Chapter 3; Lectures 3 [part 2], 4

Large Molecules

- Macromolecules are made the same way in all living things and are present in about the same proportions which means we can safely eat each other (aliens could not)
- Large molecules can form polymers from monomers by connecting many monomers
  - These generally form through condensation reactions, releasing a molecule of water for each covalent bond formed
  - Can be sped up by enzymes
  - Polymers form only if water is removed and energy is added to the system
- **Hydrolysis** (depolymerization) is the opposite, breaks up large polymer into monomers, consumes a water for this
- All macromolecules are made from smaller molecules through polymerization and can be broken down by hydrolysis. The need to do this is part of the reason you need to stay hydrated (that and flushing out waste, using it in blood, using it in the brain, etc, etc, etc, etc… gotta love water).
- Make sure to be familiar with the functional groups. The most important ones are Hydroxyl, Carboxyl, Amino, and Carbonyl

The Molecules

- **Proteins**: formed from different combinations of 20 amino acids
- **Carbohydrates:** formed by linking together of monosaccharides (simple sugars)
- **Nucleic Acids**: formed from four kinds of nucleotide monomers linked in chains
- **Lipids**: formed from non-covalent forces maintaining the interactions between lipid monomers

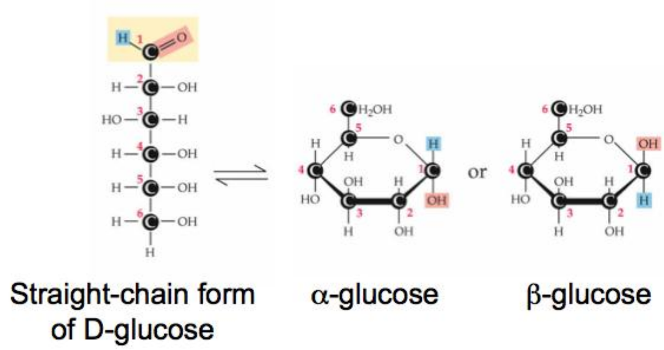
Isomers

- Isomers are molecules that have the same chemical formula but different arrangements of atoms
- **Structural isomers:** groups are attached to different carbon atoms
- **Optical isomers**: group is attached in different ways to same carbon, generally a mirror image, occur whenever a carbon has four different atoms or groups attached

(the following is more or less Alexis' original work verbatim. It's a little more than you technically need to know, but if you can learn it, you've learned the backbone for this entire midterm)

Carbohydrates - Sugars

- General formula Cn (H20) n → hydrates of carbon
- Three major biochemical roles:
  - They are a source of stored energy that can be released in a form usable by organisms
  - They are used to transport stored energy within complex organisms
  - They serve as carbon skeletons that can be rearranged to form new molecules
- Carbohydrates (sugars) act as energy storage and building blocks for other molecules (nucleic acids)
- They also serve as structural components (wood, insect exoskeleton)



- They are attached to many membrane proteins and lipids and sometimes provide identity to cells (human blood groups)
- Three major categories:
  - Monosaccharides
    - Different monosaccharides have different numbers or different arrangements of carbons
    - Glucose
      - All living cells contain the monosaccharide glucose – exists in straight chains and in ring form (ring form predominate in biological circumstances)
      - Glucose ring - α- and β- glucose → differ only in the orientation of the –H and –OH attached to carbon 1
    - Hexoses (six-carbon sugars) include the optical isomers glucose, mannose, and galactose, and the structural isomer fructose
    - Pentoses are five-carbon sugars
      - Backbone of the nucleic acids RNA and DNA contain ribose and deoxyribose
    - Monosaccharides are bonded together covalently by condensation reactions → bonds are called **glycosidic linkages**
  - Disaccharides, which consist of two monosaccharides
    - Have just one glycosidic linkage: sucrose, lactose, maltose, cellobiose
    - Maltose (α-glucose, β- glucose) and cellobiose (β- glucose, β- glucose) are structural isomers; however, they have different chemical properties and are recognized by different enzymes in biological tissues
  - Polysaccharides, which are composed o hundreds to hundreds of thousands of monosaccharides
    - Starch:

      → All are polysaccharides of glucose with α- glycosidic linkages; different starches = distinguished by the amount of branching that occurs

      - Unbranched – **amylose** in plants
      - Moderately branched – **amylopectin** in plants
      - Highly branched – **glycogen** in animals
    - Cellulose (always unbranched) – symmetrical, therefore linear, better hydrogen bonding (β-glycosidic linkages) → more stable due to β- linkages = excellent structural material
    - Chitin (modified glucose)

