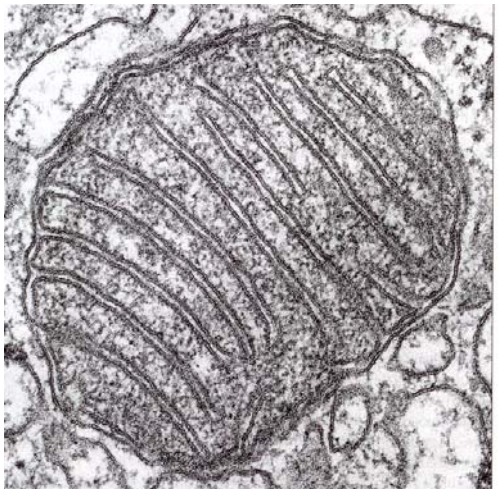
Lecture 14 10/3/05

Cellular Respiration: Harvesting Chemical Energy

Chapter 9

II.

Catabolic Oxidative Pathways

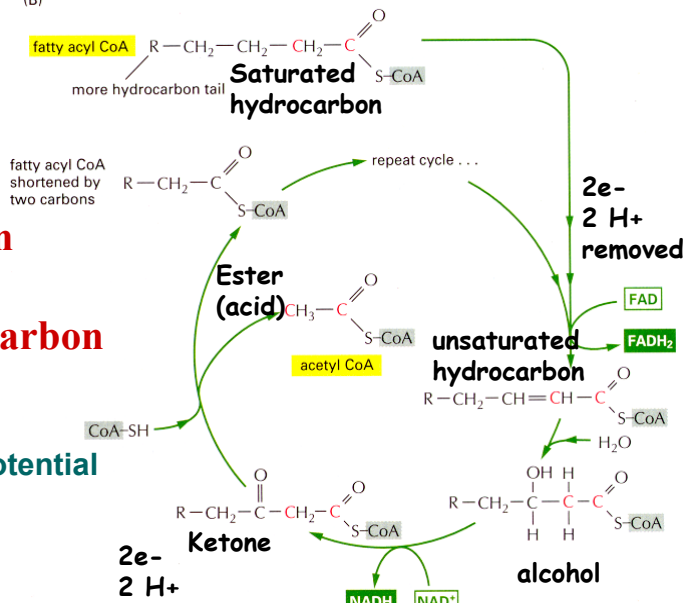


Lecture Outline

1. Review Fatty Acid Oxidation Pathway
2. Oxidation of Monosaccharides (Glycolysis Pathway)
3. Mitochondrial Spaces: Matrix, Intermembrane Space
4. Oxidation of Pyruvate
5. Complete oxidation of Carbon from FA ox & glycolysis – TCA Cycle (Kreb's Cycle)
6. Cashing in the "accumulated" Reducing Equivalents - Oxidative Phosphorylation

Fatty Acid Oxidation (β-oxidation) *in Mitochondria*

Priming Step



-steps down oxidation states of carbon

-captures Reducing potential
NADH + H+
$FADH_2$

Net Result of Fatty Acid Oxidation Pathway

Fatty acid shortened by 2 carbon unit

2 carbon acid attached to CoA (acetyl CoA)

Oxidation of Carbon to acid $-CH_2-$ to $-\underset{\underset{S\ CoA}{|}}{C}=O$

Capture reducing equivalents
2 NADH + H+
2 $FADH_2$

Glycolysis Another catabolic pathway

Oxidation of monosaccharides

(polysaccharides ***digested*** to monosaccharides; no energy harvested)

Hexoses (like glucose)

6 carbon sugar
Aldehyde with 5 alcohols

(Two)
3 carbon acid
with a ketone

oxidized to pyruvic acid

Glycolysis consists of two major phases

Energy investment phase
(Priming Steps)

