Biochemistry

5. Bio-Energetics & ATP

5.1) ADP, ATP and Cellular Respiration

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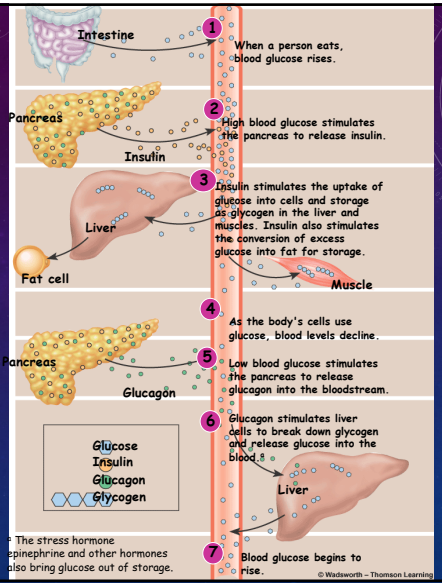
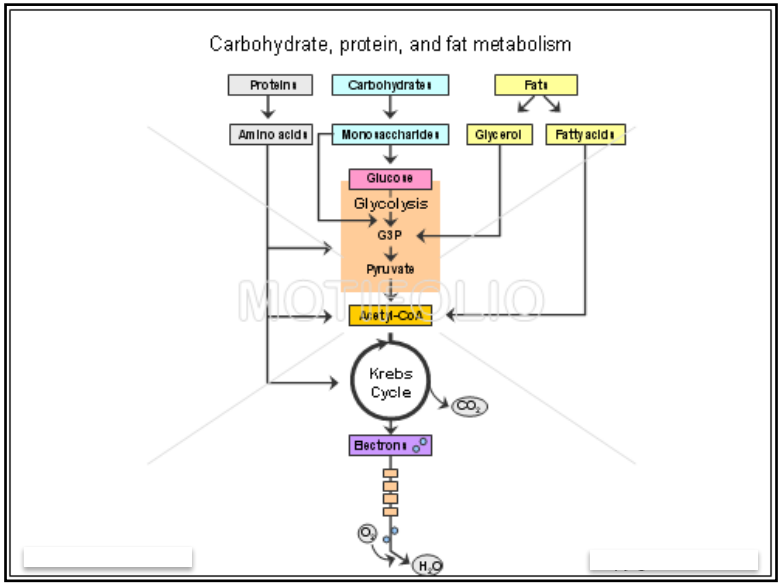
OVERVIEW OF ENERGY AND METABOLISM

1. The food we eat, (carbohydrates/'glucose'/sugar, lipids/fat, proteins), are our only source of energy for doing the biological work of cells.
2. All molecules (nutrient molecules included) have stored (potential) energy in the bonds between their atoms.
3. The energy that runs most biological systems on earth comes from solar energy
4. Plants trap solar energy via the metabolic reactions of Photosynthesis by producing these molecules

MAINTAINING BLOOD GLUCOSE HOMEOSTASIS





THREE BASIC USES OF NUTRIENTS ABSORBED BY THE DIGESTIVE SYSTEM

1. Energy for immediate use by cells to conduct their normal metabolic processes (Muscle contraction, secretions, active transport)

2. Synthesize structural or functional molecules to repair and replace cells.
(Mitosis and Cytokinesis)

3. Storage as glycogen or fat for later use as energy (nutrient reserves)

ALL LIVING THINGS FROM BACTERIA TO HUMANS CONDUCT METABOLISM

Metabolism is the ability to acquire and use energy from the environment.

