Mr. Ulrich   Name:……………………………………………

AP Biology

Structural Biochemistry Packet II

Organic Molecules

Biological Function of Lipids

Nucleic Acid Structure

Organic Molecules

Organic molecules are those chemical compounds containing carbon that are found in living things. Specific groups of atoms, called **functional groups**, attach to a carbon-hydrogen core and confer specific chemical properties on the molecule. Some organic molecules in organisms are small and simple, containing only one or a few functional groups, while others are large complex assemblies called **macromolecules**. The macromolecules that make up living things can be grouped into four classes: carbohydrates, lipids, proteins, and nucleic acids. An understanding of the structure and function of these molecules is necessary to many branches of biology, especially biochemistry, physiology, and molecular genetics. The diagram below illustrates some of the common ways in which biological molecules are portrayed. Note that the **molecular formula** expresses the number of atoms in a molecule, but does not convey its structure; this is indicated by the **structural formula**. Molecules can also be represented as **models**. A ball and stick model shows the arrangement and type of bonds while a space filling model gives a more realistic appearance of a molecule, showing how close the atoms really are.

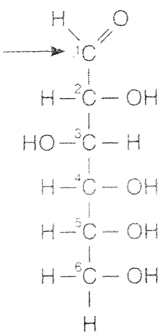
Portraying Biological Molecules

The numbers next to the carbon atoms are used for identification when the molecule changes shape

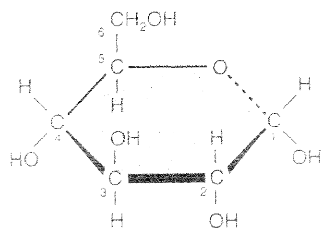
$C_6H_{12}O_6$

Glucose

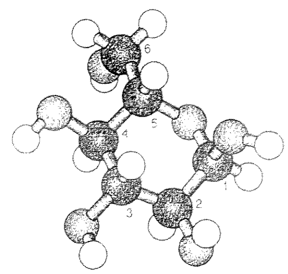
Molecular formula



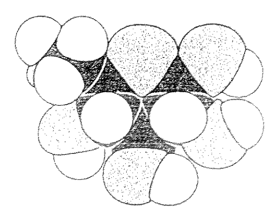
Structural formula
Glucose (straight form)



Structural formula
α glucose (ring form)



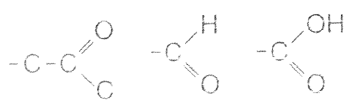
Ball and stick model
Glucose



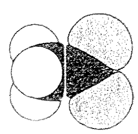
Space filling model
β-D-glucose

Example of Biological Molecules

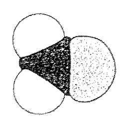
Biological molecules may also include atoms other than carbon, oxygen, and hydrogen atoms. Nitrogen and sulfur are components of molecules such as amino acids and nucleotides. Some molecules contain the C=O (carbonyl) group. If this group is joined to at least one hydrogen atom it forms an aldehyde. If it is located between two carbon atoms, it forms a ketone.



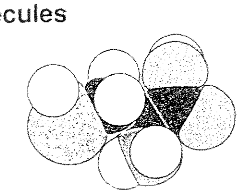
Ketone **Aldehyde** **Carboxyl**



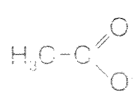
Acetate

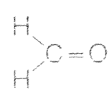


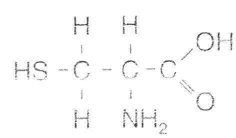
Methanal



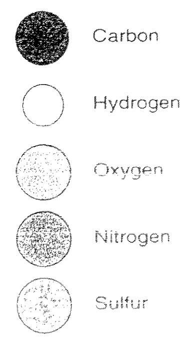
Cysteine







Key to Symbols



1. Which three main elements make up the structure of organic molecules? ______________________

2. Name two other elements that are also frequently part of organic molecules: ______________________

3. State how many covalent bonds a carbon atom can form with neighboring atoms: ______________________

4. Distinguish between molecular and structural formulae for a given molecule: ______________________

____

____

5. What is a functional group? ______________________

____

6. Classify methanal according to the position of the C=O group: ______________________

7. Identify a functional group always present in amino acids: ______________________

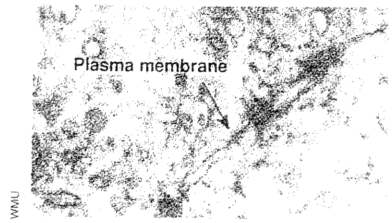
8. Identify the significance of cysteine in its formation of disulfide bonds: ______________________

