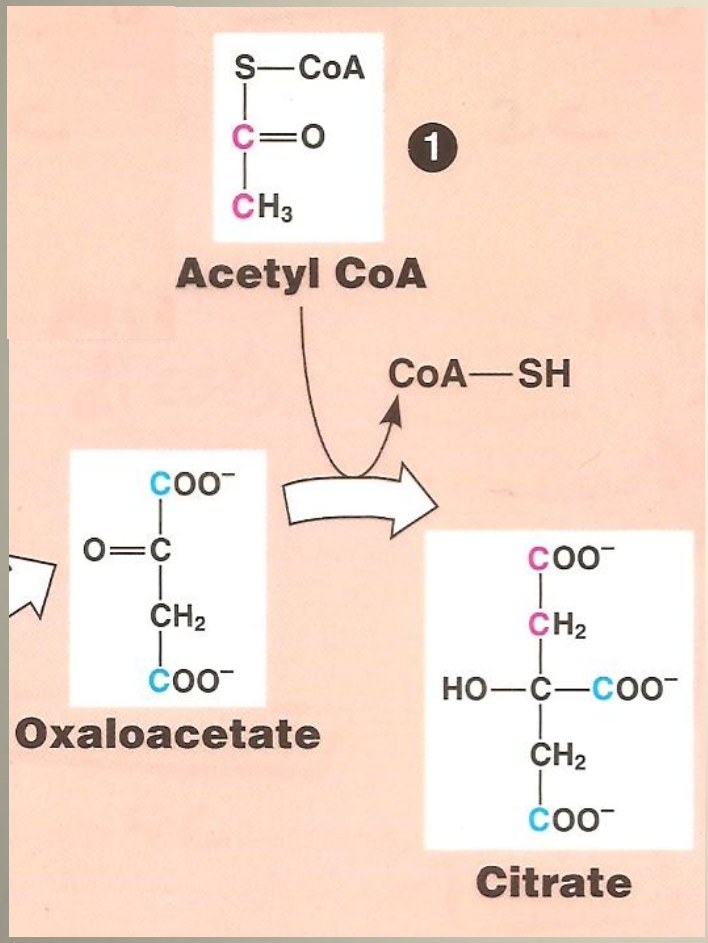
Figure 9.11

Activity

- You will given the first step in the Krebs cycle (right) along with the other 6 molecules involved
- Placed the molecules in order based on their structure
- Make sure the molecules cycle back to oxaloacetate
- Once your teacher has checked your answer, then hypothesize the class of enzyme that catalyzes each step of the reaction



Krebs Cycle: Step by Step

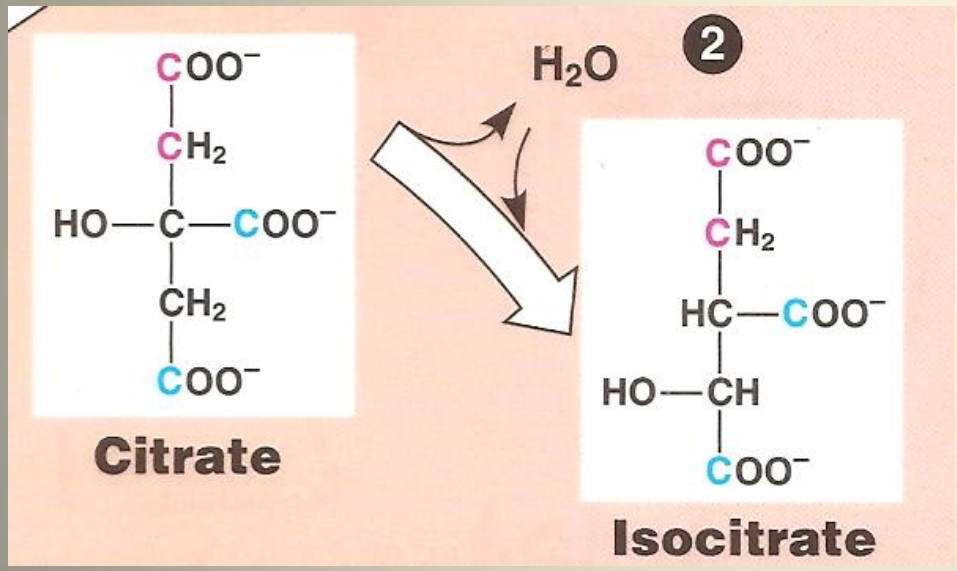


Step 1:

