Bio 20IB: Biochemistry Study Guide

Huge thanks to Jun Kim for making this!

Inorganic and Organic Molecules

- Organic relates to anything in living organisms while inorganic is for non-living matter
- Organic compounds MUST contain **carbon and hydrogen** and MUST be found in a living organism
- Approximately 10000 different molecules contain the carbon/hydrogen necessary to qualify as an organic compound
- Hydrocarbons, carbonates, and oxides of carbon are exceptions and **are not** organic compounds

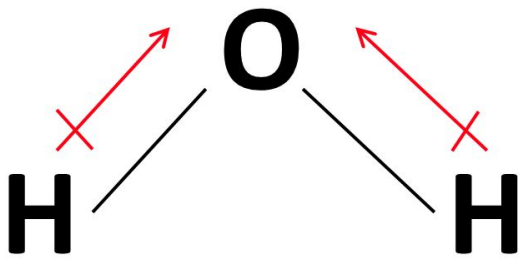
Metabolism

- Metabolism is the combination of anabolism and catabolism
- Anabolism: the building of polymers from monomers using condensation reactions
- Catabolism: the breakdown of polymers to monomers using hydrolysis
- All reactions are enzyme-catalyzed reactions (in cells or organisms)
- Condensation reactions create a water molecule leaving an oxygen atom to link the two monomers together (called a glycosidic link)
- Hydrolysis is the breakdown of two monomers by using a water molecule to separate them (thus hydro = water, lysis = breaking, hydrolysis = breaking with water)

Water Cycle Summary

- 97% of water on Earth is liquid but only 3% of that is fresh water
- Water in the atmosphere results from evaporation and transpiration
- 86% of evaporation occurs from oceans
- Water vapour is a greenhouse gas (obviously just isn't as bad as CFCs or CO_2)
- Ocean and air currents transfer and carry heat (because of water's high heat capacity)

Water Properties



- Water looks like this and the dipoles (pointing towards the slightly negative side) prove that it is polar
- Water is the universal solvent because of its polarity, meaning it is slightly negative and slightly positive on opposite sides (occurs because of its bent shape)

- Special properties include a high boiling and melting point, cohesion/adhesion, and high heat capacity
- **Cohesion:** attraction of water molecules to each other due to hydrogen bonding; cohesion is what creates surface tension and allows organic debris to float on top
- **Adhesion:** attraction of water molecules to other **polar** surfaces; capillary action is an example of this, so is the presence of a meniscus in beakers because the water attracts to the sides of the glass
- **High heat capacity:** basically means that it takes more heat/energy to heat up water, because it can absorb or lose a large amount of energy before temperature changes
- This helps organisms like us to maintain a constant temperature, and it regulates environmental temperature (like oceans for aquatic life)

Blood Solubility

Molecule	Polarity/Solubility	Method of Blood Transport
Glucose	Polar and soluble	Dissolved in plasma
Amino Acids	Partially polar and soluble	Dissolved in plasma
Cholesterol	Non-polar, with small hydrophilic region and insoluble	Inside lipoprotein complex
Fats	Non-polar and insoluble	Inside lipoprotein complex
Oxygen	Non-polar but slightly soluble due to small size	Hemoglobin (very little dissolved in warm blood)
Sodium Chloride	Ionic and soluble	The ions are dissolved in plasma (Na^+ & Cl^-)

Nutrients

- Nutrients are necessary for live to survive and grow; there are two types: **macronutrients and micronutrients**
- **Macronutrients:** carbohydrates, lipids, and proteins; they provide most of the energy and building blocks and therefore are required in large amounts
- **Micronutrients:** vitamins and minerals; they provide necessary cofactors for metabolism (to control body processes), and are essential in small amounts
- **Essential Nutrients:** nutrients that cannot be created by the body and must be consumed in the diet (such as iron)

