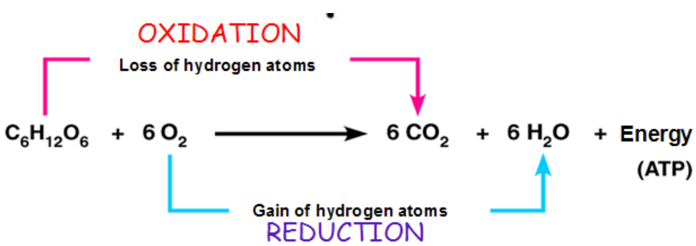
CELLULAR RESPIRATION-Chapter 9

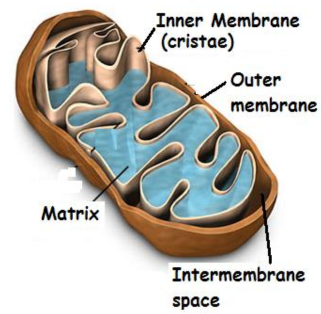
$C_6H_{12}O_6 + 6O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy

Type of oxidation-reduction (redox) reaction



OIL RIG
Oxidation Is Losing electrons
Reduction Is Gaining electrons

MITOCHONDRION STRUCTURE



Double membrane- allows compartmentalization

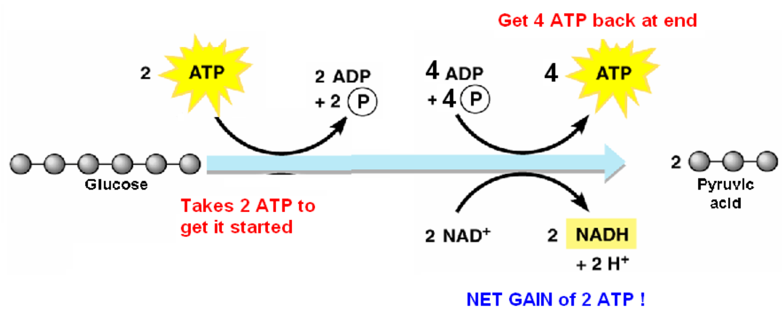
OUTER MEMBRANE

INNER MEMBRANE (CRISTAE) –contains Electron transport proteins

MATRIX- contains enzymes for KREBS CYCLE

INTERMEMBRANE SPACE- between cristae and outer membrane

Place where H^+ ions accumulate during ETC



GLYCOLYSIS

"Glykos"= sweet; "lysis"=split apart

GLUCOSE → 2 PYRUVATE

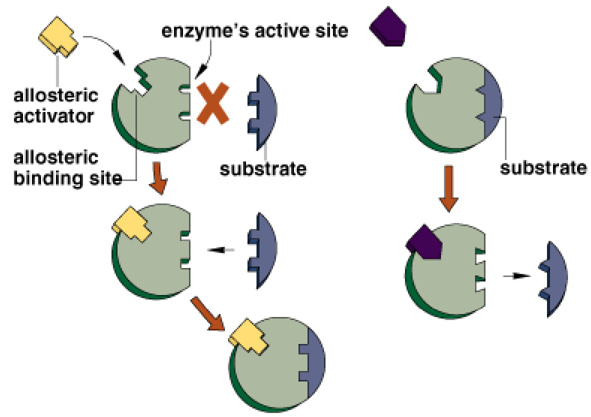
Occurs in cytosol

Requires 2 ATP to get started

Produces 4 ATP (net gain 2 ATP)

Produces 2 NADH

GLYCOLYSIS PATHWAY



Regulated by phosphofructokinase

ALLOSTERIC enzyme near beginning of pathway

AMP turns pathway on

(AMP is high when ATP is needed)

ATP turns pathway off

(don't waste energy making ATP when not needed)

