

Biochemistry

Dehydration Synthesis(monomer → polymer)

- How monomers turn into polymers (Eject a H₂O and join the monomers)
- Monomers are covalently linked by removing water for each covalent bond
- Ether linkage [R-O-R']
 - Reaction between 2 hydroxyl groups
 - Alcohol + alcohol → ethane + water
 - Hydroxyl + hydroxyl → Ether + Water
 - R-OH + HO-R' → R-O-R' + H₂O
- Ester linkage
 - Reaction between carboxyl and hydroxyl
 - Carboxyl + acid → ester + water
 - The OH and H will form a water molecule and the rest of the two molecules should join - check whether its legit before moving on (nitrogen can make 3 bonds, carbon can make 4 bonds)
 - Carboxyl + Hydroxyl → ester + water
 - R-COOH + HO-R' → R-COOR'
 - NOT testing on naming
 - Just testing on drawing molecules, the reactions between the molecule
 $=\text{O} - \text{H}$
- Peptide linkage [R - C - N-R]
 - Reaction between one carboxyl and one amino group
 - Carboxyl + amino → amide + water
 - R-COOH + H₂N → R-CONH-R' + H₂O

Hydrolysis (polymer → monomer)

- Breaking covalent bonds between monomers by the addition of a water molecule
 - Effectively reverse dehydration synthesis, work backwards from a molecule to its monomer groups
- Molecules of Life
 - H,C,O (these guys hang out everywhere)
 - N (amino acids)
 - P (DNA backbones)
 - Carbohydrates, fats, proteins, DNA are made of the ^above^

Carbohydrates (sugars)

- Contains C, H, O
- Refers to the “sugar” family
 - Glucose, fructose, starch, cellulose (fruits like broccoli have tons of cellulose)
- Body’s most important source of energy
- Are building material and cell communication
- Come from plants
- Named with -OSE

3 groups

Monosaccharides(simple sugars)

- Examples:
 - Glucose
 - Fructose (you’ll see more of these in your food)
 - Galactose
 - LACTOSE
- Simple sugars → monomers = 1
- One building block of a larger molecule
- Contains C_n, H_{2n}, O_n
- Most widely used group
- **Sweetness is proportional to the number of saccharides (more monosaccharides reduces the sweetness)**
- Occur in linear form when in water w 5 or more carbons
- Or as a ring when 5 carbons bend back to make a ring
 - The ring is more of a lie - it’s still really the single linear molecule but an oxygen atom connects the ends (we **START numbering monosaccharides with the carbon that HAS the carboxyl group**)
- 2 arrangements of the -OH ring → isomers
- Are identified based on the positions of the hydroxide groups
 - a glucose (alpha) → OH are both on bottom
 - From the rightmost hydroxide, the location of hydroxides are:
 - Down, Up, Down, Down
 - b glucose (beta) → 1 OH on top, other on bottom
 - Down, Up, Down, Up
 - Galactose is up up down down
- Other examples: glucose + galactose → optical isomers
 - Both have aldehyde group → aldose
 - Fructose has a ketone group, is numbered differently than other sugars smh
- Typically have many polar functional group → hydrophilic

- Small sugars are highly soluble in water
- Sweetest of the three sugar groups

Disaccharides(double sugars)

- 2 monosaccharides linked together through dehydration synthesis
- How to make sugars:
 - α -Glucose + α -Glucose = Maltose
 - Glucose + Fructose = Sucrose → table sugar
 - Glucose + Galactose = Lactose → milk
- Dehydration synthesis
 - One monosaccharide loses a hydroxyl group (OH) and one loses a hydrogen atom (-H)
 - These two monosaccharides produce water and disaccharide is formed
 - Process can be reversed when water is added
 - Bonds between monosaccharides are called **glycosidic bonds**
- Beta-linkage
 - What happens when two beta glucose are put together? Cellulose
 - Dehydration synthesis: one of the beta glucose's are flipped over so that a hydroxide reacts with another hydroxide to produce water and let the oxygen form the glycosidic bond
 - Beta 1,4-glycosidic linkage

Polysaccharides(complex sugars)

- Polymer of a few hundred or thousand molecules
- Polymerization - process in which small sub units are linked to form a large molecule
- Complex carbs, not sweet, very polar = hydrophilic
- Don't dissolve in water because they are so big
- Examples:
 - For Storage: Starch, glycogen
 - Structure: cellulose and chitin
- Starch
 - Polymer of alpha glucose
 - Plant storage
 - Simplest form of starch = amylose (unbranched)
 - Amylopectin → branched and more complex
 - Our saliva is amylase to break down amylose
- Glycogen
 - Energy storage for animals
 - Stored in muscles + liver
 - More extensively bonded than amylose and amylopectin
- Cellulose

- Structural component of cell wall in plants
- Polymer of β glucose joined together by β 1,4-glycosidic linkage
- Enzymes that digest starch can't digest β -linkage cellulose because of the active site of the enzyme

Summary of sugars:

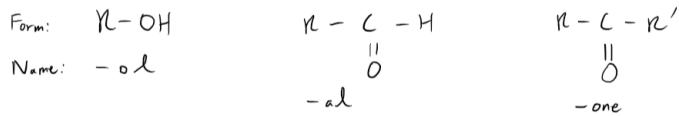
Name		Structural Unit	Linkages	Occurrence
storage	Amylose	α glucose	α 1,4	Plant starch
	Amylopectin	α glucose	α 1,4 & α 1,6	Plant starch
	Glycogen	α glucose	α 1,4 & α 1,6	Muscles, liver
structural	cellulose	β glucose	β 1,4	Plant cell wall
	chitin	Glucosamine $(\beta$ glucose + N)	β 1,4	Arthropod cuticle (shell)

- Steric Repulsion (Why mono/di/polysaccharides have a spiral shape)
 - More compact, store more in same space → like the concept of DNA
 - Amylose, amylopectin and glycogen
 - Composed of α -glucose units linked together by α -1,4,glycosidic linkage
 - These linkages are polar covalent bonds that leave the hydrogens slightly electro-positive
 - The hydrogens HATE this, and so tries to get away by bending away
 - They form spirals instead of rings to fit more
- Cellulose
 - Composed of beta-glucose units linked together by beta-1,4-glycosidic linkage
 - These linkages are polar covalent bonds that leave the hydrogens slightly electro-positive
 - The hydrogens HATE this, and so tries to get away by bending away
 - They form zigzags because of the Up-Down-Up-Down shape of the beta polysaccharide
 - Successive monosaccharides are inverted relative to one another (zig zag shape)
 - Zigzag is very strong and inflexible → used in cell wall
- <https://www.youtube.com/watch?v=jQi84TnslI4>

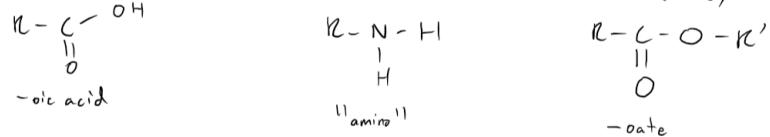
Nomenclature Quiz (after lesson, beginning at 10:45)

- Brightspace
- Covers all nomenclature stuff (sept 22 - 24) + review in MC
- Part A: 7 - 10 MC
- Part B: 3 questions - Naming molecules → give structure or give name
- Identify functional groups within structure
- Part C: 3 questions - Draw structural diagrams given name or chemical formula
- Chemical formula given → form where carbons are separated to make it easier (chemical formula will be in the form that tells you what is attached to each carbon)
- Part D: 3 - 4 questions - short answers, similar to what we did on the worksheets

Hydroxyl (alcohol) Aldehyde (sugar) Ketone (sugar)



Carboxyl (organic acid) Amino (amino acid) Ester (fats)



Ether (sugars) Amide

$\text{R}-\text{O}-\text{R}'$	$\text{R}-\text{C}-\text{N}-\text{R}'$
"ether"	$\begin{array}{c} \text{ } \\ \text{O} \\ \text{ amide} \end{array}$

Lipids

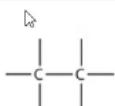
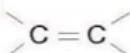
- Insoluble in water
- Hydrophobic, nonpolar
 - Have a hydrophilic head
- Composed of c, h, o (no specific ratio)
- Used by organisms to
 - Store energy long term
 - Build membranes and other cell parts
 - Hormones that regulate cell activities
 - Vitamins
- Four groups of lipids
 - Fats

- Phospholipids
- Steroids
- waxes

1 / 4 Groups of Lipids: Fats

- Most common energy storing molecule in living organism
- 20-35% of daily intake
- Carbohydrates are converted to fat
- Store droplets in cells of adipose (fat) tissue
- Other uses of fats:
 - Warmth / insulation
 - Cushioning for organs
- Functions
 - 1 gram of fat stores 9 calories compared to 1g of carbohydrate which stores 4 calories
 - Also weighs less than carbs
 - Cushioning effect for internal organs
 - Insulation for cold temperatures
- Made from 2 types of molecules: fatty acids and a glycerol
 - Glycerol makes the backbone of most lipids
 - Fatty acids consists of carboxyl group and a hydrocarbon chain
 - Most common fats in plants n animals are triglycerides
 - 1 glycerol molecule + 3 fatty acid chains
 - Hydrophilic head, Hydrophobic tail
 - Glycerol slurp water, fatty acids nono water
 - Triglycerides form through dehydration synthesis and form an ester linkage
 - Sometimes triglycerides will have a double bond on their tail resulting in a kink
 - Most common forms have even-numbered fatty acids chains of 14-22
 - As chain length increases, fatty acids become less water soluble
 - Fatty acids nono water
- Saturated vs Unsaturated fats:
 - Saturated
 - Unsaturated → better for you

Saturated vs. Unsaturated Fat

Saturated Fat	Unsaturated Fat
	One or more double bond(s) 
All the carbons are bonded to maximum number of hydrogen atoms.	Tails kinks at each C=C so molecules do not pack enough to solidify at room temperature.
Usually a solid at room temperature.	Usually a liquid at room temperature
Eg. – lard (pork & chicken), butter	Eg. Vegetable oil, olive oil



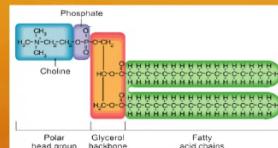
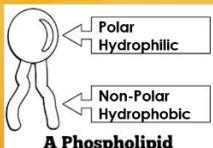
- Saturated fats are solid due to long straight chains allowing to be packed close together
- Diets rich in saturated fats can lead to heart disease
- Inuits have high fat and protein diet beneficial for cold climates
- Rich in fat diets can result in blocked arteries as atherosclerotic plaque builds up from → atherosclerotic plaque is called that when the fat builds up in the artery
- Polyunsaturated fatty acids (PUFAs) many C double bonds
 - Industrial process called hydrogenation adds hydrogen atoms to the double bond making it → semisolid
- What is fat? - George Zaidan
 - <https://www.youtube.com/watch?v=QhUrc4BnPgg>
- “Partially hydrogenated” → trans fat = bad
- Medical Procedures
- Balloon angioplasty
 - Clearing out plaque from arteries
 - Put balloon in artery and expand it so that plaque is pushed to the walls
- Bypass surgery
 - Severe surgery when other surgeries have failed
 - Take another artery from the body and replace the coronary arteries near the aorta to divert blood flow around aorta

2 / 4 Groups of Lipids: Phospholipids

- Hydrophilic head: phosphate group + glycerol
- Hydrophobic tail: 2 fatty acids

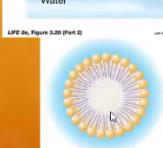
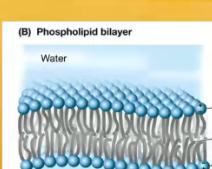
2. Phospholipids

- Consists of:
 - ⊗ Hydrophilic head: phosphate group & glycerol
 - ⊗ Hydrophobic tail: 2 fatty acids
- Amphipathic – molecules containing both hydrophobic & hydrophilic regions
- Glycerol forms the backbone, two binding sites link to fatty acids



2. Phospholipids

- Major component of cell membrane - phospholipid bilayer
- Hydrophilic heads arrange themselves facing water
- Hydrophobic tails arrange themselves facing one another
- Form spheres called micelles with added to water



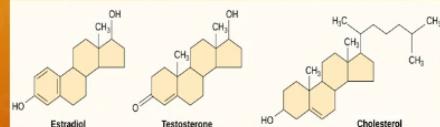
- Application of phospholipids: detergents and soaps
- Detergents and soaps are amphiatic (have both hydrophilic and hydrophobic parts)
- Dirt and grime tend to be nonpolar or oily → bind to non polar tails of detergents → pickup and take off of clothing
- Essential fatty acids
- essential fatty acids are essential → who wudda guessed
 - Some lipids are essential
 - This means the body can't make the molecule and must eat it
 - Eg. linoleic or linolenic fatty acids

3 / 4 Groups of Lipids: Steroids

3. Steroids

Also found in membranes!

- Compact hydrophobic molecules containing
 - ⊗ four fused hydrocarbon rings
 - ⊗ several different functional groups.
 - ⊗ Have a single -OH group at one end of the ring, making it slightly polar/hydrophilic
- Secreted into blood stream (golgi vesicles) for distribution.
 - ⊗ cholesterol
 - ⊗ builds up in bloodstream...dangerous!
 - ⊗ other steroids include
 - sex hormones
 - testosterone
 - estrogens
 - Progesterone

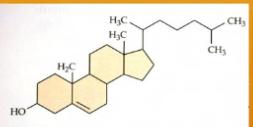


- Four fused hydrocarbon rings
- Slightly polar with the end OH
- Dangerous build up of cholesterol

3. Steroids

Cholesterol

- ✿ Cholesterol is essential for animal cell membranes and converts into a number of compounds (ie. vitamin D)
- ✿ High concentration of cholesterol in bloodstream and diet rich in saturated fats have been linked to development of atherosclerosis (fat/plaques build up in blood vessels) – heart attack!
- ✿ Two types of cholesterol:
 - ✿ High-density lipoprotein (HDL)
 - ✿ Low-density lipoprotein (LDL)



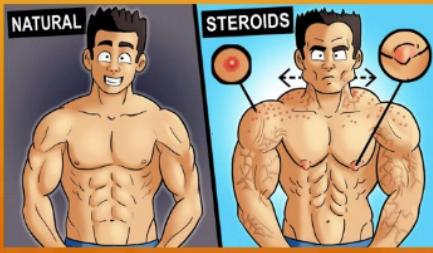
Cholesterol is a constituent of membranes and the source of steroid hormones.

- *heart
- HDL is good, when checked you want your HDL to be H (high)
- LDL is bad, when checked you want your LDL to be L (low)

3. Steroids

Sex hormones

- ✿ Ex testosterone, estrogen, progesterone
- ✿ Control development of sexual traits and sex cells



Anabolic steroids – used by athletes
May have harmful effects:
high blood pressure,
depression, suicidal
tendencies, changes in
level of sex hormones,
reduced growth in young
people

4 / 4 Groups of Lipids: Waxes

4. Waxes



- Large lipid molecules that are made of long fatty acid chains linked to alcohols or carbon rings
- Hydrophobic, extremely non-polar, soft solids over a wide range of temperatures
- Ideal for flexible waterproof coating over various plants and animal parts
- Cutin produced by plants form water-resistant coating on leaf, fruit, stem surfaces

- Cutin part of the cuticle meant to prevent water loss

Test → lipids, polymers, carbohydrates, proteins

- Quiz give back on mon-ish

Proteins

- Proteins account for more than 50% of the dry weight of most cells and involved in almost everything the cell does
- Recommended 20%, though we eat closer to 40%
- 8 Classes of proteins
 - Structural proteins
 - Contractile proteins
 - Storage proteins
 - Defensive proteins
 - Transport proteins
 - Enzymes → most important class of proteins
 - Hormones
 - Recognition/ receptor

The 8 Classes of Proteins

1. **Structural proteins** function in the cell membrane, muscle tissue, and includes the silk of spiders, the hair of mammals and the fibers that make up our tendons and ligaments.
2. **Contractile proteins** work with structural elements. They provide muscular movement.
3. **Storage proteins**, such as albumin, the main substance of egg white, which serves as a source of amino acids for developing embryos.
4. **Defensive proteins**, includes the antibodies which fight infection and are carried in the blood.
5. **Transport proteins**, include hemoglobin, the iron-containing protein in the blood that transports oxygen from our lungs to other parts of the body.
6. **Enzymes**, perhaps the most important class. Enzymes promote and regulate virtually all chemical reactions in cells.
7. **Hormones**, such as Insulin act as chemical messengers.
8. **Recognition/Receptor**, inside or on surface of target cells that receive chemical signals

- Amino acids are building blocks of proteins
 - Amino groups + carboxyl group + side chain which is different in each amino acid
 - 9 amino acids are considered essential → essential means the body can't produce and must get another way
 - 20 standard amino acids

Amino Acids

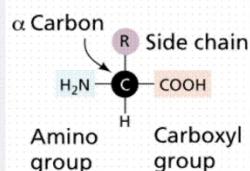
Building blocks of proteins

1. Amino group (NH_2)
2. Carboxyl Group (COOH)
3. R group (side chain)...this is different in each amino acid.

NOTE: 9 Amino Acids are considered Essential!

(histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.)

Conventional depiction

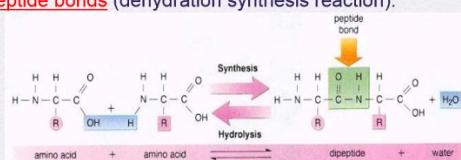


Building Proteins

- All proteins are made from the same 20 **Amino Acids (A.A.'s)**.

• DNA codes for the A.A. order. Change the A.A. order and a different protein is created.

• The A.A. monomers form polypeptide chains held together by **peptide bonds** (dehydration synthesis reaction).



- Proteins are built from the same 20 amino acids (A.A.s)

Protein structure

- Polypeptide chains

Protein Structure

- Protein length can vary from 8 amino acids long to 4000!!
- 1 A.A. = 1 A.A. monomer
- 2 A.A.'s = a dipeptide molecule
- Many A.A.'s = a polypeptide chain
- 1 or more polypeptide chains = a protein molecule.



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- 4 levels of protein structure:
- Primary structure
 - AAs are held together by covalent bonds
 - Unique sequence of amino acid in a protein molecule

1. Primary Structure

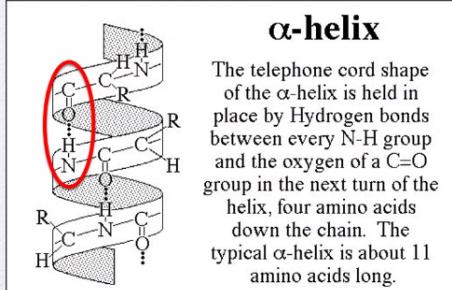
aa₁ – aa₃ – aa₁ – aa₁₇ – aa₉

- Amino acids are held together by covalent bond
- Unique sequence of amino acid in a protein molecule
- Sequence is determined by DNA
- Slight changes in the DNA molecule can affect a protein's 3D structure and function
 - Ex. sickle cell anemia

- Sickle-Cell Anemia
 - Block blood flow due to curved "sickle" shaped cells
 - Can't transport oxygen as easily
 - Genetic mutation, helps prevent contraction of malaria
- Primary bonds are stronger than secondary and tertiary
- Secondary structure
 - Alpha-helix

2. Secondary Structure

A. α -helix structure



α -helix

The telephone cord shape of the α -helix is held in place by Hydrogen bonds between every N-H group and the oxygen of a C=O group in the next turn of the helix, four amino acids down the chain. The typical α -helix is about 11 amino acids long.

- Secondary bonds not as strong as primary covalent bonds

2. Secondary Structure

A. α -helix structure

- All function proteins demonstrate a certain amount of α -helix bonding (~70%)
- Secondary bonding is weaker than covalent bond in primary structure

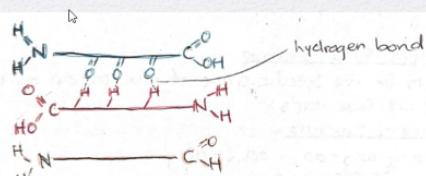
<https://www.youtube.com/watch?v=QoNKorneE04>

- Beta-pleated sheet
 - Organized in anti parallel fashion

2. Secondary Structure

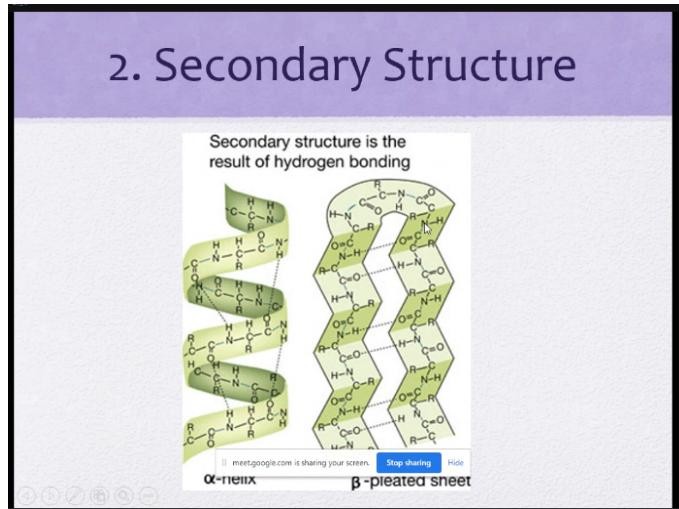
B. β pleated sheet

- Adjacent polypeptides are organized in an anti-parallel fashion
- Polypeptides are organized into two different planes. As a result, when viewed from one end, the arrangement resembles a pleated sheet



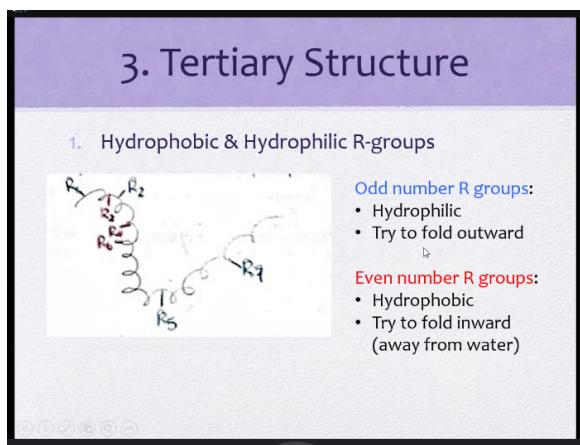
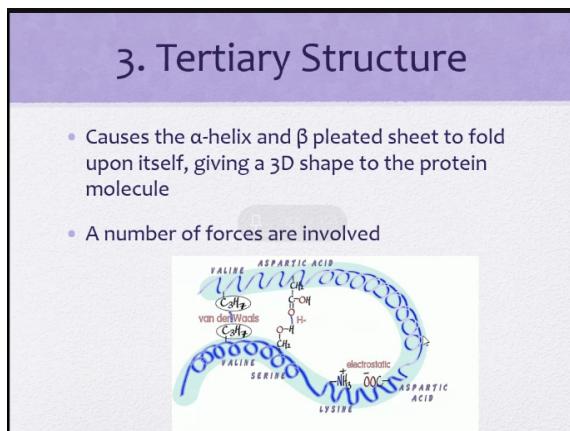
https://www.youtube.com/watch?v=4SZ-s4Zq_rE

- Ex: silk which is very elastic



- This is what a beta pleated sheet looks like in comparison to a-helix
- In a big protein molecule, it can have both a-helix and b-pleated

- Tertiary structure

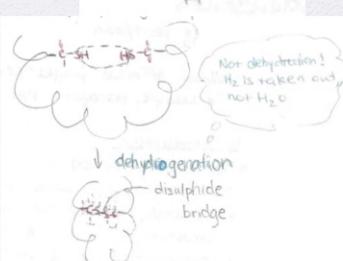
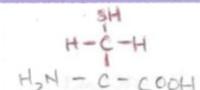


- Changes in folding causes weird shapes of tertiary structure

3. Tertiary Structure

2. Disulphide bridges

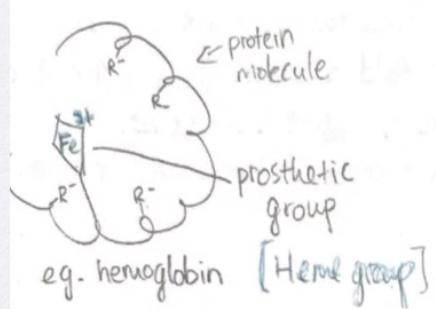
- Formed between 2 cysteine R groups by enzyme
- Can occur in the same polypeptide chain or different polypeptide chains



- Dehydrogenation to take out the hydrogen resulting in a sulfur-sulfur bond known as a disulphide bridge
- Hair grows really fast → i am speed
 - Hair salon uses reducing agent to break down sulfide bridges and then a oxidizing agent to reform them in the way you want → usually to get a perm

3. Tertiary Structure

3. Presence of prosthetic group (heme group)

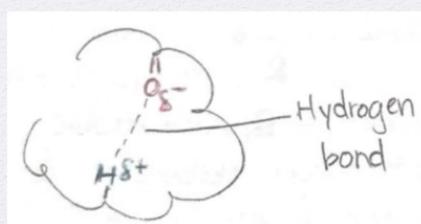


- Hemoglobin contains 4 heme groups carrying 4 O₂
- Many enzymes require prosthetic groups that contain metal ions in order to function

- Prosthetic group is anything with an iron in it
- Hemoglobin contains 4 heme groups

3. Tertiary Structure

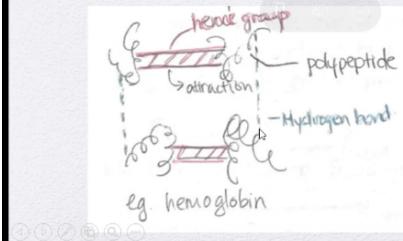
4. Hydrogen bonds between distant amino acids



- Not a real bond, just an attractive force
- Quaternary structure

4. Quarternary Structure

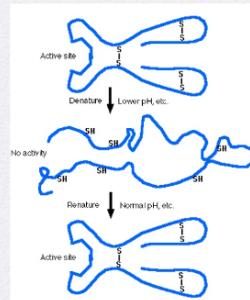
- 2 or more polypeptide chains linked together
- Ex. hemoglobin has 4 polypeptides



- Denaturing Proteins

Denatured Proteins

- A process in which the secondary, tertiary, and quaternary structure of a protein is disturbed or disrupted
- Can be caused by:
 - Temperature change
 - pH change
 - Chemicals
 - Solvent used
- Chemicals and/or heat disrupt the H bond, ionic bonds, disulfide bridges and hydrophobic interactions
- Protein can't carry out function
- Mild cases may be reversible



- Protein supplements

- Get swole by eating protein supplements

Protein Supplements

- Additional protein beyond diet...usually a powder that is mixed into a PRO shake.
- These are usually not needed b/c you can ingest enough PRO through a balanced diet!

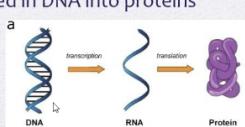



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- Nucleic acids
 - like DNA and RNA
 - Contain instruction to make proteins

Types of Nucleic Acids

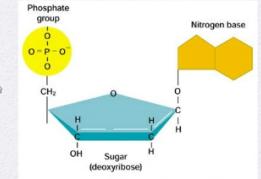
- Contain instructions to make proteins
- Two types:
 - Deoxyribonucleic acid (DNA) – stores hereditary info responsible for inherited traits
 - Ribonucleic acid (RNA) – convert information stored in DNA into proteins



- Nucleotides → the building blocks of nucleic acids
- Nucleotide Structure

Nucleotides

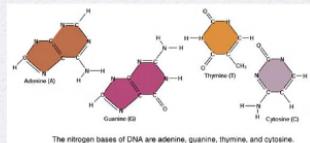
- The building block of nucleic acids
- Contains:
 - Nitrogenous base
 - 5-carbon sugar
 - Phosphate group



One DNA nucleotide, the adenine nucleotide.

Nucleotides

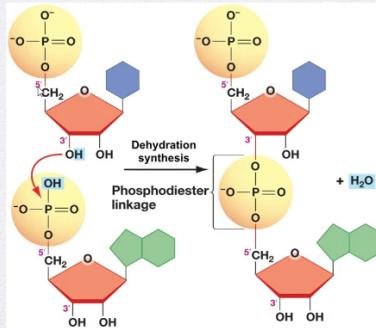
- The nitrogenous bases can be divided into two groups:
 - Purines – two rings
 - Uracil (U)
 - Thymine (T)
 - Cytosine (C)
 - Pyrimidines – single ring
 - Adenine (A)
 - Guanine (G)



- Purines: 2 rings
 - Uracil, thymine, cytosine
- Pyrimidines - single ring
 - Adenine, guanine

Polynucleotide Chain

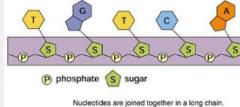
Nucleotides link together by a phosphate group forming single bonds between the 5'-carbon of one sugar and the 3'-carbon of the next sugar



- Done through dehydration synthesis

Polynucleotide Chain

- The phosphate groups and sugar molecules form the backbone of the chain, and the bases stick out like the teeth on a zipper.
- This chain forms the backbone of DNA



- DNA and RNA

2 Types of Nucleic Acids

1. DNA (Deoxyribonucleic Acid)

- The genetic code for all proteins and life functions.
- **2 nucleotide strands linked by Hydrogen bonds between nitrogenous bases (A & T, C & G).**
- A double helix.
- Unique genetic information is determined by the sequence of nucleotides.

The diagram illustrates the structure of DNA as a double helix. It shows the repeating units of a nucleotide, which consist of a phosphate group, a deoxyribose sugar, and a nitrogenous base (Adenine, Thymine, Guanine, or Cytosine). The two strands are linked by hydrogen bonds between complementary base pairs: Adenine (A) pairs with Thymine (T), and Guanine (G) pairs with Cytosine (C). The phosphate groups are shown as green circles, deoxyribose sugars as brown hexagons, and nitrogenous bases as purple, yellow, red, and blue shapes. The overall ladder-like structure is labeled "The structure of DNA".

- Double bond between A&T and triple bond between C&G

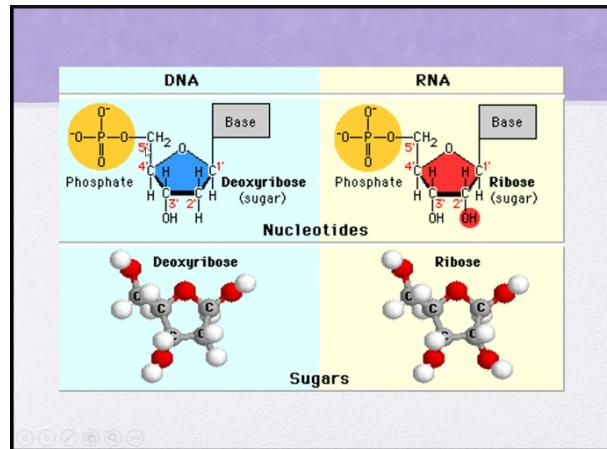
2 Types of Nucleic Acids

2. RNA (Ribonucleic Acid)

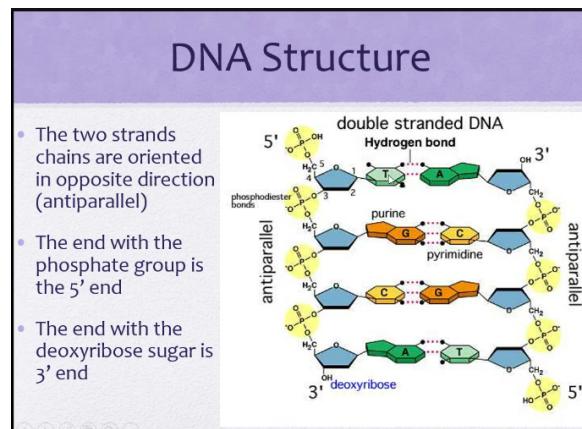
- A template of 1 gene...a code for 1 protein.
- RNA carries the “protein blueprint from nucleus to the ribosome during protein synthesis.
- **Usually 1 nucleotide strand containing A, U, C & G.**
- mRNA – Messenger
- tRNA – Transfer

The diagram shows a segment of mRNA (messenger RNA) with the codon ACT (mRNA codon) paired with a segment of DNA with the codon GCT (DNA codon). Below the mRNA, it is noted that "Three bases form each codon. Codons define a particular amino acid in a protein." This illustrates the process of protein synthesis where mRNA carries the genetic code from DNA to the ribosome.

