Ivan's Chapter 4 Study Guide
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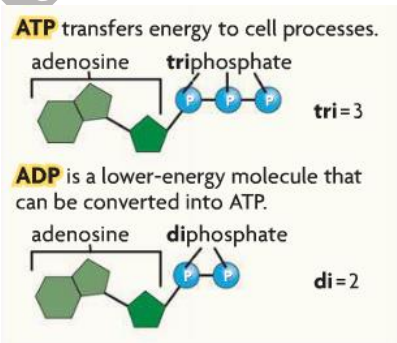
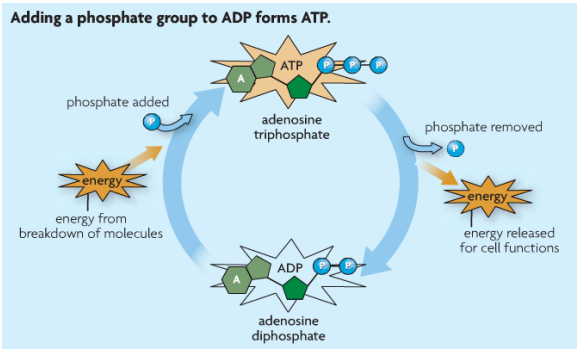
ATP – The Fuel of Cells

- All cells use ATP
  - ATP = Adenosine Triphosphate
  - Transfers energy from breakdown of food to cell processes
  - Used for building molecules, active transport, etc.
- Released when phosphate group is removed
  - Has three phosphate groups
  - Bond holding third is unstable and weak
    - Removal results in energy-producing reaction
    - Energy is released; ATP becomes ADP
- Organisms break down carbon-based molecules to produce ATP
- Food does not contain ATP
  - Must be digested into smaller molecules
- Number of ATP molecules relies on type of molecule
  - Carbohydrate, lipid, or protein
- Carbohydrates are most commonly broken down into ATP
- Breakdown of glucose yields 36-38 (38) molecules of ATP
- Lipids store most energy
  - Lipid fats store 80% of energy in body
  - Triglyceride can be broken into 146 molecules of ATP
- Proteins store same as carbs; less likely to be broken down
  - Amino acids needed to build more proteins instead of making energy
- Plants use photosynthesis to make ATP





Chemosynthesis

- Chemosynthesis = Process by which organisms use chemical energy instead of light energy to make energy-storing carbon-based molecules
  - Still need ATP for energy
- Chemosynthetic organisms make their own food, like plants

Photosynthesis – The Method of Producers

- Organisms which use photosynthesis are producers
  - Produce source of energy for themselves
- Plants, bacteria and protists are main producers & sources of chemical energy
- Photosynthesis = Process which captures energy from sunlight to make sugars that store chemical energy
- Sunlight has several types of energy
  - Ultraviolet, microwaves, visible light, etc.
- Chlorophyll = Molecule in chloroplasts which absorbs energy in visible light
  - Plants have *chlorophyll A* and *chlorophyll B*
  - Absorb mostly red and blue light
    - Don't absorb much green

Chloroplasts

- Photosynthesis occurs in chloroplasts
  - Membrane-bound organelles
  - Most in leaf cells which are specialized for photosynthesis
    - Has two main stages
- Grana and stroma needed for photosynthesis
- Grana = Stacks of coin-shaped membrane-enclosed thylakoids
  - Membranes contain chlorophyll
- Stroma = Fluid which surrounds grana