- join 2 carbon molecule with a 4 carbon molecule
- Recycling of CoA

- reaction type: synthesis
- enzyme: synthase
- energy: absorbed

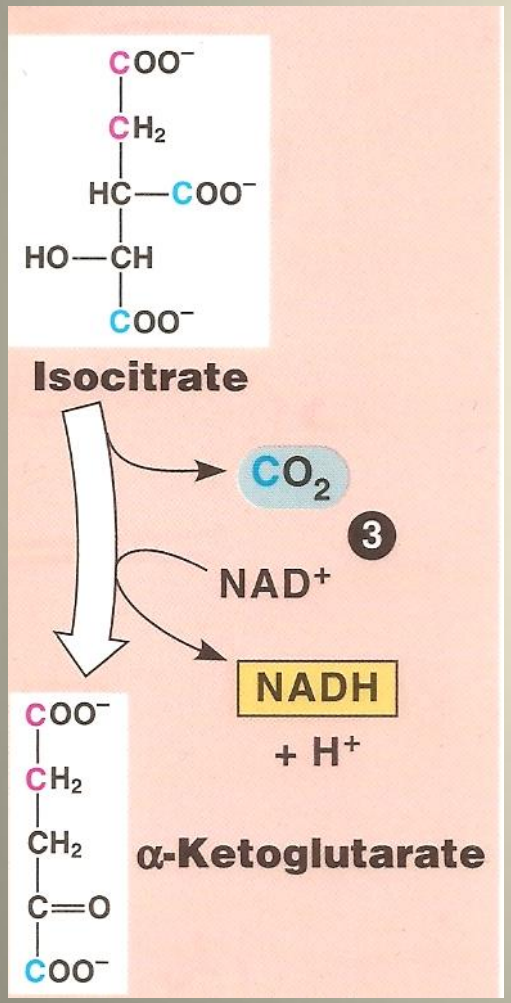
Krebs Cycle: Step by Step



Step 2:

- rearrangement of atoms with the help of H2O
- reaction type: isomerization
- enzyme: isomerase
- energy: equilibrium

Krebs Cycle: Step by Step



Step 3:

- synthesis of CO_2 and NADH
- 6C → 5C

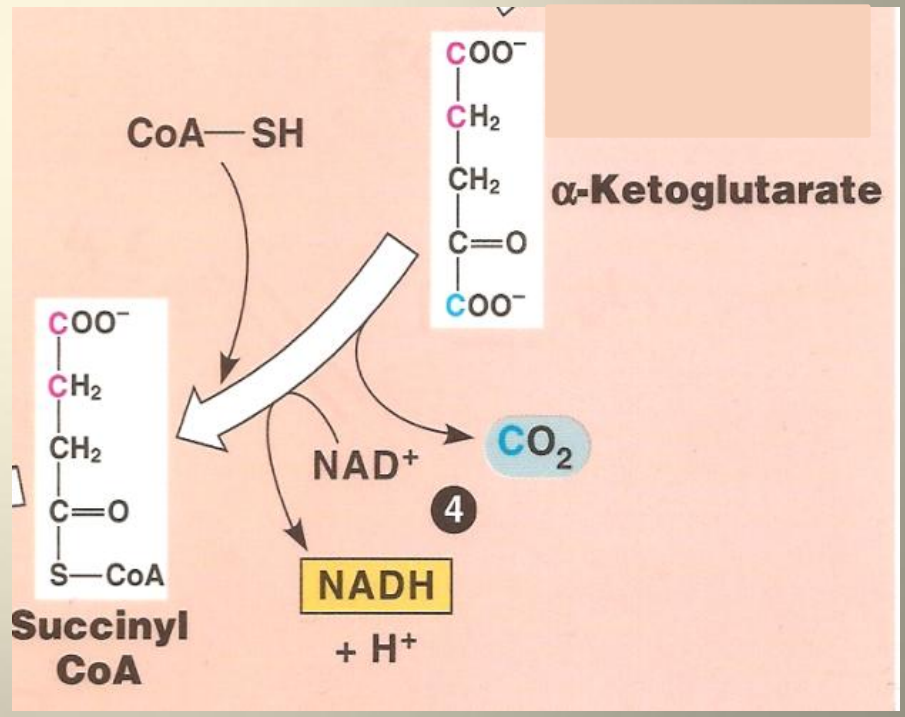
- reaction type:
  - decarboxylation
  - redox
- enzyme:
  - decarboxylase
  - dehydrogenase
- energy: released