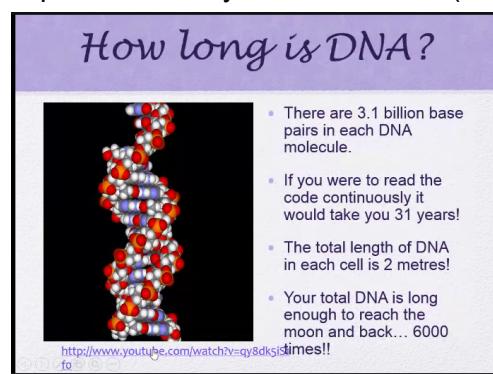
- RNA → A&U, C&G
- mRNA - leaves nucleus to deliver messages (m) to ribosomes
- rRNA - ribosomal rna to link amino acids together to form a coated protein
- tRNA - match AAs together



- Dont need to memorize these, just know big structure
- DNA structure - deoxyribonucleic acid, D for the name of the sugar
 - Antiparallel



- Pyrimidines: Cytosine, Thymine
- Purines: Adenosine, Guanine
- Double bonded: Adenosine, Thymine (AT)
- Triple bonded: Cytosine, Guanine (CG)



- ATP

Adenosine Triphosphate

- ATP is a monomer
- It is a nucleotide
- ATP is the energy providing molecule of the cell.
- $\text{ATP} \rightarrow \text{ADP} + \text{P} + \text{Energy}$

The diagram illustrates the structure of ATP and its hydrolysis. On the left, the full name 'Adenosine Triphosphate' is written in a decorative font. To the right, a detailed molecular model of ATP is shown. It consists of a green adenine base attached to a blue ribose sugar, which is further attached to three yellow phosphate groups. One phosphate group is labeled 'P'. A large red arrow points from the bond between the third phosphate group and the ribose sugar towards the right, indicating the hydrolytic cleavage of the terminal phosphate group. The word 'Energy' is written in red next to the arrow, signifying the release of energy during this process.

Levels of Biological Organization

1. Atoms
2. Chemical building blocks
3. Macromolecules
 - Dna, proteins
4. Organelles
 - Mitochondria
5. Cells
 - Heart muscle cells
6. Tissue
 - Cardiac tissue
7. Organs
 - Heart
8. Organ Systems
 - Circulatory system
9. Individual / Person
10. Population

Cells

- 10 x more cells in body than stars in the milky way
- Cell theory
 - All living things are made up of cells
 - Basic unit of living organisms
 - All cells come from preexisting cells

Cell Theory

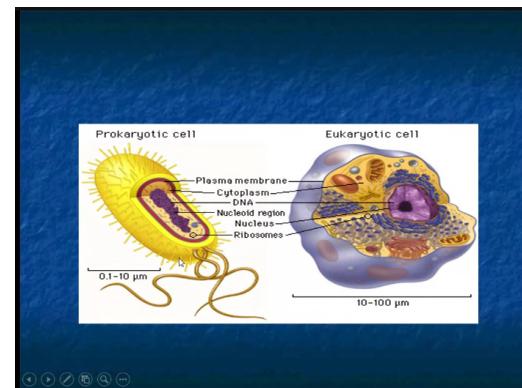
- The Human body is estimated to have 100 trillion cells.
- Different cells are specialized to perform various tasks.

Examples:

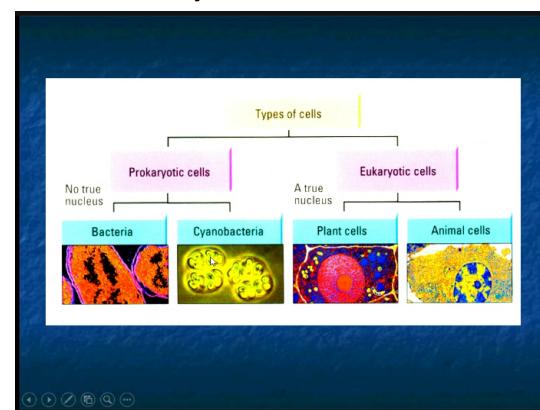
- Nerve Cells transmit electrochemical messages.
- Muscle Cells contract.

All cells:

- Digest nutrients
- Excrete wastes
- Synthesize needed chemicals
- Reproduce



- Prokaryotic cells don't have a full nucleus

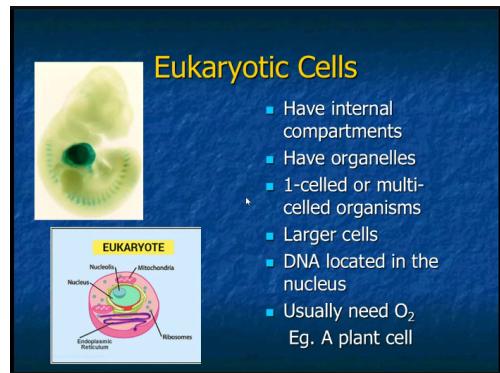


- Types of cells - prokaryotic and eukaryotic

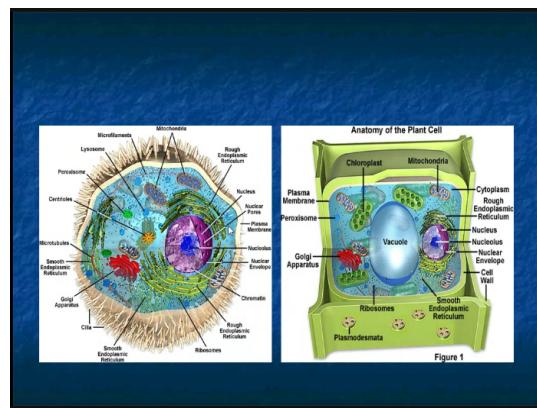
Prokaryotic Cells

- No internal compartments
- No organelles
- All prokaryotes are 1-celled organisms
- Quite small (compared to eukaryotes)
- DNA located in nucleoid region
- May not need O₂

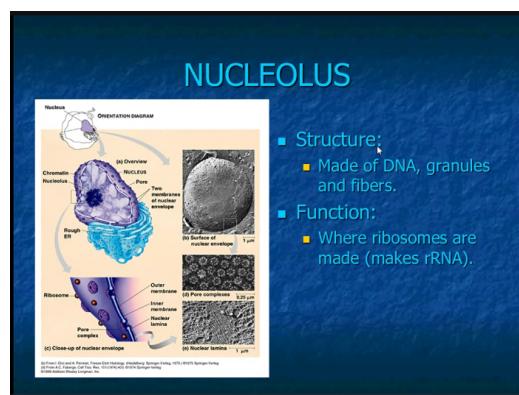
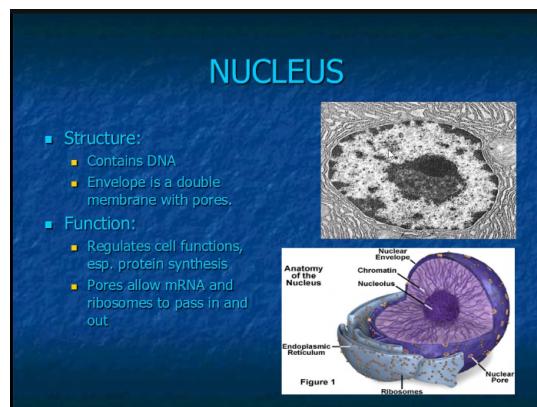
Eg. bacteria



- Cell anatomy



- Nucleus



ENDOPLASMIC RETICULUM

■ Structure:

- Series of interconnected tubules made of a single membrane.
- Can run from the nuclear envelope to the cell membrane,

■ Function:

- Transport cell products through the cytoplasm,
- Provide surface area for chemical reactions,
- Can produce lysosomes and vesicles.

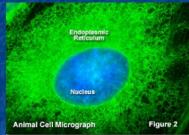


Figure 2

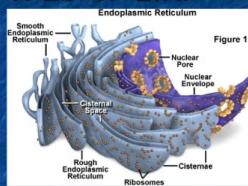
TWO TYPES OF E.R.

■ SMOOTH

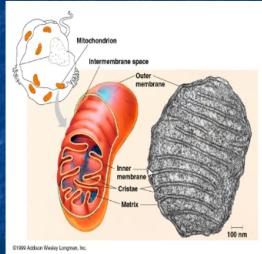
S: Has no ribosomes
F: Makes lipids (phospholipids and steroids)

■ ROUGH

S: Has ribosomes
F: Makes protein, for export
Often connected to Golgi for packaging into vesicles



MITOCHONDRIA

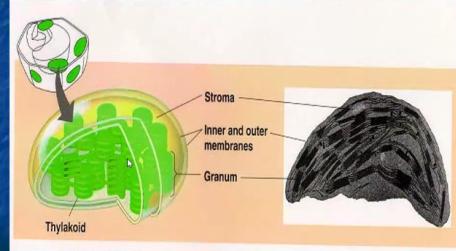


- Structure:
 - 2 membranes: smooth outer, inner folded into cristae.
 - Filled with a liquid called matrix.

■ Function:

- Site of "Cellular Respiration"
- Converts food energy (glucose) into ATP.
- Folded cristae provide maximum surface area for these chemical rxns.

CHLOROPLAST



CHLOROPLAST

- Structure:
 - Green (b/c they contain chlorophyll)
 - Found only in plant cells and a few protists
 - Double membrane on outside and a series of stacked internal membranes called "Grana"
 - Filled with a fluid called "Stroma"

- Function:
 - Site of Photosynthesis (Converts light E into glucose)
 - Chlorophyll traps the sunlight
 - Membranes provide a large surface area for the reactions

GOLGI APPARATUS



- Structure:
 - Flattened stacks of membrane.
 - Small vesicles form (are pinched off) at the end of the folds.

- Function:
 - Receive, modify and transport proteins of polypeptides made by the ER.
 - Membranes provide surface area for chemical rxns.
 - Various polypeptides are combined here to make 1 large protein molecule.
 - These are stored in vesicles and are released when needed.
Eg. Adrenalin

RIBOSOMES

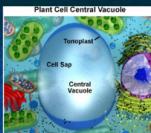


- Structure:
 - Dense-looking granules
 - 2 spheres
 - Made of RNA and protein
 - Found on E.R., floating free in cytosol

- Function:
 - Site of "Protein Synthesis"
 - mRNA is held b/w 2 spheres. Proteins are coded for and built using amino acids.
 - Proteins are then either used by or exported from the cell.

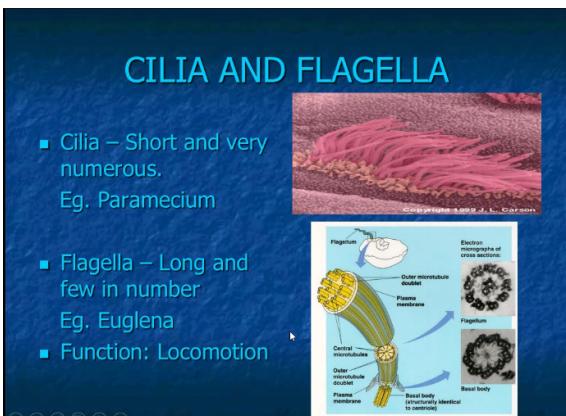
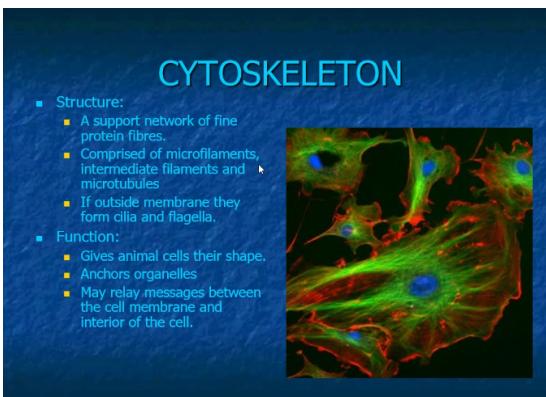
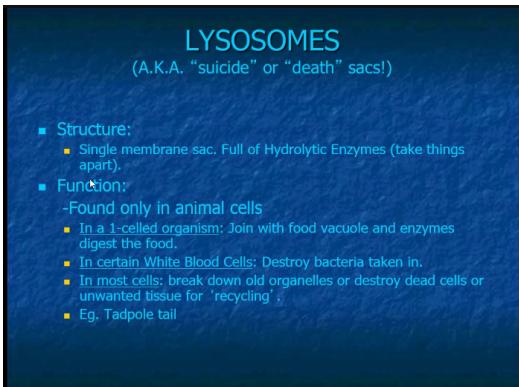
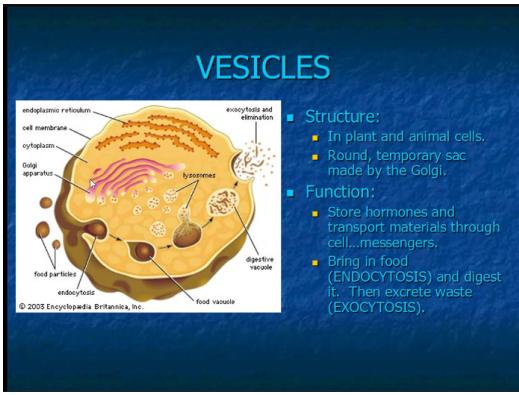
Figure 1

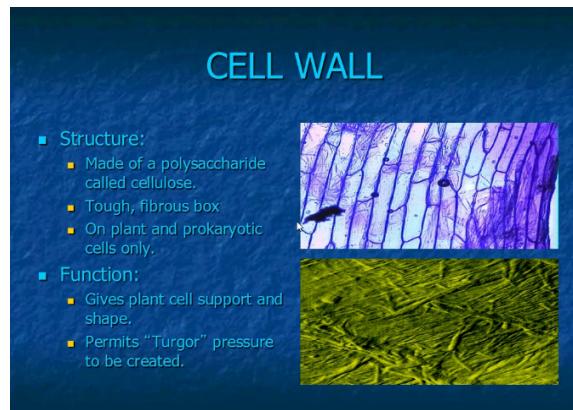
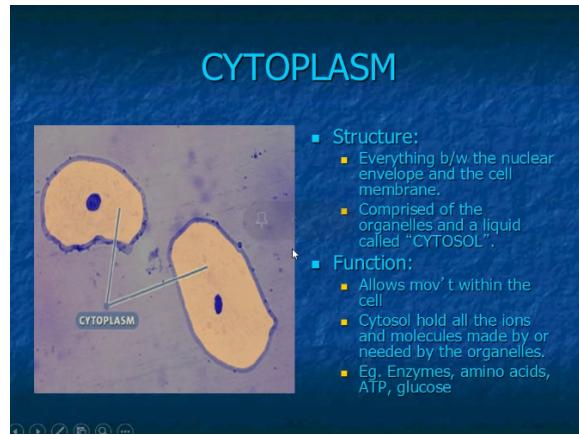
VACUOLES



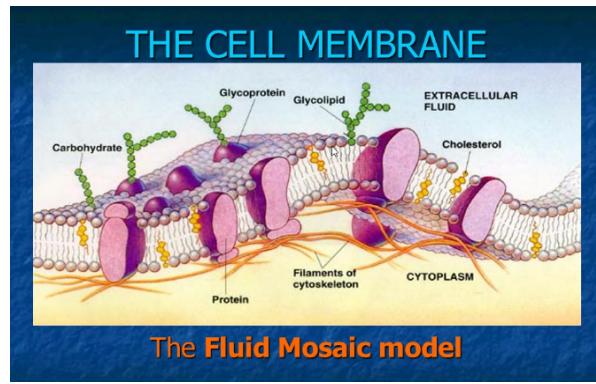
- Structure:
 - Single membrane bags, filled with water and dissolved molecules.
 - Mainly in plant cells

- Function:
 - STORAGE
 - Starch molecules or hold water to create TURGOR pressure to support the plant.





- New stuff starts here lol



- Fluid mosaic model

The Fluid Mosaic Model

- molecules can move about allowing the membrane to adjust/change.
- The phospholipids can vibrate, flex back and forth, spin around their long axis, move sideways, and exchange places within half of the bilayer
- Proteins are larger and move more slowly
- Some proteins attached to cytoskeleton are not able to move far
- Membrane solidifies when it cools, its permeability will change and the enzymatic proteins may become inactive

- Cell membrane

THE CELL MEMBRANE

- Separates cell from its external environment.
- It regulates what enters and leaves the cell = **selectively permeable**
- It mainly consists of:
 - 1)phospholipid bi-layer
 - 2)Proteins
 - 3) Cholesterol
 - 4) Carbohydrates

- Phospholipid bi-layer

1. THE PHOSPHOLIPID BI-LAYER

- Structure:
 - 2 layers of *phospholipid* molecules held together primarily by hydrophobic attraction
- Function:
 - Keeps cell intact
 - *Hydrophilic* heads and *Hydrophobic* tails regulate what enters and leaves the cells.

1. Phospholipid Bilayer

- Membrane asymmetry – internal and external bilayers differ
- External
 - consists of glycolipids and carbohydrate groups attached to proteins
 - Contains receptor proteins that can bind to hormones and growth factors and send signal within the cell
- Internal
 - Cytoskeleton components bind to proteins
-
- Example of external layer: serotonin binds to end of cell to send a signal to it
- Proteins

2. Proteins

- Can be grouped into:
 1. Transport: hydrophilic channels that change shape to allow some molecules across
 2. Enzymatic: involved in respiration & photosynthesis.
 3. Triggering signals: bind with chemicals (ie. hormones) to trigger a cascade of events within cell.
 4. Attachment and recognition: exposed to both external & internal membrane. Attachment point for cytoskeleton or used for cell-cell recognition.

