BIOLOGY 12 **NAME: ______________________________**

BIOLOGICAL MOLECULES

Although many inorganic compounds are essential to life, the vast majority of substances in living things are organic compounds.

ORGANIC MOLECULES:

Organic molecules always contain carbon and hydrogen. Carbon forms the structural backbone of all organic compounds. Of all the elements, only carbon is versatile and stable enough to make up all the tremendous variety of molecules found in all living things.

Why Carbon?

Carbon has 4 electrons in its outermost energy level. In order to achieve 8 electrons in the outer shell, a carbon atom shares electrons with hydrogen forming strong covalent bonds. Carbon atoms often share electrons with other carbon atoms to form hydrocarbons or long chains – can be straight or branched → great variety of possible combinations. It is this property that makes carbon so important as carbon atoms often must form large molecules required by living things.

FORMATION OF ORGANIC COMPOUNDS:

Most organic compounds are made of basic units, or building blocks, called monomers that repeat over and over to form larger molecules called polymers or macromolecules. The process of joining these monomers together is called **dehydration synthesis:**

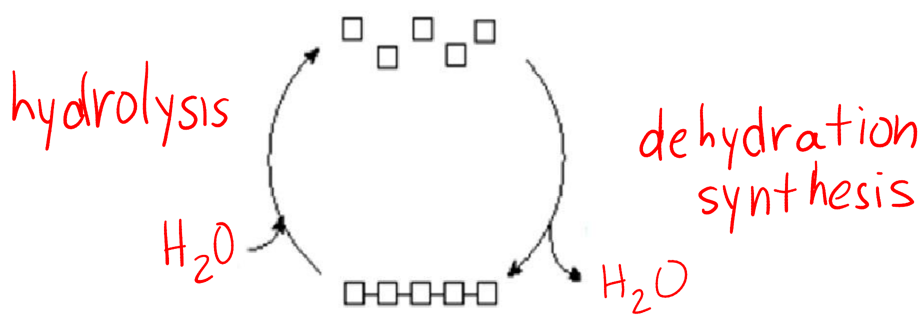
The 'making' of a molecule through H_2O removal

The process of breaking apart these polymers (macromolecules) is called **hydrolysis:**

The splitting of a bond using H_2O

Use the following words to fill in the blanks on the diagram below: hydrolysis, synthesis, ~~macromolecule~~ polymer, monomers water.

monomers



polymer

FOUR MAIN GROUPS OF MOLECULES:

Although the number of possible organic compounds is almost limitless, it is possible to classify many important organic compounds found in living things into four main groups: **PROTEINS, CARBOHYDRATES, LIPIDS, AND NUCLEIC ACIDS.** By knowing the characteristics of just these four groups, you will know a great deal about the chemistry of living things.

1. PROTEINS

Every one of us has tens of thousands of different kinds of proteins, each with a unique, three-dimensional structure that corresponds to a specific function.

A. THREE MAIN FUNCTIONS OF PROTEINS:

i. STRUCTURAL SUPPORT form parts of structures:
Keratin - component of hair and nails
collagen - found in connective tissue

ii. MOVEMENT Actin/Myosin - movement of cells, muscle contraction

iii. METABOLIC FUNCTIONS:

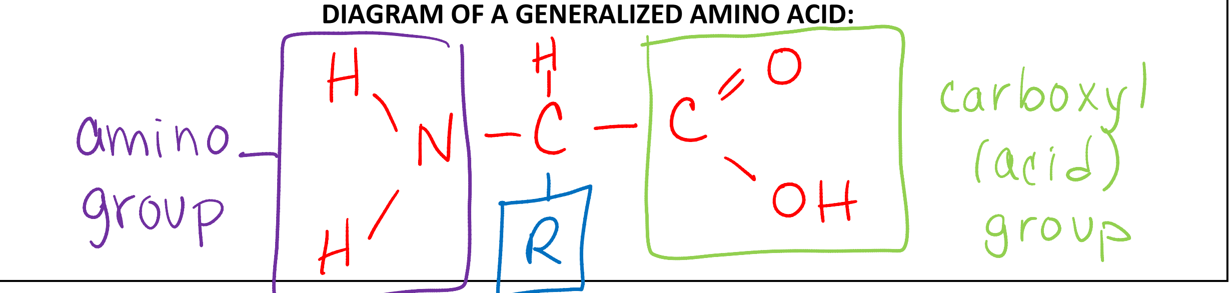
- Enzymes speed up chemical reactions
- Antibodies proteins that combine with foreign substances
- Transport Hemoglobin in the blood transports oxygen
- Hormones messengers that influence cellular metabolism

