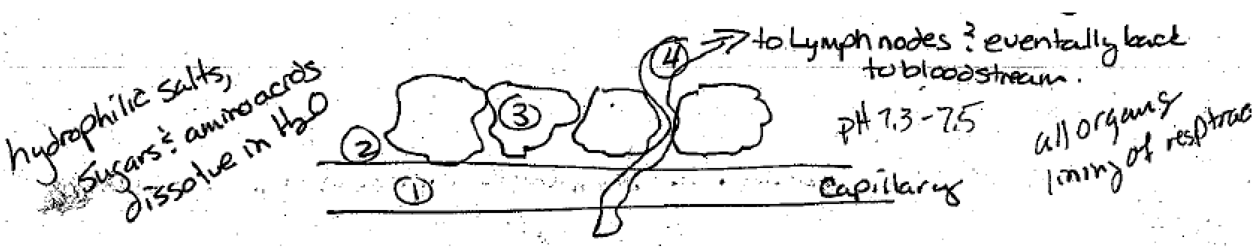
Biochemistry Notes

What is meant by the term **biochemistry?** __**study of compounds and chemical reactions of living organisms.** ____

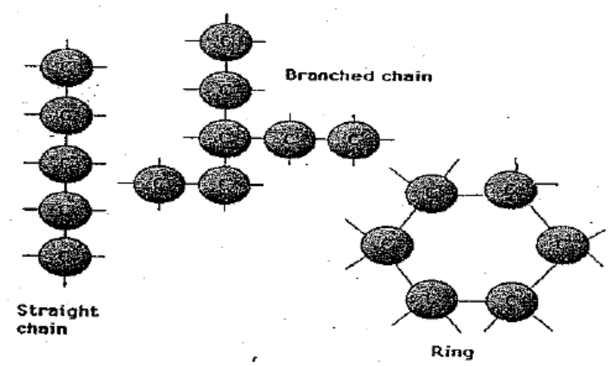
You will recall that organisms are made up of 70% water, and that water is an important solvent in living things. Even though water is found abundantly in organisms, it is an **inorganic** compound, meaning that it does not contain carbon. Review where you find water in organisms. ___1) blood, 2) ICF (intercellular fluid) or tissue fluid, 3) cytosol w/in cytoplasm, 4) lymph fluids ____



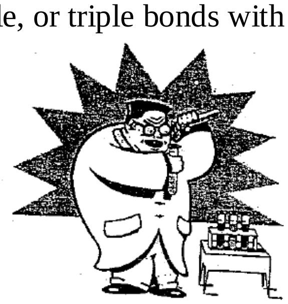
Besides for the 70% water, organisms are mostly made up of ^simple and complex **organic** compounds that contain both carbon and hydrogen. The reason organic compounds are often large and complex molecules has to do with the properties of the carbon atom. Can you explain this?

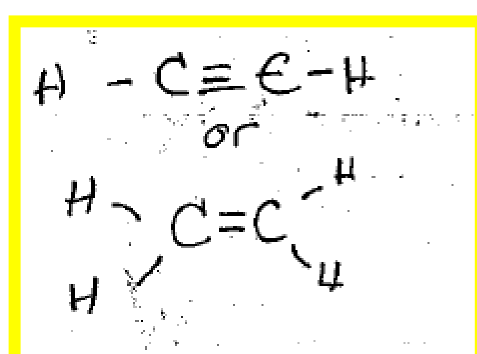
_carbon must form 4 bonds to become stable – because its electron configuration has 4 e- and 4 vacancies in the valence level. It can therefore bond in a variety of 3D configurations with many different elements. (*recall HONC 1234)

Carbon atoms can join to form **long chains, branched chains,** or **ring structures.**
Examples:



Carbon can also form single, double, or triple bonds with other atoms.





IMPORTANT BIOLOGICAL ORGANIC COMPOUNDS

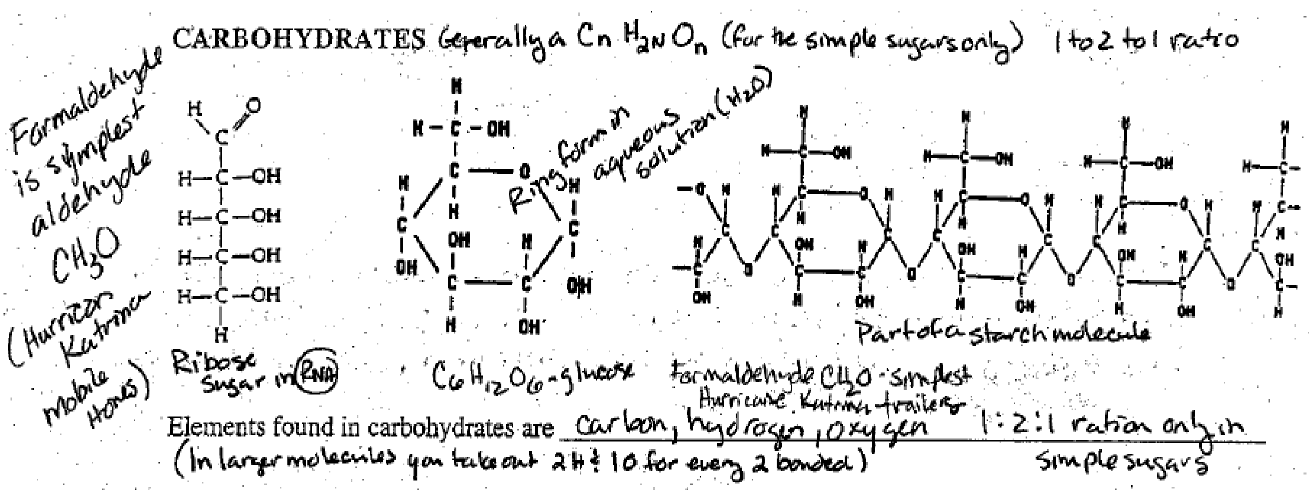
The 4 most important types of organic compounds found in living systems are:

1.____carbohydrates____
2.__ _lipids_____
3.____proteins__
4._____nucleic acids___

nutrients - needed for normal body functioning. can provide energy

These organic compounds, along with other important substances that are needed by the body, are called **nutrients.** Can you name some other nutrients in addition to these four?
____H_2O, vitamins, minerals such as Na+/Cl- (needed for ion balance), Mg2+ (impt for enzymes), K+ (impt in blood clotting), Zn (insulin component), Fe (hemoglobin component), trace elements

Cells are three-dimensional structures that are made up of different chemical compounds arranged in various ways. When you look at a structural formula of a chemical compound, it looks two-dimensional, but in reality there is a three dimensional structure, similar to the structures you put together in lab. It makes sense that molecules are three-dimensional if the cells they make up are three-dimensional.