Krebs Cycle: Step by Step

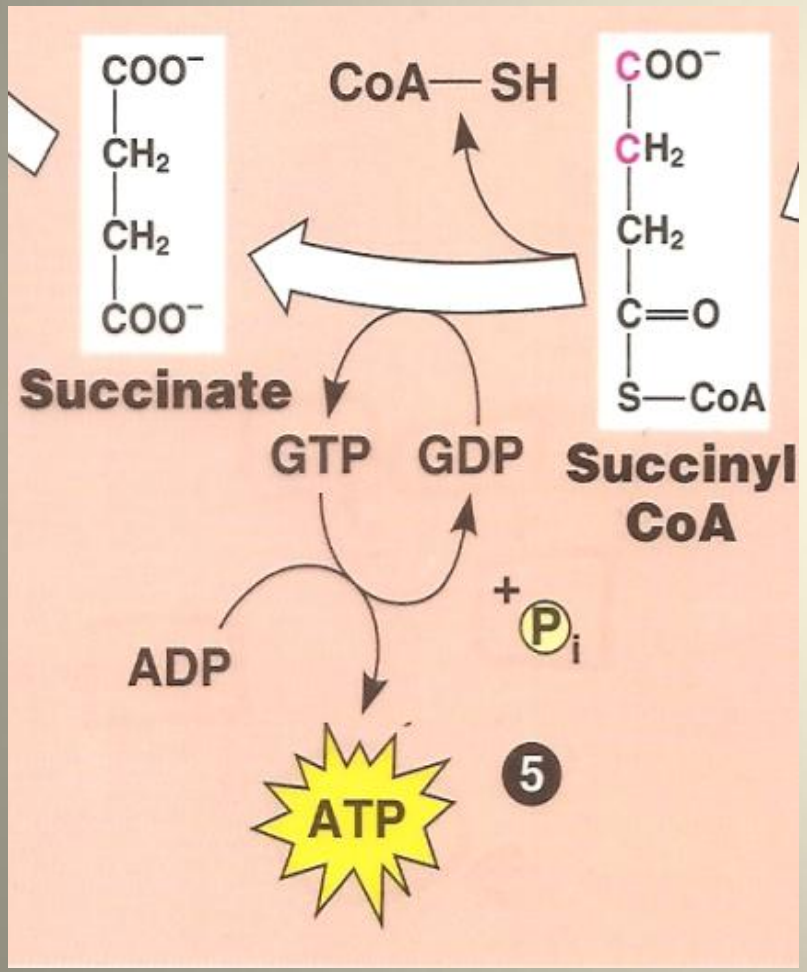
Step 4:

- synthesis of CO_2 and NADH
- 5C → 4C
- CoA returns

- reaction type:
  - decarboxylation
  - redox
  - synthesis
- enzyme:
  - decarboxylase
  - Dehydrogenase
  - synthase
- energy: released