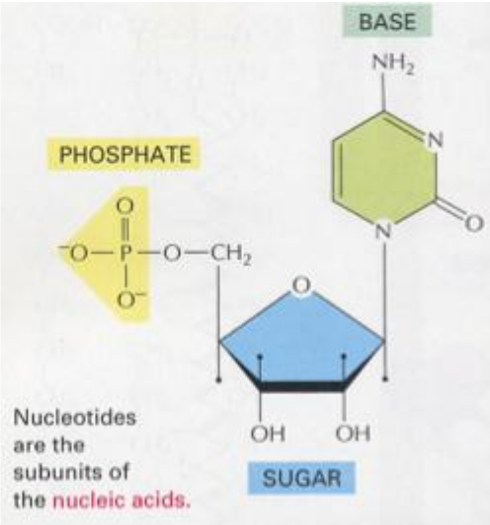
<u>Nucleic Acids</u>

→ Polymers specialized for storage, transmission between generations, and use of genetic information

Roles for nucleic acids and nucleotides (monomers) in organisms include:

- DNA (deoxyribonucleic acid) contains the information to make our genes
- DNA is transcribed into RNA (ribonucleic acid), which is translated into proteins
- Nucleotides have additional functions as signaling molecules and energy transducers

A nucleotide consists of a nitrogen-containing base, a five-carbon sugar, and one or more phosphate group → Nucleotides are the subunits of the nucleic acids



Bases: take one of two chemical forms:

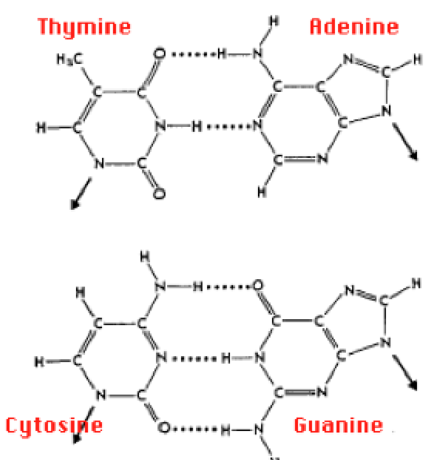
- A six-membered single-ring structure called a **pyrimidine -** uracil, cytosine, thymine
- Or…
- A fused double-ring structure called a **purine** - adenine, guanine

Phosphates: the phosphates are normally joining to C5 hydroxyl of the ribose or deoxyribose sugar (designated 5').

Mono-, di-, and triphosphates are common → the phosphate makes a nucleotide negatively charged

DNA:

→ Base pairing rules, occurs through hydrogen bonding



DNA Structure:

- Major groove: distance from the backbone is smaller than that of the distance between the backbone and the minor groove
- Double strand of the DNA allows the transmission of genetic information

Main function of RNA: intermediate between DNA and protein (mRNA)

3.3 Distinguishing RNA from DNA

NUCLEIC ACID	SUGAR	BASES
RNA Usually single-stranded	Ribose	Adenine Cytosine Guanine **Uracil**
DNA Usually double-stranded	Deoxyribose	Adenine Cytosine Guanine **Thymine**

Some RNAs have a complex 3D structure → some RNAs are catalytic (ribozymes)

➔RNAs may have carried out function of DNA and proteins when life evolved

Lipids

- Lipids are insoluble in water
- This insolubility results from the many non-polar covalent bonds of hydrogen and carbon in lipids
- Lipids aggregate away from water, which is polar, and are attracted to each other via weak, but additive, van der Waals forces
- Roles for lipids in organisms include:
  - Energy storage (fats and oils)
  - Cell membranes (phospholipids)
  - Capture of light energy (carotenoids and chlorophylls)
  - Hormones and vitamins (steroids and modified fatty acids)
  - Thermal insulation (fat in animal bodies)
  - Electrical insulation of nerves (lipid coating)
  - Water repellency (waxes and oils)

Synthesis of a Triglyceride:

Triglyceride – Glycerol + 3 Fatty acid molecules

→ Condense out 3 water molecules (forming 3 covalent bonds)➔ forms ester linkage ➔ triglyceride (fat or oil → solid at room temperature = fat; liquid at room temperature = oil)

- Saturated fatty acids: have only single carbon-to-carbon bonds and are said to be saturated with hydrogen atoms; straight and form part of animal fats; solid at room temperature
- Unsaturated fatty acids: have at least one carbon-carbon double-bond – the chain is not completely saturated with hydrogen atoms; a double bond causes kinks that prevents easy packs; form part of plant oils; liquid at room temperature

Fatty acids→ Cis and Trans conformations of double bonds

- Cis: both single bonds off the double bond are pointed in the same direction
- Trans: single bonds off the double bond are pointed in opposite direction

