Lecture #9 – 9/24 – Dr. Hirsh

Basics of Energy Metabolism:
Catabolism and Anabolism

Focus your studies in order to know broad outlines; don't memorize all the molecules and reactions. Know the general shape of reactions, where energy comes out or goes into reactions, where the control points are and the important molecules.

Combustion of Glucose

$C_6H_{12}O_6 + 6O_2 \rightarrow 6\ CO_2 + 6H_2O$ + Energy (as heat and light)
When this is performed in an adiabatic container (such as a Thermos® jug),
ΔG = -686 kcal/mol

This is a redox reaction:

$AH_2 + B \rightarrow BH_2 + A$

Metabolism releases Energy slowly; the cells store E and use E as reactions happen.

Figure: Source of all E on earth is the sun; captured by photosynthesis, stored as reduced carbons.
Released through aerobic respiration -> yield 36 ATP's
Released through anaerobic respiration -> yield 2 ATP's (incomplete oxidation)

For anaerobic bacteria, oxygen is poisonous; thus they survive with the lower E yield

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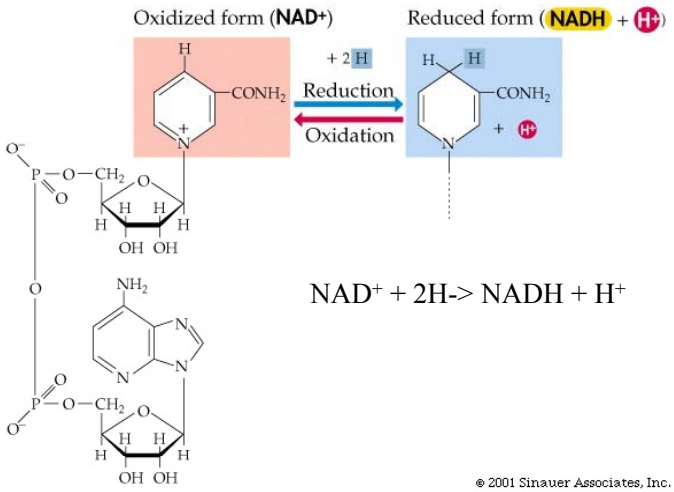

$NAD^+ + 2H \rightarrow NADH + H^+$

Oxygen reacts with NADH and H+ to form NAD+ and water; $\Delta G = -52.4$ kcal/mol

NAD acts as an energy carrier – an intermediate energy-rich molecule

There are 4 major pathways to metabolize glucose in the presence of oxygen:

1. Glycolysis: glucose -> 2 pyruvate molecules
2. Pyruvate oxidation -> acetate, a compound requiring further metabolism via the
3. Citric acid cycle [also known as the Krebs cycle] -> NADH
4. The respiratory chain that uses the products of the citric acid cycle

Overall schematic:

With oxygen:

Glycolysis -> ATP, NADH, pyruvate
Pyruvate oxidation -> CO_2, NADH, Acetate
CAC -> NADH, FADH2, ATP, CO_2
Respiratory Chain -> NAD+, FAD, water, ATP

Without oxygen:

Glycolysis -> 2 ATP, Pyruvate
Fermentation (a reduction reaction) uses energy -> Lactate or Alcohol (waste products)

Where do these processes happen?

Prokaryotes

Glycolysis, Fermentation, CAC all in the cytoplasm.
Pyruvate oxidation, respiratory chain on the inner face of the plasma membrane

Eukaryotes

Glycolysis in cytoplasm
Pyruvate oxidation in the mitochondrial matrix
CAC in the mitochondrial matrix
Respiratory chain in the cristae membrane and inner cristae space