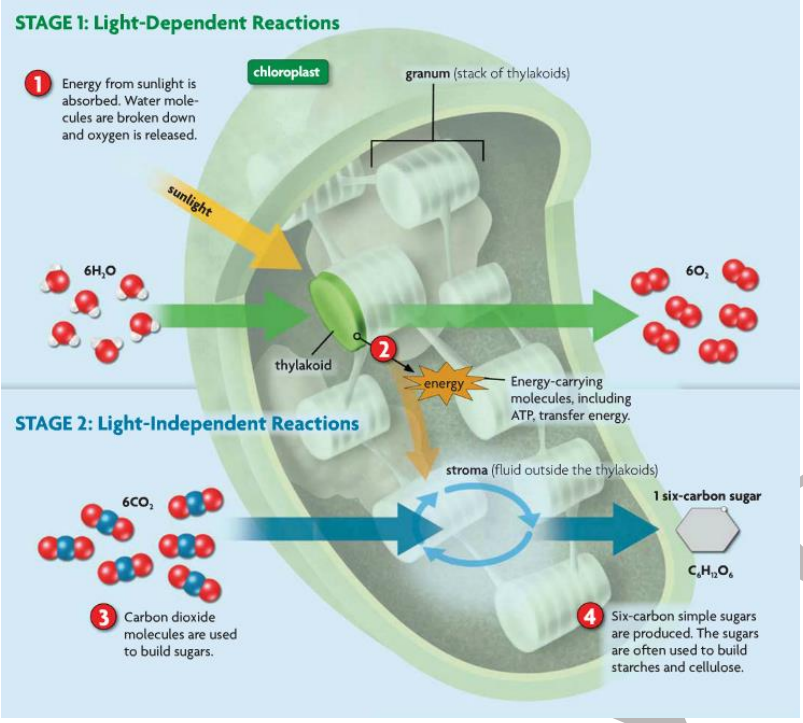
Reactions

- Light-dependent reactions = Capture energy from sunlight; take place across thylakoids; needs water and sunlight
  - Stage 1: Chlorophyll absorbs energy from sunlight
    - Energy is transported across thylakoid membrane
    - H_2O is broken down
    - O^2 is released
  - Stage 2: Energy carried across membrane is transferred to energy-carrying molecules (such as ATP)
- Light-independent reactions = Use energy from light-dependent reactions to make sugars; reaction occurs in stroma; CO_2 is needed
  - Stage 3: CO_2 is added to a cycle to build larger reactions
    - Energy from light-dependent reactions is used
  - Stage 4: Molecule of simple sugar (usually glucose [$C_6H_{12}O_6$]) stores energy captured from sunlight

Equation for Photosynthesis

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

- Light-independent reactions only need one molecule of CO_2 at a time
- Plants need simple sugars to build starch and cellulose



Light-Dependent Reactions

- Energy is captured and transferred in thylakoid by two groups of photosystem molecules
  - Photosystem I and Photosystem II
- Energy from molecules is used to make molecules that act as energy carriers
  - Carriers are ATP and NADPH
- ATP from light-dependent reactions is not usually used as the cell's general energy
  - Goes along with NADPH to later stages of photosynthesis