FUNCTIONS OF CARBOHYDRATES

1.___Energy Storage molecules___________________________________
2.___Structural components of: plant cell walls, fungi cell walls, exoskeleton of insects, other organic molecules such as lipids, proteins, other carbs, nucleic acids__________

Where is the energy stored in the carbohydrate?__in the bonds between atoms (potential chemical energy)

Kinds of carbohydrates:

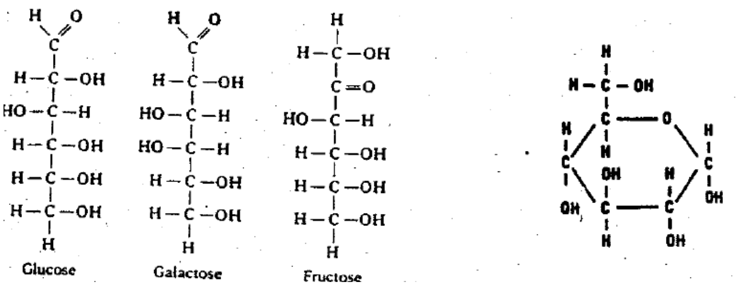
1.__monosaccharides ($C_nH_{2n}O_n$) – simple sugar – one unit of a carbohydrate) (monomer) 
2.___ disaccharides – two simple sugars bonded together (two units = dimer) 
3.__polysaccharides – complex sugars (many monomers joined. 

Examples of monosaccharides:

1.___glucose_______________________________2.________fructose_____________________

3.___galactose_____________________________

*sweet in taste, polar covalent bonds allow these to dissolve easily in H2O



Glucose Galactose Fructose

Take a look at glucose molecule. Its chemical formula is $C_6H_{12}O_6$. Now look at fructose. What is its chemical formula? ________same – C6H12O6____________________________

Glucose and fructose are isomers:

Isomers: ____molecules with the same chemical formulas, but with different structural formulas. Form leads to function – each will differ in its function.

Notice that galactose is an isomer of glucose and fructose. Because these three monosaccharides all have different structures, they will have slightly different functions in the cell.

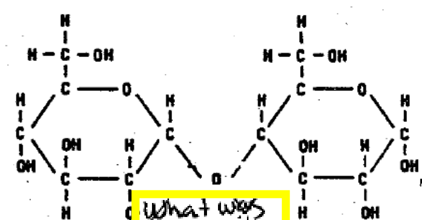
Examples of disaccharides: (*note these three are also isomers C12H22O11)

1._____sucrose_(table sugar) = 1 glucose + 1 fructose________________________

2.___lactose (milk sugar) = 1 glucose + 1 galactose________________________________

3._____maltose (in plant seeds) = 1 glucose + 1 glucose

*small, sweet, still able to dissolve in H2O.



What was removed? One H_2O

Examples of **polysaccharides:**

1.__starch – energy storage molecule in plants (stores glucose)

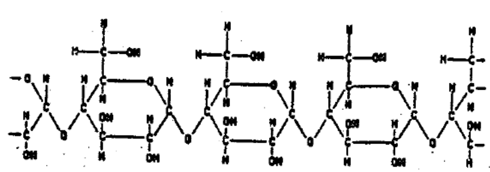
2.___glycogen – energy storage molecule in animals (humans) (stores glucose)

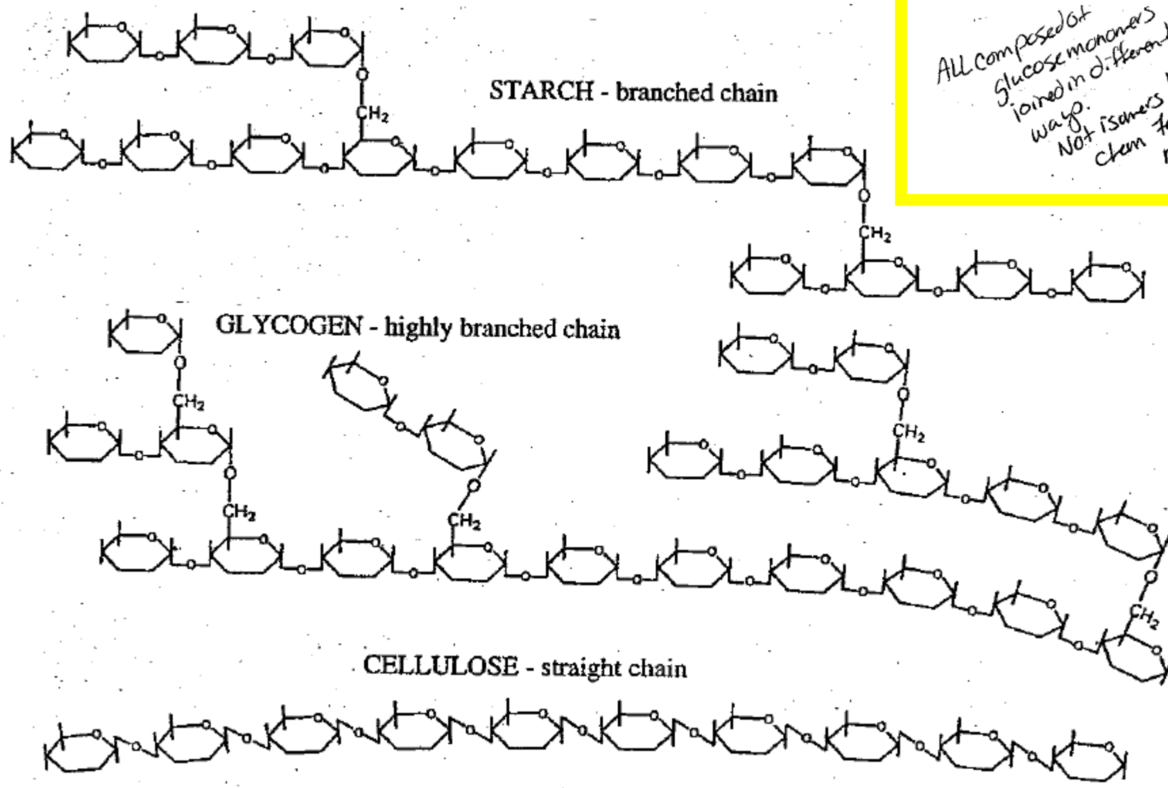
3.___cellulose – "fiber" – makes up plant cell walls.

***4. Add: Others – like chitin in insect exoskeletons & fungi cell walls.**

***Not sweet – too big to dissolve in H2O.**

***Note, all three of these are composed of glucose monomers.**





ALL composed of glucose monomers joined in different ways. Not isomers because chem formula not the same

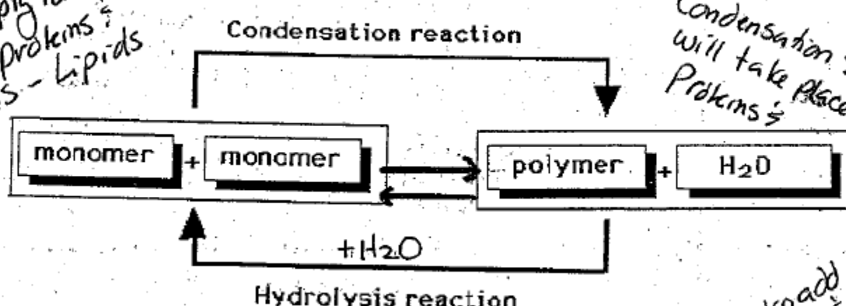
Although starch, glycogen, and cellulose are made of glucose, they have *different functions* because the glucose is arranged differently in each molecule, giving each molecule a *different overall structure.*

Monomer- __a single unit of an organic compound. Can function on its own or be joined with other similar monomers to form polymers.