B. STRUCTURE OF PROTEINS:

i. **Protein macromolecules are polymers of monomers called** amino acids.

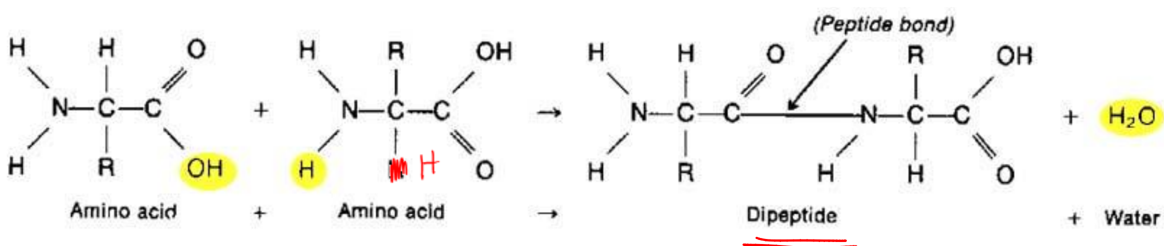
- There are 20 amino acids in the human body.
- Some of these our body can make (non-essential), others we cannot make (essential amino acids), which must be provided in our diet by our food.
- The name amino acid refers to the fact that the molecule has two functional groups:
  1. The amino group ($-NH_2$)
  2. The acidic (or carboxyl) group (-COOH)
- Amino acids differ from one another by their 'R' (Remainder group). Since there are 20 different amino acids, there are about 20 different types of R-groups. These have varying sizes, shapes, and atomic structures.

DIAGRAM OF A GENERALIZED AMINO ACID:



Amino acids can be linked by peptide bonds: cells link amino acids by dehydration synthesis.

- The amino group ($-NH_2$) of one amino acid reacts with the acid group (-COOH) of another amino acid, and a molecule of water is lost when a covalent bond is formed.
- The resulting covalent bond is called a peptide bond.



Note: a peptide bond is polar (the atoms involved share electrons in such a way that the oxygen carries a partial negative charge and the hydrogen carries a partial positive charge); as a result, hydrogen bonding occurs frequently in polypeptides.

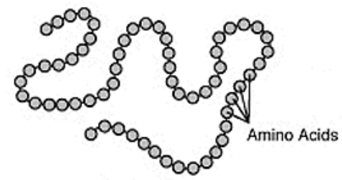
- The product of the reaction in the figure above is called a dipeptide, because it was made from two amino acids. Additional amino acids can be added by the same process to form a chain of amino acids called a polypeptide (3 or more a.a.'s)

- Polypeptides range in length from a few amino acids to a thousand or more. When one or more polypeptides combine and assume a unique three-dimensional shape, it is called a __protein__.

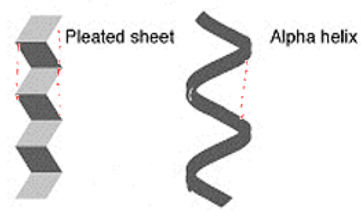
ii. **Levels of Protein Organization:**

The structure of most proteins is very complex, with numerous twists and folds of the various parts and numerous additional chemical bonds to stabilize the protein a particular three-dimensional shape. To make some sense out of protein structure, we divide it into four levels of organization.