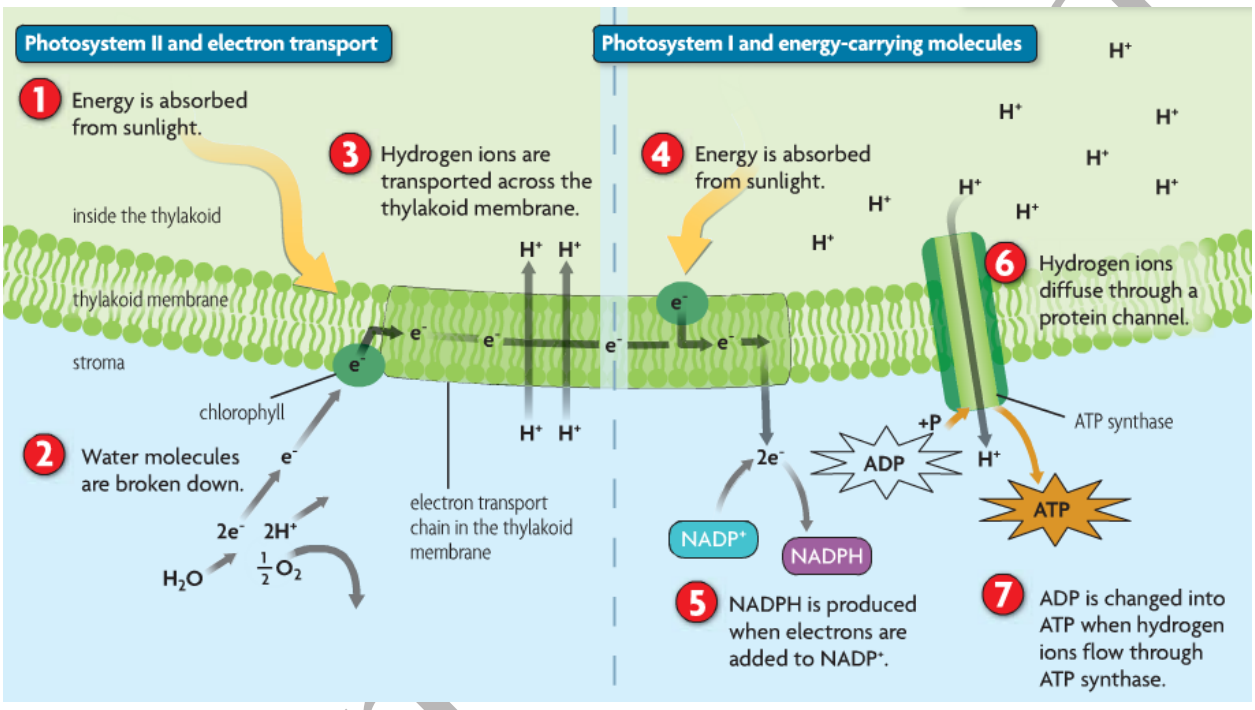
Photosystem II and Electron Transport

- Needs water to function
- Stage 1: Energy is absorbed from sunlight
  - Chlorophyll & light-absorbing molecules in thylakoid absorb energy
    - Energy is transferred to electrons (e^-)
  - Electrons leave chlorophyll and enter electron transport chain
    - Series of proteins in membrane of thylakoid
- Stage 2: Water molecules split
  - Enzymes break down water molecules
  - Oxygen, hydrogen ions (H^+) and electrons are separated
    - Oxygen is released as waste
  - Electrons from water replace those which left chlorophyll
- Stage 3: Hydrogen Ions transported

- Electrons move from protein to protein in electron transport chain
- Their energy is used to pump H^+ ions into the thylakoid against concentration gradient
- H^+ builds up inside thylakoid
- Electrons move onto Photosystem I

Photosystem I and Energy-Carrying Molecules

- Light energy is still absorbed
  - Added to electrons, some of which come from photosystem II



- Stage 4: Energy is absorbed from sunlight
  - Electrons are energized by thylakoid membrane light-absorbing molecules
    - Leave the molecules
- Stage 5: NADPH produced
  - Energized electrons are added to $NADP^+$ which functions like ADP
  - NADPH molecules are made
    - Functions like ATP
    - Go to light-independent reactions

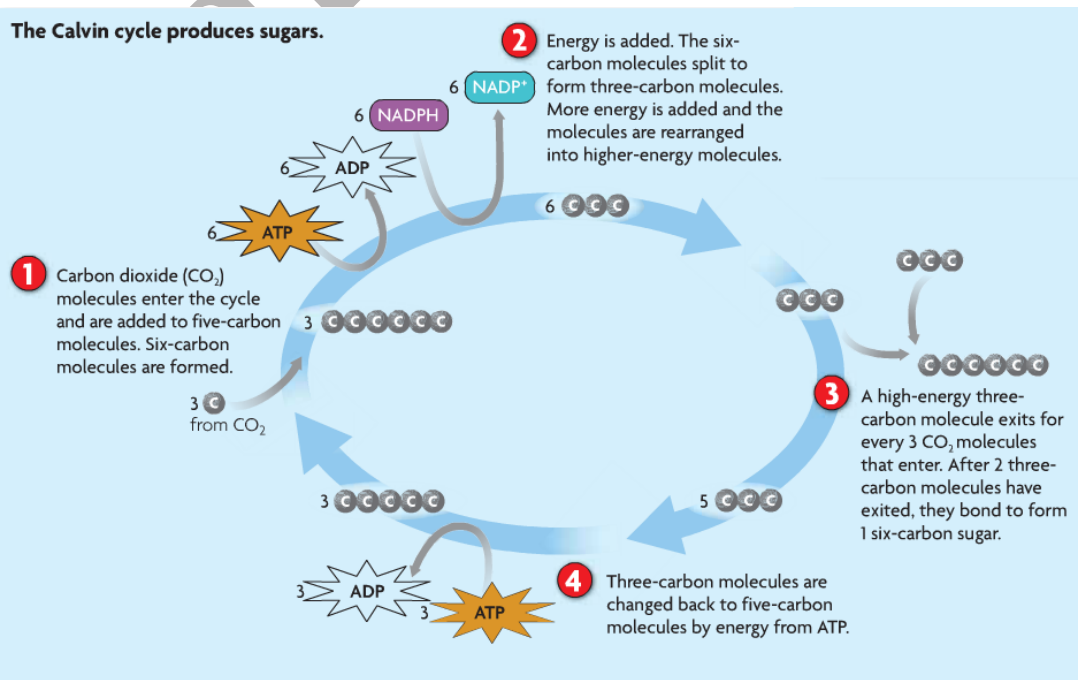
ATP Production

- Production of ATP depends on H^+ which built up in the thylakoid from photosystem II and enzymes
- Stage 6: Hydrogen ion diffusion
  - Hydrogen ions flow through thylakoid membrane protein channel
  - Difference in H^+ concentration = chemiosmotic gradient

        - Stores potential energy
    - Ions flow through channel by diffusion
- Stage 7: ATP produced
    - ATP synthase = Complex enzyme
        - As ions flow through channel, makes ATP by adding phosphate groups to ADP