EVOLUTIONARY LINKS

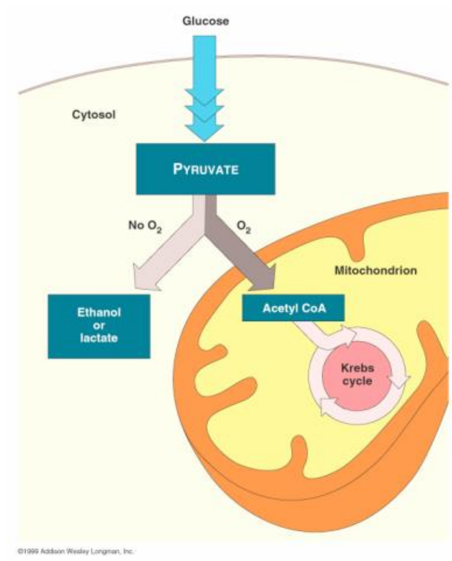
Glycolysis = Most widespread metabolic pathway

- Earliest fossil bacteria (3.5 billion years ago) but large amounts of oxygen not present until 2.7 BYA
- Works without oxygen
  ~suggests ancient prokaryotes probably used glycolysis to make ATP before oxygen was present
- happens in cytoplasm without mitochondria
  ~ suggests it was in early prokaryotic cells before eukaryotes appeared
  eukaryotes appeared 1 billion years after prokaryotes (Endosymbiotic theory)

WITHOUT OXYGEN (anaerobic)

Pyruvate → FERMENTATION

Regenerates NAD+ carriers to allow glycolysis to continue



ALCOHOLIC FERMENTATION

Pyruvate → CO_2 + alcohol + NAD^+

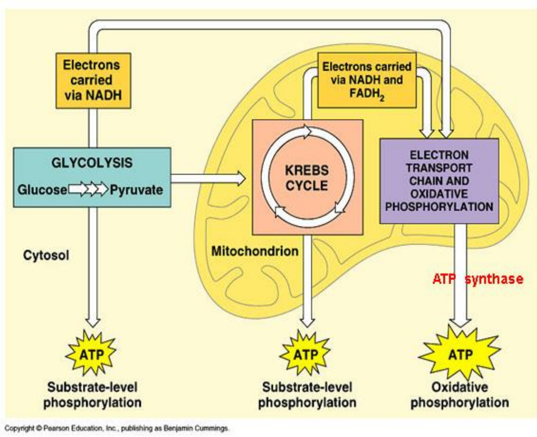
Used by microorganisms to make beer/wine

Used by yeast to make bread

LACTIC ACID FERMENTATION

Pyruvate → lactic acid + NAD^+

Human muscle cells when oxygen is low during exercise



WITH OXYGEN

GLYCOLYSIS → KREBS CYCLE → ETC

HIGH ENERGY ELECTRON CARRIERS:

(B-vitamin coenzymes)

NAD^+ → NADH FAD → $FADH_2$

FACULTATIVE ANAROBES (Ex: yeast/some bacteria)

can switch back and forth between fermentation/respiration depending on O_2 availability

Pyruvate transported into mitochondrial matrix

Uses 1 ATP/pyruvate for active transport

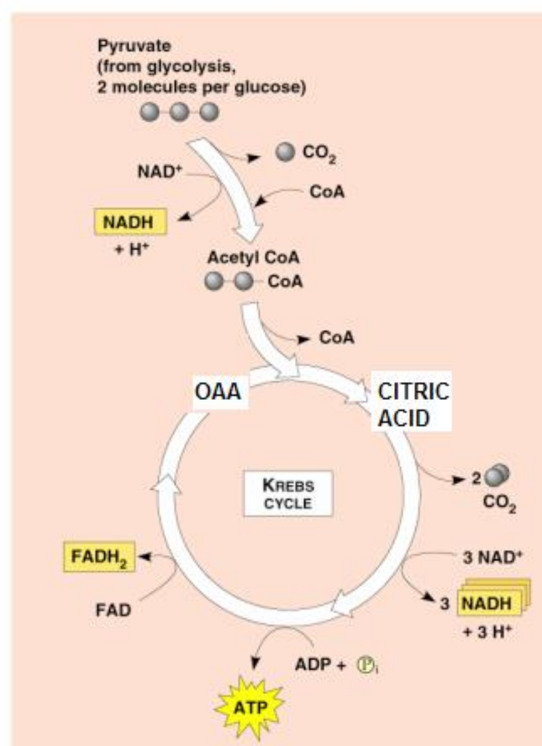
ACETYL CO-A CHARGING (B-vitamin coenzyme)