Energy payoff phase

Net Harvest
Of Pathway

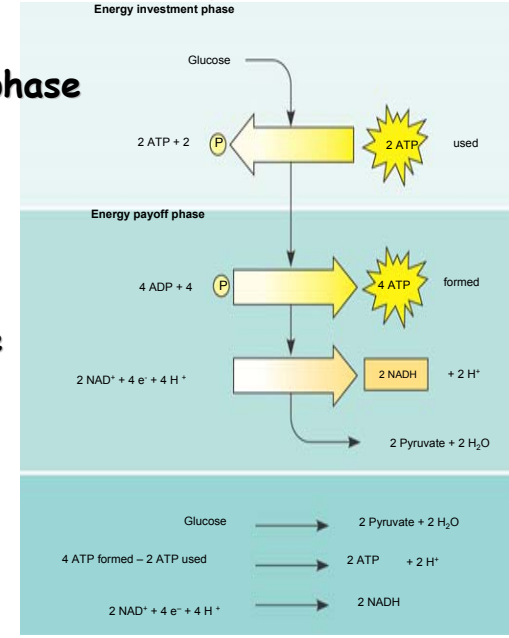


Figure 9.8

Glycolysis
Energy Priming Stage

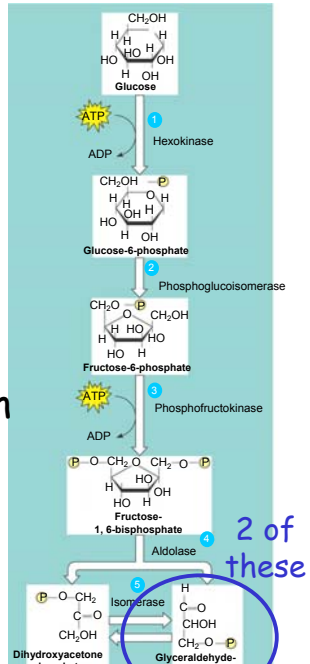
Add P_i to #6 carbon

Rearrange

Add P_i to #1 carbon

Split into two
3 carbon units

rearrange



Glycolysis
Energy **PAYOFF** Stage

Two Of these

Oxidize #1 aldehyde to Acid
$NADH + H^+$, high energy phosphate

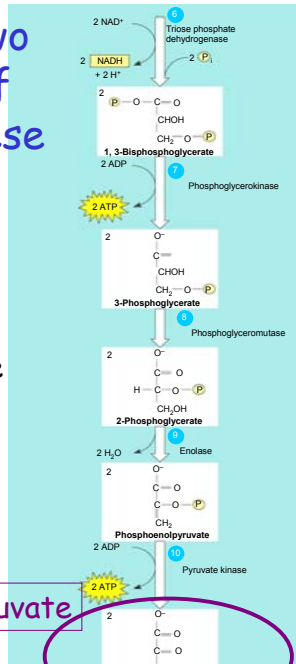
Harvest Phosphate
Substrate Level Phosphorylation
ATP made

rearrange

Oxidize #2 alcohol to Ketone
High energy phosphate

Harvest Phosphate
Substrate Level Phosphorylation

pyruvate



Net Result of Glycolysis Pathway

6 Carbon Sugar oxidized to
TWO Pyruvate (acid with ketone)

Net yield of **2 ATP** produced
by substrate level phosphorylation

Capture reducing equivalents
2 NADH + H^+

Fate of the 2 Pyruvate molecules?

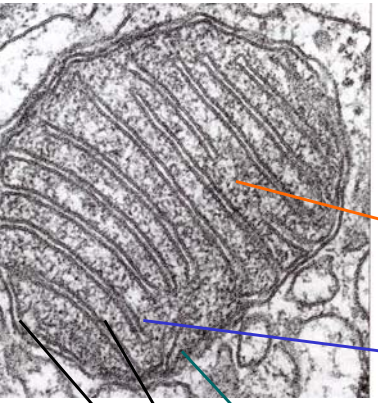
enter the mitochondrion for further oxidation

produce 6 CO_2

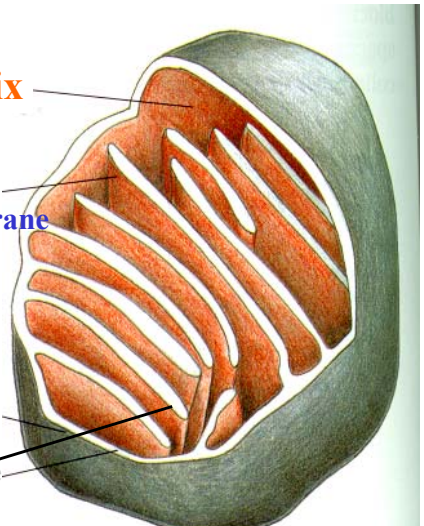
Pathway called the TCA cycle

What does it mean to "get into" the mitochondrion?