Krebs Cycle: Step by Step

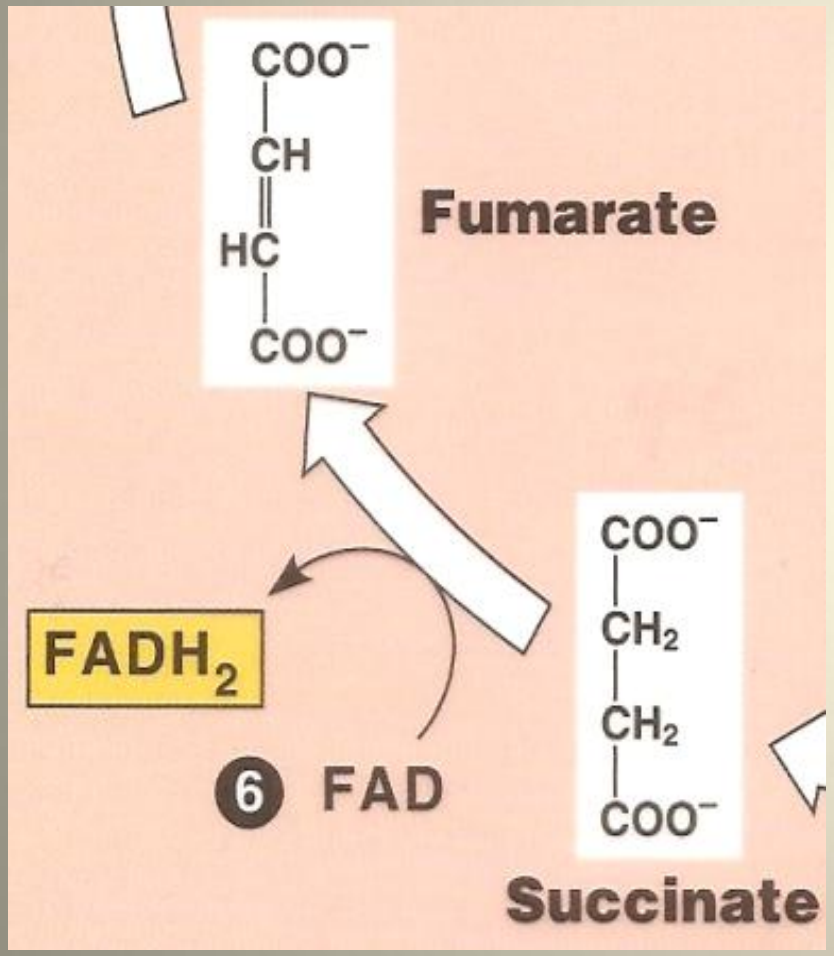


Step 5:

- ADP phosphorylation to ATP
- CoA recycled

- Reaction type:
  - substrate-level phosphorylation
  - Cleavage
- enzyme:
  - kinase
  - lyase
- energy: released