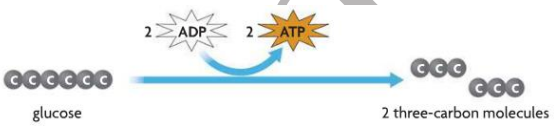
The Calvin Cycle

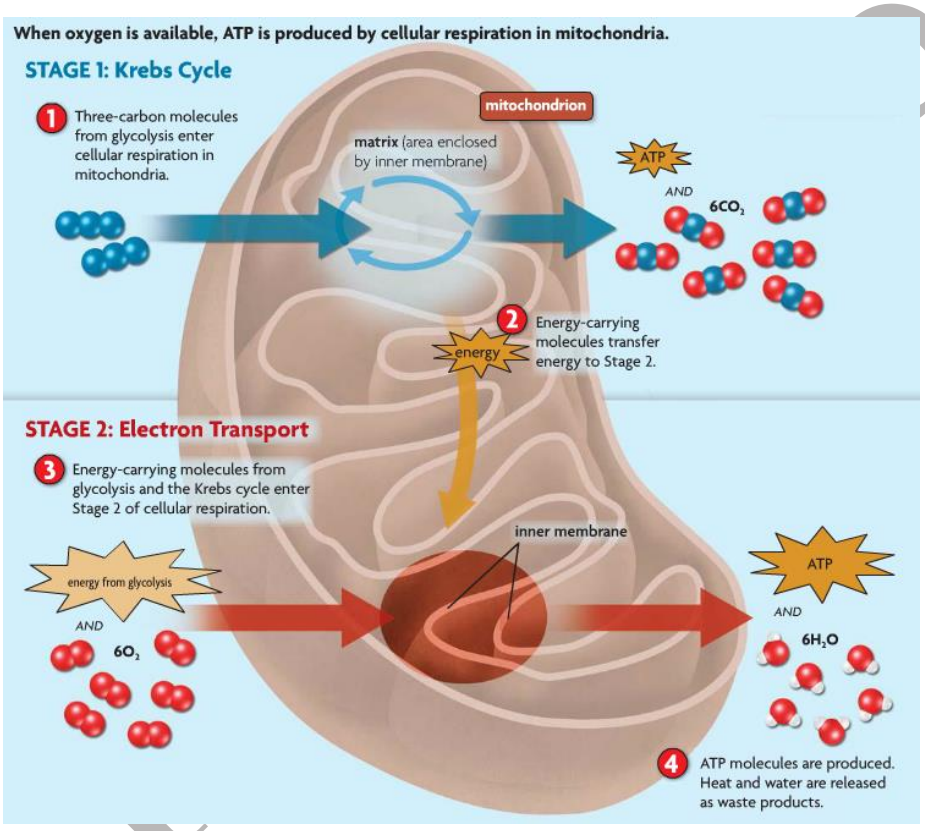
- Can't take place without ATP from light-dependent reactions
- The Calvin Cycle runs on CO_2 and energy carried by ATP and NADPH to make simple sugars
- Only one molecule of CO_2 is added at a time
    - Simplified diagram shows three
- Stage 1: CO_2 added
    - CO_2 molecules are added to preexisting 5-carbon molecules
        - Six-carbon molecules are formed
- Stage 2: Three-carbon molecules formed
    - ATP and NADPH are used by enzymes to split six carbon molecules
        - Three-carbon molecules are formed and rearranged
- Stage 3: Three-carbon molecules exit
    - Most three-carbon molecules stay in cycle
        - One high-energy molecule leaves
    - After two leave, they're bonded to build a six-carbon sugar
        - Such as glucose
- Stage 4: Three-carbon molecules recycled
    - Energy from ATP is used to change three-carbon into five-carbon molecules
        - Five-carbon molecules stay in cycle
        - Added to new CO_2 molecules

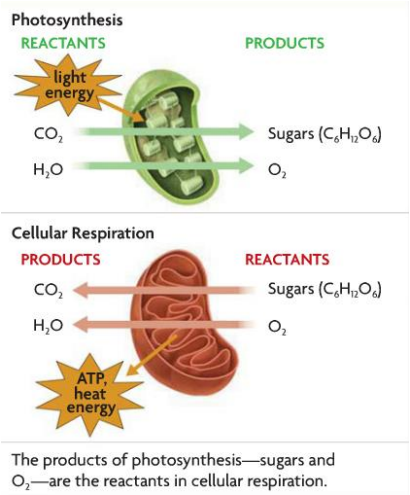


Cellular Respiration and Glycolysis

- Cellular respiration releases chemical energy from sugars and other carbon-based molecules
  - Makes ATP when oxygen is present
  - Is an aerobic process
    - Needs oxygen to take place
  - Takes place in mitochondria
- Glycolysis splits glucose into two three-carbon molecules
  - Makes two molecules of ATP
  - Takes place in cytoplasm
  - Is an anaerobic process
    - Does not need oxygen to take place
  - Necessary for cellular respiration