Glycolysis occurs in cytosol



Mitochondria
Functional Spaces



Folds of inner membrane Called *Cristae*

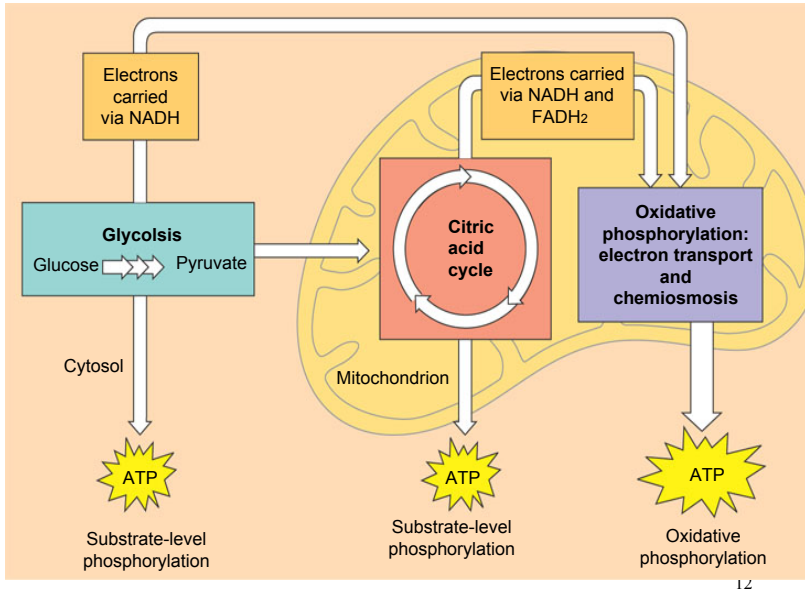


Figure 9.6

Matrix

Contains DNA
Contains bacterial-like ribosomes
Site of three important oxidative reaction cycles
- Fatty Acid Oxidation
- Pyruvate oxidation
- TCA Cycle

Intermembrane Space

Reservoir to hold H+ ions

Inner Mitochondrial Membrane

Densely packed with proteins
Site of "oxidative phosphorylation"
electron transport and ATP production

Oxidation of Pyruvate to Acetyl CoA

Familiar?