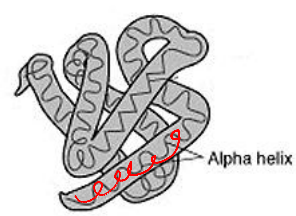
__PRIMARY__:
Is the linear sequence of the amino acids joined by peptide bonds (any number of the twenty amino acids joined in any sequence)



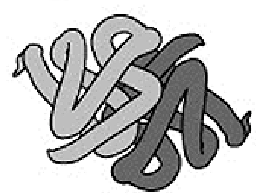
__SECONDARY__:
Polypeptide chain takes a particular orientation in space
Since peptide bonds are polar, H-bonding occurs between amino acids in the primary line → this causes the chain to coil up into a right-handed coil called an alpha helix or into layers called __β__-pleated sheets.



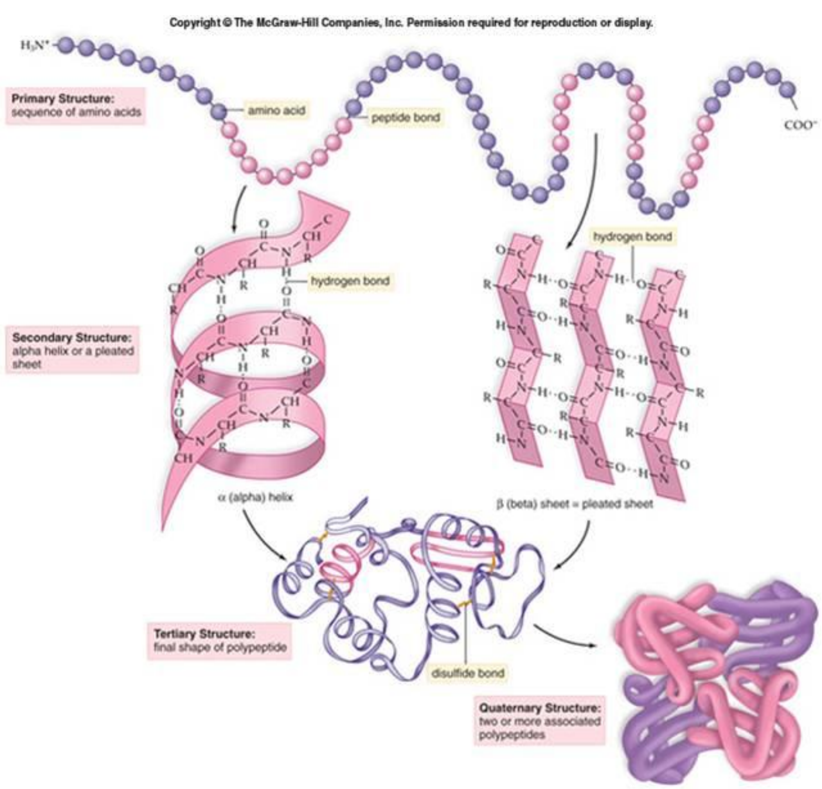
__TERTIARY__:
Different types of bonding (covalent, ionic, hydrogen) between –R groups makes the alpha helix bend and turn, forming an overall, three-dimensional shape. (amino acid chain folds upon itself – and the shape is stabilized and maintained by these bonds)



__QUARTERNARY__:
The binding of two or more polypeptide chains
Example: hemoglobin (carries oxygen in our blood): composed of __4__ polypeptide chains interlocked in a specific way.



SUMMARY :



C. PROTEIN DENATURING:

- The final shape of a protein is very important to its function
- Changes __in heat__ and __pH__ can disrupt the bonds that hold a protein together in its particular shape (protein unfolds as a result)
- When a protein loses its normal configuration it is said to be __denatured__ and can no longer perform its usual function (permanently inactivated).
- Examples of denaturation:
  - Heating an egg white (above 50 °C) will cause the egg protein to denature (goes from a clear liquid to a solid white)
  - Adding vinegar to milk (changing the pH) will cause the milk protein to curdle.