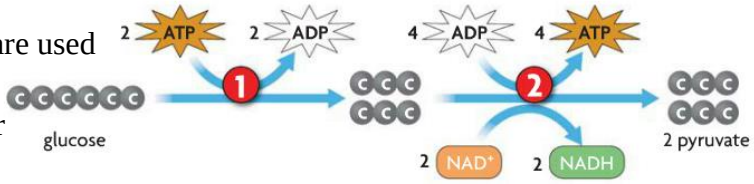
- The Krebs Cycle produces molecules which carry energy to 2nd part of cellular respiration
- Stage 1: Three-carbon molecules from glycolysis are broken down
  - Small number of ATP molecules are made
  - CO_2 is given off as waste product
- Stage 2: Energy is transferred to 2nd stage of cellular respiration

- Electron transport chain of proteins needs energy molecules from Krebs cycle and O_2 to make ATP
  - Takes place in/across inner mitochondrial membrane
- Stage 3: Energy is transferred to chain of proteins in inner membrane
- Stage 4: Large amounts of ATP molecules are made
  - O_2 enters and is used to make H_2O
  - Water and heat are given off
- Up to 38 ATP molecules are produced from breaking down one glucose molecule
  - 2 from glycolysis and 36 from cellular respiration

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

Glycolysis and Cellular Respiration

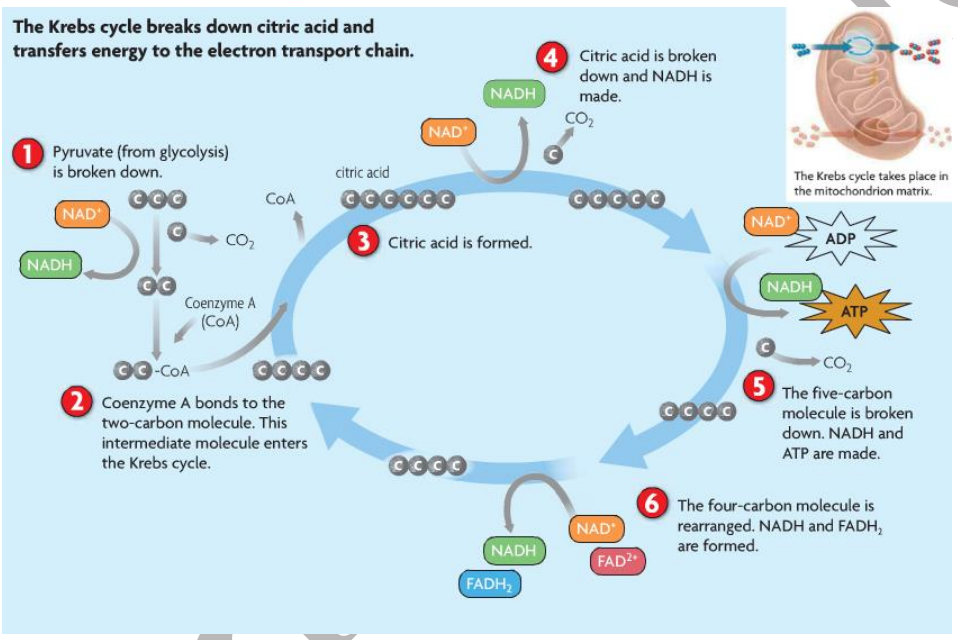
- Stage 1: Two ATP molecules are used to energize a glucose molecule
  - Glucose splits into two three-carbon molecules
  - Enzymes and chemical reactions rearrange molecules
- Stage 2: Energized electrons from three-carbon are transferred to NAD^+ molecules
  - NADH molecules are formed
  - Reactions convert three-carbon molecules to pyruvate which enters cellular respiration
  - Four ATP molecules are made
- Although four molecules are made, two are used to split the glucose molecule
- Pyruvate and NADH are used for cellular respiration when oxygen is present
- NADH is an electron carrier