Polymer- many monomers bonded together. Large molecules with many different functions (ex, starch, cellulose, glycogen)

NOTE: The terms **monomer** and **polymer** are general terms used to also describe other compounds, as well as carbohydrates. (*Note: Dimer = 2 monomers bonded such as sucrose)

monomers will apply to carbohydrates, proteins & nucleic acids - Lipids will be a special case.

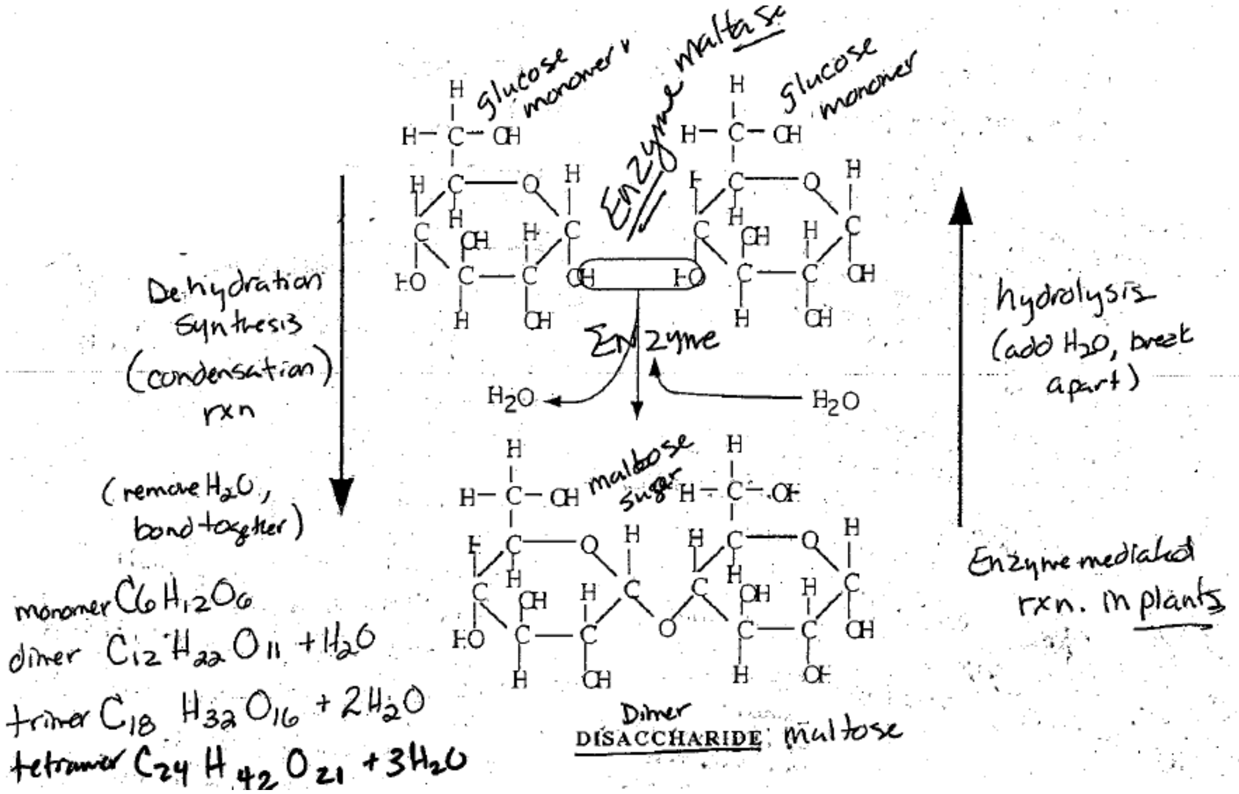


Condensation & Hydrolysis rxn will take place in Carbs, Lipids, Proteins & nucleic Acids.

2 monomers → dimer + 1 H_2O
3 monomers → trimer + 2 H_2O
4 monomers → polymer + 3 H_2O
5 monomers → polymer + 4 H_2O
n monomers → polymer + n-1 H_2O

Can also add dimers & trimers to make polymers.

n



Dehydration synthesis __process of joining monomers chemically by removing water. Smaller molecules are joined to form larger molecules. Monomer→polymer.__
Example: ___glucose (C6H12O6) + glucose (C6H12O6) → maltose (C12H22O11) + H2O__

Hydrolysis___process of separating monomers chemically by adding water. Large units are broken down into smaller ones. Polymers→ monomers.
Example:_H2O + maltose → 2 glucose OR H2O + sucrose → glucose + fructose

***These two reactions are not specific for carbohydrates; they are involved in producing and breaking down fats, proteins, and other organic compounds.**

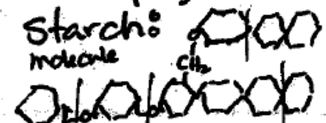
Remember, we cannot produce our own carbohydrates. Only autotrophs can do this, in the process of photosynthesis. We obtain our carbohydrates in our diet.
What are some good sources of carbohydrates in the diet? __pasta, veggies, fruit, potatoes, dairy, wheat, grain, corn, rice, cereals. Sweet→starchy. Simple vs. complex carbs.

Processing and Utilization of Carbohydrates in Our Bodies

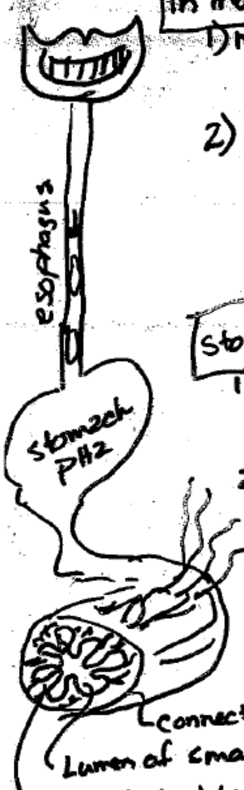
Eat a Bagel

Consume a polysaccharide

Starch:



In mouth:



1) mechanical digestion
mastication food separates molecules

2) salivary amylase enzyme in saliva
speeds hydrolysis of starch
breaks down into smaller polys
smaller bits
smaller polysaccharides

Stomach:

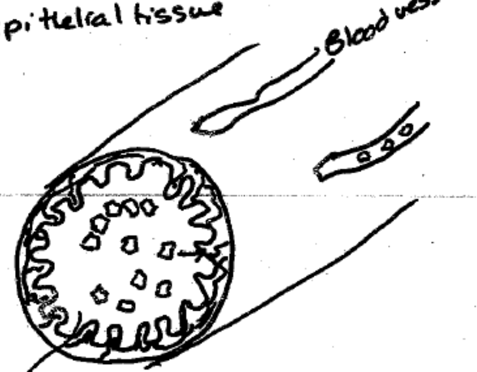
1) more mechanical digestion separates 4SA for enzaction

2) chemical brkdwn of proteins only
smaller bits
smaller polys

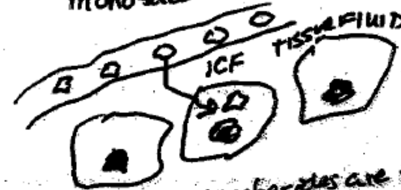
Small intestine:

1) more chemical + mechanical digestion (hydrolysis)

2) pancreatic amylase + enzymes from lining of the intestine hydrolyze polysaccharides into monosaccharides



monosaccharides in blood are sent:



monosaccharides are transported to all cells of the body.