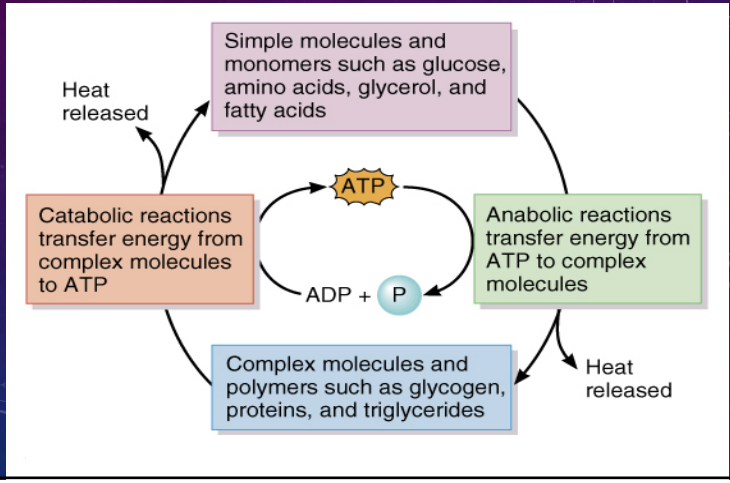
Metabolic processes are all the chemical reactions that occur in cells, tissues, organs, and organ systems.

Two Kinds of Metabolic Reactions:

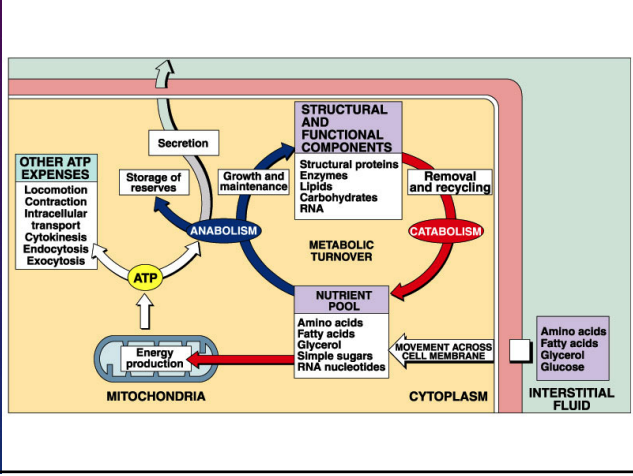
1. Catabolism = breakdown of large molecules into simple ones to produce energy (release energy).

2. Anabolism = build large molecules from simple molecules (requires energy input).

TWO BASIC KINDS OF CHEMICAL REACTIONS FOUND IN BIOLOGICAL SYSTEM



METABOLIC TURNOVER AND CELLULAR ATP PRODUCTION



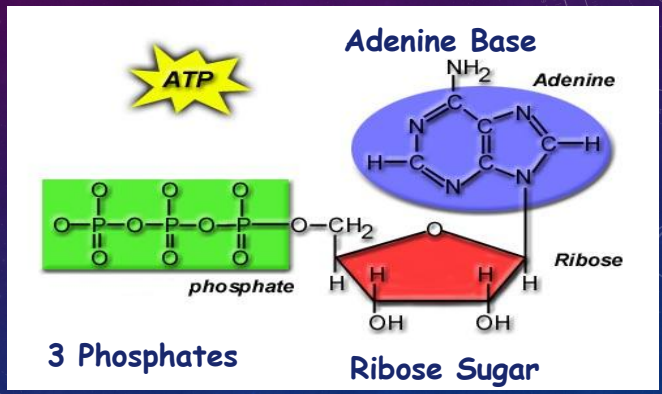
WHAT IS ATP?

Energy used by all Cells

Adenosine Triphosphate

Organic molecule containing high-energy Phosphate bonds

CHEMICAL STRUCTURE OF ATP

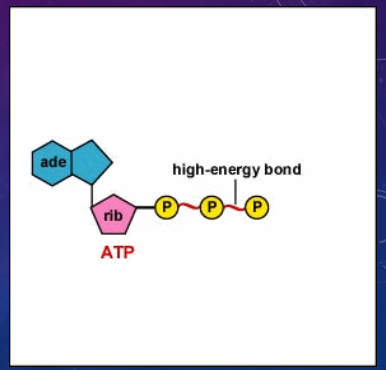


WHAT DOES ATP DO FOR YOU?