Krebs Cycle: Step by Step



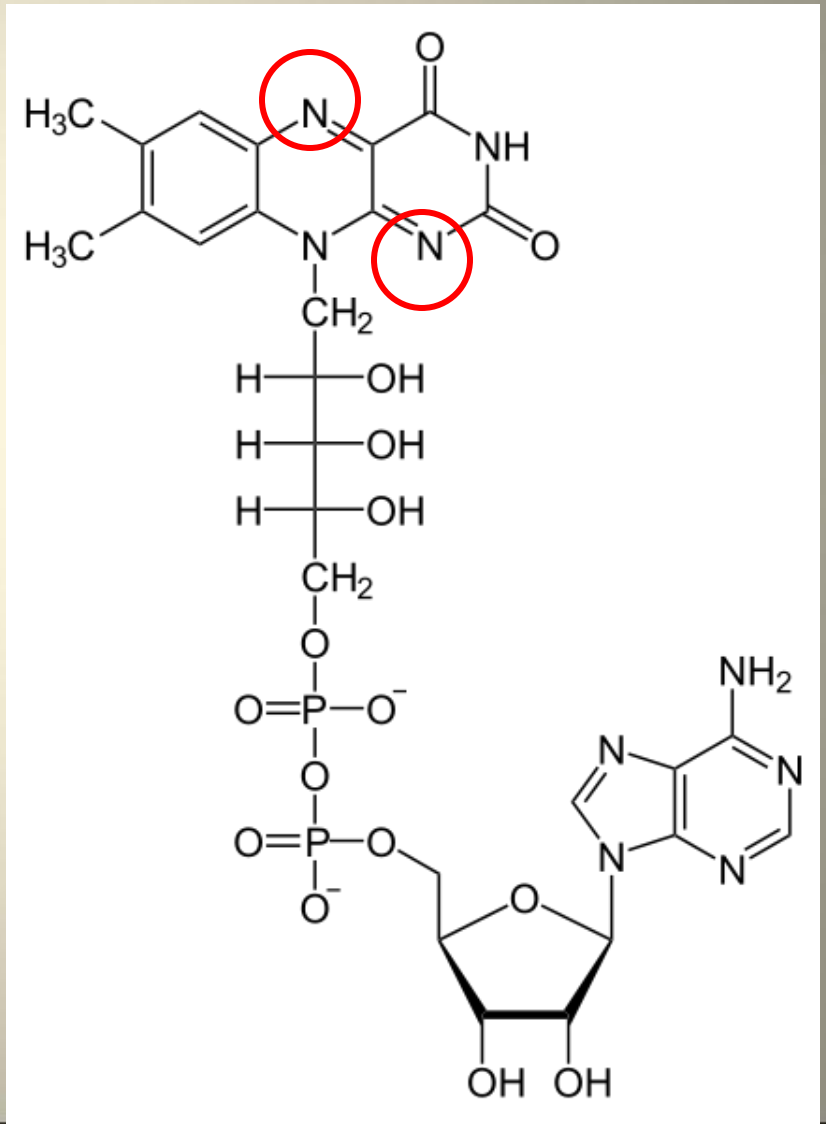
Step 6:

- $FADH_2$ (energy molecule) formation

- reaction type: redox
- enzyme: dehydrogenase
- energy: released

FAD / $FADH_2$

- FAD – flavin adenine dinucleotide (oxidized form)
- $FADH_2$ – flavin adenine dinucleotide (reduced form)
- Acts the same way as NAD+ → NADH by accepting electrons