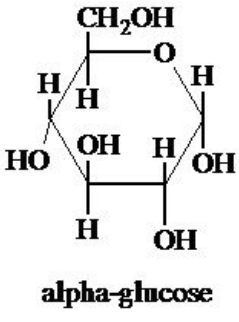
- Vitamins are **organic** carbon compounds and are essential, for example lack of vitamin D or calcium affects bone mineralization and causes rickets or osteomalacia
- Essential Fatty Acids such as omega-3 are necessary for “good health” because they help with processes (does not provide energy tho)
- 9 out of 20 amino acids cannot be synthesized by our bodies and are called **essential amino acids**; a lack of essential amino acids affects the production of proteins

Carbohydrates

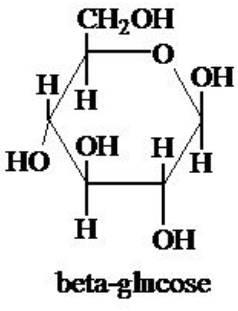
- Built from monosaccharides/simple sugars to create polysaccharides
- Produced by plants, **used for energy, structure, and storage**
- Always contain **carbon, hydrogen, and oxygen** in a 1:2:1 ratio (ex. $C_6H_{12}O_6$)
- **Monosaccharides:** ex. glucose, fructose, and galactose are all isomers (alternate forms of bonding $C_6H_{12}O_6$, meaning they have the same atoms just different configuration)
- **Disaccharides:** ex. sucrose (glucose & fructose), lactose (glucose & galactose), and maltose (glucose & glucose)
- **Polysaccharides:** more than 2 sugar units such as cellulose, starch (amylose and amylopectin), and glycogen

Roles of Carbohydrates

- **In animals:**
    - Glucose: used to make ATP
    - Lactose: sugar in milk, used to give energy to newborns
    - Glycogen: energy storage in the liver
- **In plants:**
    - Fructose: makes fruits taste sweet so animals eat them and disperse the seeds
    - Sucrose: energy source
    - Cellulose: component of cell walls
    - Starch: short term energy storage for plants

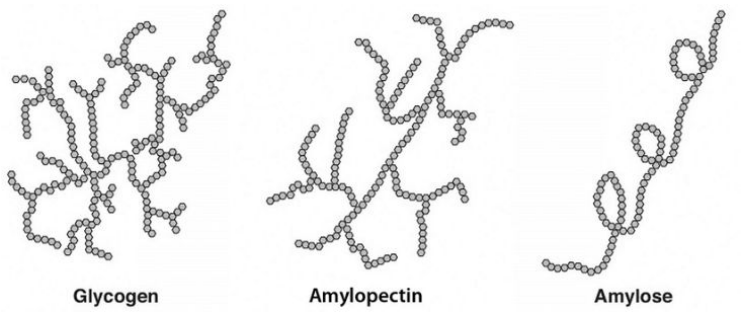


alpha-glucose



beta-glucose

- Alpha-glucose makes starches and beta-glucose makes cellulose
- The OH on the right and left hand sides of the glucose are used in condensation reactions
- The hydroxyl group (OH) separates completely from one and removes just H from the other leaving just one oxygen atom connecting the two molecules



- In hydrolysis, H_2O is added to the connected molecules and separates them creating two separate hydroxyl groups
- Testing for carbohydrates: **Benedict's test for reducing sugars** will test for all monosaccharides and disaccharides excluding sucrose, blue is a negative result (no sugars), red is a positive result (yes sugars)
- **Iodine test for starch**: when iodine get stuck in the branches of the starch it will change colours

<u>Lipids</u>

- Hydrophobic, non-polar, and insoluble in water
- Are high energy, found in fats and oils, more than twice the energy per gram compared to carbs due to the number of chemical bonds (efficient for storing energy)
- Lipids are made up of glycerol and fatty acid molecules
- **FUNCTIONS OF LIPIDS: Energy storage, insulation, component of cell membranes** (phospholipid)**, protects organs, carries for fat-soluble vitamin absorption** (A, D, E, K)**, steroid hormone synthesis** (ex. testosterone)
- Triglycerides are made from 1 glycerol and 3 fatty acid chains, each chain connects to the glycerol with a condensation reaction, meaning 3 water molecules are created when producing 1 triglyceride
- Fatty acid chains can be either **unsaturated or saturated**
- **Unsaturated fatty acids**: have at least one **double bond** between carbon atoms
    - Monounsaturated have 1 double bond while polyunsaturated have more than 1 double bond
    - They are oils and are usually liquid (from plants)
    - They are reactive and easier to breakdown and therefore, thought as healthier
    - Hydrogenating: making an oil into a fat by adding a hydrogen; for example hydrogenation of a cis unsaturated fatty acids creates trans unsaturated fatty acids
- **Saturated fatty acids:** have no double bonds between carbon atoms
    - They are animal fats and hard to break down; also somewhat solid at room temperature