Biological Functions of Lipids

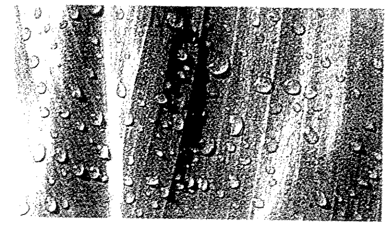
Lipids are a group of organic compounds with an oily, greasy, or waxy consistency. They are relatively insoluble in water and tend to be water-repelling (e.g. cuticle on leaf surfaces). Lipids are important biological fuels, some are hormones, and some serve as structural components in plasma membranes. Proteins and carbohydrates may be converted into fats by enzymes and stored within cells of adipose tissue. During times of plenty, this store is increased, to be used during times of food shortage.

Important Biological Functions of Lipids

Lipids are concentrated sources of energy and provide fuel for aerobic respiration.



Phospholipids form the structural framework of cellular membranes.



Waxes and oils secreted onto surfaces provide waterproofing in plants and animals.

Fat absorbs shocks. Organs that are prone to bumps and shocks (e.g. kidneys) are cushioned with a relatively thick layer of fat.

Lipids are a source of metabolic water. During respiration stored lipids are metabolized for energy, producing water and carbon dioxide.

Stored lipids provide insulation. Increased body fat levels in winter reduce heat losses to the environment.

1. Explain how fats can provide an animal with:

   (a) Energy: ______________________________

   (b) Water: ______________________________

   (c) Insulation: ______________________________

2. Explain why marine mammals (e.g. whales and seals) have thick layers of fat, or blubber, surrounding their bodies:

____

3. Oils and waxes are water repelling. Give two examples in animals or plants where this property would be useful:

____

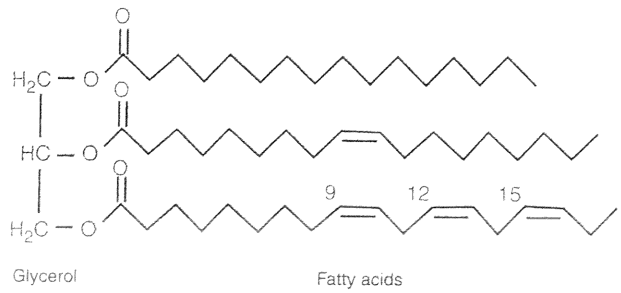
4. Phospholipids have a polar head and non-polar tail. Explain how this allows them to spontaneously form the plasma membrane of a cell.

____

Lipids are a diverse group of chemicals that lack an affinity for water, i.e. they are **hydrophobic**. They consist mainly of covalently bonded hydrogen and carbon molecules. Lipids can be divided into fats (comprising fatty acids and glycerol), phospholipids, and steroids. They can be solids or liquids at room temperature depending on the length of their carbon chains.

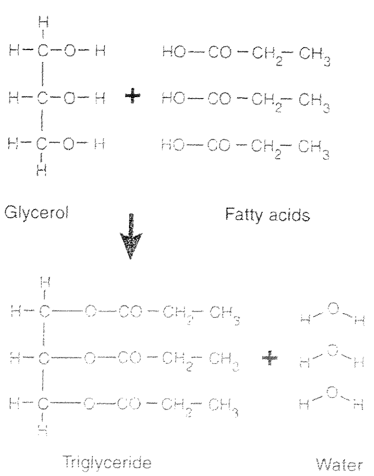
Neutral Fats and Oils

The most abundant lipids in living things are neutral fats. They make up the fats and oils found in plants and animals. Fats are an economical way to store fuel reserves because they yield more than twice as much energy as the same quantity of carbohydrate. **Neutral fats** are composed of a glycerol molecule attached to one (monoglyceride), two (diglyceride) or three (triglyceride) fatty acids. The fatty acid chains may be saturated or unsaturated (see below). Waxes are similar in structure to fats and oils, but they are formed with a complex alcohol instead of glycerol.