FAD / $FADH_2$

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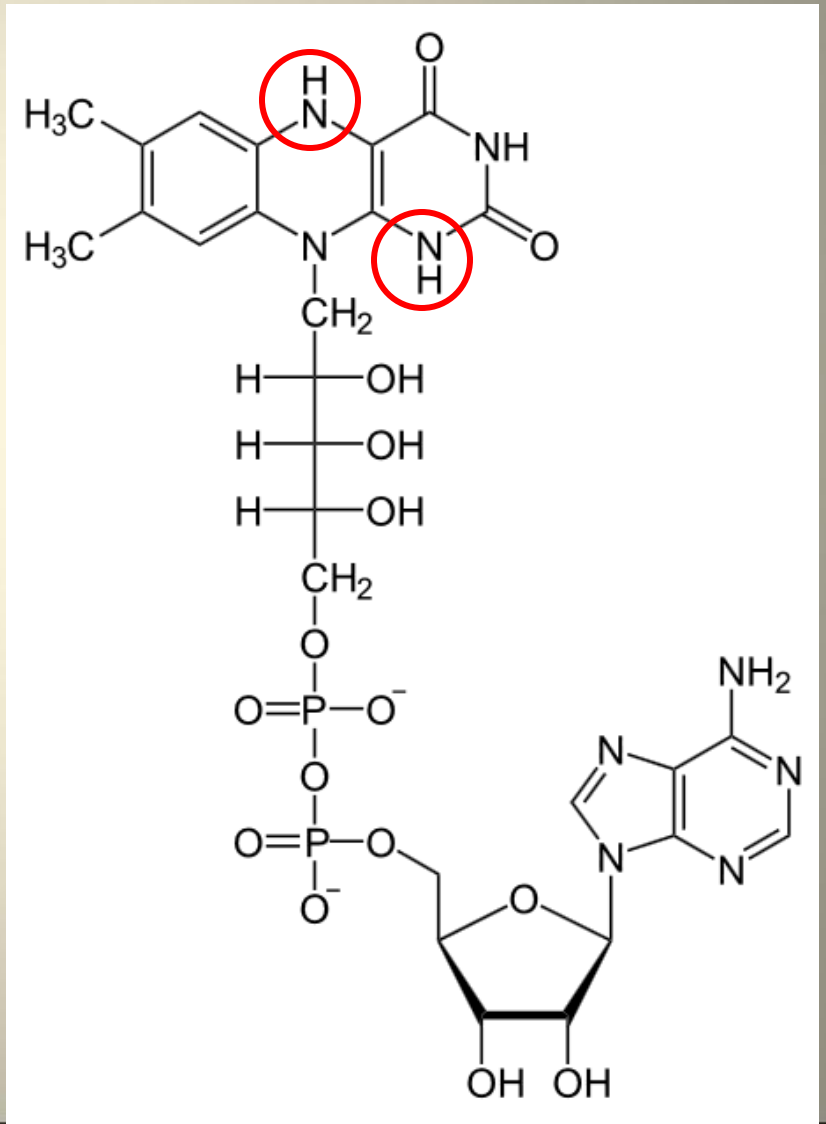
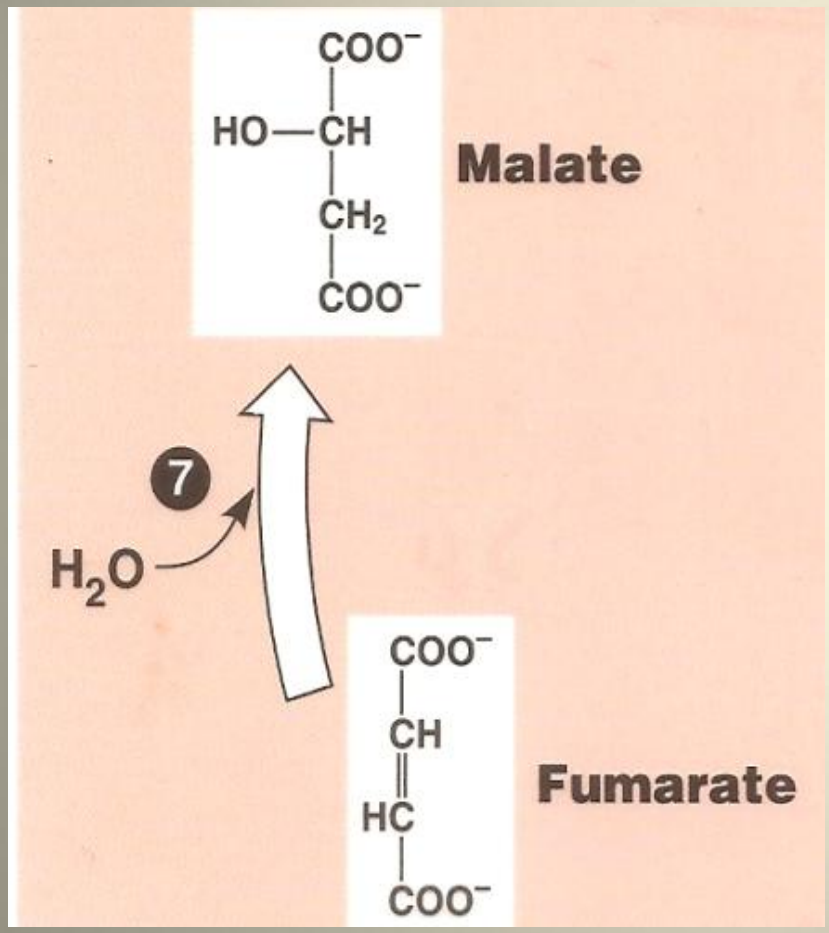