What does the cell do w/ glucose:

1) used as reactant in cell resp to help form ATP.

2) used to synthesize glycogen
Requires enzymes to help speed dehydration synthesis
In the process water mol. will be produced. Glycogen is a short-term energy storage molecule.

3) Use to build cells: build molecules like DNA, RNA, Amino acids etc. vitamins

4) Can convert to fat which is stored in fat cells in the adipose tissue.

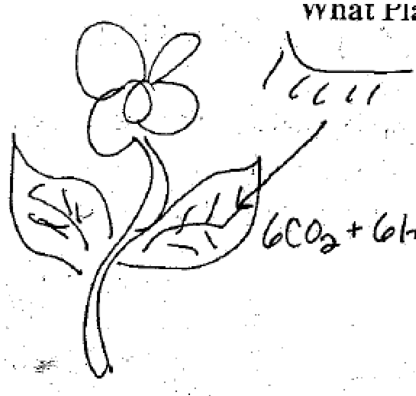
What happens if your blood sugar drops?

1) Hydrolyze glycogen to glucose by adding water & using an enzyme.

2) Hydrolyze fats & proteins to obtain molecules which can be used as energy.

What Plants do with the Glucose They Produce

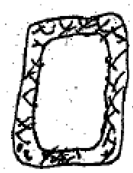
What Plants Do with the Glucose They Produce



$6CO_2 + 6H_2O \rightarrow \underbrace{C_6H_{12}O_6} + 6O_2$

1) Can use as reactants in cellresp to form ATP. Cellwork or to build new plant parts ½ of glucose → cellresp ½ buildcells

2) Convert glucose → cellulose to form plant cell walls provide structure & protection.



cellulose fibers

glucose monomers

Humans & mammals (including herbivores) cannot break down or hydrolyze cellulose. We lack the enzyme needed.

Some Bacteria do have the enzyme - in termite guts & cow innards.

Cellulose = Fiber - Lettuce, Celery, Grains
Irritates & cleans the bowel - used as lax.

3) Store as starch in leaves or in tubers & roots.
Can break down starch when needed
Starch $+ H_2O \rightarrow$ glucose

4) ~~Convert to proteins, aminoacids, nucleicacids, chlorophyll~~ (enzymes that speed rxns)
a) Proteins
b) lipids
c) othercarbs

lipids (oils & waxes), Vitamins etc. carbs like fructose ribose and deoxyribose - DNA RNA

LIPIDS

Kinds of lipids:

1.___fats___________________________

_______triglyerides._______________________

2.___oils___________________________

3.___waxes___________________________

4.___steroids – cholesterol, testosterone, estrogen ___

5. phospholipids – in cell membrane

What elements are found in lipids? ___carbon, hydrogen, oxygen (not 1:2:1 – much less oxygen)

What do all lipids have in common? __ hydrophobic_(don't dissolve in h20

Function of lipids:

1.__energy storage – gram for gram 2x as much energy compared to carbs – not quickly broken down____

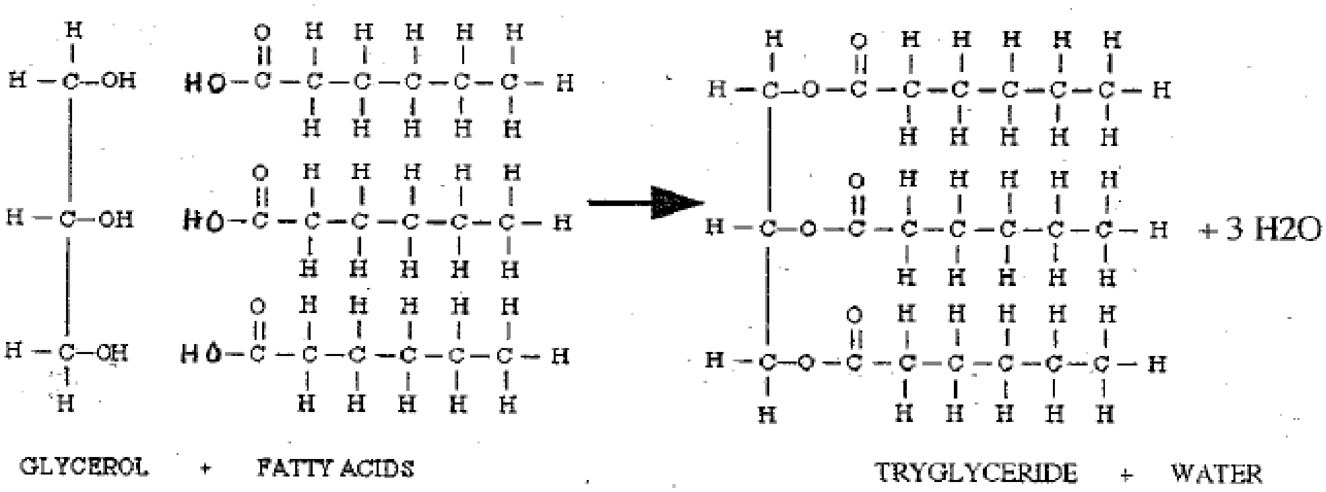
2.__insulation & protection of internal organs (adipose = fat tissue)_______________________

3.__structural components of cell membranes – phospholipids _______________________

A **triglyceride** is a large molecule made up of two types of smaller molecules:

1.___glycerol (alcohol - hydrophilic___ 2.__fatty acid (hydrophobic & carb group)

Note: a triglyceride is not considered a polymer, because it is made of different types of molecules, and they are not long chains of repeating, similar units.



All fatty acids contain two chemical groups:

1.___carboxyl group –COOH (hydrophilic) 2._hydrocarbon tail (hydrophobic) ________

What is the process involved when the glycerol is bonded to the fatty acid?

____dehydration synthesis (condensation reaction – remove water, join subunits)

Which process in is involved in the breakdown of a triglyceride into glycerol and fatty acids?