2. Proteins

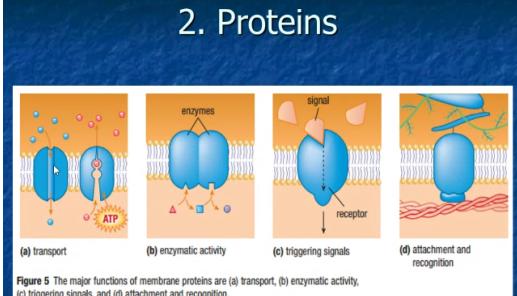
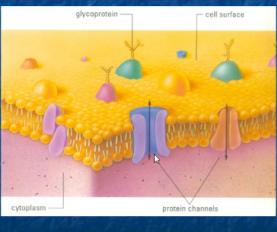


Figure 5 The major functions of membrane proteins are (a) transport, (b) enzymatic activity, (c) triggering signals, and (d) attachment and recognition.

2. PROTEINS

A. Integral Proteins

- Structure:
 - embedded randomly b/w the phospholipids
- Function:
 - Transport larger items through the membrane
 - Allow hydrophilic particles through.



2. PROTEINS

B. Glycoprotein

- Structure:
 - Proteins with attached sugar molecules.
- Function:
 - Attachment sites for molecules needing to enter, or for messenger molecules such as hormones.
 - These are very specific to each person and play a role in recognizing our own cells (organ transplants).

2. Proteins

C. Other Peripheral protein

- not embedded in the lipid bilayer, found on surface. Interacts with integral proteins
- do not interact with the hydrophobic part of the membrane
- Held by non-covalent bonds
- Most are on the cytosol (external) side, some are part of the cytoskeleton (ex. microtubules, microfilament)

- *Cytosol should be on the inside
- Cell-cell recognition

- Cholesterol

3. CHOLESTEROL

- It is an essential structural component of cell membranes, where it is required to establish proper membrane permeability and fluidity

- Carbohydrates

4. Carbohydrates

- Found on the surface of the cell
- Important for cell-cell recognition and immunological reactions

- Membrane fluidity

Membrane Fluidity

- dynamic of the bilayer depends on how densely the individual lipid molecules can pack together
- Major factors:
 - Composition of the lipid molecules in the membrane (saturated vs. unsaturated lipid)
 - Temperature (forms highly viscous semisolid gel when extremely cold)
 - Sterols (help restrain movement at high temperature and ensure fluidity at low temperature)

//////////

Experimental Quiz over the weekend → not for marks, just to practice

Test → Tuesday

Time → Will give us more time?

- Will take ~1 hour, shes gonna reduce uploaded questions
- Mostly typing answers
- 1 hour lesson + 1 hour test
- Starting at latest 10:30

On → everything after nomenclature, starting from carbohydrates

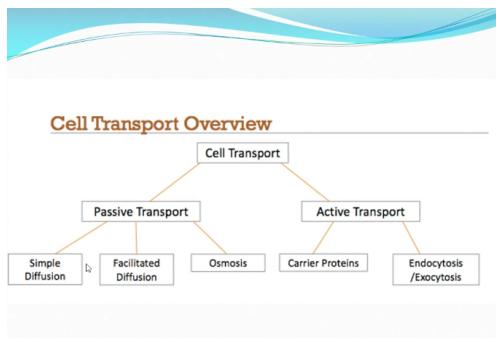
- Includes dehydration synthesis
- Everything up to tomorrow
- Diagrams will be optional if they help you explain

Homework

- 81-85 in textbook
- Cell membrane questions

//////////

Cell Transport



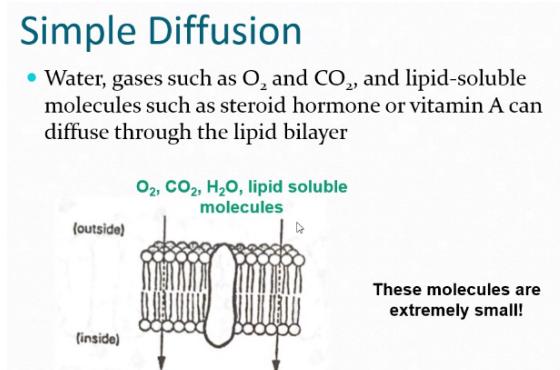
Diffusion

Diffusion Across Cell Membrane

- Diffusion is the movement of particles through a semipermeable membrane
- Molecules cross the phospholipid bilayer at different rate
- The rate of transport depends on:
 - Size of the substance
 - Its solubility in the hydrocarbon interior of the membrane
 - Concentration gradient of the molecule
- Simple Diffusion

Simple Diffusion

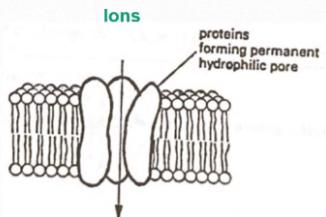
- Water, gases such as O_2 and CO_2 , and lipid-soluble molecules such as steroid hormone or vitamin A can diffuse through the lipid bilayer



- Facilitated diffusion

Facilitated Diffusion through a Pore

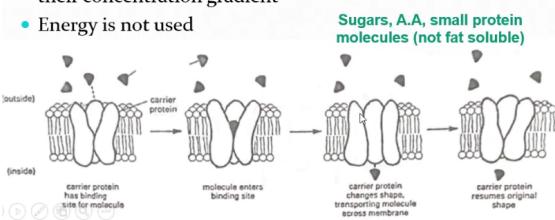
- Most water-soluble molecules cannot diffuse through the lipid bilayer
- These molecules move across through a protein hydrophilic pore
- In many cases, electrical charges and pore size produce highly selective channels



1 2 3 4 5 ←

Carrier-mediated Facilitated Diffusion

- Carrier proteins bind to specific molecules
- Binding triggers a shape change that move molecule across the membrane
- Molecules can move across in either direction, driven by their concentration gradient
- Energy is not used



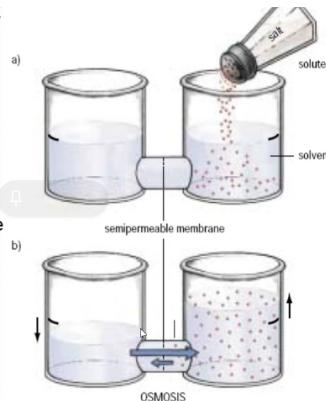
1 2 3 4 5 ←

Osmosis

Osmosis is the diffusion of water across a selectively permeable membrane

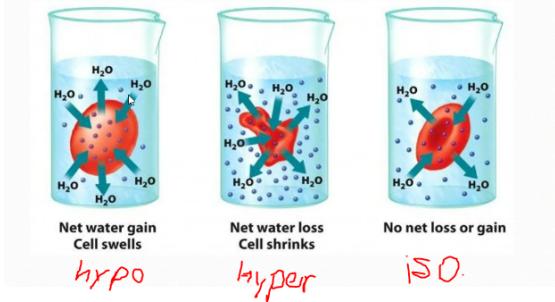
- water is free to move across the semipermeable membrane, but the solute cannot.
- as a result water will move across the membrane
- Passive; with the concentration gradient

1 2 3 4 5 ←



- Water moves to the salt side to maintain the concentration gradient

Types of Solutions:



hypo *hyper*

iso.

- Good way to remember → hypertonic is like a cucumber going into a salt water pool and becoming a pickle

Active Transport

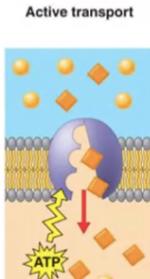
Active Transport

- Transporting substances **against a concentration gradient**
- Molecules are moving from a low concentration to a high concentration
- Required by cell to **keep the internal environment of the cell different from the external environment**

- Going low to high → against concentration gradient

Active Transport

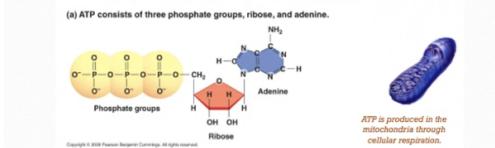
Characteristics of Active Transport:



- ATP

ATP

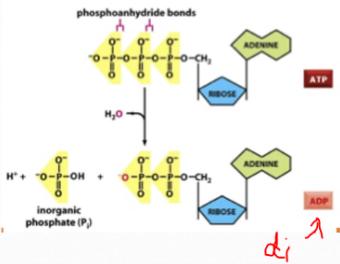
- ATP (adenosine triphosphate)
- the energy of ATP is used to change the shape of the transport protein, which moves the glucose across the cell membrane



ATP

- The hydrolysis of ATP releases energy that is used by the cell

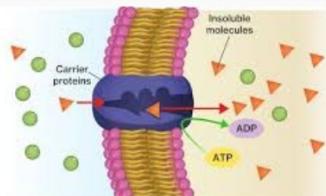
- ADP and inorganic phosphate are produced



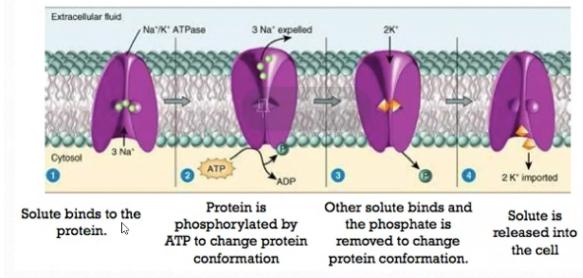
- Carrier proteins

Carrier Proteins

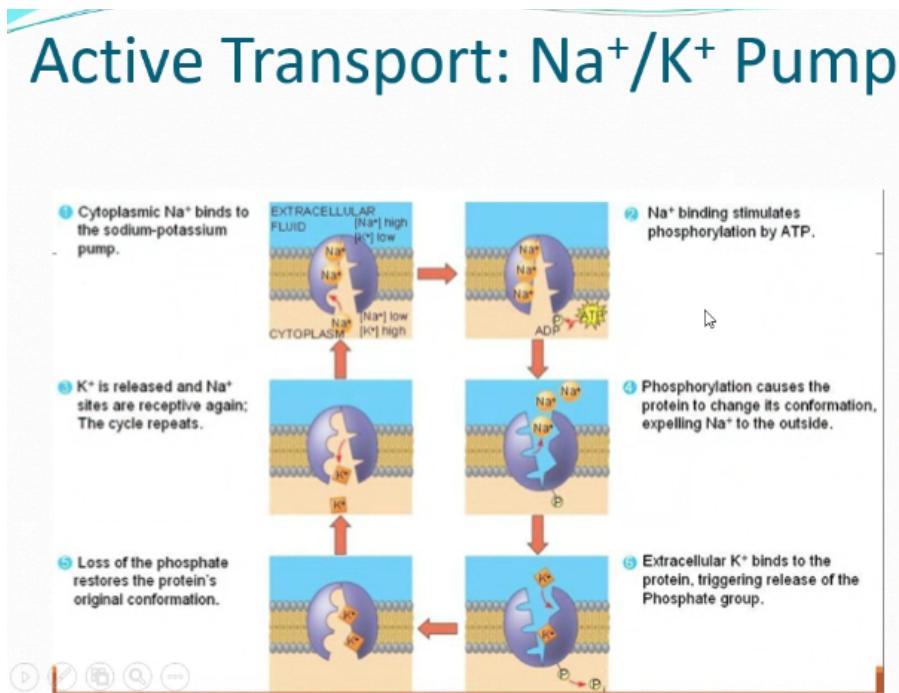
- Help pump the nutrients into the cell against its concentration gradient
- Use the energy from ATP breakdown to move the nutrients across the bilayer
- has recognition/binding sites



Active Transport

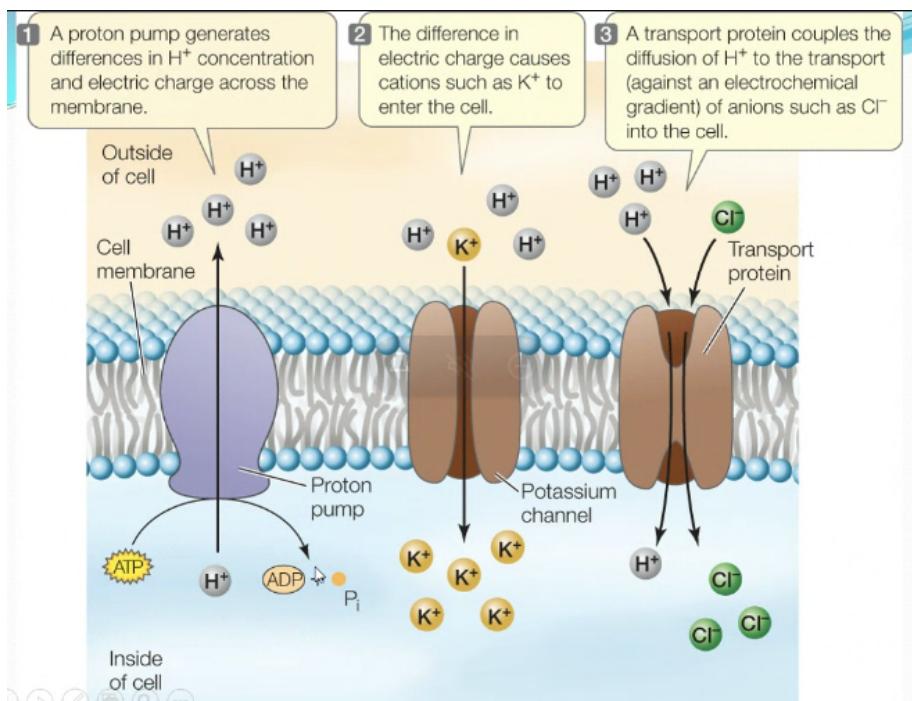


Active Transport - Sodium Potassium channels



- Basically just amoeba sisters everything for this unit

Active transport - Co transporter / proton pumps



Active transport - Membrane Assisted

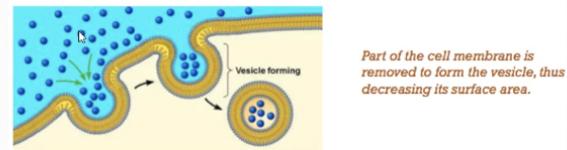
Active Transport – Membrane assisted

- Membrane-assisted transport is a method used to move materials that are too large to move across the cell membrane through channels or carrier proteins
- Two forms:
 1. Endocytosis
 2. Exocytosis

- Endo coming in, exo leaving
- Endocytosis

1. Endocytosis

- Exterior medium is brought into the cell by folding the cell membrane and pinching off to form a vesicle
- Used by cells to incorporate extracellular substances.

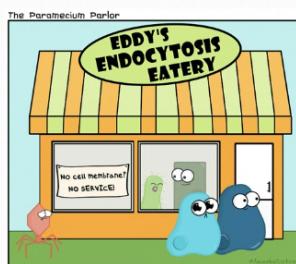


- Blue is outside

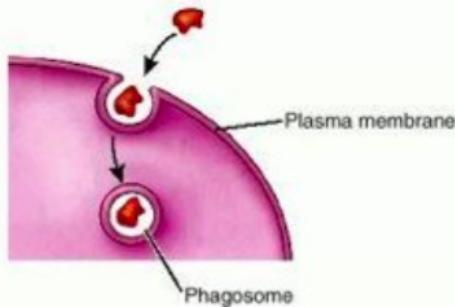
1. Endocytosis

Three types of endocytosis:

- 1) Phagocytosis
- 1) Pinocytosis
- 1) Receptor-mediated endocytosis



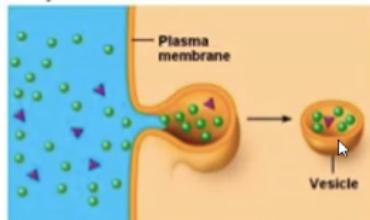
Phagocytosis (aka cell eating):



The large particle is enclosed within a membrane-enclosed vacuole. Particles are digested when the vacuole binds to a lysosome.

1. Endocytosis

Pinocytosis (aka cell drinking):

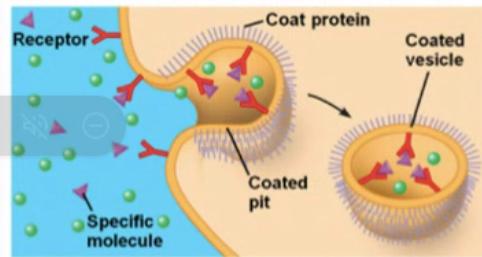


The cell gulps droplets of extracellular fluid into vesicles.