2. CARBOHYDRATES

A carbohydrate is a simple sugar or a molecule made up to two or more sugar units. Carbohydrates are important as fuel substances (energy) and structural molecules in cells.

A. FUNCTIONS OF CARBOHYDRATES:

i. Most carbohydrates are used as a short term __energy__ source.

- Monosaccharide sugars (glucose) are the primary energy source of the body (most carbohydrate polymers can be broken down into monosaccharides that either are, or can be, converted into glucose). In the process of __cellular respiration__ (in the mitochondria), this glucose is converted into ATP energy:

$$Glucose + O_2 \rightarrow ATP + H_2O + CO_2$$

ii. Storage of Energy:

- Starch Granules: used by plants as a concentrated form of stored energy (potatoes, wheat, corn, etc.). Starch is broken down into glucose by hydrolyzing the bonds between the glucose monomers.
- Glycogen: used by animals as a concentrated form of stored energy in the liver. When the blood glucose levels fall, liver cells hydrolyze glycogen and release glucose into the blood.

iii. Joined with other molecules, carbohydrates also play a __structural__ role.

- Cellulose: the most abundant organic compound on Earth; forms cablelike fibrils in the walls that enclose plant cells, providing strength and rigidity

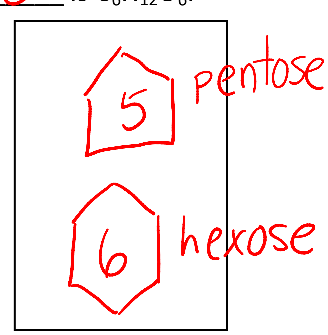
B. STRUCTURE OF CARBOHYDRATES:

Carbohydrates are organic compounds that are composed of __carbon__, hydrogen, and oxygen.

1. They contain hydrogen and oxygen in the same proportion as in __water__, (2 hydrogen: 1 oxygen). The major carbohydrates have a hydrogen ion (H+) and a hydroxide ion (OH-) linked to most of the carbon atoms. Like water, this gives carbohydrates a __polar__ property which makes them highly soluble in water.
2. The empirical formula for a carbohydrate is __$C_nH_{2n}O_n$__, where n can be almost any number. Example: if n = 6, the molecular formula for __hexose__ is $C_6H_{12}O_6$.

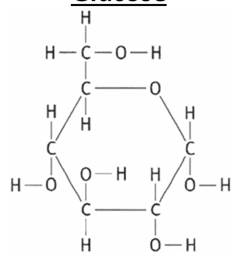
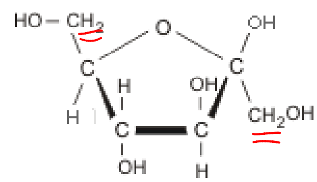
C. CLASSES OF CARBOHYDRATES:

"Saccharide" comes from the Greek word meaning sugar. There are three classes of carbohydrates: monosaccharides (single sugars); disaccharides (two sugars); and polysaccharides (linked chains of sugars). 3 or more



i. **Monosaccharides**

- Simple sugars consisting of one molecule unit; most are sweet tasting; dissolve readily in water; and are indicated by the ending __-ose__.
- Most monosaccharides are either 5 carbon sugars (__pentoses__) or 6 carbon sugars __hexoses__ arranged in a ring.
- Glucose, fructose, and galactose all have the same molecular formula (C6H12O6) but differ in the shape of the ring and in the arrangement of the hydrogen and hydroxyl groups attached to the ring. Compounds like these, in which the same atoms are arranged differently, are called __isomers__.