____hydrolysis (add H2O, break apart into subunits) ________________________________

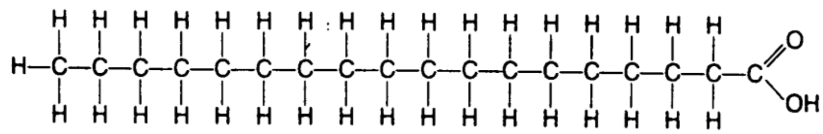
Saturated and Unsaturated Fat

Characteristics of Saturated Fats: (Called "FATS")

1.___triglyceride that contains units of fatty acids that have no C to C double bonds. Hydrocarbon tail is "saturated" with H's.

Stearic acid
(saturated)

$C_{18}H_{36}O_2$



2.___triglyceride that tends to be solid at room temperature__

3.___triglyceride that tends to be found in animal products__

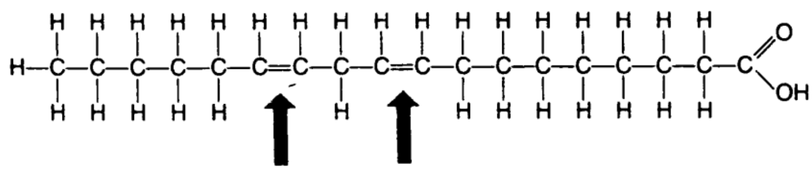
Examples of saturated fats:___butter, animal fat, lard, dairy products, coconut oil.

Characteristics of Unsaturated Fats: (Called "OILS")

1.___Triglycerides that contain units of fatty acids that have one ore more C to C double bonds.

Linoleic acid
(polyunsaturated)

$C_{18}H_{32}O_2$



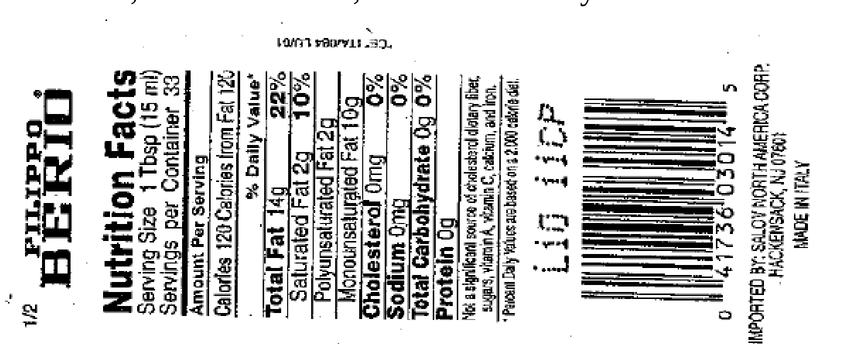
2.__Triglyceride that tends to be liquid at room temperature_
3.____triglyceritde that tends to be found in plant oil products_
Examples of unsaturated fats:___olive oil, corn oil, peanut oil, fish oil, canola oil

Unsaturated fatty acids can be **mono**unsaturated, or **poly**unsaturated.
___mono = 1 C to C double bond; Poly = more than one.

What makes a saturated fat solid at room temp and an unsaturated fat liquid at room temp?
___ the double bonds in the unsaturated FA's make the molecules not "fit" together (they have a slightly "bent" shape) as nicely (saturated are more linear) into a solid repeating structure. Different melting points.

*Health importance – monounsaturated is best

NOTE: When a fat is unsaturated, such as olive oil, it contains mostly unsaturated fats but it will contain some saturated fats.



Phospholipids

Function of phospholipids _important structure of cell membrane____________________

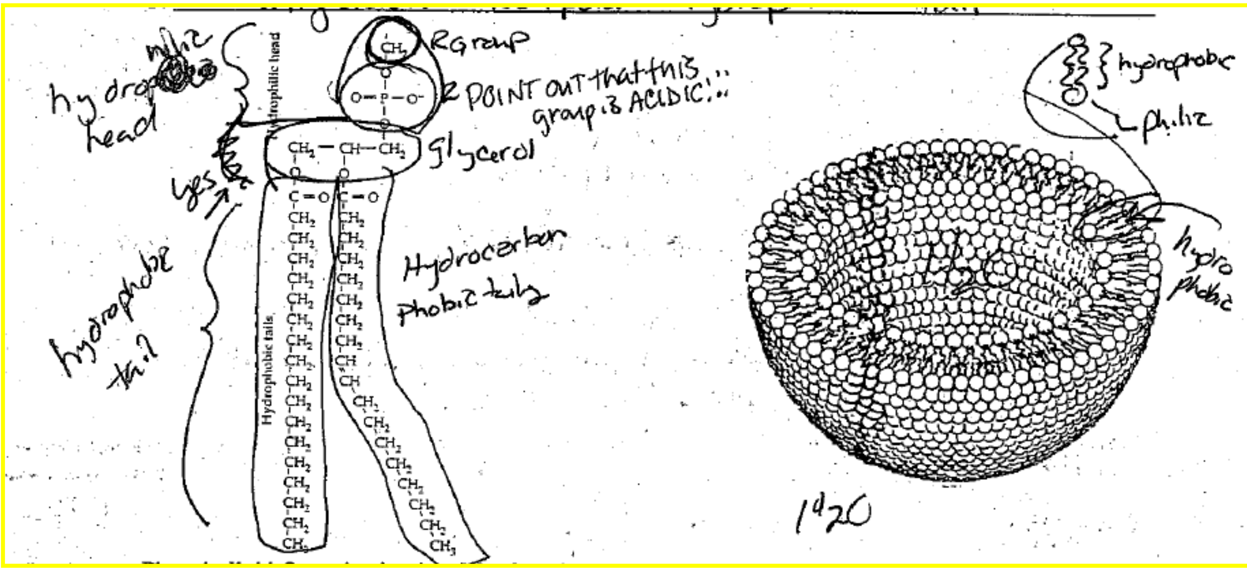
All phospholipids contain:

1.____glycerol__________________________

_________hydrophilic "head"_______________

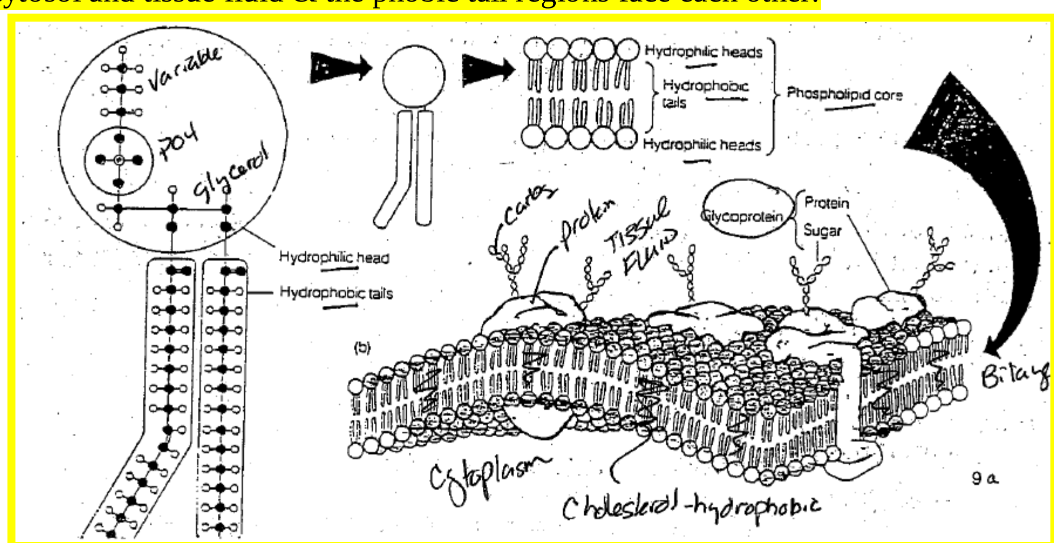
2.____phosphate group + R group__________________________