1. Endocytosis

Receptor-Mediated:

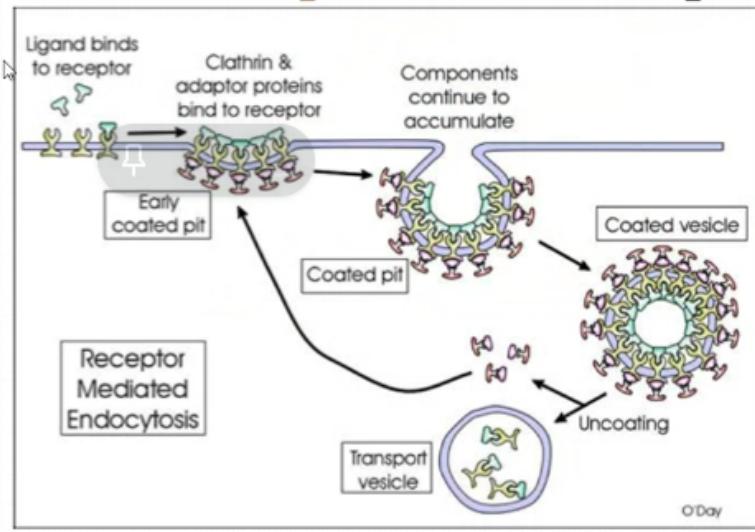
- The membrane has receptors that bind to specific molecules
- The receptors are clustered in 'coated pits' which are coated proteins that line the interior part of the cell



1. Endocytosis

Receptor-Mediated:

- Example: LDL
- LDLs are ligands that bind to the LDL receptors on the surface of the membrane
- Cholesterol enters the cell through receptor-mediated endocytosis
- Defective protein receptors can lead to hypercholesterolemia (accumulation of cholesterol in the blood)



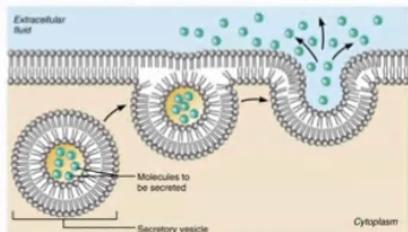
Hypercholesterolemia.

- the cholesterol receptors on the liver cells are either absent or greatly reduced in number.
- People who completely lack cholesterol receptors are unable to remove excess cholesterol from their blood and may die from heart disease while still in childhood.
- Others who have fewer than normal receptors are also at risk, but may be treated with a low-fat diet and cholesterol-lowering drugs.

- Exocytosis

2. Exocytosis

- The cell secretes macromolecules by fusing a vesicle with the cell membrane
- **Vesicle** usually budded from the ER or Golgi and **migrates to plasma membrane (increasing its S.A.)**



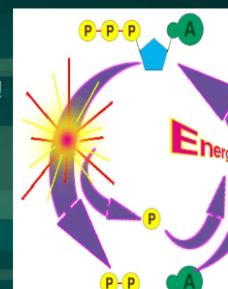
- Kind of the opposite of endocytosis



EVERYTHING PAST HERE IS NOT ON TEST

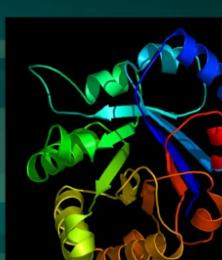
Cells at work

- ATP is the energy molecule of the cell.
- Billions are used and reassembled every second!!
- Endergonic Rxn – Requires energy
(ie. Photosynthesis)
- Exergonic Rxn – releases energy
(ie. Cellular Respiration)
- Glucose = 1 dollar
- ATP = 1 penny

A diagram illustrating the structure and function of ATP. On the right, a purple circle labeled "Energy" contains a central yellow starburst with red rays. Two purple arrows point from the starburst to two green circles labeled "A" (adenine). Each "A" is attached to a blue pentagon representing a ribose sugar, which is further attached to two yellow circles representing phosphate groups (P). The labels "P-P-P" are placed above one set of phosphates and "P" is placed below another, indicating the high-energy bonds of ATP.

- Enzymes → key to biochemical reactions

- Proteins that accelerate chemical reactions
- Almost all processes in the cell need enzymes in order to occur – Cellular Respiration, Photosynthesis, food digestion etc.
- Are extremely selective – very specific to certain reactions



- **For Example:**
Lysozyme
digests
bacterial cell
walls, and is
found in
human tears,
egg-white, etc

ENZYMES

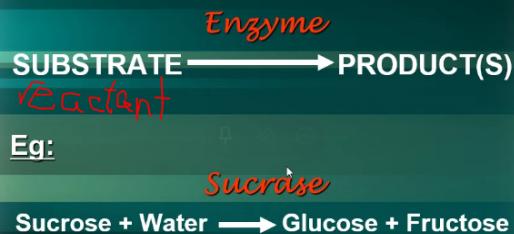
- Enzymes are known to catalyze about 4,000 reactions in the human body
 - Remain unchanged after reactions
 - Most are named after the reaction they catalyze and their names end in "-ase"
- Ex: Lactase breaks down lactose



HOW ENZYMES WORK:

- By providing a lower activation energy for a reaction and dramatically accelerating its rate
- For example...
the reaction catalysed by orotidine-phosphate decarboxylase will consume half of its substrate in 78 million years if no enzyme is present. However, when the decarboxylase is added, the same process takes just 25 milliseconds

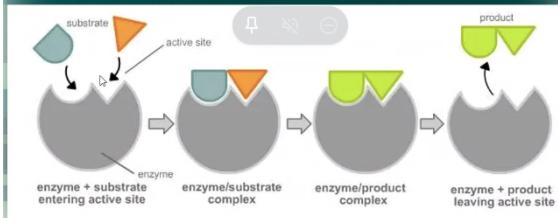
HOW ENZYMES WORK:

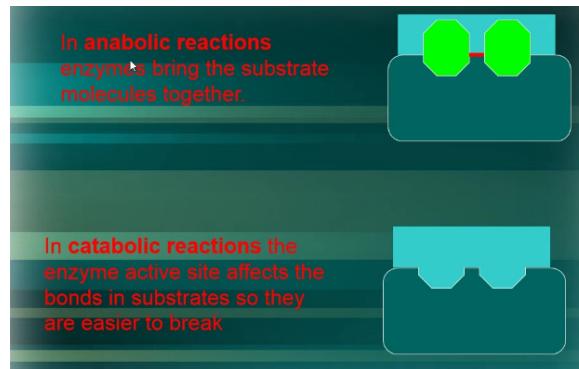


Enzymes help a reaction to occur ... without being directly involved!!!

Enzyme Structure

- The substrate must fit precisely in the active site in order for the reaction to proceed
- All enzymes are highly specific!

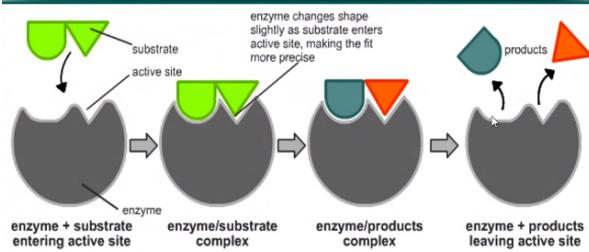




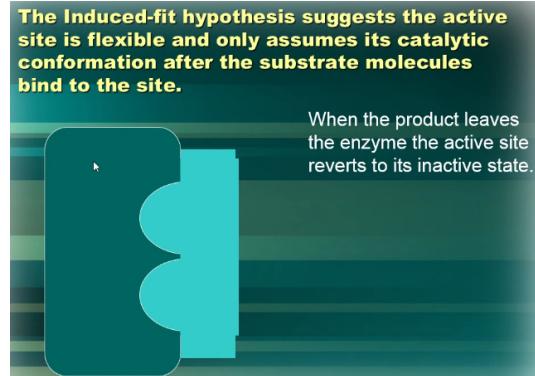
- A is like add, C is like cut

Enzyme Structure

- “Lock and Key” Model:



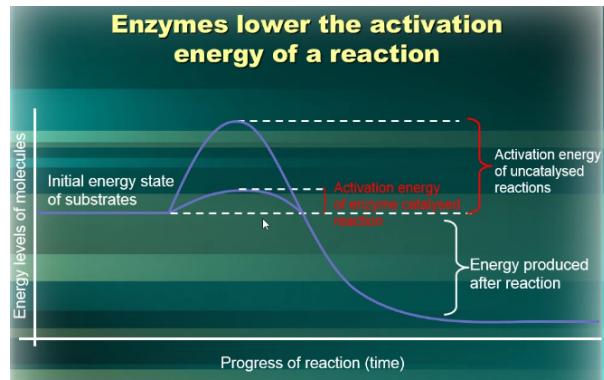
- Lock and key is prob wrong cuz proteins have been proven to be flexible



Induced Fit Model

- When the substrate and enzyme interact, it causes the enzyme to change its shape and better fit the substrate

https://www.youtube.com/watch?v=pVoytz_3H_s



Activation Energy

Normal circumstances:

- Obtain activation energy (usually thermal energy from surrounding)
- Absorption energy increases the speed of the molecules in reactants, colliding more often & forcefully

With enzymes:

- Lowers the energy barrier required for the reaction to occur → speeds up process

Activation Energy

Enzymes can lower the activation energy by:

- The R-group of the protein interferes with the molecule's bond in the substrate
- Transfer of electrons between the enzyme and substrate
- Add or remove hydrogen ions or from the substrate

- Factors affecting enzyme activity

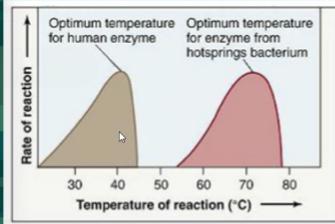
Rate of Enzymes

- Enzymes function in an optimal environment
- Factors affecting activity:
 - Temperature
 - pH
 - Enzyme concentration
 - Substrate concentration

Factors Affecting Enzyme Activity

1) Temperature

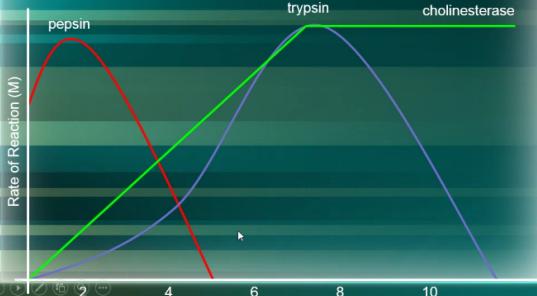
- Rate of reaction increase with temperature
- Enzymes denature at 60° C
- Some **thermophilic** bacteria have enzymes with optimum temperatures of 85°C



Factors Affecting Enzyme Activity

2) pH:

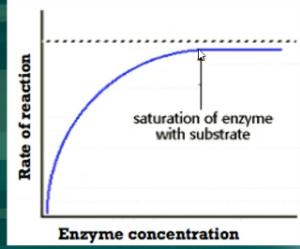
- Bonds between the functional groups that hold the protein together are sensitive to H⁺ concentration



Factors Affecting Enzyme Activity

3) Enzyme Concentration:

- The more enzymes in the solution, the more likely they are to collide with the substrate

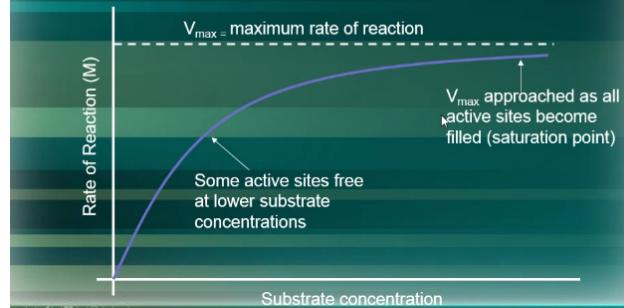


- The more seats u have in a movie theater, the more people that can sit

Factors Affecting Enzyme Activity

4) Substrate Concentration:

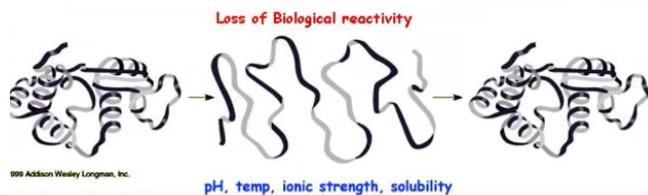
- Increase in substrate concentration increases the rate of reaction until it reaches saturation point



- Summary

In Summary...

- Work at optimal concentrations, temp. & pH
- If it is too hot, an enzyme can become DENATURED... and will no longer function properly



Define the following terms:

1. Anabolic reactions: Reactions that build up molecules
2. Catabolic reactions: Reactions that break down molecules
3. Metabolism: Combination of anabolic and catabolic reactions
4. Catalyst: A substance that speeds up reactions without changing the produced substances
5. Metabolic pathway: Sequence of enzyme controlled reactions
6. Specificity: Only able to catalyse specific reactions
7. Substrate: The molecule(s) the enzyme works on
8. Product: Molecule(s) produced by enzymes

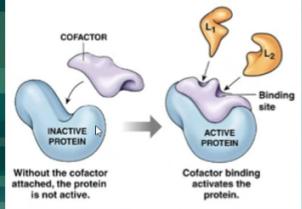
- Enzyme regulation

Enzyme Regulation

- Regulation mechanisms:
 - Cofactors/ Coenzymes
 - Competitive inhibitors
 - Non-Competitive inhibitors
 - Allosteric Changes
 - Feedback Inhibition
 - Precursor Activation

1. Cofactors/Coenzymes

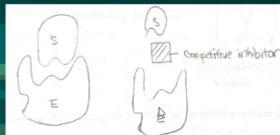
- Non-protein helper
- Enzymes can't speed up reaction without them



1. Cofactors/Coenzymes

- Example: Vitamin B₂ (riboflavin)
- Involved in energy metabolism (ie. metabolism of fat, carbohydrates and proteins)
- Deficiency: body will have problem metabolizing (fats, carbs, proteins)
- Often caused by dietary inadequacy
- Can be obtained from meat, nuts, cheese, eggs
- Diagnosis: measure activity of enzyme glutathione
- Symptoms: bloodshot eyes, mouth, inflammation, sores, burning tongue
- Not common because most countries fortify their breads and cereals with vitamin B₂

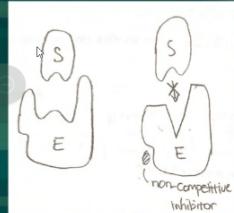
2. Competitive Inhibitors



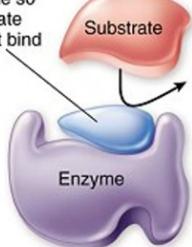
- Resembles the normal substrate and compete for admission into the active site
- Reduces the productivity of the enzyme by locking the active site from substrate
- If the inhibitor attaches to the enzyme by covalent bond, the inhibition is usually irreversible (ex. nerve gas, cyanide, arsenic)
- If the inhibitor binds to the enzyme by a weak bond, the inhibition is reversible; it can be overcome by increasing the concentration of substrate

3. Non-Competitive Inhibitors

- Inhibits enzymatic reaction **without** actually entering the active site
- The inhibitor binds to a part of the enzyme separated from the active site, causing the enzyme to change its shape in such a way that the active site is no longer receptive to the substrate

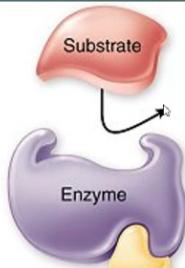


Competitive inhibitor interferes with active site of enzyme so substrate cannot bind



(a) Competitive inhibition

Noncompetitive inhibitor changes shape of enzyme so it cannot bind to substrate



(b) Noncompetitive inhibition

- Inhibitors are there to either poison or to save energy

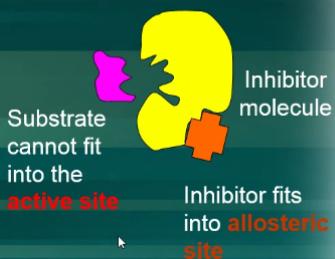
4. Allosteric Regulation

- Process where a regulator molecule will influence an enzyme's activity by combining with the enzyme to change its shape
- Regulator molecule may inhibit or stimulate enzyme activity
- The activator/inhibitor binds to the allosteric site

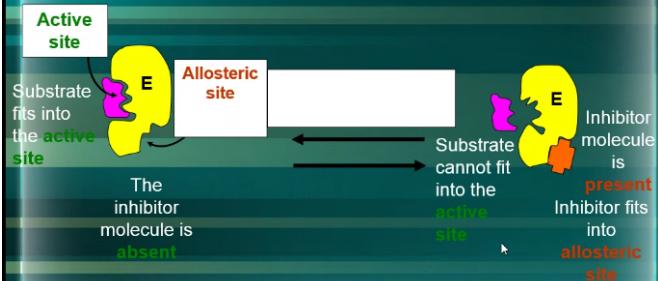
- This one can also start the reaction
- Missed one