Co enzyme A receives carbons from pyruvate

feeds them into Krebs cycle

Enzyme removes CO_2 from pyruvate producing Acetyl CoA

Each glucose produces 2 CO_2 + 2 NADH



KREBS (CITRIC ACID) CYCLE

Releases 6 original carbons in glucose as 6 CO_2;

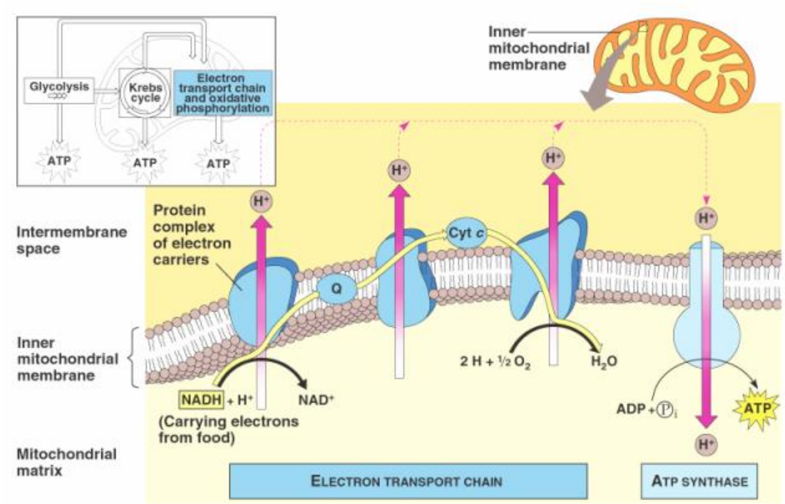
Stores energy in NADH/$FADH_2$

Occurs in Mitochondrial MATRIX

OAA (oxaloacetic acid) receives 2 carbons from Acetyl CoA to make CITRIC ACID

Each glucose requires TWO turns of cycle

1 GLUCOSE produces: 6 CO_2, 2 $FADH_2$, 2 ATP, 8 NADH



ELECTRON TRANSPORT-

stage that produces the MOST ATP

Attached to CRISTAE inner membrane

Uses energy from NADH & $FADH_2$ to
create proton gradient and make ATP

Includes:

THREE transmembrane PROTON PUMPS;

Carrier molecules between pumps =
UBIQUINONE (Q); and CYTOCHROMES

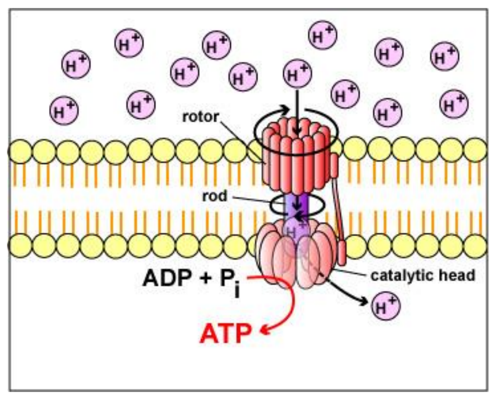
Each NADH makes 3 ATP (drops its electrons at top of ETC; hits all 3 proton pumps)

Each $FADH_2$ makes 2 ATP (drops its electrons at Q; skips 1^{st} proton pump; so makes less ATP)

Electrons passing down ETC provide energy for pumping H^+ ions into INTERMEMBRANE SPACE

Final electron acceptor at end of ETC = O_2 (O_2 + 2e- +$2H^+ \rightarrow H_2O$)