Krebs Cycle: Step by Step

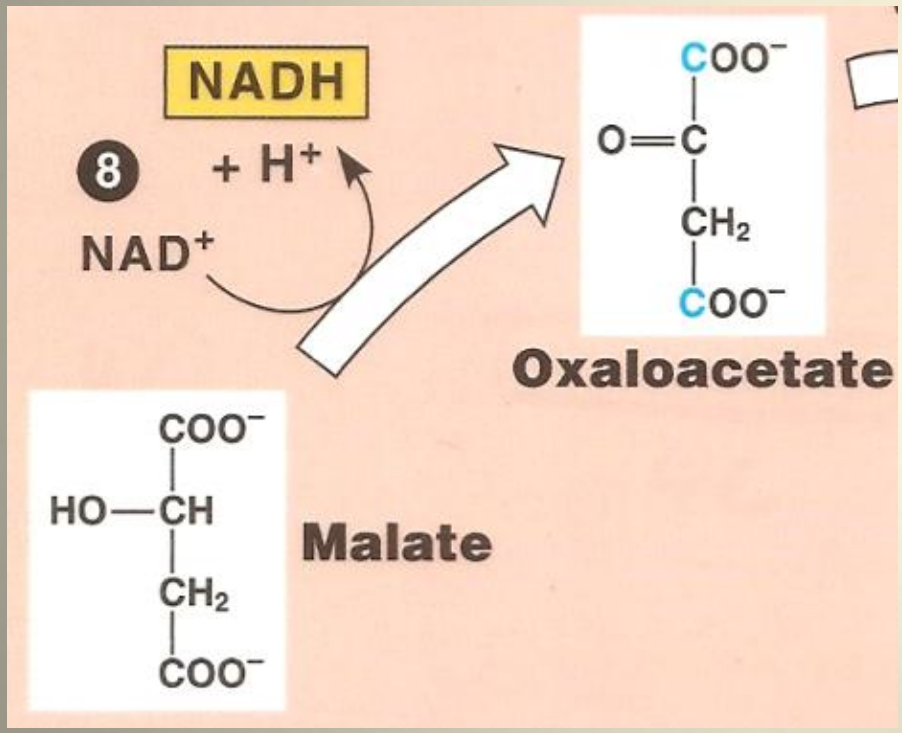


Step 7:

- rearranging the molecule for the next reaction

- reaction type: hydration
- enzyme: hydrase
- energy: absorbed

Krebs Cycle: Step by Step



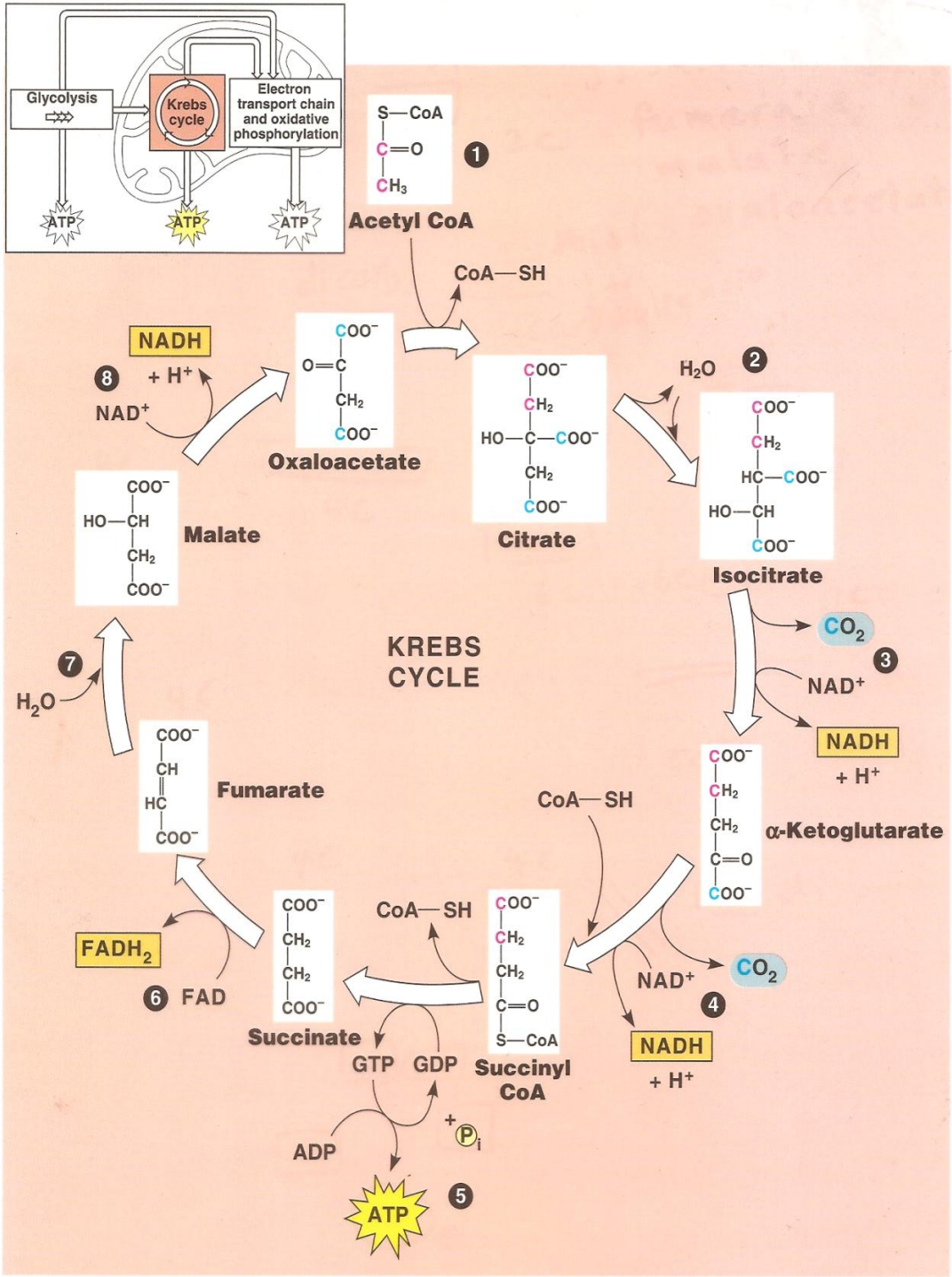
Step 8:

- energy molecule formation & recreating molecules for Krebs cycle

- reaction type: redox
- enzyme: dehydrogenase
- energy: released

Krebs Cycle Summary

- Per cycle count:
  - 2 CO_2 released
  - 3 NADH produced
  - 1 $FADH_2$ produced
  - 1 ATP produced
- Two cycles of Krebs for EACH glucose molecule



Molecule Count: Per Glucose

	ATP	NADH	$FADH_2$	CO_2
Glycolysis	2	2	0	0
Pyruvate Oxidation	0	2	0	2
Krebs				
Subtotal				
Conversion in ETC				

Molecule Count: Per Glucose

	ATP	NADH	$FADH_2$	CO_2
Glycolysis	2	2	0	0
Pyruvate Oxidation	0	2	0	2
Krebs	2	6	2	4
Subtotal				
Conversion in ETC				

Molecule Count: Per Glucose

	ATP	NADH	$FADH_2$	CO_2
Glycolysis	2	2	0	0
Pyruvate Oxidation	0	2	0	2
Krebs	2	6	2	4
Subtotal	4	10	2	**6**
Conversion in ETC				

Recall: Overall Reaction

glucose + oxygen → carbon dioxide + water + energy

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

36 ADP + 36 P → 36 ATP

or

38 ADP + 38 P → 38 ATP

Molecule Count: Per Glucose

	ATP	NADH	$FADH_2$	
Glycolysis	2	2	0	
Pyruvate Oxidation	0	2	0	
Krebs	2	6	2	
Subtotal	4	10	2	
Conversion in ETC	4	30	4	38

Recall: Overall Reaction

glucose + oxygen → carbon dioxide + water + energy

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

36 ADP + 36 P → **36** ATP

or

38 ADP + 38 P → **38** ATP

Molecule Count: Per Glucose

	ATP	NADH	$FADH_2$	
Glycolysis	2	2	0	
Pyruvate Oxidation	0	2	0	
Krebs	2	6	2	
Subtotal	4	10	2	
Conversion in ETC	4	30	4	36-38