Switching off

- These enzymes have two receptor sites
- One site fits the substrate like other enzymes
- The other site fits an inhibitor molecule

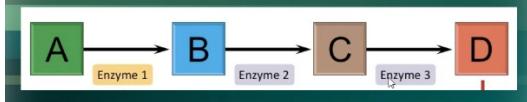


The allosteric site the enzyme “on-off” switch



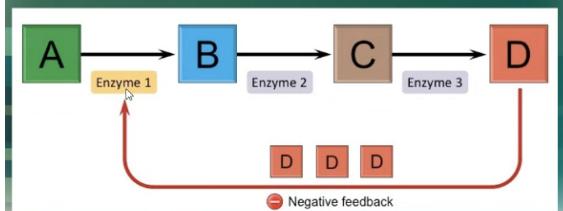
5. Feedback Inhibition

- The product of one reaction becomes the substrate of another reaction
- The product formed in the last step of the pathway can become an inhibitor



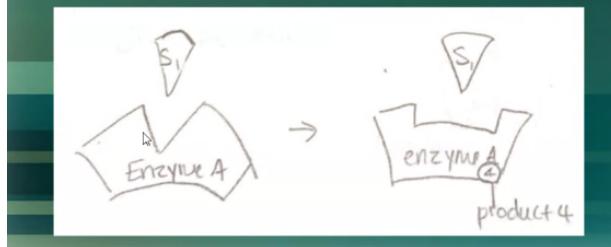
5. Feedback Inhibition

- Accumulation of product inhibit the activity of enzyme 1
- If enzyme 1 is inhibited, everything will slow down



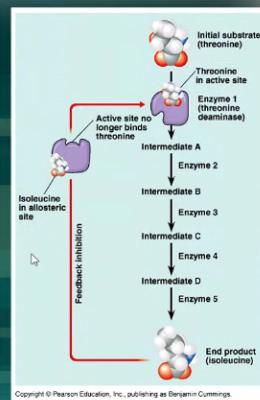
5. Feedback Inhibition

- Product 4 binds to allosteric site of enzyme 1, changing its shape



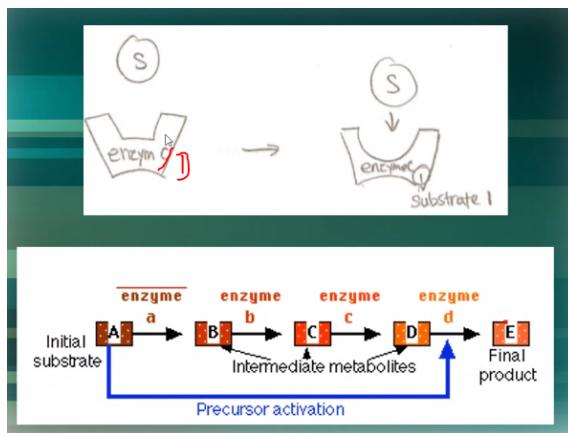
This example demonstrates how an end product can inhibit the first step in its production.

- Isoleucine binds to the allosteric site of threonine deaminase and prevents threonine from binding to the active site because the shape of the active site is altered.
- When the level of isoleucine drops in the cell's cytoplasm, the isoleucine is removed from the allosteric site on the enzyme, the active site resumes the activated shape and the pathway is "cut back on" and isoleucine begins to be produced.



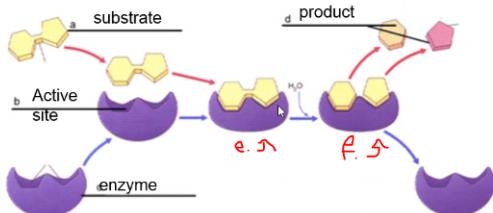
6. Precursor Activation

- Requires a reactant to activate enzyme further along a reaction series
- It may combine with the enzyme, changing its shape, so that the active site fits with its substrate
- Substrate 1 activates enzyme C



Check your Understanding

Label the following diagram



- E. substrate-enzyme complex
- F. product-enzyme complex

Check your Understanding

Determine whether the following statements are true or false:

- A) Enzymes interact with specific substrates
- B) enzymes change shape after a reaction occurs
- C) Enzymes speed up reactions
- D) Adding more enzyme will decrease the rate of reaction.
- E) Enzyme reactions can be slowed or halted using inhibitors.
- F) All enzymes have an optimal pH of 8.

Homework

- 50 - 56 textbook
- Optional enzyme worksheet
- Enzyme gizmo lab → for marks

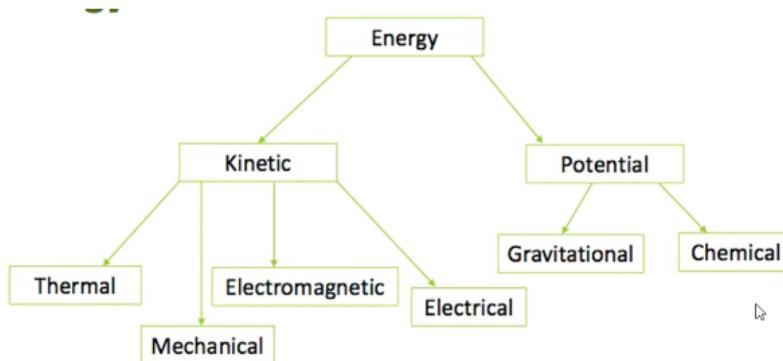
Nomenclature Functional Group Priority for Bio

- Carboxylic Acid + derivatives like ester
- Amino
- Aldehyde
- Ketone
- Alcohol
- Alkyne
- Alkene
- /33, 10 marks for MC, 3 naming diagrams,
- Acetone is the common name for 2-propanone
- Prioritize triple over double bonds

Metabolism

Energy

- Ability to do work
- Must continuously capture, store and use energy
- Organisms do majority of work on a cellular level
- Must manage amount of energy used w amount produced
- Anabolic reactions:
 - Energy + small molecules → larger molecules
- Catabolic reactions:
 - Large molecules → energy + smaller molecules
- Kinetic energy (Ek) has to do with movement, potential energy (Ep) is stored



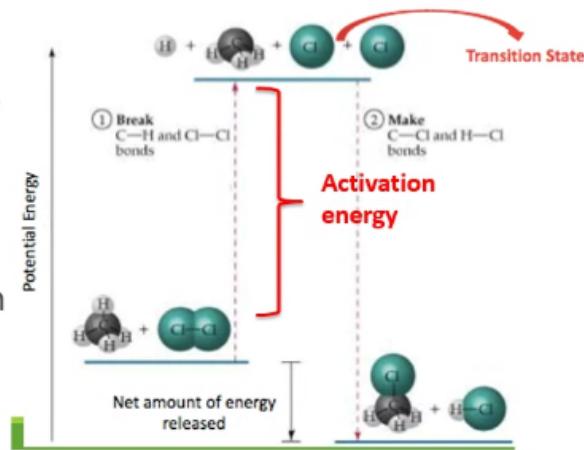
Laws of Thermodynamics

- Looks at physical rules of organisms and how energy is transferred between them
1. Total amount of energy in any closed system is constant. Energy cannot be created or destroyed, only converted from one form to another
 - Bond energy
 - Measured in kJ/mol
 - Farther the electrons away from nucleus the more potential energy
 - Energy is released when bonds break and is absorbed when they form new bonds
 - Enthalpy: sum of internal energy (heat content) of a system
 - $H = U + P(v)$
 - Energy is absorbed when reactant bonds break and energy is released when product bonds form

Enthalpy

A few terms...

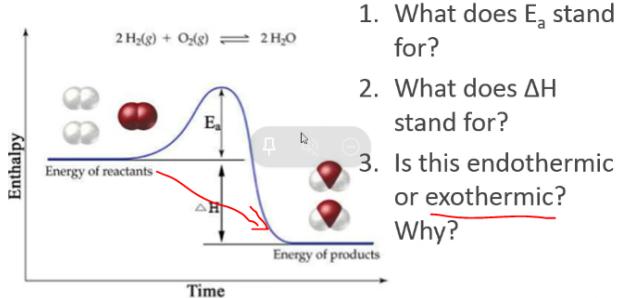
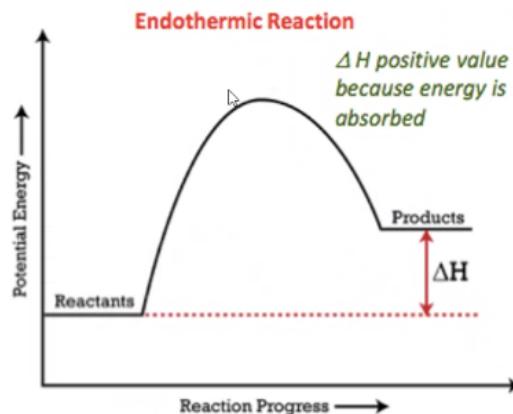
- Activation energy (E_a) – the minimum amount of energy that reactants must absorb to start a reaction
- Transition state – a temporary condition during a chemical reaction in which the bonds in the reactants are breaking and the bonds in the products are forming
- Change in potential energy (ΔH)



- Exothermic reactions

Endothermic Reaction

- energy absorbed, products have higher E_p than reactant
- Positive ΔH



2. In every transfer or conversion, some of the useful energy in the system becomes unusable and increases the entropy
- Energy transformation is never 100% efficient
 - Entropy is a measure of disorder in a system
 - Think of a room and how it always gets messier
 - Entropy: in chemical reactions, entropy will increase in following circumstances
 - Solid becomes liquid
 - Liquid becomes gas
 - Complex molecule becomes simpler
 -
 - Catabolic reaction → energy released, entropy increases
 - exothermic reaction and spontaneous process
 - Anabolic reactions → cells trying to become less messy as their building things
 - While it seems this way, it's probably not cuz anabolic reactions require energy which they most likely get from catabolic reactions
 - There is order within the disorder
 - Look at cells and ATP using entropy tomorrow
 - Gibbs free energy
 - Gibbs discovered relationship between energy change and temperature of reaction n how relationship could help determine...

- The free energy change can be calculated:

$$\Delta G = \Delta H - T\Delta S$$

$$\text{Gibbs's Free Energy} \quad \Delta G = \Delta H - T\Delta S$$

		$\Delta H < 0$	$\Delta H > 0$
$\Delta S > 0$	$\Delta G < 0$	$\Delta G < 0$ at higher temp $\Delta G > 0$ at lower temp	
	$\Delta G < 0$ at lower temp $\Delta G > 0$ at higher temp		$\Delta G > 0$

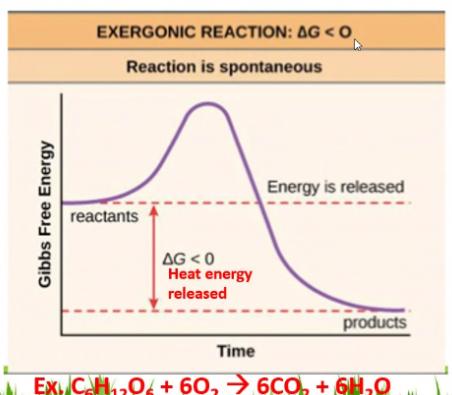
Where

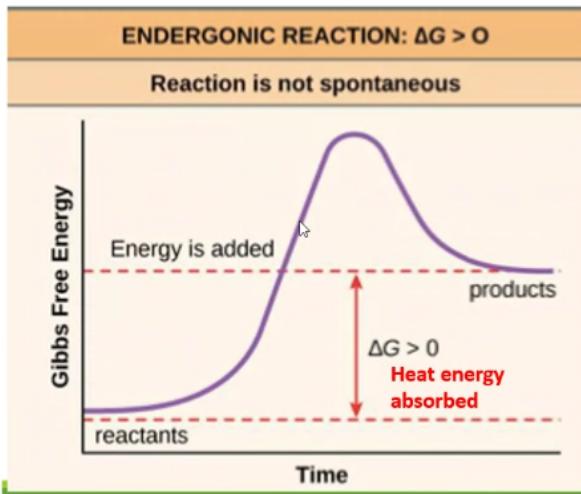
ΔG = change in free energy

ΔH = change in enthalpy

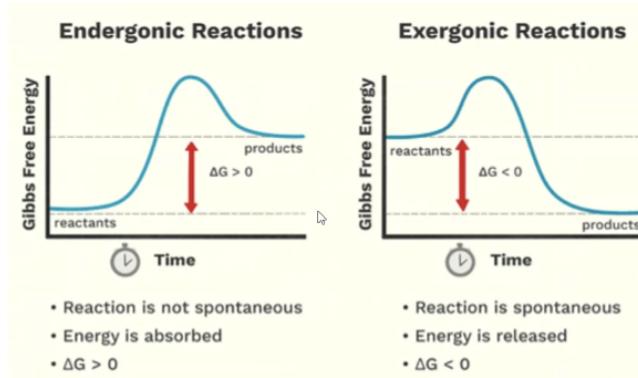
T = Temperature in Kelvin

ΔS = change in entropy





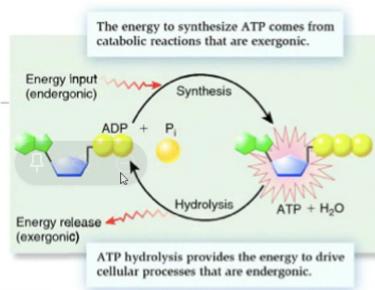
- So many words starting with E → review lol



- Delta G not affected by enzyme
- Coupled reactions

Cells are able to make endergonic reactions from the energy supplied by the exergonic reactions.

Energy coupling is the transfer of energy from one reaction to another in order to drive the second reaction.

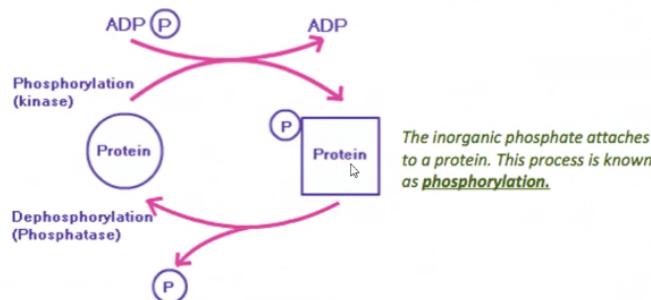


ADP and Inorganic Phosphate

The inorganic phosphate can participate in a wide range of chemical reactions:

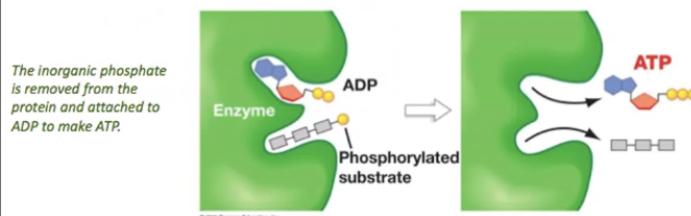
1. Phosphorylation
2. Substrate level Phosphorylation
3. Oxidative phosphorylation

1. Phosphorylation



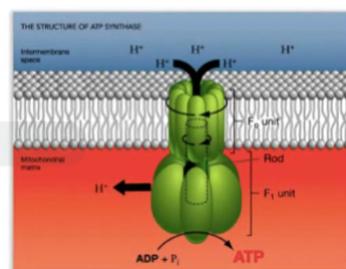
2. Substrate Level Phosphorylation

Used to form ATP directly in an enzyme-catalyzed reaction.



3. Oxidative Phosphorylation

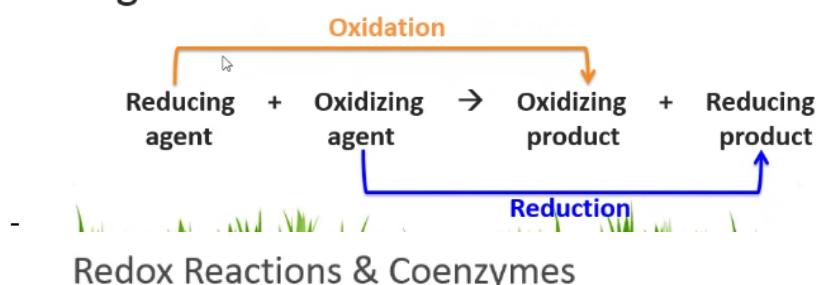
- Used in cellular respiration within mitochondria to produce ATP
- Channel opens when there is a high concentration of H⁺ in the intermembrane space
- H⁺ are pumped back in to create ATP



- Redox omni LEO says GER
- Oxidation or “Ox”
 - Energy metabolism in cells involves oxidation reactions
 - Oxidation involves the transfer of an electron from a molecule which is said to be oxidized to another molecule which is said to be reduced
 - .
- Reduction
 - Overall charge is reduced i.e. gains electrons

Oxidation	Reduction
Addition of Oxygen	Removal of Oxygen
Removal of Hydrogen	Additional of Hydrogen
Loss of electron	Gain of electron

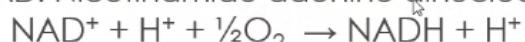
In general:



Redox Reactions & Coenzymes

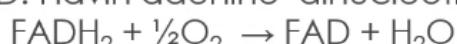
The redox reactions of cellular respiration commonly involve the following coenzymes:

1) NAD: Nicotinamide adenine dinucleotide



Oxidative phosphorylation

2) FAD: Flavin adenine dinucleotide



LEO the lion says GER

- Lose
 - Electrons
 - Oxidized!
- SAYS...
- Gain
 - Electrons
 - Reduced!