It supplies YOU with ENERGY!

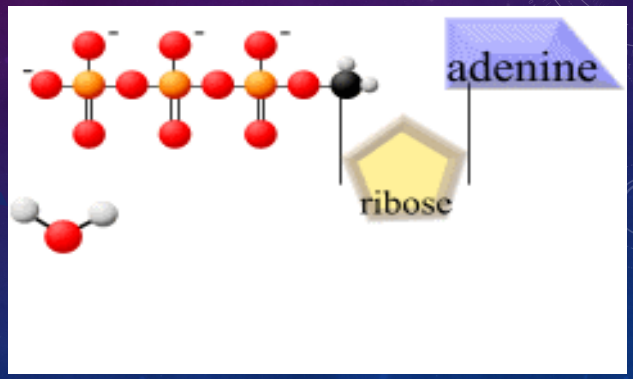
HOW DO WE GET ENERGY FROM ATP?

By breaking the high- energy bond between the last two phosphates in ATP



WHAT IS THE PROCESS CALLED?

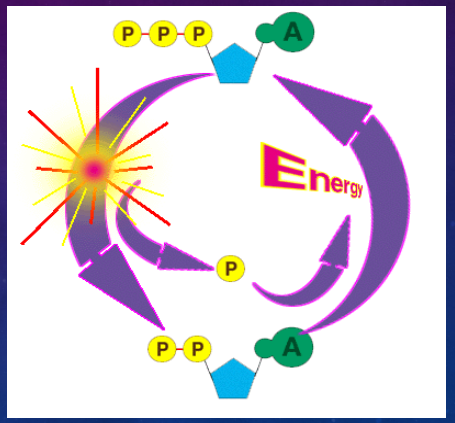
HYDROLYSIS (adding H_2O)



HOW DOES THAT HAPPEN?

An Enzyme!

ATPase



HOW IS ATP RE-MADE?

The reverse of the previous process occurs.

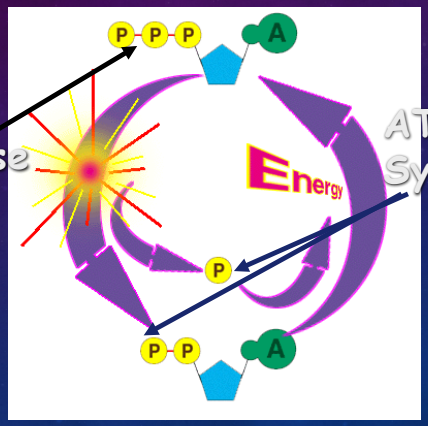
Another Enzyme is used!

ATP Synthetase

THE ADP-ATP CYCLE

ATP-ase

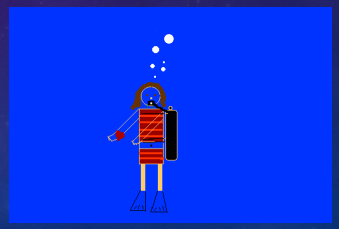
ATP Synthetase



WHEN IS ATP MADE IN THE BODY?

During a Process called:
Cellular Respiration

or: oxidative phosphorylation



CELLULAR RESPIRATION

- Includes pathways that require oxygen
- Glucose is oxidized and O_2 is reduced
- Glucose breakdown is therefore an *oxidation-reduction* reaction
- Breakdown of one glucose results in 36 to 38 ATP molecules

Overall Equation for Cellular Respiration

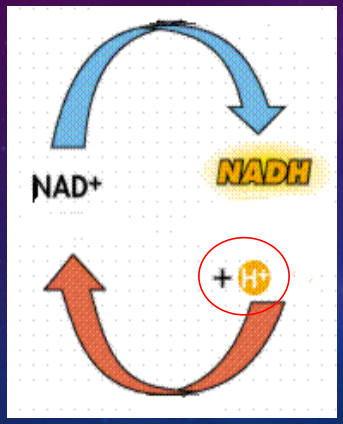
$$C_6H_{12}O_6 + 6O_2 \rightarrow \text{yields} \rightarrow 6CO_2 + 6H_2O + e^- + 36\text{-}38ATP's$$

RedOx Reaction !
e- flow !