Triglyceride: an example of a neutral fat

Condensation

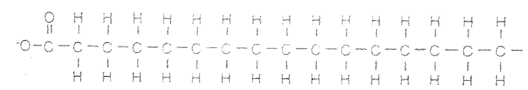


Triglycerides form when glycerol bonds with three fatty acids. Glycerol is an alcohol containing three carbons. Each of these carbons is bonded to a hydroxyl (-OH) group.

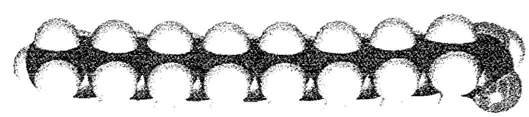
When glycerol bonds with the fatty acid, an ester bond is formed and water is released. Three separate condensation reactions are involved in producing a triglyceride.

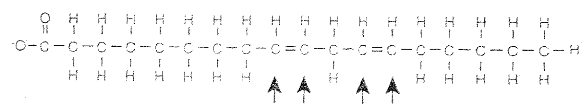
Saturated and Unsaturated Fatty Acids

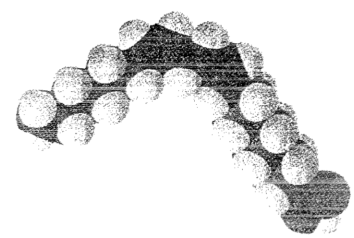
Fatty acids are a major component of **neutral fats** and **phospholipids**. About 30 different kinds are found in animal lipids. **Saturated fatty acids** contain the maximum number of hydrogen atoms. **Unsaturated fatty acids** contain some carbon atoms that are double-bonded with each other and are not fully saturated with hydrogens. Lipids containing a high proportion of saturated fatty acids tend to be solids at room temperature (e.g. butter). Lipids with a high proportion of unsaturated fatty acids are oils and tend to be liquid at room temperature. This is because the unsaturation causes kinks in the straight chains so that the fatty acids do not pack closely together. Regardless of their degree of saturation, fatty acids yield a large amount of energy when oxidised.



Formula (above) and molecular model (below) for **palmitic acid** (a saturated fatty acid)







Formula (above) and molecular model (right) for **linoleic acid** (an unsaturated fatty acid). The arrows indicate double bonded carbon atoms that are not fully saturated with hydrogens.

1. (a) Distinguish between saturated and unsaturated fatty acids: ______________________________

____

____

(b) Explain how the type of fatty acid present in a neutral fat or phospholipid is related to that molecule's properties:

____

____

____

2. Describe two examples of steroids. For each example, describe its physiological function:

(a) ______________________________

(b) ______________________________

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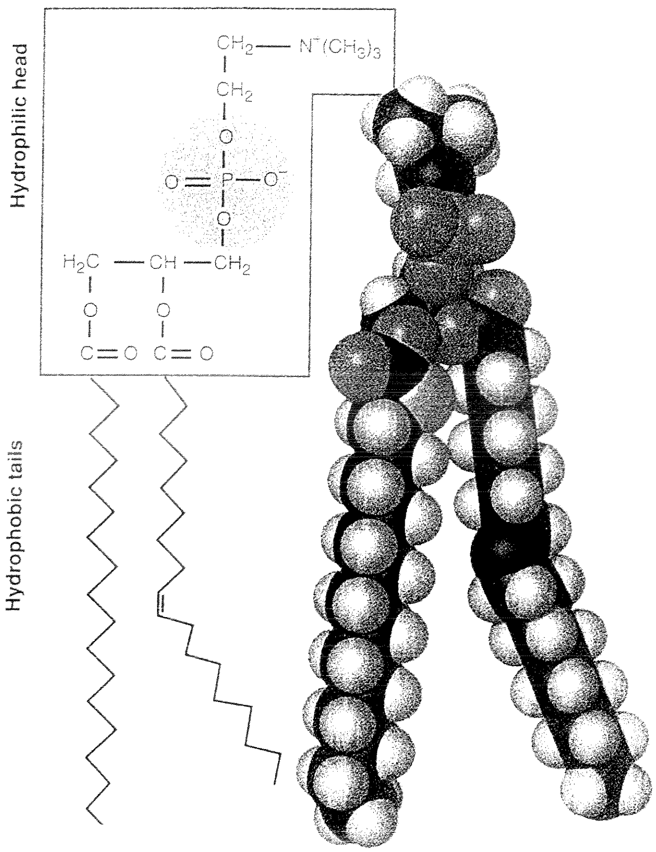
Phospholipids