The Krebs Cycle and Cellular Respiration

- Stage 1: Pyruvate broken down
  - A pyruvate molecule is split into a two-carbon molecule and molecule of CO_2, which is a waste product
  - Electrons and transferred from two-carbon molecule to NAD^+
    - Forms molecule of NADH
    - NADH moves to electron transport chain
- Stage 2: Coenzyme A
  - Bonds to two-carbon molecule
  - Intermediate molecule goes to Krebs cycle
- Stage 3: Citric acid formed
  - Two-carbon part of intermediate molecule is added to four-carbon molecule
    - Forms six-carbon molecule called citric acid
    - Coenzyme A goes back to stage 2
- Stage 4: Citric acid broken down
  - Citric acid is broken down by enzyme and five-carbon molecule is formed

    - NADH molecule is made and leaves cycle
    - A CO_2 waste product is created
- Stage 5: Five-carbon molecule broken down by an enzyme
    - One four-carbon, NADH, and ATP molecule is formed
    - NADH leaves the cycle
    - CO_2 waste product is produced
- Stage 6: Four-carbon molecule rearranged by enzymes
    - High-energy electrons are released
    - NADH and $FADH_2$ electron carrier molecules are made
        - Both leave the cycle
        - Four-carbon molecule remains

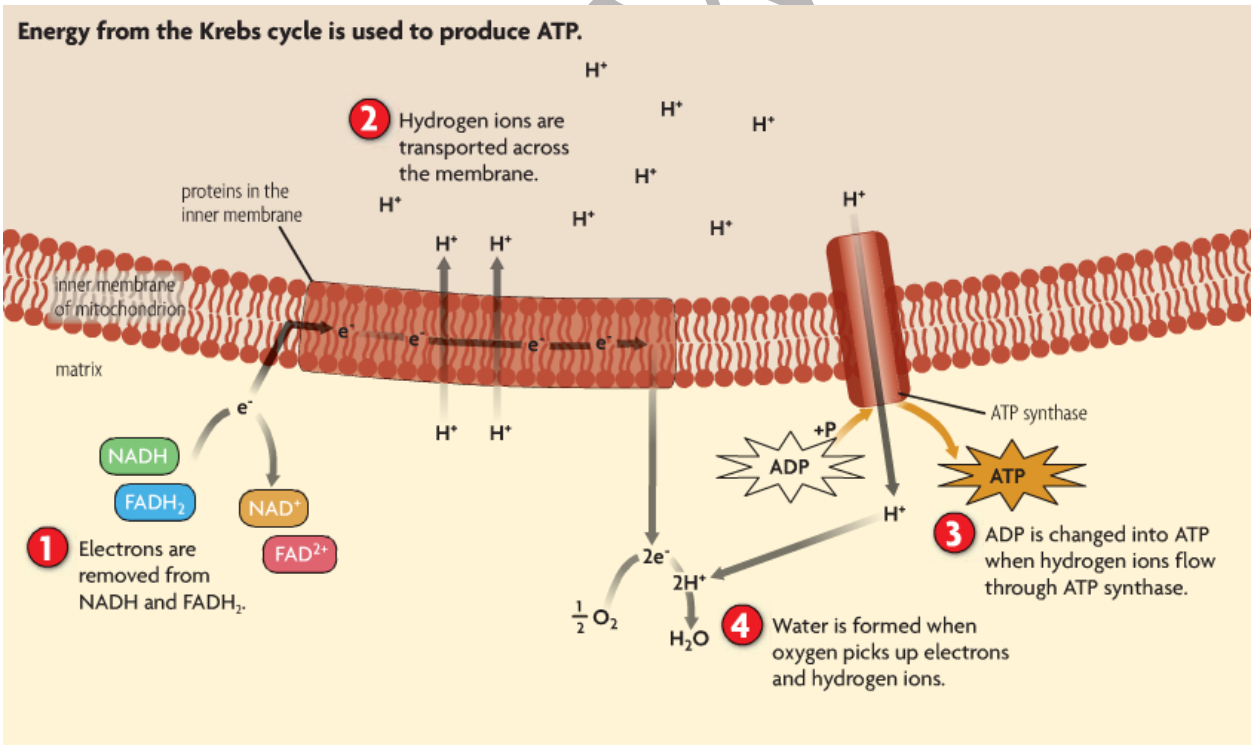


- Products from the breakdown of one pyruvate molecule are…
    - Three molecules of CO_2 waste product
    - One molecule of ATP
    - Four molecules of NADH to electron transport chain
    - One molecule of $FADH_2$ to electron transport chain
- Glycolysis produces two pyruvate molecules
    - Totals six CO_2, two ATP, eight NADH, and two $FADH_2$ molecules

<u>The Electron Transport Chain is the 2nd Main part of Cellular Respiration</u>

- Electron transport chain takes place in and across mitochondrion inner membrane
    - Made of proteins
    - Use energy from NADH and $FADH_2$ to pump H^+ against concentration gradient and across membrane
- Ions flow back through membrane to produce ATP

