BIOL 300 – Foundations of Biology
Summer 2017 – Telleen
Lecture 4

Biochemistry and Biological Macromolecules

I. Macromolecules
- A. What are **macromolecules**?
  1. Very large molecules
  2. Mostly **organic** (which means they are mostly made of the element carbon with special functional groups attached that have different properties)
  3. Assembled by sticking together smaller molecules (sort of like a train, which is made up of individual train cars). We have a term for molecules like this:
     Polymer – a molecule built of long chains of similar subunits (called **monomers**) (see diagram in class)
- B. There are 4 basic types macromolecules in biological systems:
  1. **Proteins** are made up of amino acids
  2. **Nucleic acids** are made up of nucleotides
  3. **Carbohydrates** are made up of simple sugars
  4. **Lipids** are long hydrophobic organic molecules

II. Organic Molecules
- A. **Organic chemistry** in the chemistry of carbon
- B. Organic molecules are made mostly of carbon and hydrogen covalently bonded together
- C. However, there are also other types of atoms mixed in that provide certain organic molecules with unique properties
- D. The other common atoms are **O**, **N**, **S**, and **P**.
- E. When these other atoms appear they create **functional groups** that have special properties. Without these other atoms, organic molecules consisting of only C and H are non-polar/hydrophobic (see lipids)
- F. O and N form polar functional groups that can interact with water and other polar molecules, such as –OH (hydroxyl), =O (carbonyl), and $–NH_2$ (amine).
- G. We're going to keep it simple, but organic chemistry can get extremely complex as the molecules get bigger.

III. Proteins
- A. **Proteins** are polymers of **amino acids** linked together by **peptide bonds**. Peptide bonds are formed by a dehydration (loss of water) reaction between two amino acids. The bonds can be broken again by adding water and energy.
- B. We also call long chains of amino acids **polypeptides** (which means more or less the same things as protein).
- C. Amino acids have a very specific structure (see textbook or diagrams in class)
- D. In known biological systems, there are 20 different amino acids. Each has the same basic structure, but differs in the chemical properties of the **R groups**.
- E. Each R groups has different functional groups that make each amino acid unique. These groups can have a variety of different properties (including polar, non-polar, acidic, basic, etc.).
- F. In life, proteins do not simply exist as long chains of amino acids. Proteins also have higher levels of structure:
  1. **Primary (1^o) Structure** refers to the sequence of amino acids in the linear polypeptide

2. **Secondary (2º) Structure** refers to folding back of the polypeptide and forming hydrogen bonds with itself to produce structures such as alpha-helices and beta-sheets
3. **Tertiary (3º) Structure** refers to the folding of a polypeptide with secondary structure into even more complex (and often globular) structures
4. **Quaternary (4º) Structure** refers to proteins that are made of more than one polypeptide subunit in which the functional protein contains several interacting polypeptides with 3^o structure.

G. Protein folding (as described above) is critical for proper function. Proteins can be **denatured** by outside forces (such as heat) that disrupt the folding. Some proteins spontaneously fold into their proper structure, but others need help.
H. Prions (such as the causal agent of Mad Cow Disease) are misfolded proteins that are extremely stable and promote the misfolding of other proteins.
I. Proteins are the real work horses of life. They are responsible for many structural features of living things, catalyzing chemical reactions, and copying DNA (to name just a few). We'll talk more about some of these functions later

IV. Nucleic Acids

A. **Nucleic acids** are the information storage molecules in biological systems
B. **DNA** and **RNA** are both nucleic acids
C. Like proteins, nucleic acids are also polymers of simple subunits
D. The monomers of nucleic acid are called **nucleotides**
E. Nucleotides are made up of three basic parts: **a base, a sugar, and a phosphate** (see diagram of structure)
F. There are only four different nucleotides (which differ only by which base they carry) in DNA. They are **Adenine, Guanine, Cytosine, and Thymine**.
G. DNA forms a double helix in which the bases of one strand interact with the bases in the other through hydrogen bonds. (A-T pairs have 2 H-bonds, while G-C pairs have 3 H-bonds)
H. RNA also has four different bases. They are the same as in DNA except Thymine is replaced by **Uracil**. RNA is usually single stranded.
I. DNA specifies the amino acid sequences of proteins, but we'll talk more about that and the details of the chemical structure of DNA and RNA later.

V. Carbohydrates

A. **Carbohydrates** are polymers of sugars and play a critical role in energy storage and structure
B. **Sugars** are organic molecules with a 1:2:1 ratio of C:H:O
C. Sugar monomers (and also dimers, which are two monomers linked together) are called simple sugars. They are sometimes called **monosaccharides** (or **disaccharides**).
D. Long chains of sugars are called complex carbohydrates, or **polysaccharides**.
E. Carbohydrates contain many C-H bonds which are energy rich and store energy
F. **Glucose** is a 6 Carbon monosaccharide (see structure). It is linear, but forms a ring structure in water.
G. **Sucrose** is a dimer of 1 glucose and 1 fructose (another 6 C monosaccharide).
H. Polysaccharides are long chains of mono- or disaccharides and are utilized by all living things. Some are involved primarily in energy storage: such as starch and glycogen (which are both polymers of glucose). Others are involved in structure: cellulose (another polymer of glucose) in plant cell walls and chitin (polymer of N-acetyl glucosamine) in fungal cell walls and arthropod exoskeletons

VI. Lipids

A. **Lipids** are fats, oils, and biological molecules that are not soluble in H_2O, but are soluble in oil

B. Although carbohydrates can be used to store energy, lipids are used for long term storage because they are more energy rich (they have more C-H bonds than sugars). However, because lipids are non-polar sugars provide an easier energy source to utilize
C. Fats are composed of two different types of subunits: **fatty acids** and **glycerol**
D. Fatty acids are long chains of C-H atoms (hydrocarbons) with carboxyl groups (COOH) at the end
E. Glycerol is a 3 C molecule to which three fatty acids are attached (see diagram)
F. **Saturated fats** contain no double bonds between carbons in the fatty acid chains, while **unsaturated fats** do have double bonds in their FAs that form kinks in the chains so they cannot pack together as densely.
G. Other types of lipids include:
    1. **Phospholipids** – Similar to fats, but one fatty acid chain is replaced by a polar phosphate group. Biological membranes are made primarily of phospholipids
    2. **Steroids** are lipids with ringed structures. They are present in membranes and also make up many of the animal sex hormones
    3. Others include rubber, waxes, and pigments (such as chlorophyll and retinal)