OIL RIG

- Oxidation
 - Is
 - Loss of electron
- Reduction
 - Is
 - Gain of electron

3. a

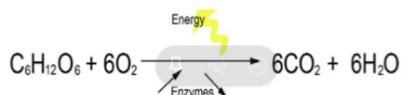
Cellular respiration

Introduction

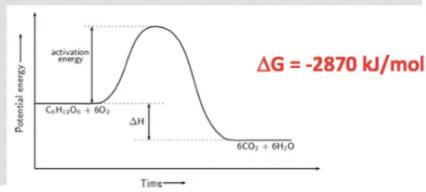
- Most energy entering the biosphere is solar radiation
- Energy from food → stored as ATP
- Obligate aerobes → animals that require oxygen??

Aerobic cellular respiration

- Process that uses oxygen to harvest energy from organic compounds to create ATP



- Processes involves a series of reactions involving enzymes and input/out of energy



- Exothermic reaction
- Recall in cellular respiration:
 - Many exothermic reactions in this process are REDOX reactions
 - Redox involves the transfer of electrons between 2 molecules
 - NAD and FAD are electron carriers and become NADH and FADH₂

3 main goals of cellular respiration:

Three main goals:

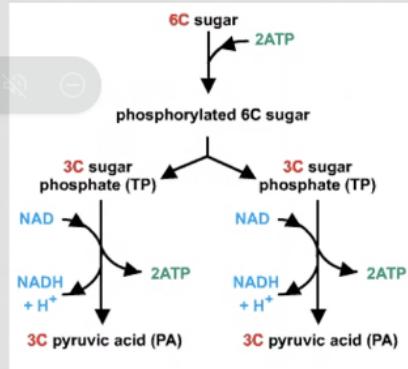
1. To break the bond in glucose (6C molecule) to create 6CO₂ molecules
2. To move hydrogen atoms from glucose to oxygen to create 6H₂O molecules
3. To trap a large quantity of free energy so that it can be used to create ATP

4 stages of cellular respiration

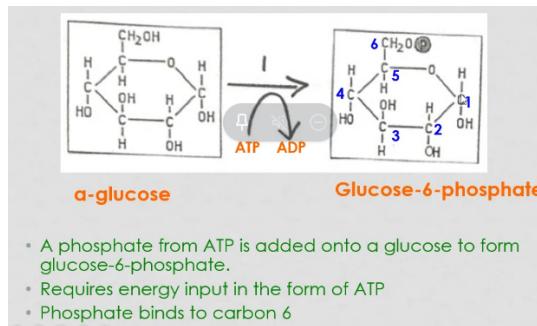
- Glycoysis
- Pyruvate oxidation
- Krebs cycle (citric acid cycle)
- Electron transport chain and chemiosis (ETC)
- Make sure u didnt miss anythign

Glycolysis

- Glucose → 2C₃H₄O₃ (pyruvic acid) + 2NADH₂ + 2ATP
- First stage in cellular respiration
- Can be broken down into 10 steps

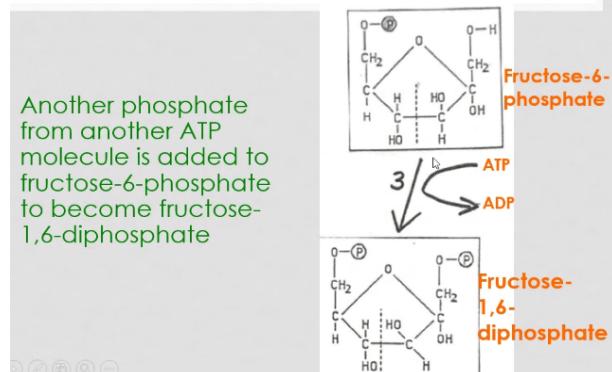


- Step 1: activation
 - A phosphate from ATP is added on a glucose to form glucose 6-phosphate

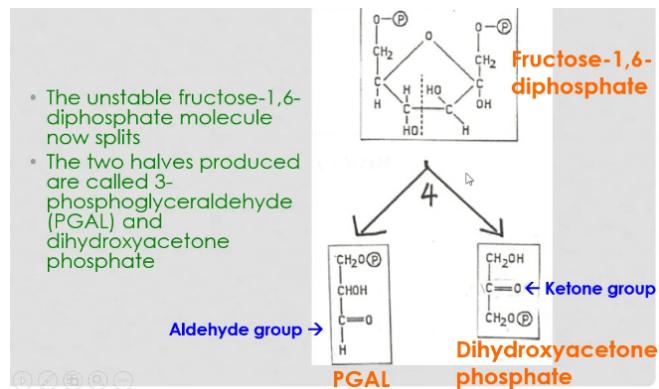


- Step 2: isomerization
 - Glucose 6 phosphate is rearranged to become fructose phosphatase
- Step 3:

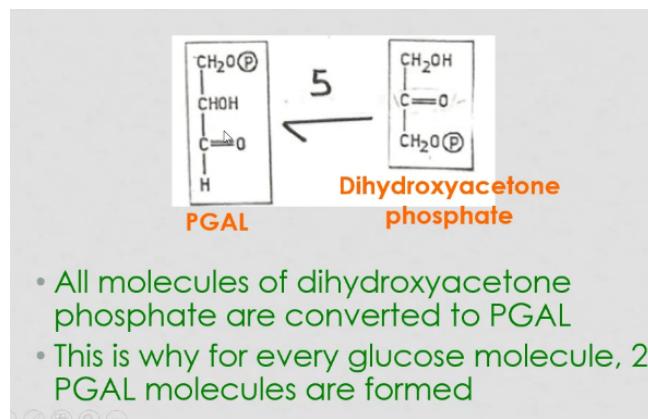
STEP 3: ACTIVATION



- Step 4 - cleavage

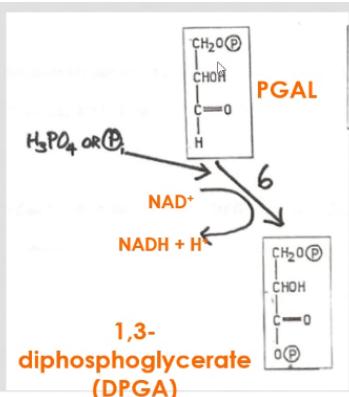


- Just call it PGAL and dihydroxyacetone phosphate :_)
- Step 5: isomerization

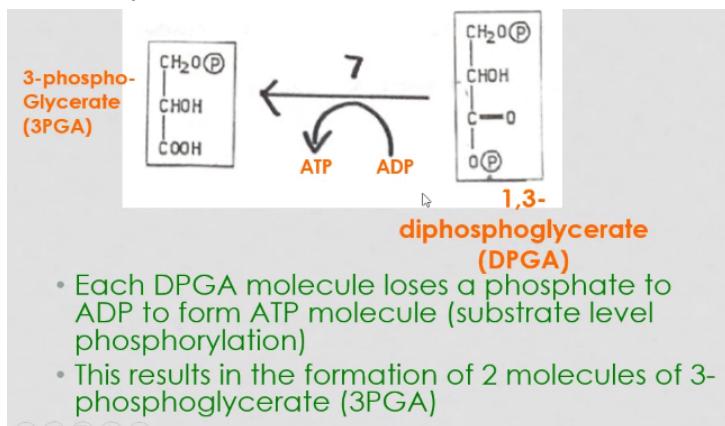


- Step 6: phosphorylation oxidation

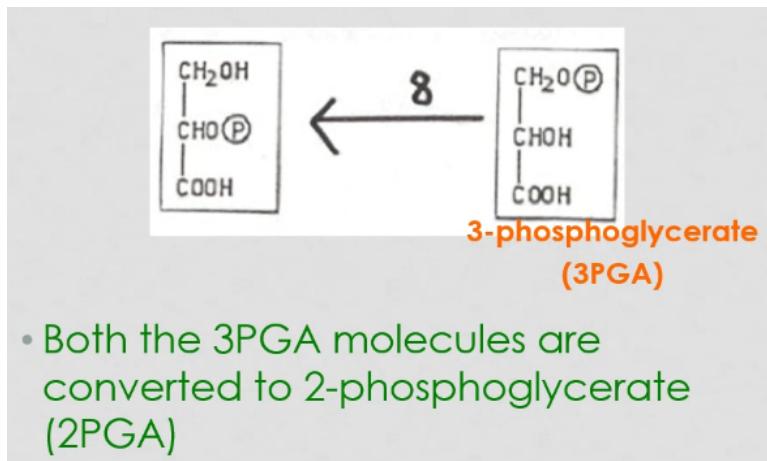
- Both molecules of PGAL are converted to 1,3-diphosphoglycerate (DPGA) by the addition of phosphate obtained from phosphoric acid (H_3PO_4) and oxidation by NAD^+
- After this step, 2NADH and 2DPGA are formed for each glucose molecule



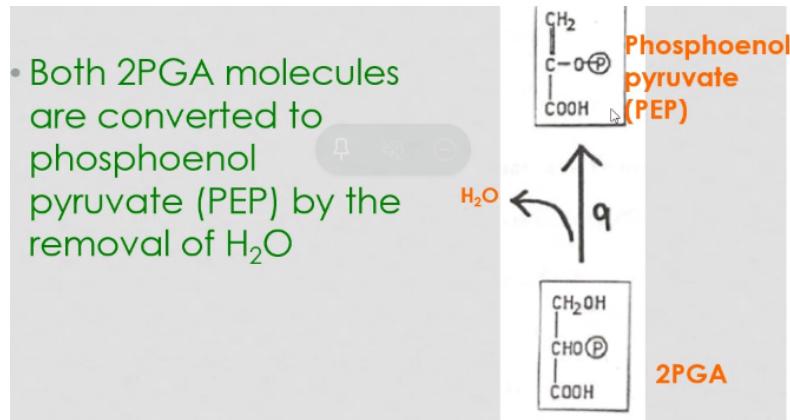
- Step 7: phosphorylation



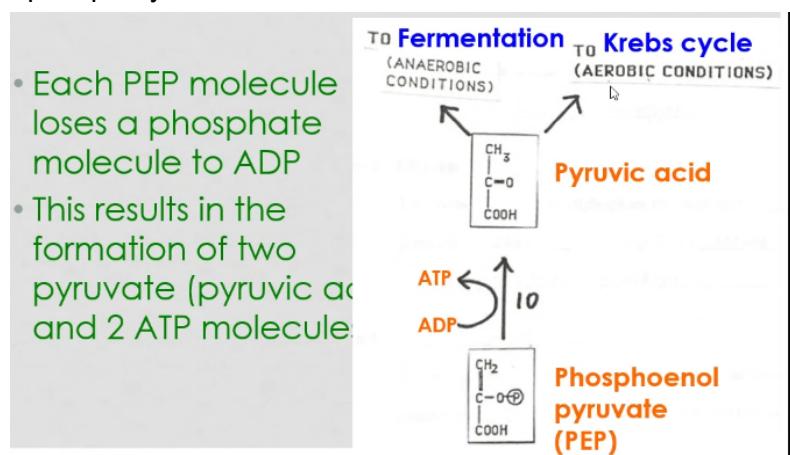
- Recall substrate level phosphorylation
- Step 8: isomerization



- Step 9: dehydration

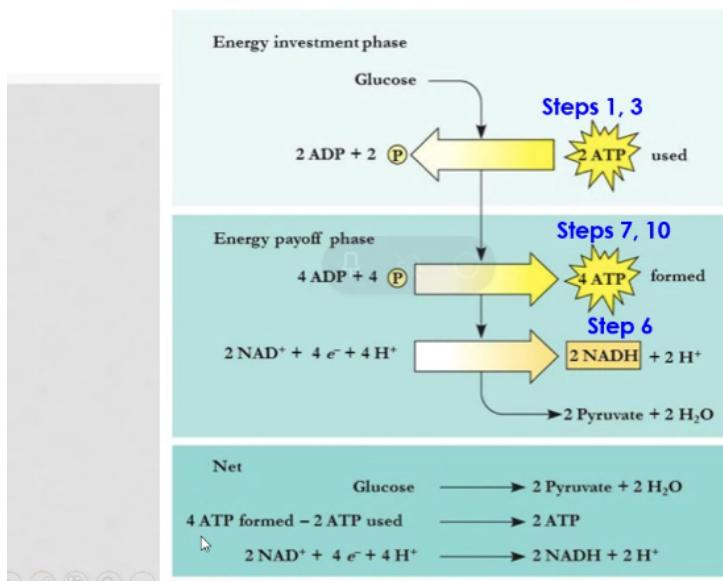


- Step 10: phosphorylation



- Time for some killleeeerrrr youtube videos

NET PRODUCTION OF ATP AND NADH



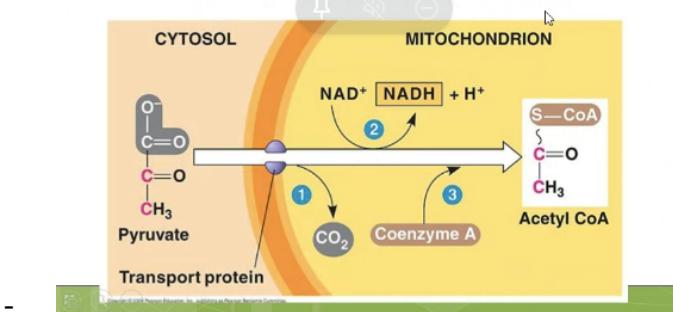
Homework - 172-174

Complete the puzzle name and structure
Glycolysis fill in the blank worksheet

Krebs Cycle

2. Pyruvate oxidation

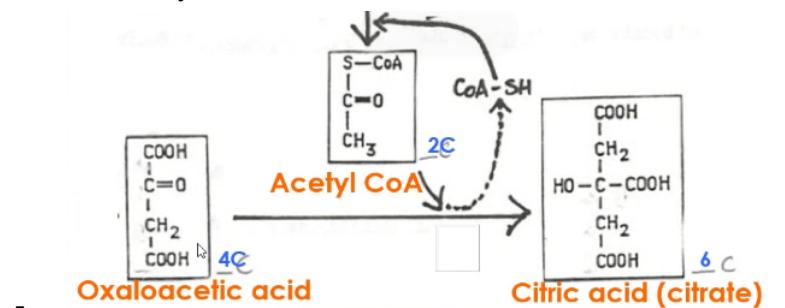
- Two pyruvate molecules actively transported into mitochondrial matrix
- Carboxyl group of the pyruvate acid loses a CO_2
- The remaining 2C fragment is oxidized to acetyl CoA while NAD^+ is reduced to $\text{NADH} + \text{H}^+$



- At the end you have Acetyl CoA left

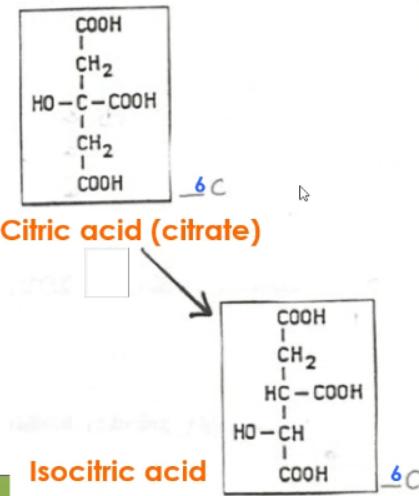
3. Krebs cycle

- Aka citric acid cycle
- Occurs in the mitochondrial matrix
- Main goal is to produce energy
- Many enzymes, coenzymes and other molecules are in an organized pattern on the inner membrane.
- Can be divided into 8 steps.
- Step 1 - formation of citric acid cycle
 - The acetyl CoA is bonded with oxaloacetic acid