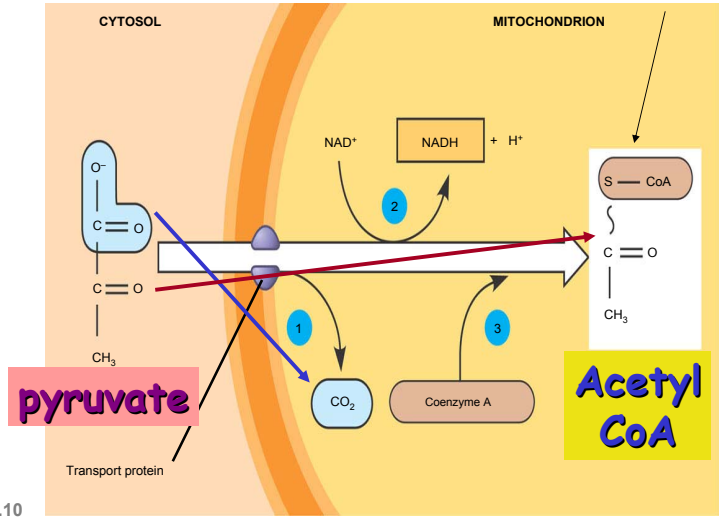


Figure 9.10

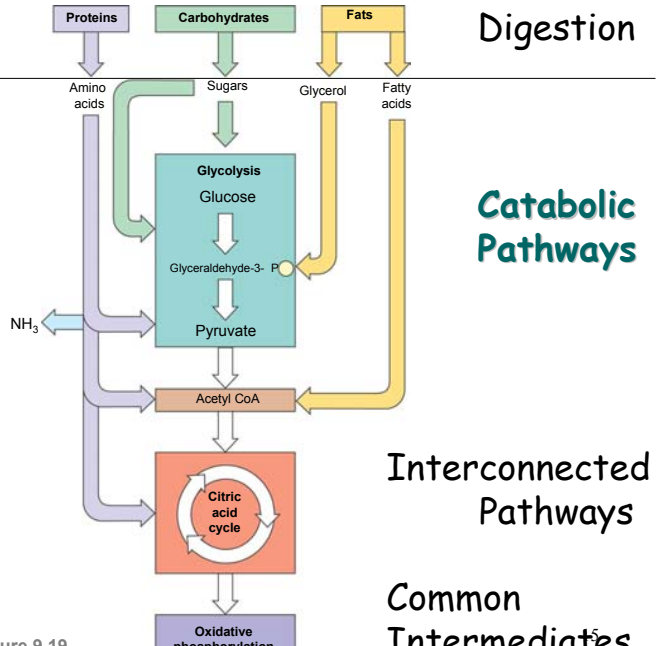


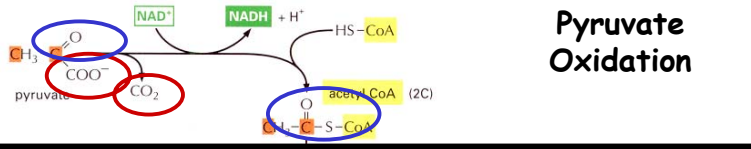
Figure 9.19

Digestion

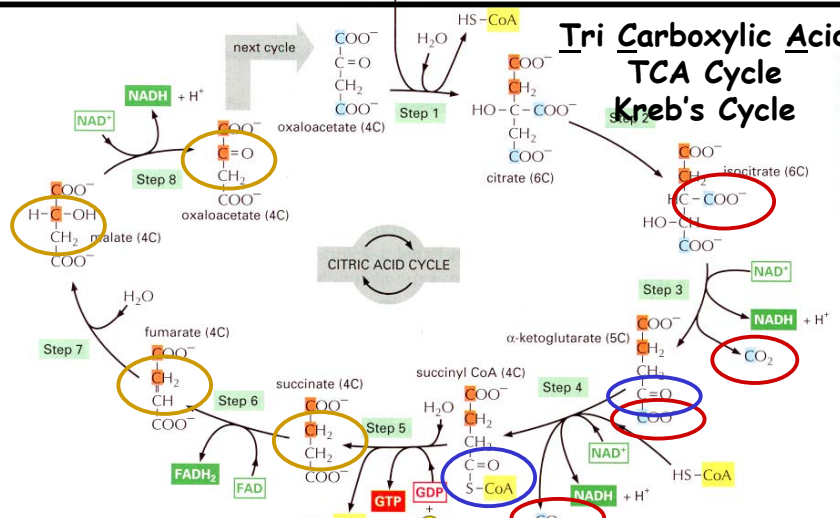
Catabolic Pathways

Interconnected Pathways

Common Intermediates



Pyruvate Oxidation



TCA Cycle

Stepping down the Oxidation Series of Carbons

- -Acid to CO_2
- -Ketone to acid (thioester)
- - saturated to unsaturated
- - unsaturated to alcohol
- - alcohol to ketone or carboxylic acid
- - decarboxylation

Capture reducing equivalents

$NAD^+ \quad 2e^- + 2H^+ \longrightarrow NADH + H^+$

$FAD \quad 2e^- + 2H^+ \longrightarrow FADH_2$

TCA Cycle

- Oxidize the 2 carbon unit
  - Acetyl CoA
  - To 2 CO_2
- Five key oxidation steps
  - 3 NADH + H^+
  - 1 $FADH_2$
  - 1 GTP