1 glucose yields 36 net ATP



Proton gradient powers ATP SYNTHASE to ADP + $P_i \rightarrow$ ATP

PROTON MOTIVE FORCE = potential energy of hydrogen ion gradient

CHEMIOSMOSIS = Generation of ATP from a proton gradient

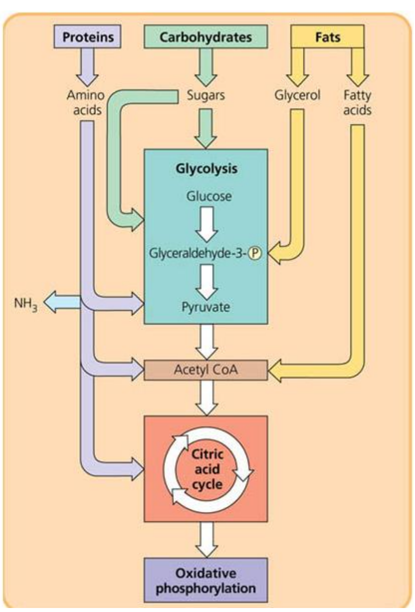
(It occurs in all living things)

OXIDATIVE PHOSPHORYLATION using proton gradient created by electron transport chain in cristae membrane to make ATP

ETC + CHEMIOSMOSIS = OXIDATIVE PHOSPHORYLATION

SUBSTRATE LEVEL PHOSPHORYLATION (found in glycolysis & Krebs cycle)

Addition of phosphate group directly WITHOUT proton gradient and ATP synthase



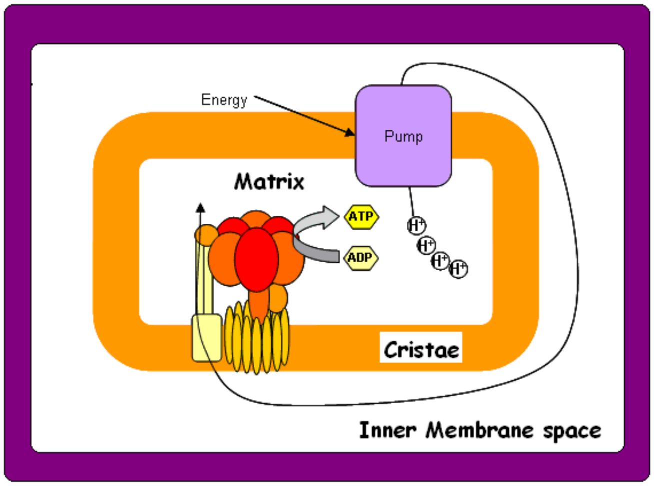
OTHER FUEL MOLECULES

Fats, proteins, carbohydrates can be broken down to release energy

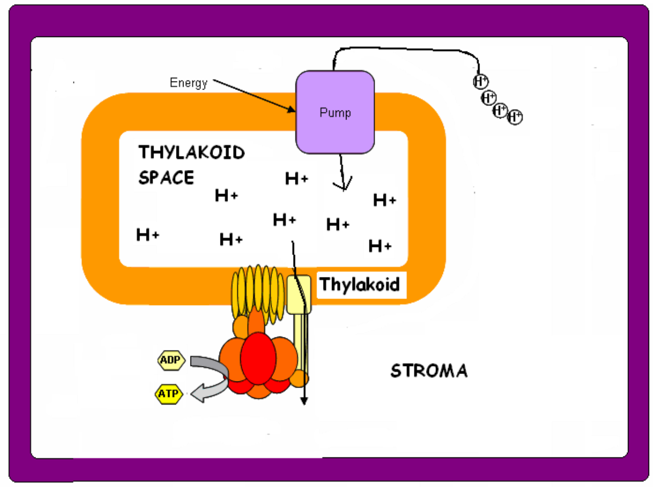
1 g of fat → twice as much ATP as 1 g of carbohydrate

BETA OXIDATION = breakdown of fatty acids into 2 carbon fragments
can enter Krebs cycle as acetyl CoA

Intermediates from glycolysis and Krebs cycle can be diverted into anabolic pathways to provide building blocks for many macromolecules



Energy
Pump
Matrix
ATP
ADP
H+
Cristae
Inner Membrane space



Energy
Pump
THYLAKOID
SPACE
H+
Thylakoid
ADP
ATP
STROMA