WHAT TYPE OF PROCESS IS CELLULAR RESPIRATION?

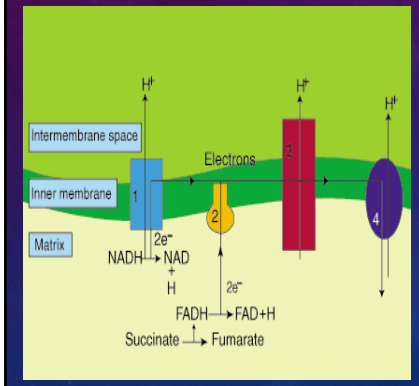
- An Oxidation-Reduction Process or RedOx Reaction
- Oxidation of GLUCOSE --> $CO_2 + H_2O$ (e^- removed from $C_6H_{12}O_6$)
- Reduction of O_2 to H_2O (e^- passed to O_2)

WHAT CARRIES THE ELECTRONS?



- NAD^+ (nicotinadenine dinucleotide) acts as the energy carrier
- NAD^+ is a coenzyme
- It is reduced to NADH when it picks up two electrons and one hydrogen ion

ARE THERE ANY OTHER ELECTRON CARRIERS?



- YES! Another Coenzyme!
- FAD+ (Flavin adenine dinucleotide)
- Reduced to $FADH_2$

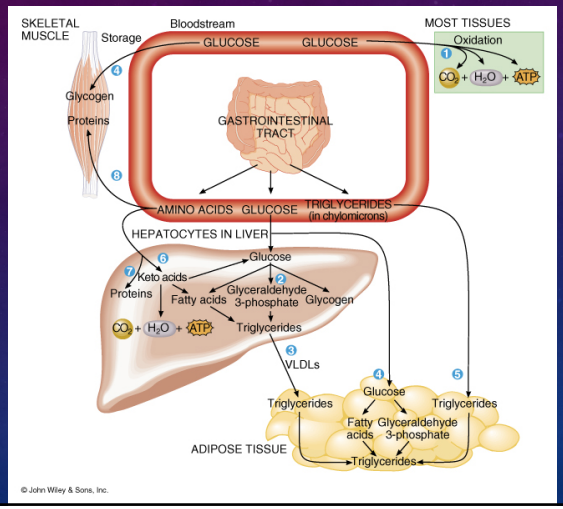
OTHER CELLULAR RESPIRATION FACTS

- Metabolic pathway that breaks down carbohydrates
- Process is exergonic as high-energy glucose is broken into CO_2 and H_2O
- Process is also catabolic because larger glucose breaks into smaller molecules

WHAT ARE THE STAGES OF CELLULAR RESPIRATION?

- Glycolysis
- The Krebs Cycle
- The Electron Transport Chain

SUMMARY OF GLUCOSE METABOLISM

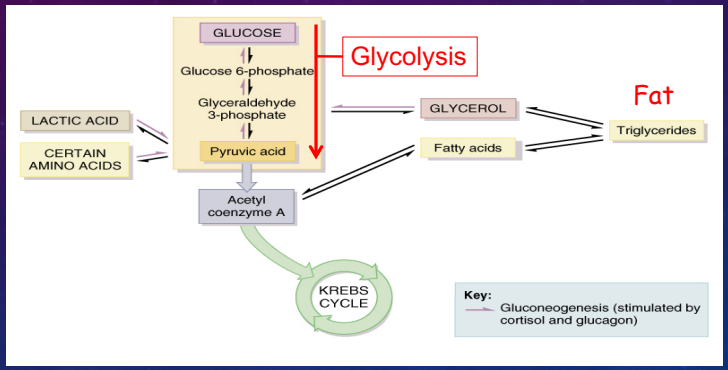


Glycogenesis:
The process by which glycogen is synthesized from glucose; in which glucose molecules are added to chains of glycogen for storage.