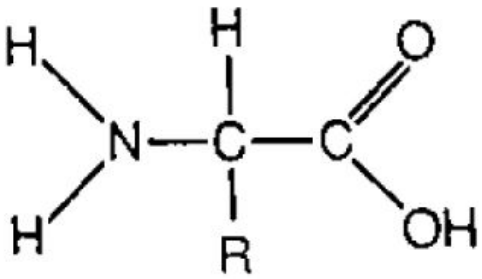
- Since they are hard to break down, they can block arteries

Tests for fats: Translucence test: basically light shines through the paper bag if fats are present

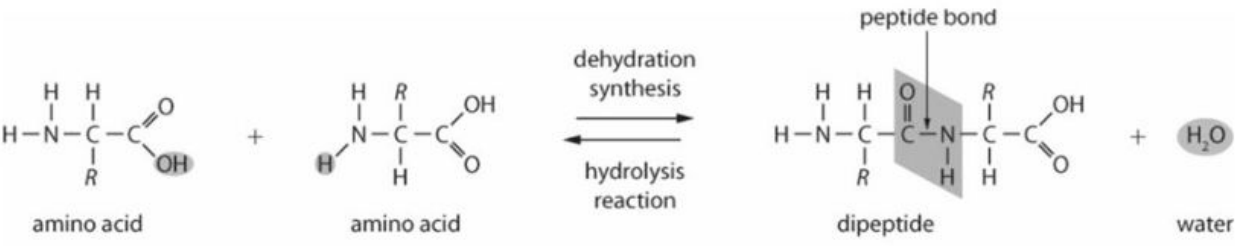
Nomograms: use a ruler from weight to height to determine the BMI (example here)

Proteins

- living organisms can synthesize many different types
- **USES OF PROTEINS:**
  - **enzymes:** as biological catalysts
  - **antibodies**: found in immunoglobulins
  - **hormones**: insulin
  - **pigments**: such as rhodopsin in vision
  - **structure**: ex. spider silk or collagen in skin
- 50% of the dry weight of organisms is made up of proteins
- they are synthesized as polypeptides on ribosomes
- Proteomics: the study of the structure, function, and interaction of cellular proteins
- the entire collection of a species' proteins is the proteome, and each individual has a unique proteome



- The "R" group is what makes the amino acid different
- These amino acids are the building blocks of proteins; there are 20 kinds of human proteins and 9 are essential
- Also use hydrolysis and condensation reactions (shown below)



- Protein 3D conformation process
  - **Primary Structure**: there are huge varieties and are coded by genes (DNA), determines the next structures
  - amino acid sequence (including size of polypeptide and types of amino acids)

    - **Secondary Structure**: interactions between functional groups with hydrogen bonds to create alpha helix or beta sheets
    - **Tertiary Structure**: interactions of R groups and uses hydrogen, ionic, and covalent bonding to cause additional folding of the secondary structure
    - **Quaternary Structure**: interactions of polypeptides, more than one tertiary polypeptide makes a protein

Protein Tests

Biuret test: they test for peptide bonds; blue is negative, purple is positive

PKU (Phenylketonuria)

- Genetic metabolic disorder where the enzyme that turns phenylalanine into tyrosine is not present
- This makes phenylalanine build up to a toxic level which could cause brain damage
- Babies are tested to ensure their diets are low in phenylalanine to prevent long-term effects (they avoid aspartame)

Starvation/Malnutrition

- **Starvation:** result of severe or total lack of nutrients and energy needed for the maintenance of life
- **Malnutrition**: can be caused by **too little or too much** of a particular nutrient