Glucose	**Fructose**
	

$C_6H_{12}O_6$

ii. **Disaccharides**

- Monosaccharides are the basic building blocks, or monomers, of more complex carbohydrates.
- Complex carbohydrates are made by a process of __dehydration synthesis__ in which two or more monosaccharides are combined to form larger molecules.
  - ➢ For example, two monosaccharides can bond together to form a __di__saccharide.
- When two monosaccharide monomers are joined together, the hydroxyl group (-OH) from one molecule combines with the hydrogen (-H) of the hydroxyl group of another molecule, removing a molecule of __H_2O__. Because of the loss of water, the joining of two sugars is an example of dehydration synthesis and the reverse is __hydrolysis__ (water is used to split a bond).

Example: dehydration synthesis and hydrolysis of a disaccharide: maltose

The new bond is between __-OH__ from one glucose molecule and __-H__ from the other glucose molecule.

glucose + glucose → Maltose (disaccharide)

Disaccharides:

Sucrose (table sugar) is made from: __glucose + fructose__

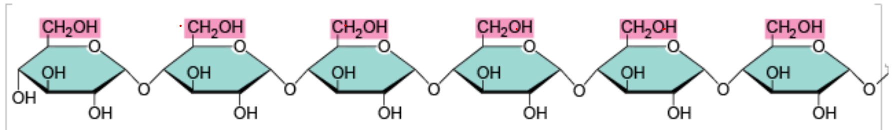
Lactose (milk sugar) is made from: __glucose + galactose__

Maltose is made from: __glucose + glucose__

iii. **Polysaccharides**

- A polysaccharide is a carbohydrate that contains a large number of monosaccharide molecules linked together by dehydration synthesis
- Polysaccharides are the form in which living things store excess sugar.

- Three polysaccharides are common in organisms: starch, glycogen, and cellulose: all of these are polymers, or chains, of glucose molecules.
  - ➢ STARCH: storage form of glucose in plants
    - A relatively straight chain of glucose molecules with a few side branches



  - ➢ GLYCOGEN: storage form of glucose in animals
    - A highly branched chain of glucose molecules
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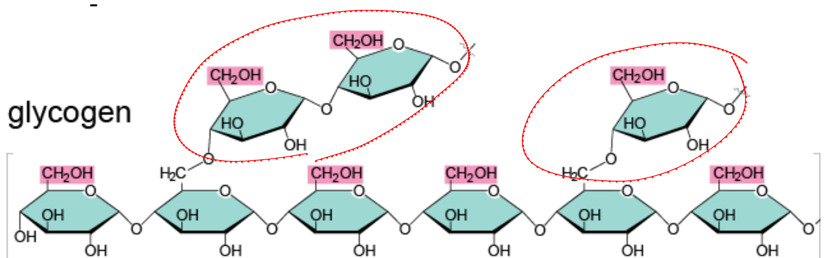
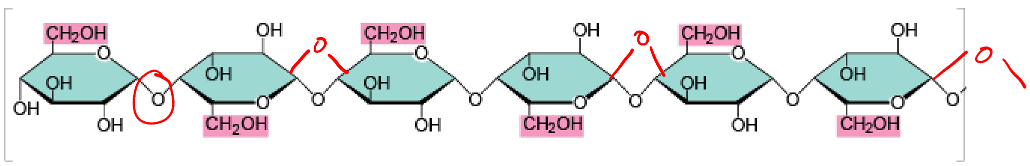


  - ➢ CELLULOSE: found in plant cell walls
    - A straight chain of glucose molecules with no branches



    - In cellulose, the glucose units are joined by a slightly different type of linkage than that of starch or glycogen. Animals are unable to digest foods containing this type of linkage (ie. Grass); therefore, cellulose largely passes through our digestive tract as fibre, or roughage. It is important to have fiber in our diet for good health, and it is believed that it may help prevent colon cancer. Horse, cows, goats, etc. can eat grass because their guts contain bacteria that can break this unique bond.