Glycogenolysis:
(also known as "Glycogenlysis") is the break down of glycogen to glucose-1-phosphate and glucose for ATP production.

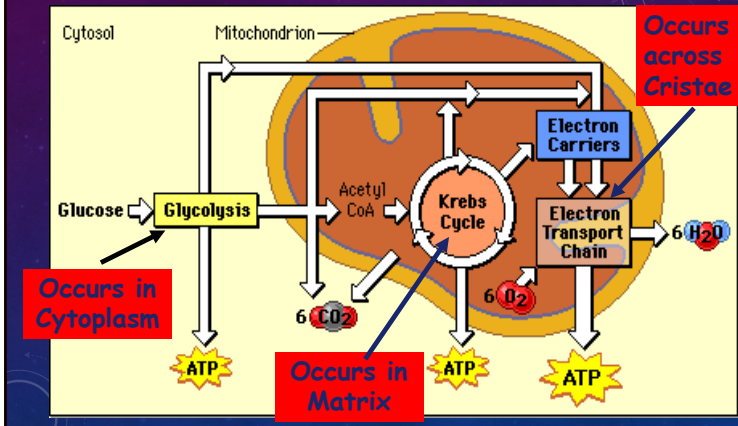
Gluconeogenesis (abbreviated GNG) is a metabolic pathway that results in the generation of glucose from non-carbohydrate carbon substrates such as pyruvate, lactate, glycerol, and glucogenic amino acids; the process by which protein or fat is converted into glucose.

OVERVIEW



OVERVIEW:

DIAGRAM OF THE PROCESS



GLYCOLYSIS SUMMARY

Takes place in the Cytoplasm

Anaerobic (doesn't use Oxygen)

Requires input of 2 ATP

Glucose split into two molecules of Pyruvate or Pyruvic Acid

GLYCOLYSIS SUMMARY

- Also produces 2 NADH and 4(2) ATP
- Pyruvate is oxidized to Acetyl CoA and CO_2 is removed

ATP PRODUCTION FROM CARBOHYDRATES

Glycolysis

Substrates required: Glucose, 2 ATP, 4 ADP, and 2 NAD^+

Intermediate Reactants: Glucose-6-phosphate, Fructose-1,6 bisphosphate

Products: 2 molecules of Pyruvic Acid
2 ATP (4)
2 NADH

ATP PRODUCTION FROM CARBOHYDRATES

Formation of Acetyl-CoA

Substrates required: 2 Pyruvic Acid
2 NAD^+
2 Coenzyme A

Products: 2 Acetyl-CoA
2 NADH
2 CO_2

FERMENTATION

- Occurs when O_2 is NOT present (anaerobic)
- Called Lactic Acid fermentation in muscle cells (makes muscles tired)
- Called Alcoholic fermentation in yeast (produces ethanol)
- Nets only 2 ATP

A LITTLE KREBS CYCLE HISTORY

- Discovered by Hans Krebs in 1937
- He received the Nobel Prize in physiology / medicine in 1953 for his discovery
- Forced to leave Germany prior to WWII because he was Jewish