Phospholipids (form biological membranes)→ have two hydrophobic fatty acids (tails) and one hydrophilic head group attached to glycerol

- Self-assemble into bilayer because of hydrogen bonding and hydrophobic interactions → Hydrophilic "heads" and hydrophobic "tails"
- Certain fishes and plants increase the number of unsaturated fatty acids in their membranes in winter to keep them fluid

Carotenoids: light- absorbing pigments found in plants and animal

- In photosynthesis β - carotene is one pigment that traps light
- In humans, molecule of β - carotene can be broken down into two vitamin A molecules = *cis*-retinal (required for vision)

Steroids:

→ Cholesterol is an important constituent of membranes; synthesized in the liver and is the starting material for making testosterone and other steroid hormones

Vitamins: not synthesized in the human body → Vitamin A and D are added to milk because they are lipid soluble

<u>Proteins</u>

- Many functions: enzymatic activity, defense, hormonal regulation, storage, structural support, transport, and genetic regulation
- Proteins are polymers of amino acids
- Proteins range in size from a few amino acids to thousands of them

All proteins consist of one or more polypeptide chains – unbranched polymer of covalently linked amino acids. The composition of a protein refers to the relative amounts of the different amino acids present in its polypeptides chains. Variation in the sequence of the amino acids in polypeptide chains is the source of the diversity in protein structure and function

- Amino acids are the building blocks of proteins:
  - All 20 amino acids have the structure; each with a central carbon atom (α -carbon) with a hydrogen atom, amino group, and a carboxyl group attached to it → isomeric
  - The five amino acids that have electrically charged side chains (+1, -1) attract water and attract oppositely charged ions of all sorts
  - The five amino acids that have polar side chains tend to form hydrogen bonds with water and with other polar or charged substances. These amino acids are also hydrophilic
  - Seven amino acids have side chains that are non-polar hydrocarbons or very slightly modified hydrocarbons. In the watery environment of the cell, these hydrophobic side chains may cluster together in the interior of the protein
  - Three amino acids – cyseine, glycine, and proline – are special cases
    - Cyseine: disulfide bridge or disulfide bond
    - Glycine: single hydrogen atom
    - Proline: lacks a hydrogen → ring structure (found where protein bends or loops)

Primary structure: the precise sequence of amino acids in a polypeptide chain held together by peptide linkages → established by covalent bonds

Secondary structure: regular, repeated spatial patterns in different regions of a polypeptide chain → two basic types of secondary structure, both determined by hydrogen bonding between the amino acids that make up the primary structure

α Helix: forms a straight rod

→ The H-bonds are formed by the backbone and are parallel to the axis of the helix

→ The side groups (R groups) of the amino acids project outward (away) from the helix

➔ Because all the H-bonds run parallel to the helix axis, alpha helices can insert in plasma membranes if the helix contains only hydrophobic amino acid side chains

<u>Coiled Coils</u>

Coiled coils arise when two alpha helices have hydrophobic amino acids at every 4^{th} position (one complete turn 3.6 amino acids)

Fibrous structural proteins consist mainly of alpha helices arranged as coiled coils, such as the keratins in hair and feathers

β Pleated Sheet: makes flat plates

→ R groups project up and down from the sheet

→ The strands of the beta sheet can run in anti-parallel or parallel direction

→ They can even come from different polypeptides

Proline fits neither in an alpha helix nor in a beta sheet because it makes a kink in the peptide and because the N carries no H for hydrogen bonding

Tertiary structure is the three-dimensional shape of the completely folded polypeptide

→ Determined by:

- Location of disulfide bridges
- Location of secondary structures
- Ionic interactions between positive and negative charges deep in the protein, away from water
- Hydrophobic aggregation of R groups stabilized by van der Waals forces

→ The final folding of a protein is largely determined by non-covalent interactions, of which hydrophobic interactions are the most important

This loss of a protein's normal three-dimensional structure and function is called denaturation → proteins refold (renature) in the test tube. This shows that a) proteins automatically fold into a conformation of lowest energy and b) all folding information is contained within the primary sequence

- Changes in temperature of pH (among others) can cause denaturation
- Usually, a denatured protein cannot be refolded; it is degraded by the proteasome
- Protein turnover (breakdown and re-synthesis occurs constantly in cells)
- **Chaperones** are specialized proteins that help keep other proteins (temporarily exposed hydrophobic regions) from interacting inappropriately with one another
- They do so by sequestering some newly synthesized proteins to give them time to fold

Quaternary structure is the structure of multiple polypeptides forming a protein complex