3. LIPIDS

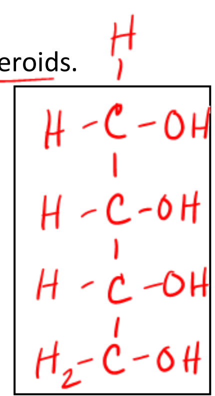
Lipids are among the simplest of the organic compounds. They are similar to carbohydrates in that they contain carbon, hydrogen, and oxygen atoms. However, the proportion of hydrogen to oxygen is much greater in lipids.

- ➢ Common names for lipids are fats and oils.
- ➢ At room temperature, fats are solids and oils are liquids.
- ➢ Lipids are non-polar molecules which are insoluble in water.
- ➢ The lipids can be divided into three subclasses: neutral fats, phospholipids, and steroids.

A. NEUTRAL FATS (TRIGLYCERIDES):

- Make up the majority of the lipids in the body, and it is these molecules which are generally referred to simply as "fats".

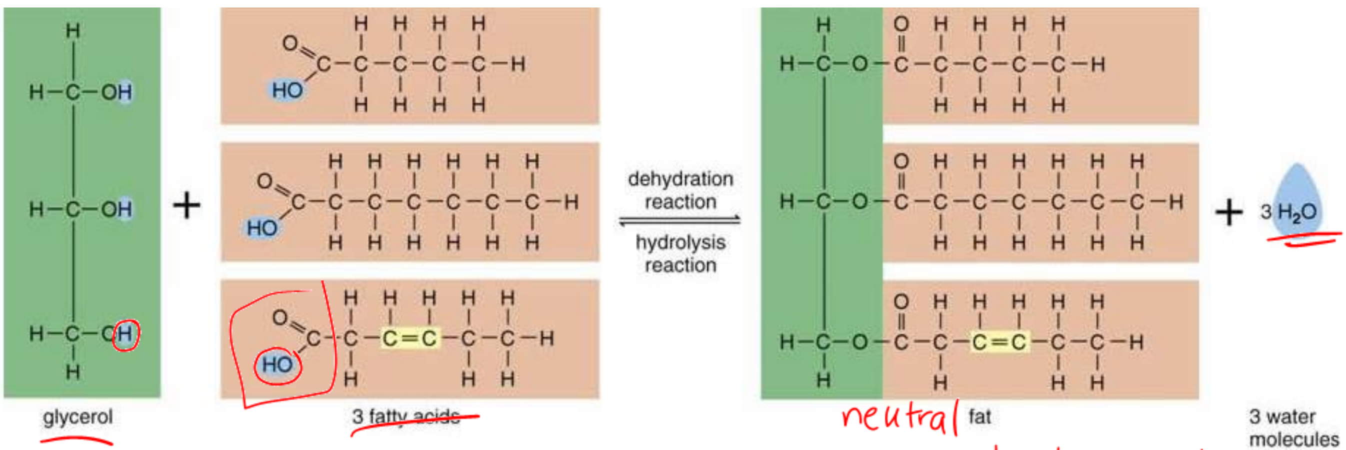
glycerol:



- The term neutral fat is used because the molecule is non-polar. (i.e. has no groups that can ionize or become charged)
- Neutral fats are formed by linking a __glycerol__ molecule to three __fatty acids (FA)__ molecules. (F.A.) (A fat is sometimes called a __triglyceride__ because of its three part structure).
  - Again, this is an example of dehydration synthesis as three water molecules result.

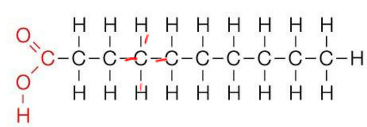
Dehydration synthesis and hydrolysis of a neutral fat:

triglyceride



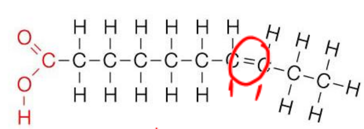
- A fatty acid has a long chain of carbon atoms with hydrogens attached (__hydrocarbon chain__) and ends in an acid (carboxyl) group (-COOH).
- Most of the fatty acids in cells contain __16-18__ carbon atoms per fatty acid molecule.
- **Fatty acids are either saturated or unsaturated:**
  - **Saturated:** fatty acids with __single__ __covalent__ bonds between the carbon atoms
    - the carbon chain is "saturated" with all the __hydrogen__ atoms that can be held.
    - Usually make up fats that come from animal sources, example: __lard, butter__
    - Usually __solid__ at room temperature
    - Known to contribute to heart disease and strokes by promoting a condition called __atherosclerosis__ - a disease in which fatty deposits in the walls of blood vessels interfere with blood flow.