Per 2 carbon unit

Regenerate the initial
4 carbon acid
repeat

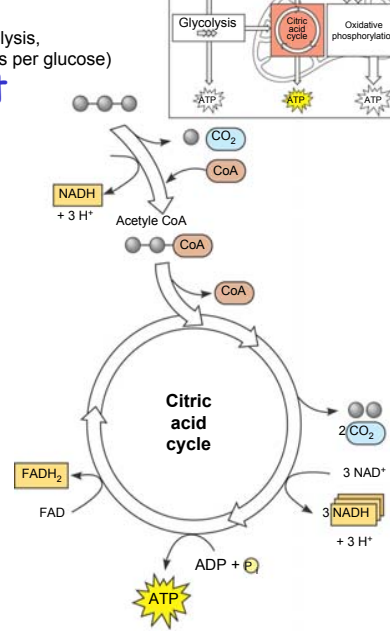


Figure 9.11

Reactions of the TCA cycle pathway

Note oxidation points
Capture of 3 NADH + H^+
Capture of 1 $FADH_2$
Capture of 1 high energy phosphate bond (GTP)
per 2 carbon unit

So some GTP harvested,
but a lot of reducing equivalents accumulated
these are worth a lot more ATP

How?

What good are "accumulated" reducing equivalents?

$H_2 = 2e^- \; 2H^+$

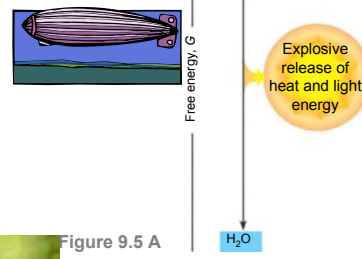
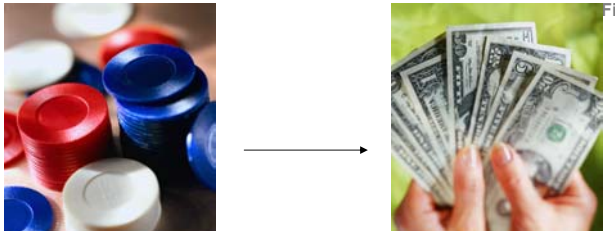


Figure 9.5 A

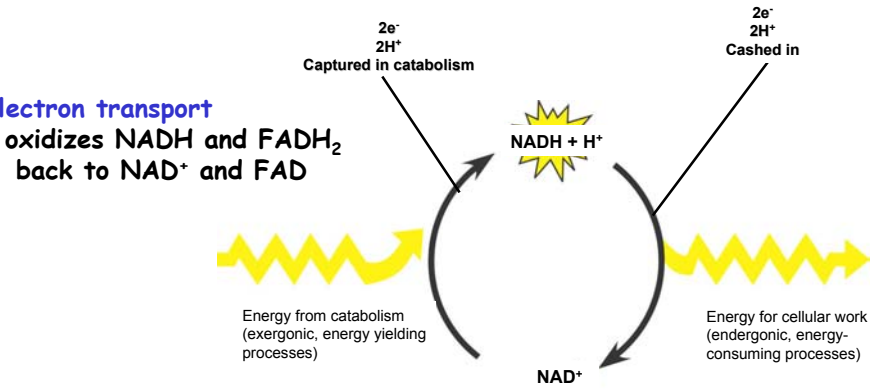
$2H_2 + O_2 = H_2O +$ **BOOM!**



The Regeneration Energy Carriers

Energy carriers (ATP, NAD^+, FAD) present in only minute amounts

nly *limited amounts* of reducing equiv carriers must "cash them in" - oxidize them



Mitochondrial Functions

Oxidize compounds to $CO_2 + H_2O$

Fatty acid Oxidation

Oxidation of Pyruvate

TCA Kreb's Cycle

Produce reduced carriers NADH & FADH

Generate >90% of Typical Cell's ATP

Oxidative Phosphorylation

"electron transport"

ATP synthesis

Oxidize reduced carriers to produce ATP or equiv

Next time

How cash in the **NADH + H+** and **$FADH_2$** "poker chips" for **ATP**

Oxidative Phosphorylation

Summary

-FA oxidation in matrix of mitochondrion
-Glycolysis (ox of sugar) in cytosol
-Oxidation of pyruvate in matrix of mitochondrion
-TCA cycle (oxidation of acetyl CoA) in matrix

- "accumulate" reducing equivalent carriers
- must "cash in" for ATP – oxidative Phosphorylation