Denaturation of Proteins

- Proteins only work due to their 3D structure and will have an optimal pH and temperature
- **Denaturation:** when proteins change shape and lose their function due to a change in conditions (this is usually irreversible even when conditions are turned back to optimal)
    - **Temperature:** too much heat/energy causes hydrogen bonds (and other bonds) to break and changes the protein's shape
    - **pH**: acidic and basic conditions affect the hydrogen bonding and result in proteins changing shape

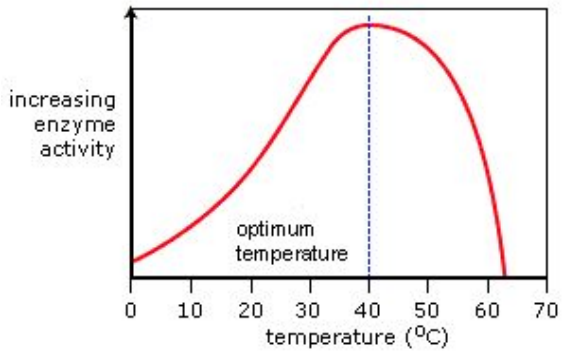
Enzymes

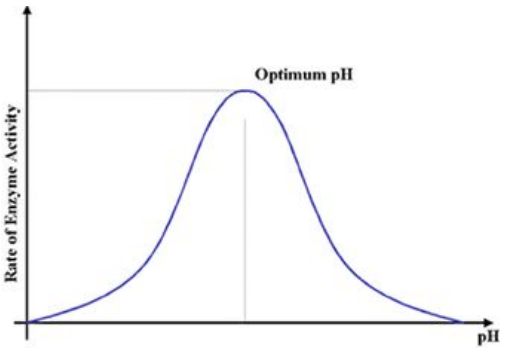
- They are crucial because body temperature is too cold for most reactions to occur efficiently on their own, and high body temperatures would denature proteins
- Therefore, catalysts in the form of enzymes speed up the reactions
- Enzymes lower the amount of energy required by reactants (activation energy)
- All enzymes have an **active site** where **substrates** bind

- **Substrate**: the reactants in an enzyme-catalyzed reaction
- **Active site:** the location of the enzyme where the reaction takes place
- Metabolic pathways in the body consist of chains and cycles of enzyme-catalyzed reactions (so several enzymes are required to accomplish one thing usually)
- **Induced-Fit model of Enzymes:**
    - each active site is suited for a particular substrate
    - multiple reactions can be catalyzed by some enzymes
    - once the substrate binds to the active site, the enzyme changes very slightly to completely fit the substrate and after the reaction, the enzyme returns to its original conformation

<u>Denaturation Rates</u>

- **Temperature:**
    - Enzyme catalysis involves molecular motion and collision of substrates with the active site
    - When temperature is too high, enzymes denature due to broken bonds
    - When temperature is too low, enzymes lose flexibility and motion
    - Both result in lower reaction rates
- **pH:**
    - Acids and bases affect the amount of hydrogen that is bonded to amino acids and will affect the hydrogen bonding and shape of proteins
    - Enzyme activity will decrease because shape of proteins will change
    - ex. Human blood plasma has a very narrow pH range for health





- **Other Factors:**
    - Substrate concentration: if there is more substrate than active sites available, eventually the reaction rate will level off
    - Enzyme concentration: if there is too many enzymes in relation to substrate, the reaction rate will eventually decrease

- Examples in industry: Lactose-free milk is made with the enzyme lactase
- “lactose + water -> glucose + galactose” reaction is catalyzed with lactase and makes a sweeter milk that contains no lactose and also means less sugar needs to be added

Enzyme Inhibition

- **Competitive Inhibition:**
    - certain things block the enzyme active sites and compete with the substrate
- **Non-competitive Inhibition:**
    - attach to the enzyme at a different site **not** at the active site but it makes the active site change shape, meaning the substrate can no longer fit
- **End-product Inhibition:**
    - Since metabolic pathways can be controlled, the final product in a reaction inhibits the action of the initial enzyme to stop the product from being overproduced