Saturated F.A.



  - **Unsaturated:** there are __double__ __covalent__ bonds between carbon atoms and therefore fewer hydrogen atoms (not saturated with hydrogen atoms)
    - If there is one double bond = __monounsaturated__ fat
    - If more than one double bond = __polyunsaturated__ fat
    - Examples: __soybean oil, corn oil, fatty fish, some nuts, seeds__
    - Usually __liquid__ at room temperature- the double bonds cause kinks in the carbon chain of the fatty acids and prevent the fat molecules from packing tightly together and solidifying at room temperature
    - Thought to be healthier for your heart

Unsaturated F.A.



- trans fat is an example of "hydrogenated vegetable oil" meaning that an unsaturated fat have been converted to a saturated fat by adding hydrogen.

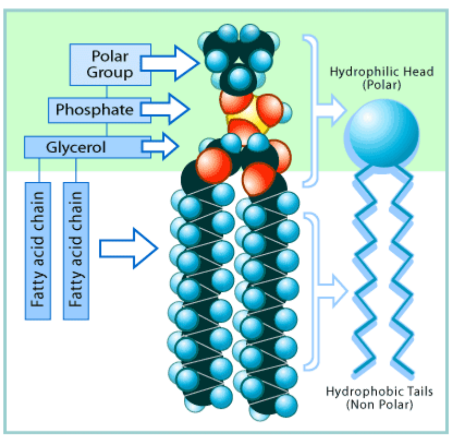
- **Function of neutral fats:**
  Fats have several functions in the body:

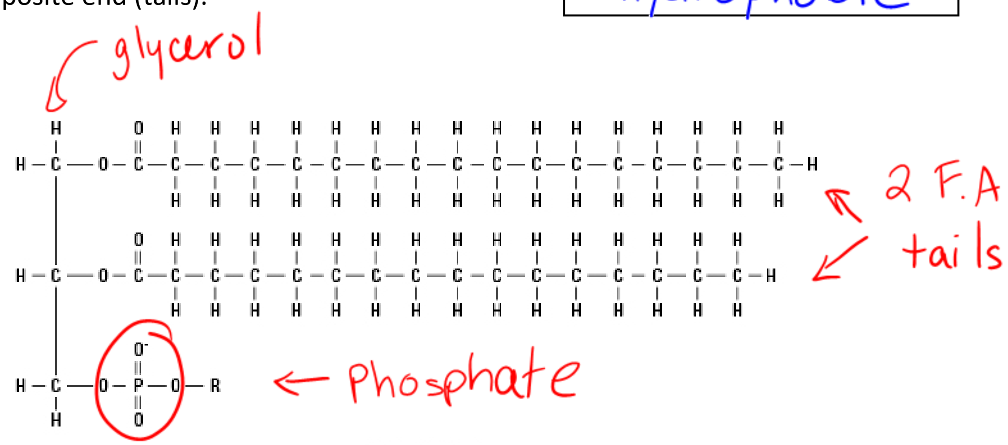
1. It is used for long term energy storage: a gram of fat can produce over twice as much energy as a gram of carbohydrate.
   - Stored energy becomes a secondary source of energy (carbohydrates are a primary source)
2. It insulates against heat loss.
3. It forms a protective cushion or padding around major organs. Fat absorbs shocks Organs prone to bumps and shock (i.e. kidneys) are cushioned with a thick layer of fat.