Energetics of Glycolysis

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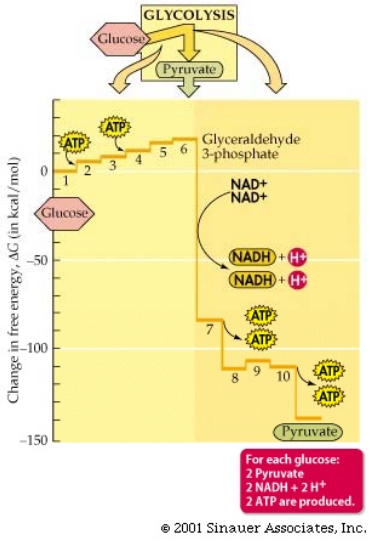
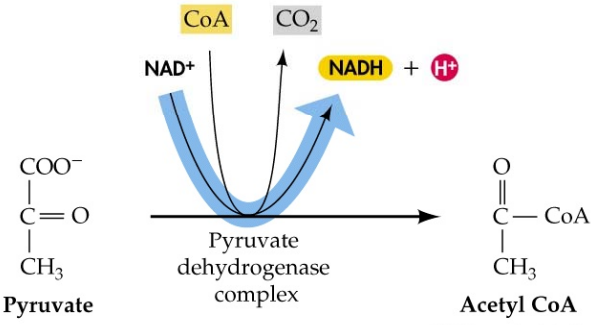
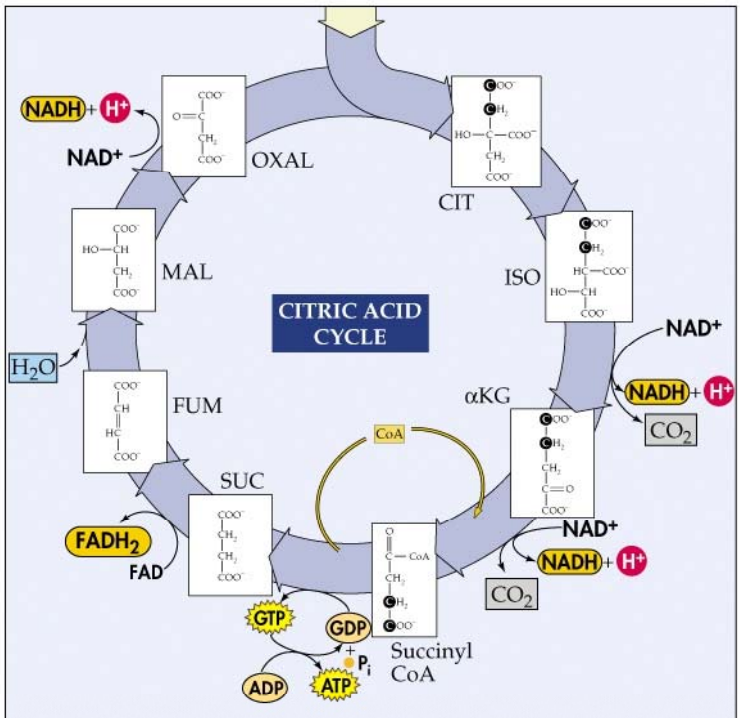
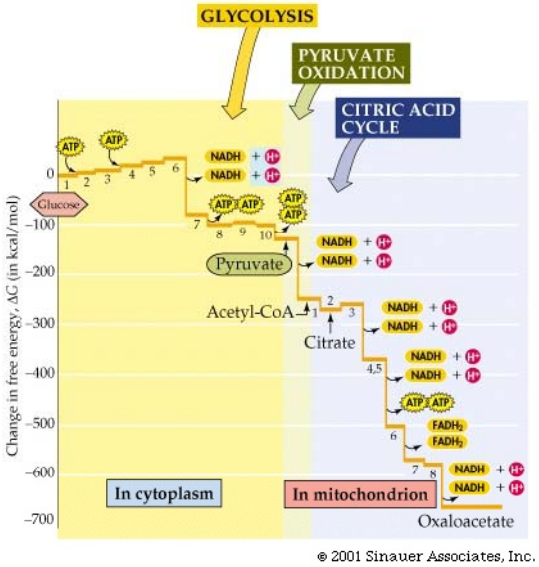


Pyruvate Oxidation-> Citric Acid Cycle





Energetics of Gluc-> OAA



Intermediates from these reactions are used in many other cellular processes – a means of generating these intermediates

Respiratory Chain

Also known as Oxidative Phosphorylation

A means to convert NADH and $FADH_2$ to ATP

There are sets of coupled enzymes in the inner mitochondrial membrane. These take electrons from NADH, $FADH_2$ – move the electrons down a gradient, deliver electrons to Oxygen to make water.

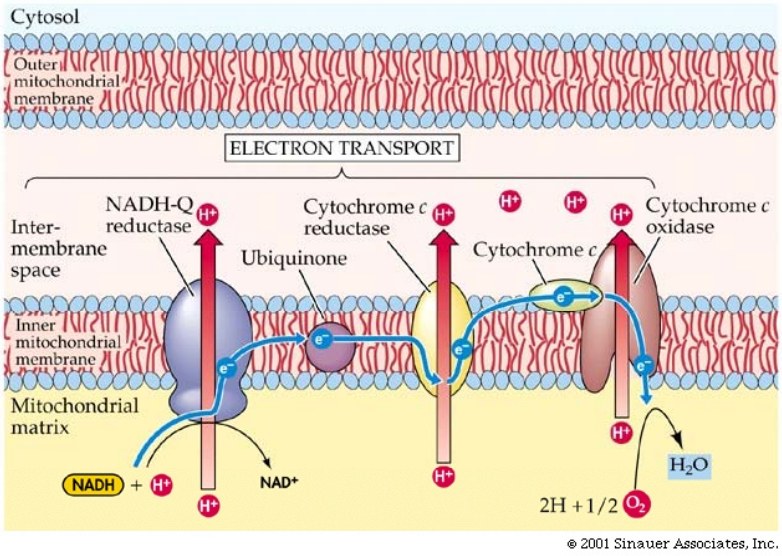
Coupling to H+ transport

Oxidize NADH -> NAD+

Electron transfer is used to pump H+ ions from outer to inner mitochondrial space

Process recycles NADH to NAD+, generates an H+ gradient across the membrane

H^+ Pumping by Respiratory Chain



Inhibitor – Cyanide (CN^-) – blocks cytochrome oxidase, prevents transfer of electrons to Oxygen to make water.

Uncouplers – uncouple the NADH -> NAD+ from the H+ pump, just generates heat. Used by some hibernating animals to generate heat. The drug Ecstasy is an uncoupler!

Use H+ gradient – drive H+ through ATP synthase "motor" molecule -> coupled synthesis of ATP.

ATP Synthase: A rotary motor