- Oxygen is needed to pick up electrons which have gone through the chain
- Step 1: Electrons removed
  - Protein inside inner membrane takes electrons from NADH and $FADH_2$
  - Two molecules of NADH and one molecule of $FADH_2$ are used
- Step 2: Hydrogen ions transported
  - Electrons travel through transport chain proteins
    - Use energy from electrons to pump hydrogen ions across inner membrane to produce chemiosmotic gradient
  - Hydrogen ions build up inside mitochondria
- Step 3: ATP produced
  - Flow of hydrogen ions is used to make ATP
  - Ions diffuse through protein channel in inner membrane of mitochondrion
    - Channel is part of ATP synthase
    - ATP Synthase adds phosphate groups to ADP to make ATP
  - For each pair of electrons, three ATP molecules are made
- Step 4: Water formed
  - Oxygen enters the process
  - Oxygen picks up electrons and hydrogen ions to form water
  - Water is given off as a waste product.

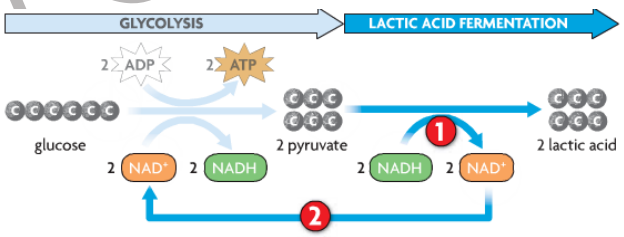


- Products from cellular respiration including glycolysis are…
  - CO_2 from the Krebs cycle and broken-down pyruvate
  - Water from transport chain
  - Up to 38 ATP per glucose molecule
    - 2 from glycolysis, 2 from Krebs cycle, and up to 34 from transport chain

	Photosynthesis	Cellular Respiration
Organelle for Process	Chloroplast	Mitochondrion
Reactants	CO_2 and H_2O	Sugars (glucose) and O_2
Electron transport chain	Proteins within thylakoid membrane	Proteins within inner mitochondrial membrane
Cycle of chem. Reactions	Calvin cycle in stroma builds sugar molecules	Kerbs cycle in matrix breaks down carbon-based molecules
Products	Sugars (glucose) and O_2	CO_2 and H_2O

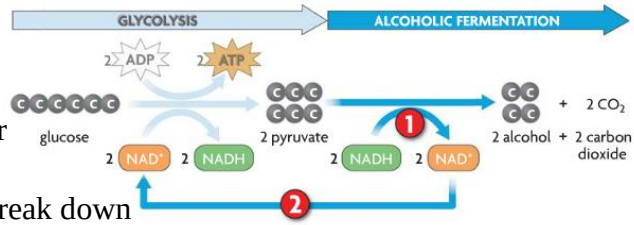
Lactic Acid Fermentation

- Fermentation is an anaerobic process which allows glycolysis to continue
  - Does not make ATP
  - Removes electrons from NADPH and recycles NAD^+
- Lactic Acid ($C_3H_6O_3$) is what causes your muscles to burn during hard exercise
  - Product of lactic acid fermentation
- Once oxygen is available, cells go back to using aerobic respiration
- Waste products of bacteria and mold fermentation are essential for making cheese, yogurt, and bread



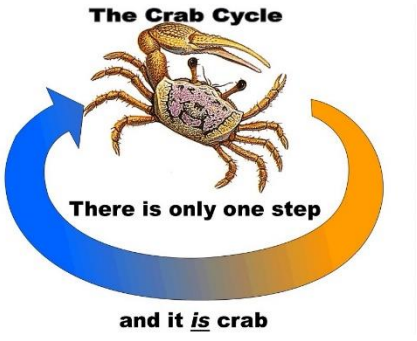
Alcohol Fermentation

- Alcohol fermentation is used by yeast and plants
  - Begins at same point as lactic acid
- Stage 1: Pyruvate and NADH from glycolysis enter alcoholic fermentation
  - Two NADH molecules provide energy to break down pyruvate into an alcohol and carbon dioxide
    - NADH is converted back into NAD^+
- Stage 2: The molecules of NAD^+ are recycled back to glycolysis
  - The recycling allows it to continue
- Products of this process include…
  - Two molecules of alcohol
    - Often ethyl alcohol
  - Two molecules of carbon dioxide
  - Two molecules of NAD^+