ATP PRODUCTION FROM CARBOHYDRATES

Krebs cycle

Substrates required: 2 Oxaloacetic Acid
2 Acetyl-CoA
6 NAD+
2 FAD
2 GDP

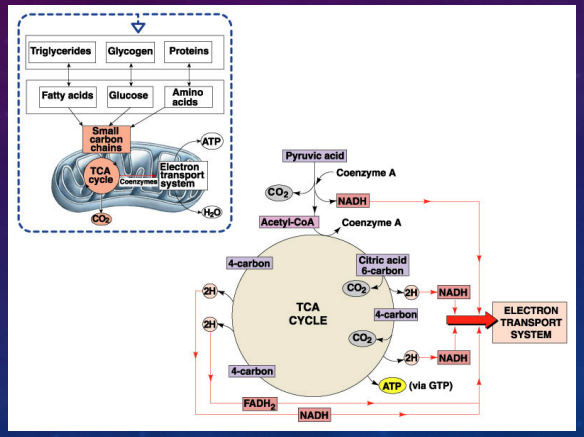
Intermediate Reactants: Citric Acid

ATP PRODUCTION FROM CARBOHYDRATES

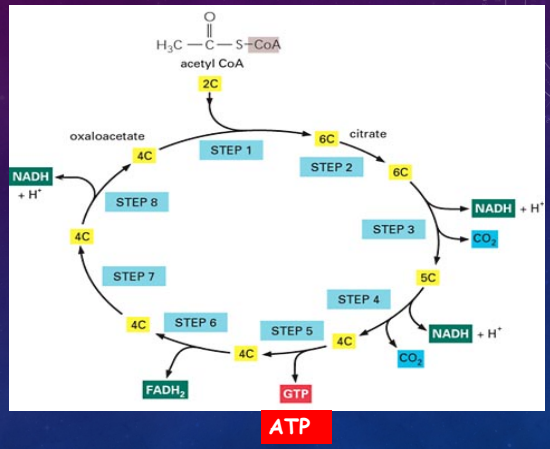
Krebs cycle

Products: 2 Oxaloacetic Acid
6 NADH
2 $FADH_2$
2 GTP
4 CO_2

OVERVIEW OF THE KREBS CYCLE



OVERVIEW OF THE KREBS CYCLE



NETS: 3NADH, 1ATP, 1$FADH_2$, & 2CO_2

KREBS CYCLE SUMMARY

- Requires Oxygen (Aerobic)
- Cyclical series of oxidation reactions that give off CO_2 and produce one ATP per cycle
- Turns twice per glucose molecule
- Produces two ATP
- Takes place in matrix of mitochondria

KREBS CYCLE SUMMARY

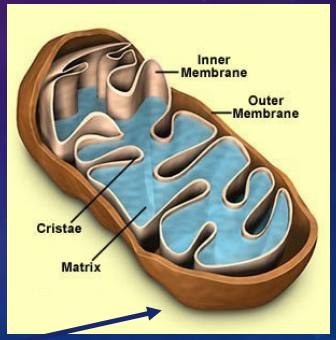
- Each turn of the Krebs Cycle also produces 3NADH, 1$FADH_2$, and 2CO_2
- Therefore, for each Glucose molecule, the Krebs Cycle produces 6NADH, 2$FADH_2$, 4CO_2, and 2ATP

WHERE DOES CELLULAR RESPIRATION TAKE PLACE?

It actually takes place in two parts of the cell:

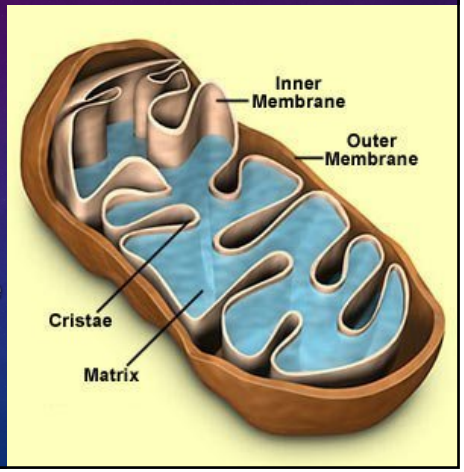
Glycolysis occurs in the Cytoplasm

Krebs Cycle & ETC take place in the Mitochondria



REVIEW OF MITOCHONDRIA STRUCTURE

- Smooth outer Membrane
- Folded inner membrane
- Folds called Cristae
- Space inside cristae called the Matrix



ATP PRODUCTION FROM CARBOHYDRATES

Electron Transport Chain

A series of Oxidative Phosphorylation reactions

Oxidation = the removal of electrons from a molecule and results in a decrease in the energy content of the molecule. Because most biological reactions involve the loss of hydrogen atoms, they are called dehydrogenation reactions.