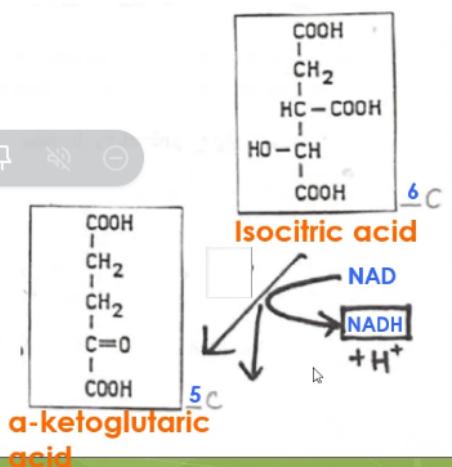
- Step 2 isomerization

Citric acid is converted to its isomer, isocitric acid



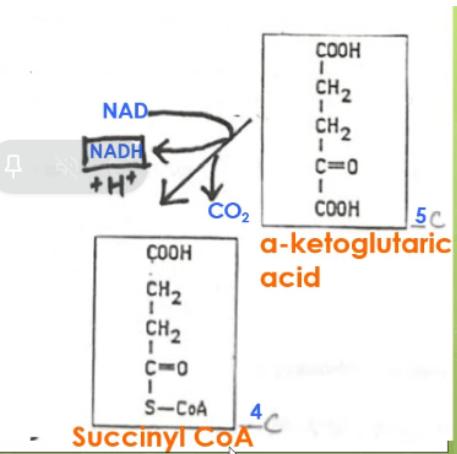
- Step 3 - Decarboxylation

Isocitric acid loses a CO_2 molecule, and is oxidized, reducing NAD^+ to $\text{NADH} + \text{H}^+$



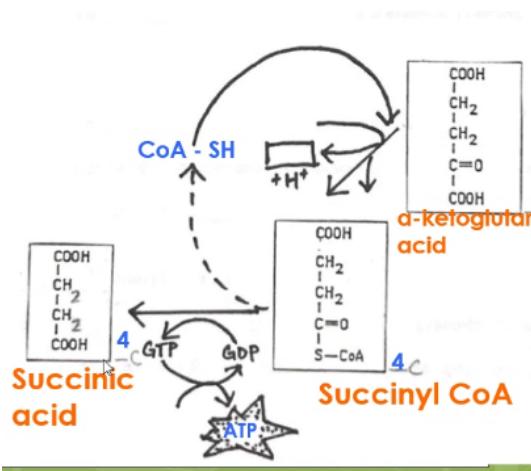
- NADH will be later used to help make ATP
- Step 4 - Decarboxylation

CO_2 is lost and the remaining 4-carbon compound is oxidized by the transfer of electrons to NAD^+ to form $\text{NADH} + \text{H}^+$

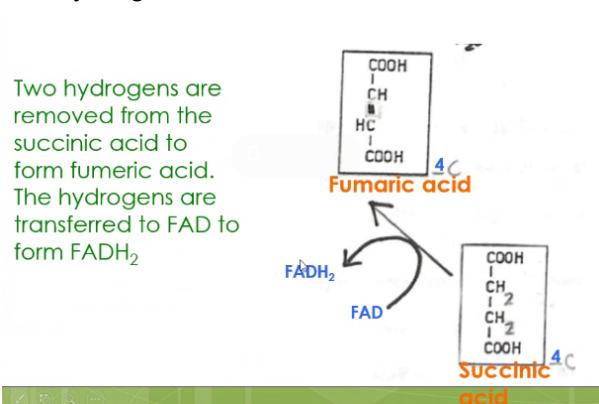


- Step 5 - Substrate level phosphorylation
 - CoA is displaced by a phosphate group to form guanosine triphosphate (GTP)

- GTP is similar to ATP which is formed when GTP donates a phosphate to ADP



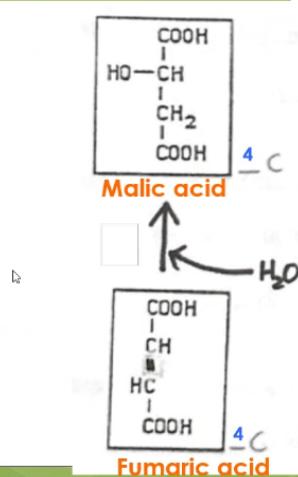
- Step 6 - Decarboxylation (again yay)
 - Two hydrogens are removed from the succinic acid to form fumaric acid
 - The hydrogens are transferred to FAD to form FADH₂



- Step 7 - Hydration

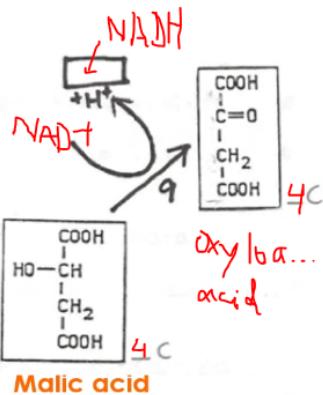
Step 7: Hydration

The addition of a water molecule rearranges the bonds in fumaric acid to malic acid



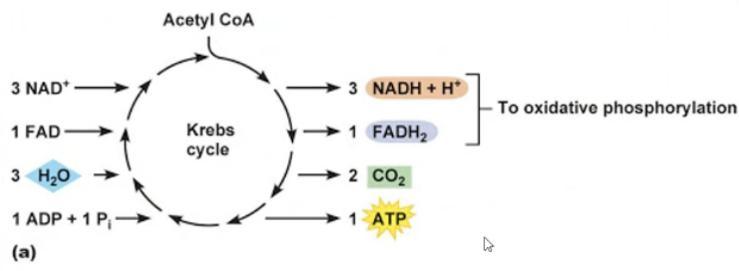
- Step 8 - formation of oxaloacetic acid

NAD⁺ is reduced to produce another molecule of NADH + H⁺ and generates oxaloacetic acid, which accepts a 2-carbon fragment from acetyl CoA for another turn of the cycle.



Krebs Cycle (again?)

- Net reaction
 - Net reaction:



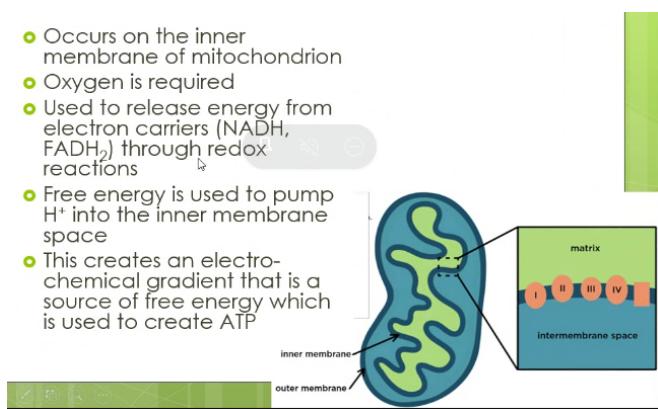
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- She's going to put up a sheet that has the entire cycle
- Glycolysis
 - In assignments somewhere

Stage 4: Electron transport chain (ETC)

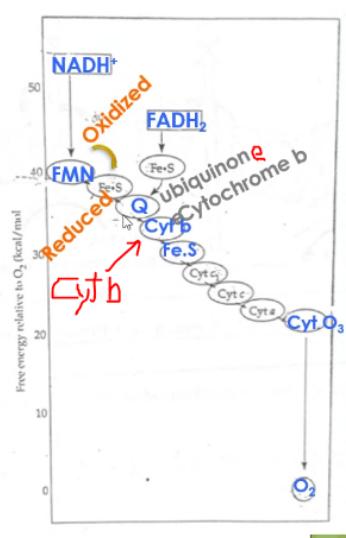
- Occurs on inner membrane of mitochondria

- Occurs on the inner membrane of mitochondrion
- Oxygen is required
- Used to release energy from electron carriers (NADH, FADH₂) through redox reactions
- Free energy is used to pump H⁺ into the inner membrane space
- This creates an electrochemical gradient that is a source of free energy which is used to create ATP

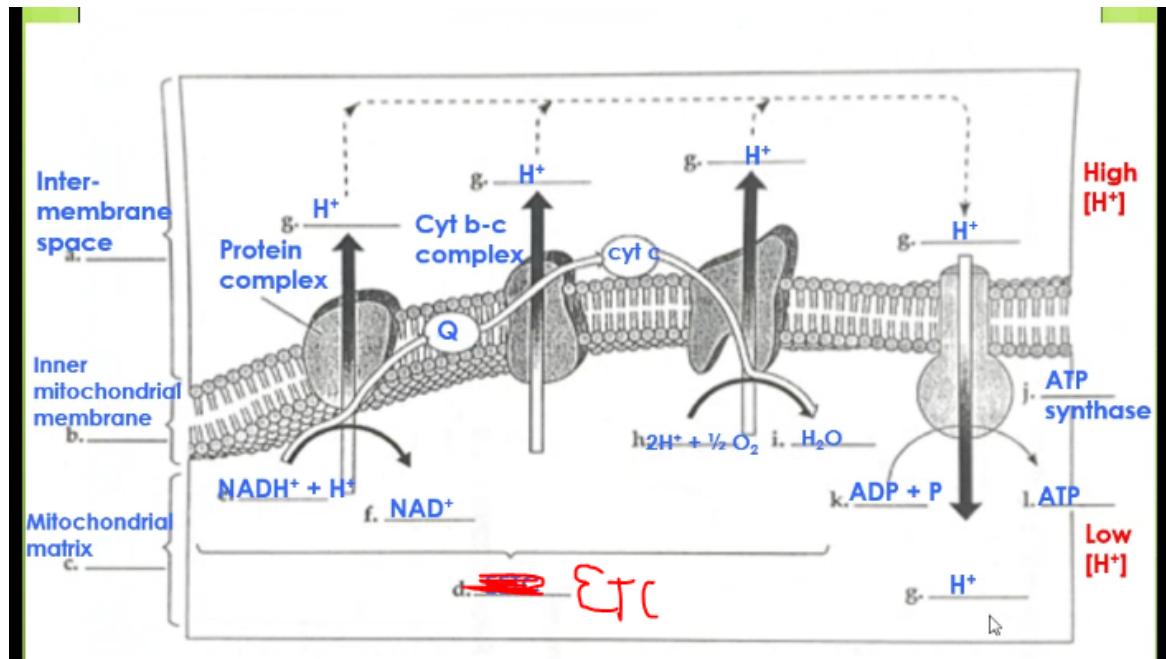


Stage 4 - ETC

- REDOX reactions: pass electrons from $\text{NADH}^+ \rightarrow \text{O}_2$
- High energy electrons are transferred from NADH^+ to flavoprotein called flavin mononucleotide (FMN).
- FMN changes back to its oxidized form as it passes electrons to an iron-sulphur protein (Fe-S).
- Each component of the chain becomes reduced when it accepts electrons from its uphill neighbour
- Each member of the chain reverts back to its oxidized form as it passes electrons to its downhill neighbour
- Oxygen is the final acceptor of electrons that pass through the ETC



- Overall energy drop:
 - Just know what these stand for, don't need to memorize this process

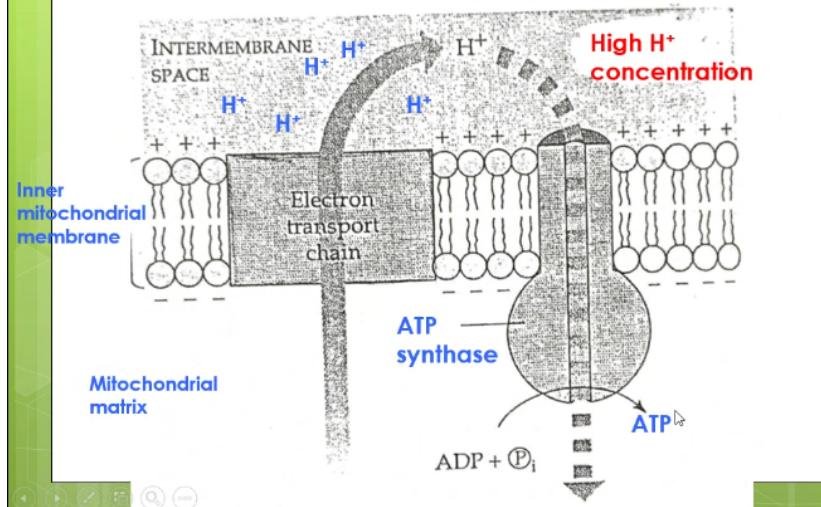


- Stage 4: Chemiosmosis

Stage 4: Chemiosmosis

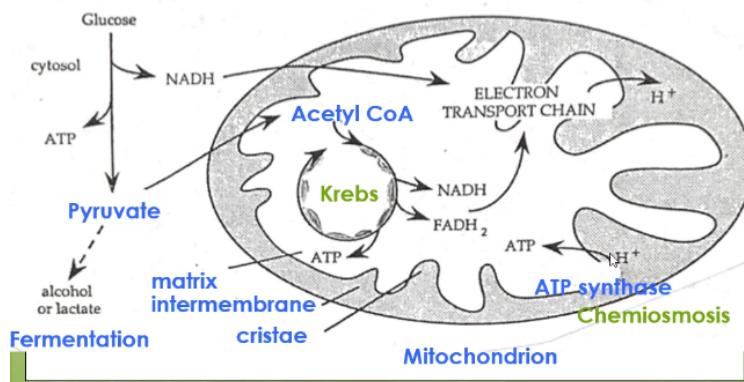
- As the protons are pumped out of the matrix to the intermembrane space, it creates an electrochemical gradient
- The potential energy stored in the proton gradient is called proton motive force
- Protons can diffuse back into the matrix through ATP synthase molecule channels
- As the protons diffuse back into the matrix, they lose their energy, permitting the ATP synthase to make ATP through chemiosmosis

Stage 4: Chemiosmosis

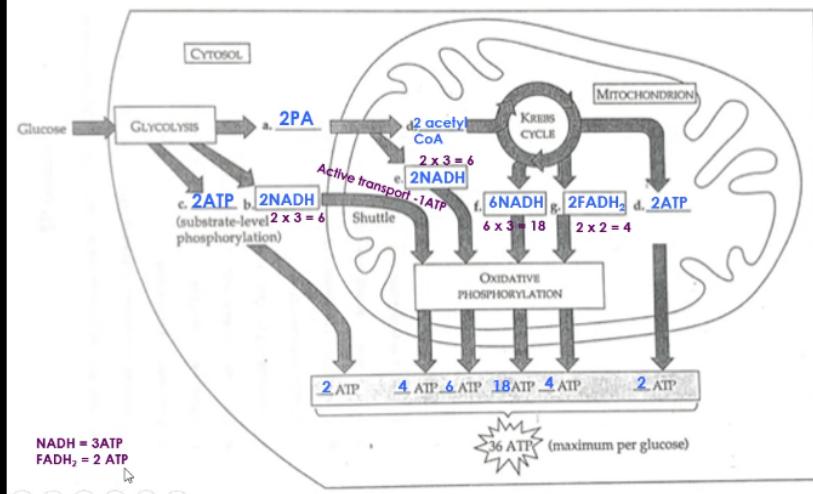


Summary

Glycolysis



Counting ATP



ATP Games

How many ATP's would be gained by a cell from the aerobic respiration of:

- 1 molecule of fructose-1,6-disphosphate?
- 2 molecules of phosphoenol pyruvate?

ATP Games

How many ATP's would be gained by a cell from the aerobic respiration of:

- a) 1 molecule of fructose-1,6-disphosphate?

Glycolysis: $2 \text{ NADH} - 2\text{ATP} = 4 \text{ ATP}$

$$4 \text{ ATP} = 4 \text{ ATP}$$

Krebs Cycle:

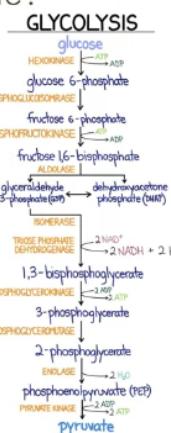
$$8 \text{ NADH} = 24 \text{ ATP}$$

$$2 \text{ FADH}_2 = 4 \text{ ATP}$$

$$2 \text{ ATP} = 2 \text{ ATP}$$

Total:

$$38 \text{ ATP}$$



ATP Games

How many ATP's would be gained by a cell from the aerobic respiration of:

b) 2 molecules of phosphoenol pyruvate?

Glycolysis:

$$2 \text{ ATP} = 2 \text{ ATP}$$

Krebs Cycle:

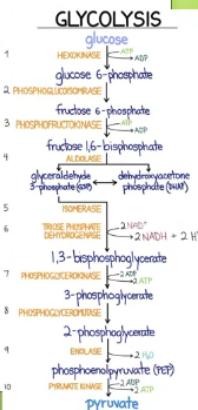
$$8 \text{ NADH} = 24 \text{ ATP}$$

$$2 \text{ FADH}_2 = 4 \text{ ATP}$$

$$2 \text{ ATP} = 2 \text{ ATP}$$

Total:

$$\underline{\hspace{1cm}} \quad 32 \text{ ATP}$$



- Homework
- Potato lab