3.____2 fatty acids – nonpolar & hydrophobic ("tail)

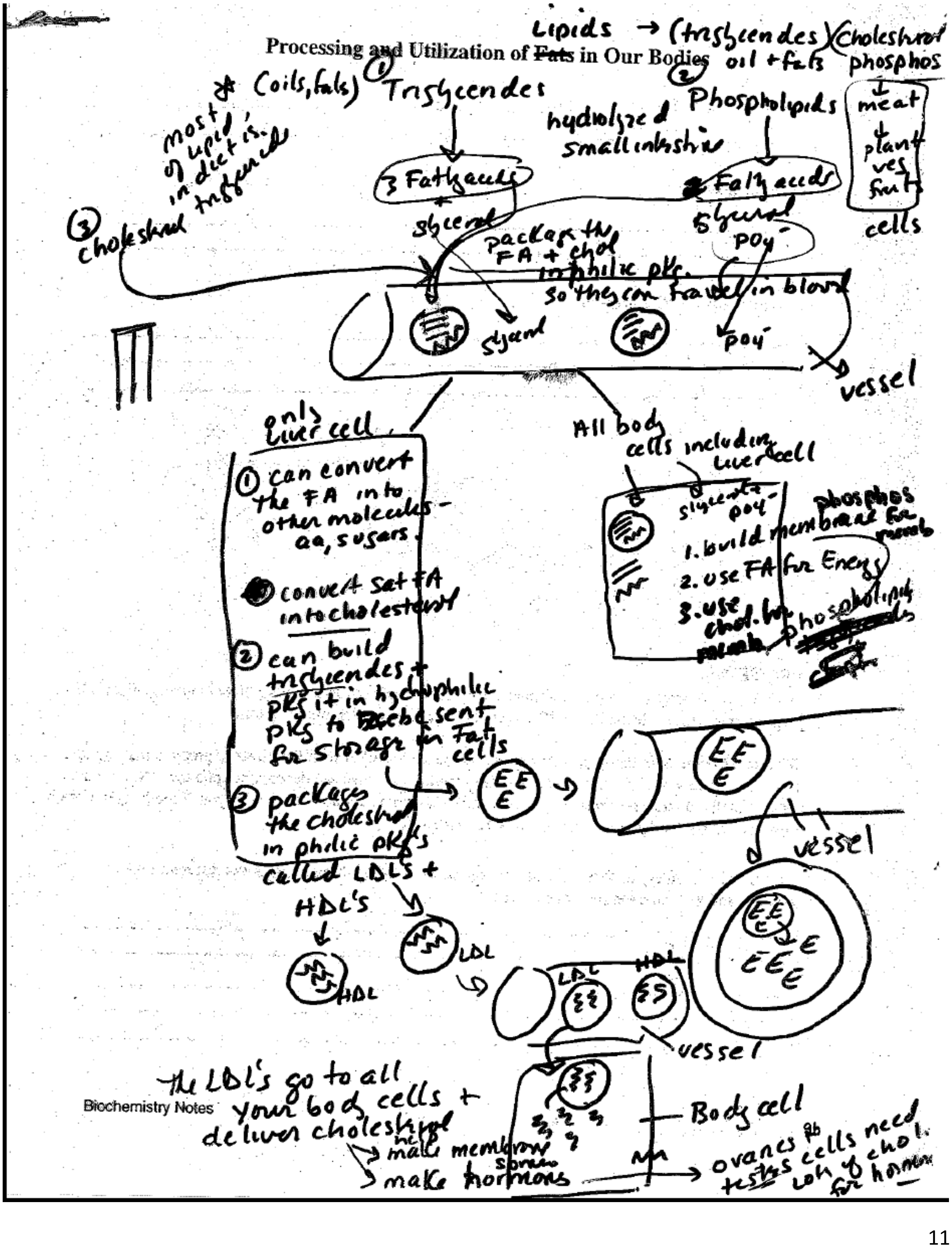


Phospholipid Organization in a Membrane

__Phospholipids form a lipid bilayer where the hydrophilic head regions interact with the water in the cytosol and tissue fluid & the phobic tail regions face each other.



Processing and Utilization of Lipids in Our Bodies

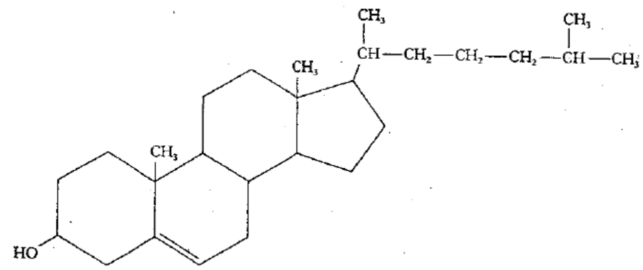


Steroids
Structural characteristics of steroids___4 interlocking carbon rings and other chemical groups (variable groups_

Types of steroids
1.___cholesterol______________________________vitamin D – aids in calcium uptake ____
2.___sex hormones________
3.___cortisone_______

Characteristics of **Cholesterol**
1.__found in animal cell membranes (not plants) _
2.___important in synthesis of steroid hormones, testosterone, estrogen__
3.___in excess, can cause plaque formation in blood vessels and contribute to atherosclerosis and strokes. _

*Note, dietary cholesterol isn't main source of body cholesterol. Liver makes it from saturated FA's → that is why they are so bad for you!



PROTEINS
Proteins are some of the largest and most complex biological compounds. Most of an organism (70%) is made up of water. Most of the 30% that is remaining is made up of protein.

What makes you different from other organisms has a lot to do with the kinds of proteins making up your body. You will find out later on that the proteins you have are dependent upon the DNA in your cells. You have more proteins in common with your parents than you do with your friends, and more in common with your friends than you do with your pets.

There are thousands of different kinds of proteins in the human body, and there are billions of total proteins in every cell of your body. Proteins take on many different forms and functions in your body and in all living things. List some different types of proteins, and give an example of each type:
1.___cell membrane proteins (receptor, transport, channel)_protective antibodies_
2.____structural proteins______________________enzymes_____
3.____contractile proteins_____
4.____storage___
5.____transport

THE STRUCTURE OF PROTEINS

The elements found in protein are: __CHON___________________________________

All proteins are made up of smaller molecules called ___amino acids _______________

Therefore, proteins are considered to be polymers, and the amino acids are the monomers.