Reduction = the opposite of oxidation; the addition of electrons to a molecule, and results in an increase in the energy content of the molecule.

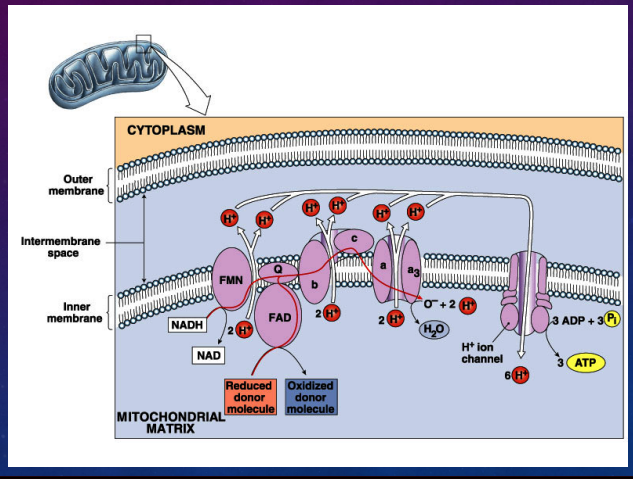
ATP PRODUCTION FROM CARBOHYDRATES

Electron Transport Chain

Substrates required: 10 NADH
2 $FADH_2$
6 O_2

Products: 32 ATP
6 H_20

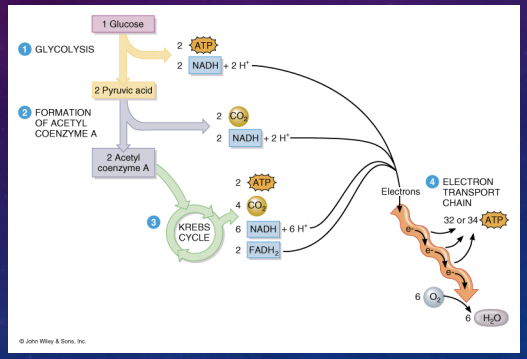
OVERVIEW OF ELECTRON TRANSPORT SYSTEM



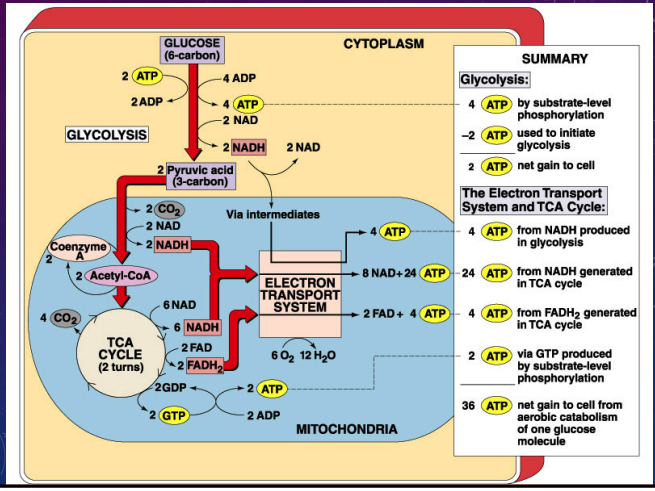
ELECTRON TRANSPORT CHAIN SUMMARY

- 34 ATP produced
- H_2O produced
- Occurs across Inner Mitochondrial membrane
- Uses coenzymes NAD^+ and FAD^+ to accept e- from glucose
- NADH = 3 ATP's
- $FADH_2$ = 2 ATP's

SUMMARY OF ATP PRODUCTION



Overview of Cellular Respiration



PROTEIN METABOLISM

Deamination: removal of the amino group (NH_2) leaving a acetyl molecule

Transamination: Adding an animo group to pyruvic acid to produce any of the nonessential amino acids

Protein Synthesis: Production of protein molecule using an RNA model.