Phospholipids are the main component of cellular membranes. They consist of a glycerol attached to two fatty acid chains and a phosphate (PO_4^{3-}) group. The phosphate end of the molecule is attracted to water (it is hydrophilic) while the fatty acid end is repelled (hydrophobic). The hydrophobic ends turn inwards in the membrane to form a **phospholipid bilayer.**

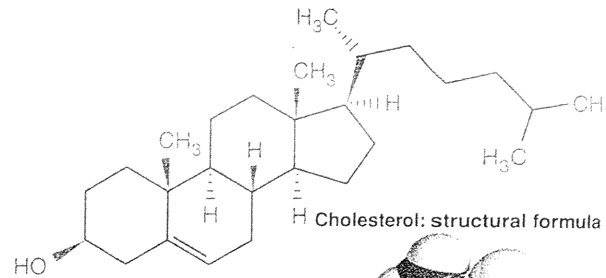


Steroids and Cholesterol

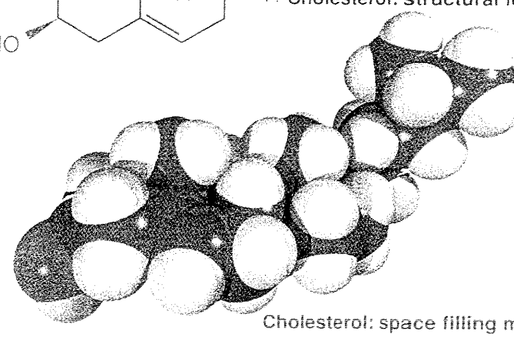
Although steroids are classified as lipids, their structure is quite different to that of other lipids. Steroids have a basic structure of three rings made of 6 carbon atoms each and a fourth ring containing 5 carbon atoms. Examples of steroids include the male and female sex hormones (testosterone and estrogen), and the hormones cortisol and aldosterone.

Cholesterol, while not a steroid itself, is a sterol lipid and is a precursor to several steroid hormones. It is present in the plasma membrane, where it regulates membrane fluidity by preventing the phospholipids from packing too closely together.

Like phospholipids, cholesterol is **amphipathic.** The hydroxyl (-OH) group on cholesterol interacts with the polar head groups of the membrane phospholipids, while the steroid ring and hydrocarbon chain tuck into the hydrophobic portion of the membrane. This helps to stabilise the outer surface of the membrane and reduce its permeability to small water-soluble molecules.



Cholesterol: structural formula



Cholesterol: space filling molecule

3. Outline the key **chemical** difference between a phospholipid and a triglyceride: ______________________

4. Explain why saturated fats (e.g. lard) are solid at room temperature: ______________________

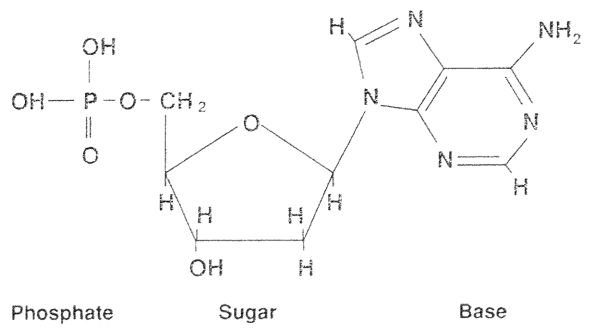
5. (a) Relate the structure of phospholipids to their chemical properties and their functional role in cellular membranes:

   (b) Suggest how the cell membrane structure of an Arctic fish might differ from that of tropical fish species:

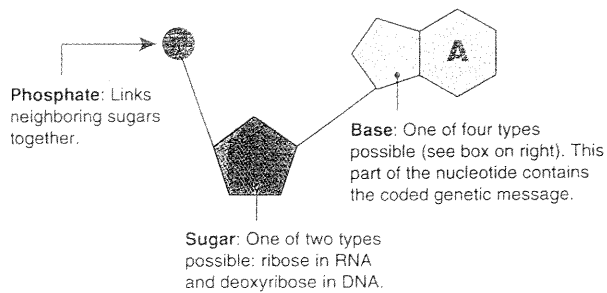
6. Explain how the structure of cholesterol enables it to perform structural and functional roles within membranes:

Nucleic acids are a special group of chemicals in cells concerned with the transmission of inherited information. They have the capacity to store the information that controls cellular activity. The central nucleic acid is called **deoxyribonucleic acid** (DNA). DNA is a major component of chromosomes and is found primarily in the nucleus, although a small amount is found in mitochondria and chloroplasts. Other **ribonucleic acids** (RNA) are involved in the 'reading' of the DNA information. All nucleic acids are made up of simple repeating units called **nucleotides**, linked together to form chains or strands, often of great length (see the activity *DNA Molecules*). The strands vary in the sequence of the bases found on each nucleotide. It is this sequence which provides the 'genetic code' for the cell. In addition to nucleic acids, certain nucleotides and their derivatives are also important as suppliers of energy (**ATP**) or as hydrogen ion and electron carriers in respiration and photosynthesis (NAD, NADP, and FAD).

Chemical Structure of a Nucleotide



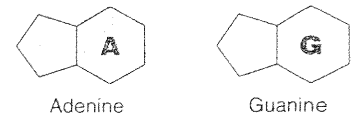
Symbolic Form of a Nucleotide



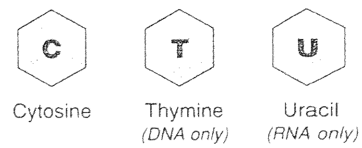
Nucleotides are the building blocks of DNA. Their precise sequence in a DNA molecule provides the genetic instructions for the organism to which it governs. Accidental changes in nucleotide sequences are a cause of mutations, usually harming the organism, but occasionally providing benefits.

Bases

Purines:

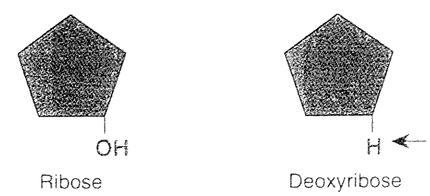


Pyrimidines:



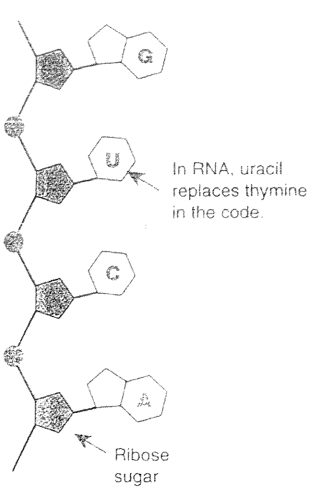
The two-ringed bases above are **purines**. The single-ringed bases are **pyrimidines**. Although only one of four kinds of base can be used in a nucleotide, **uracil** is found only in RNA, replacing **thymine**. DNA contains A, T, G, and C, while RNA contains A, U, G, and C.

Sugars

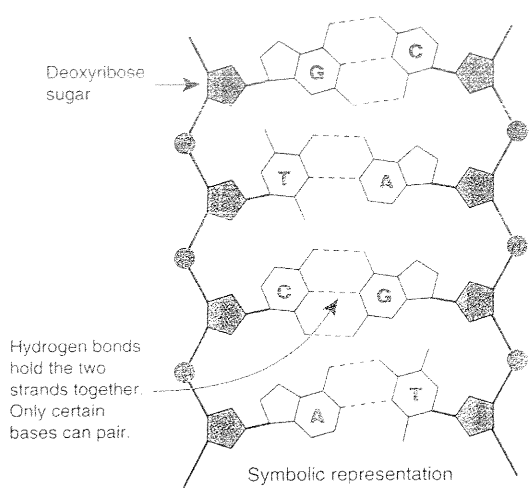


Deoxyribose sugar is found only in DNA. It differs from **ribose** sugar, found in RNA, by the lack of a single oxygen atom (arrowed).