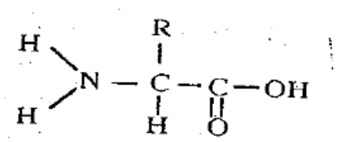
There are three chemical groups in all amino acids; what are they?

1.____amino group – NH2

2.____carboxyl group -COOH___

3.____R group – variable group off central carbon – hydrogen

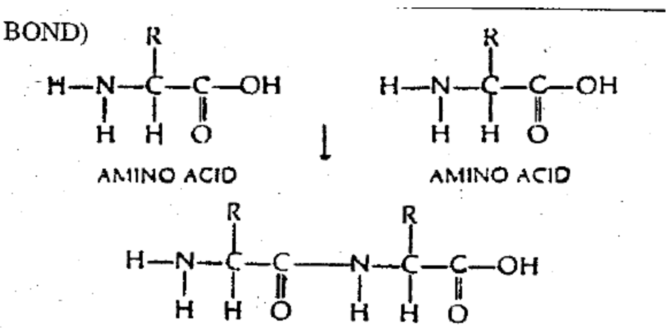
Circle these 3 groups in the diagram:



Two amino acids bonded together form a __dipeptide____

The bond that forms between them is called a _peptide bond (covalent bond betw carboxyl group of one AA and amino group of next____

(CIRCLE THIS BOND)



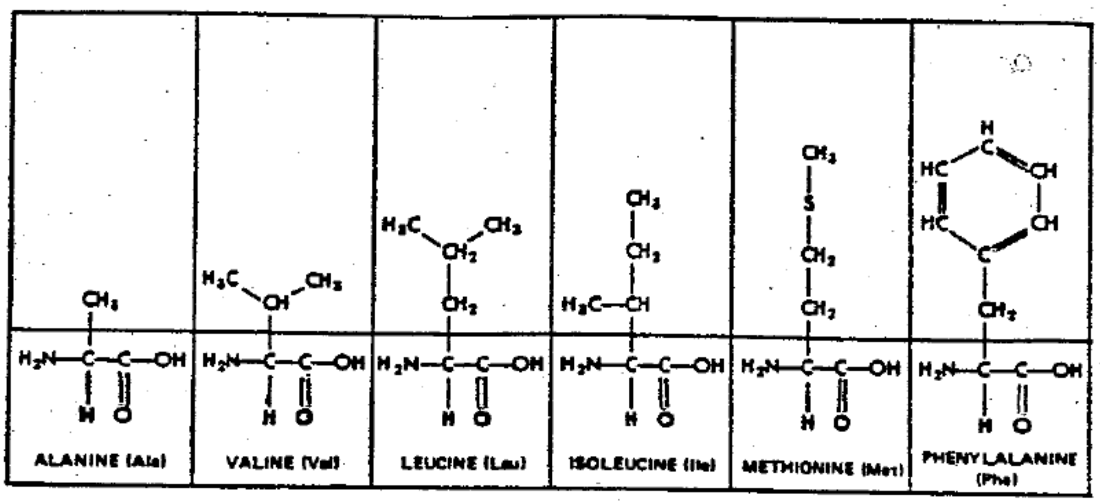
When amino acids bond together to form a dipeptide or polypeptide, the process is called ___dehydration synthesis _____________. If you break a peptide down into its separate amino acids, the process is called ____hydrolysis___

How many **different kinds** of amino acids occur in living things?_____~20___________

Of these acids, there are 8 that are considered **essential amino acids.** What does this mean? ____your body cannot synthesize the 8 essential aa's . they can synthesize all others from (17) other compounds like glucose and fats – the 8 essential must be consumed via foods. (TVTILLPM)_

Complete Protein contains all the amino acids which you can't synthesize on your own (there's 8 or so your body can't make and therefore HAS to take in from food)

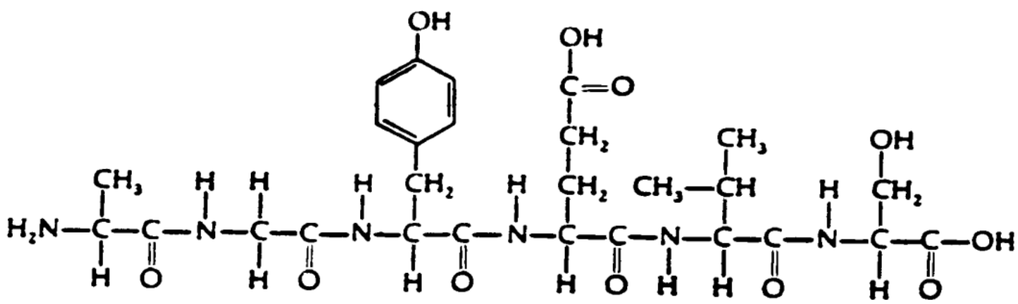
Examples of amino acids



What do all amino acids have in common? ___amino, carboxyl, central C-H___

How do the amino acids differ from one another? __R group (variable group) __________

Many amino acids bonded together is called a ____polypeptide or protein (polymer)



How many *amino acids* are in this polypeptide? _6_______

How many *peptide bonds* are present? ___5______

How many *water molecules* were *removed* to from this polypeptide? ___5______

Like the 26 letters of the alphabet which, when arranged in different ways can form many different words, the 20 amino acids, when arranged in different ways and in different numbers, can form many different types of proteins.

What differs from one protein to another? (below is hw)