Protein catabolism: breaking down a protein into individual Amino Acids.

LIPID METABOLISM

- **Lipoproteins: surrounding triglycerides with apoproteins to make them more transportable in water**
  - **Very low-density lipoproteins (VLDL's)**
  - **Low-density lipoproteins (LDL's)**
  - **High-density lipoprteins (HDL's)**

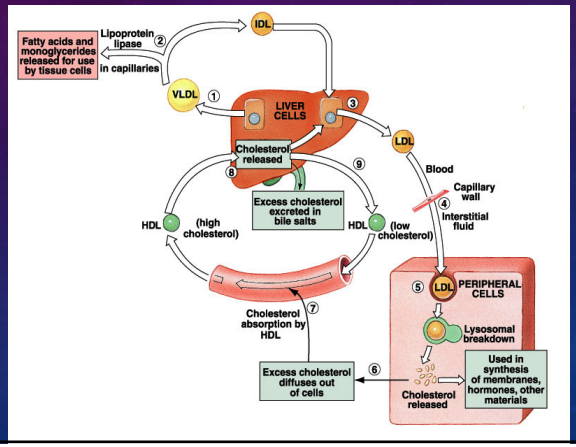
Lipolysis: break down lipids

Beta Oxidation: breaking a fatty acid into 2 carbon compounds

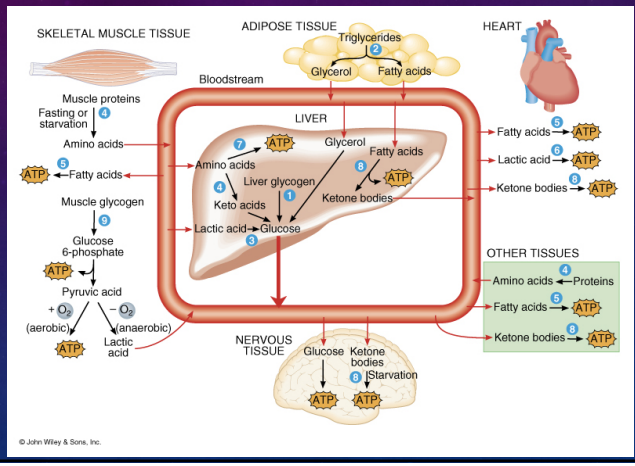
Lipogenesis: formation of lipids from non-lipids

OVERVIEW:

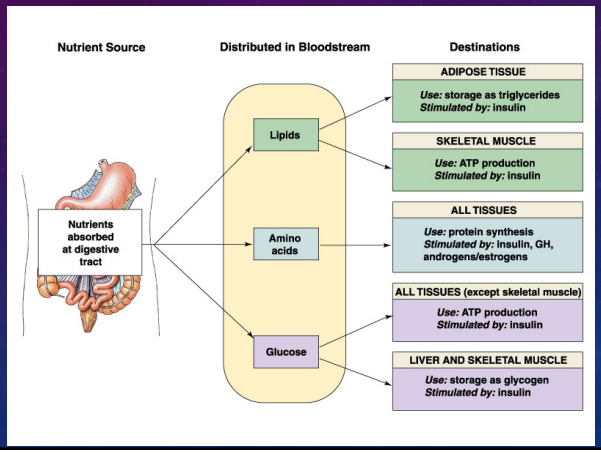
THE ROLE OF THE LIVER IN LIPID METABOLISM



SUMMARY OF THE INTERCONNECTION BETWEEN TISSUES AND METABOLISTIC REACTIONS



METABOLIC OVERVIEW: THE ABSORPTIVE STATE



METABOLIC OVERVIEW: THE POSTABSORPTIVE STATE