B. PHOSPHOLIPIDS:

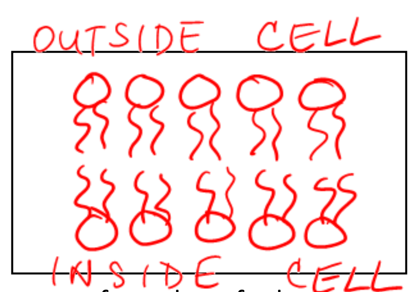
on test

- Phospholipids are important components of the cell membrane in the form of a lipid bilayer.
- Phospholipids are similar in overall structure to neutral fats with one important difference: one fatty acid is replaced by a phosphate group with a charged nitrogen attached. This forms a polar (charged) region at one end of the phospholipid molecule, and the fatty acid chains provide a non-polar (uncharged region at the opposite end (tails).





A Phospholipid

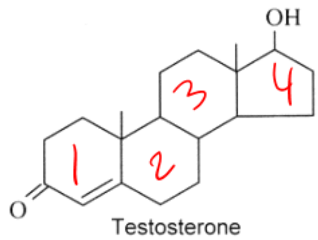


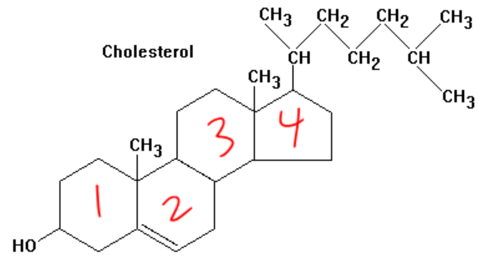
- The cell membrane is a phospholipid bilayer in which the polar "heads" face outwards (attracted to water or hydrophilic) and the tails face each other because they are water repelling (hydrophobic).

C. STEROIDS:

- Although steroids are classified as lipids, they have a distinctly different structure from that of other lipids
  - 4 interconnected rings of carbon form the basic skeleton of all steroids
- One of the most common steroids is Cholesterol: it is an important part of the cell membrane and is used as a starting material for making other steroids. However, excessive cholesterol in the diet is a risk factor in heart disease. It is found in animal products (meat, dairy) but not in plant foods.
- Examples and functions of steroid hormones:

- Estrogen and testosterone: sex hormones – regulate female and male sexual characteristics
- Aldosterone: helps regulate the sodium level of blood





4. NUCLEIC ACIDS

A. FUNCTION:

1. Important for structure + function and hereditary information of cells and organisms.
2. The nucleic acid polymer: DNA = deoxyribonucleic acid makes up human genes and chromosomes.
3. The nucleic acid polymer: RNA = ribonucleic acid works in conjunction with DNA to direct protein synthesis.

B. STRUCTURE:

DNA and RNA are polymers of nucleotides. These monomers form nucleic acids by dehydration synthesis: nucleotide + nucleotide → nucleic acid + H_2O

A nucleotide is composed of three molecules: a phosphate group, a sugar (pentose), and a nitrogenous base unit.

There are four types of nucleotides: adenine, cytosine, guanine, and thymine. DNA consists of two strands of nucleic acids. Each strand has a backbone made up of the alternating sequence of sugar and phosphate. The nitrogenous bases stick out to the side and hydrogen bond with the complementary bases to hold the two strands of DNA together. Sections of DNA are called genes. A gene is the recipe that gives the instruction for making one polypeptide and is about 1000 nucleotides in length, approximately. RNA is a single strand of nucleic acid that is formed from a DNA template in the nucleus. It migrates to the cytoplasm during protein synthesis. *More on this to come!*

C. ATP:

ATP stands for adenosine triphosphate.

It is a nucleotide that has the function of being the primary carrier of energy in cells. ATP consists of the sugar ribose, the base adenine, and three phosphate groups. The bond between the outer two phosphates is very high in energy. When the bond is broken, much energy is released which can be used by the cell. ATP is formed inside the mitochondria during the process of cellular Respiration.