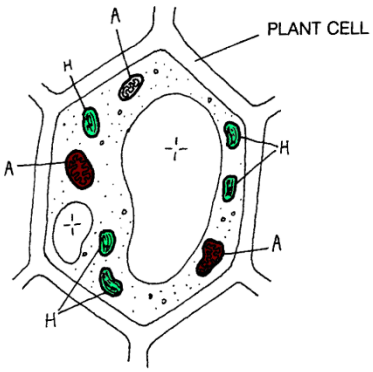
Microorganisms and You

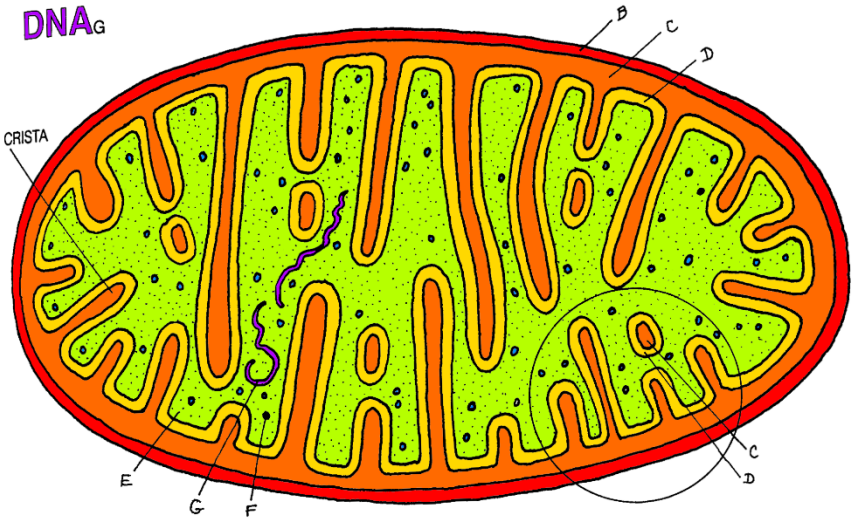
- As yeast breaks down sugar, it produces CO_2
  - This is why bread rises

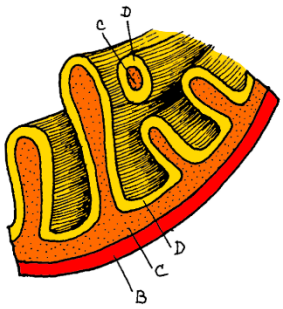


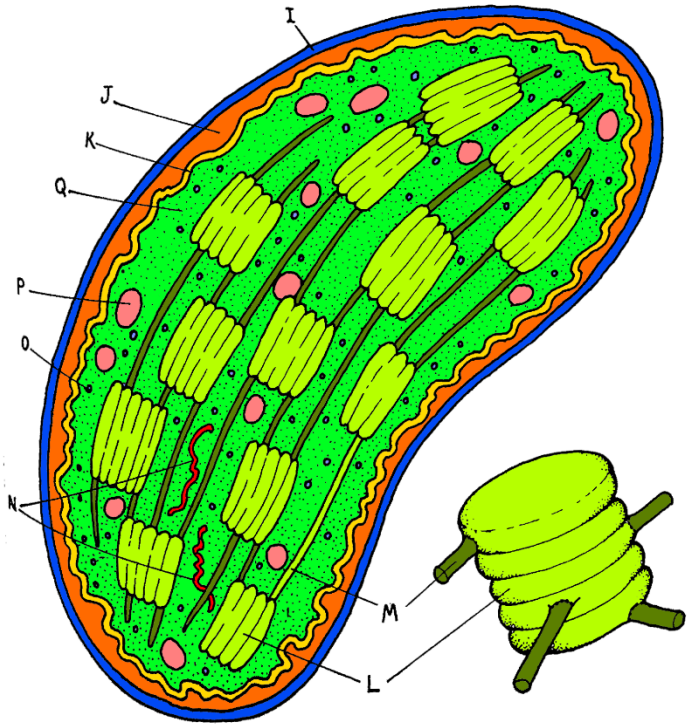
MITOCHONDRION AND CHLOROPLAST.

MITOCHONDRION$_A$
OUTER MEMBRANE$_B$
INTERMEMBRANE SPACE$_C$
INNER MEMBRANE$_D$
MATRIX$_E$
RIBOSOME$_F$
DNA$_G$









CHLOROPLAST$_H$
OUTER MEMBRANE$_I$
INTERMEMBRANE SPACE$_J$
INNER MEMBRANE$_K$
GRANUM$_\star$
THYLAKOID$_L$
STROMAL LAMELLA$_M$
DNA$_N$
RIBOSOME$_O$
STARCH GRAIN$_P$
STROMA$_Q$