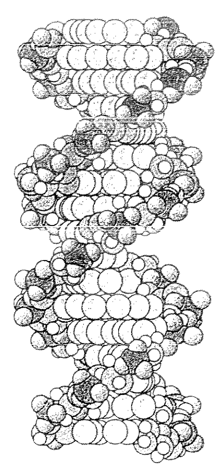
RNA Molecule



DNA Molecule



DNA Molecule



Space filling model

Ribonucleic acid (RNA) comprises a *single strand* of nucleotides linked together.

Deoxyribonucleic acid (DNA) comprises a *double strand* of nucleotides linked together. It is shown unwound in the symbolic representation (left). The DNA molecule takes on a twisted, double-helix shape as shown in the space filling model on the right.

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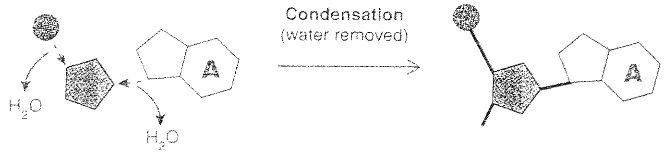
***Related activities**: DNA Molecules, Creating a DNA Molecule*
***Weblinks**: DNA Anatomy*

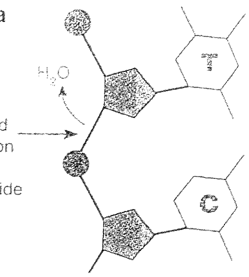
Formation of a nucleotide



A nucleotide is formed when phosphoric acid and a base are chemically bonded to a sugar molecule. In both cases, water is given off, and they are therefore condensation reactions. In the reverse reaction, a nucleotide is broken apart by the addition of water (**hydrolysis**).

Formation of a dinucleotide

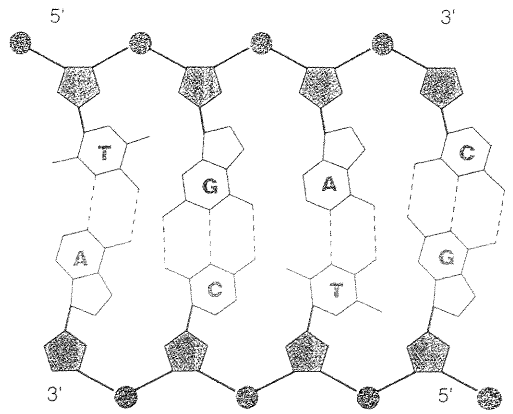
Two nucleotides are linked together by a condensation reaction between the phosphate of one nucleotide and the sugar of another.



Double-Stranded DNA

The double-helix structure of DNA is like a ladder twisted into a corkscrew shape around its longitudinal axis. It is 'unwound' here to show the relationships between the bases.

- The DNA backbone is made up from alternating phosphate and sugar molecules, giving the DNA molecule an asymmetrical structure.
- The asymmetrical structure gives a DNA strand a **direction**. Each strand runs in the opposite direction to the other.
- The ends of a DNA strand are labeled the 5' (five prime) and 3' (three prime) ends. The **5'** end has a terminal phosphate group (off carbon 5), the **3'** end has a terminal hydroxyl group (off carbon 3).
- The way the pairs of bases come together to form hydrogen bonds is determined by the number of bonds they can form and the configuration of the bases.



1. The diagram above depicts a double-stranded DNA molecule. Label the following parts on the diagram:
   (a) **Sugar** (deoxyribose)
   (b) **Phosphate**
   (c) **Hydrogen bonds** (between bases)
   (d) **Purine** bases
   (e) **Pyrimidine** bases

2. (a) Explain the **base-pairing rule** that applies in double-stranded DNA: ______________________

   (b) How is the base-pairing rule for mRNA different? ______________________

   (c) What is the purpose of the hydrogen bonds in double-stranded DNA? ______________________

3. Describe the functional role of nucleotides: ______________________

4. (a) Why do the DNA strands have an asymmetrical structure? ______________________

   (b) What are the differences between the 5' and 3' ends of a DNA strand? ______________________

5. Complete the following table summarizing the differences between DNA and RNA molecules:

	DNA	RNA
Sugar present		
Bases present		
Number of strands		
Relative length		