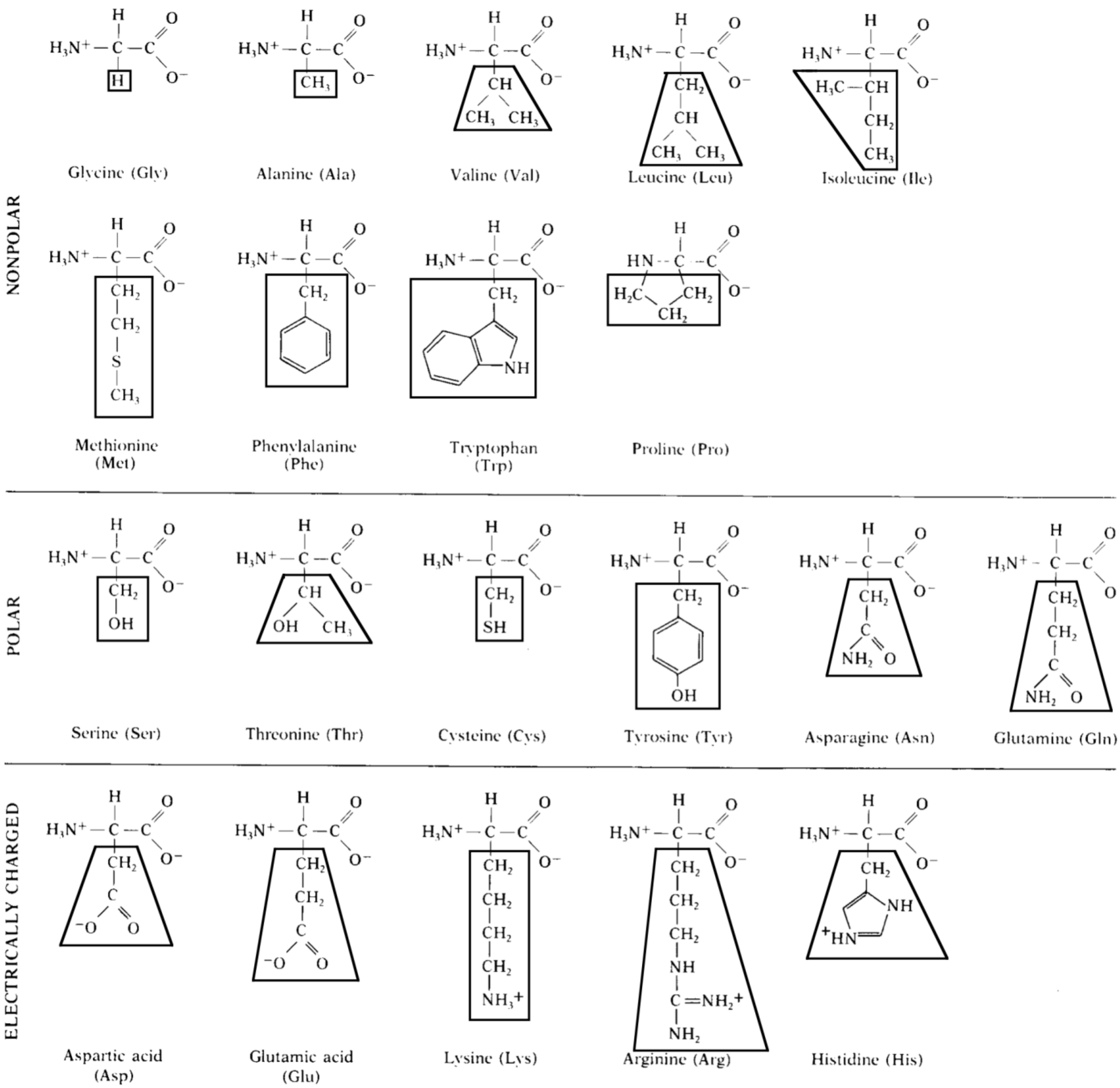
1.___# amino acids (length of chain__

2.___types of amino acids (20 types)___

3.___sequence of amino acids__

4. # of polypeptides used to form final protein (some composed of 2 or 3 poly's)

A closer look at the 20 amino acids



Amino acids can be grouped according to the chemical properties of their variable groups.

1. ____nonpolar (hydrophobic)
2. ____polar (hydrophilic)
3. __electrically charged: - (acidic)
4. __electrically charged: + (basic)

The Three-Dimensional Structure of Proteins

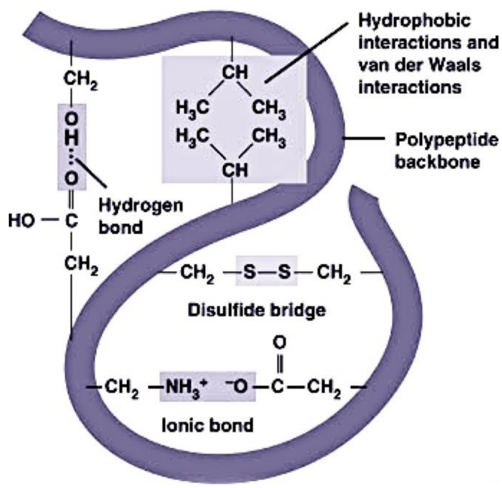
Proteins, like all organic molecules, have a three-dimensional structure. After the amino acids are bound by peptide bonds, they interact with each other, causing the molecule to fold up into a three-dimensional shape. Furthermore, a protein can be made up of one or several polypeptides. Take a look at the protein *hemoglobin*. It is made up of 4 polypeptide chains.

Primary structure __single, straight chain of amino acids (straight chain polypeptide)

Secondary structure ___chain folds into helix (coil) due to hydrogen bonding between R groups.

Tertiary structure ____folding of helix into 3-d globular structure due to R group interactions.

Quaternary structure ___only occurs when >1 polypeptide joins to form protein

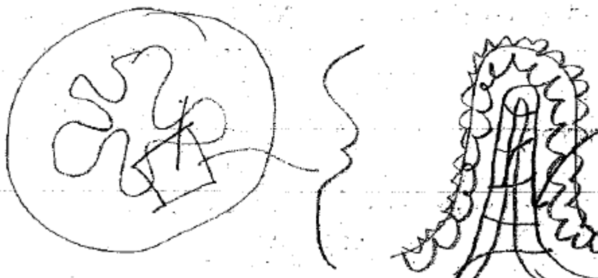


If just one amino acid is changed in a protein, this will usually result in a change in the protein's structure. If the structure is changed, what else may be changed? __function!_______________
An example of this occurs in the protein hemoglobin, where one change in the amino acid sequence in the entire protein results in a disease called **sickle-cell anemia.**

Part of Regular hemoglobin:	Part of Sickle-cell hemoglobin:
__leu – thr – pro – glu – glu - lys	____leu – thr – pro – val – gly – lys

The function of hemoglobin is to bind to oxygen and carry it throughout the body. Each red blood cell contains millions of molecules of hemoglobin. If all of the hemoglobin molecules have an altered shape, and there are millions in each RBC, than the entire structure of the RBC tends to change into a "sickle" shape. This shape does not allow for easy movement through capillaries, so organs of the body are often deprived of oxygen.

Processing and Utilization of Proteins in Our Bodies



steak
beans
nuts
cereal

→ to liver Δ

Hydrolysis in Stomach + Small int to aa's

Liver

→ Excess aa's → converted to urea & disposed of in kidneys
d+ aa's

→ 1) Some used as energy molecules in cellular respiration to form ATP.

→ 2) Converted to other special proteins like albumen & hemoglobin used in liver

2) convert to other nutrients (glucose etc)

3) Carried to body cells via vessels

a) used in protein synthesis in cells to form various proteins.

b) used as energy and in cell resp.

Many functions!

c 4) when proteins are old, broken down & aa's go back to Liver to be converted to urea.

Denaturization____loss of proteins secondary, tertiary and/or quaternary structure

What factors might denature a protein? __heat, pH extremes, salt concentr.___

How do these factors denature proteins?

interfere the hydrogen bonding and R-group interactions between one portion of the molecule and another, so they "unfold"

Why do you suppose that we could die from a temperature above 105^o or 106^o F?

denatures essential proteins. chem. rxns with enzymes slow or stop.

CHEMICAL REACTIONS IN CELLS: ENERGY AND ENZYMES

All chemical reactions in cells require the use of biological catalysts called **enzymes.**

Without enzymes, chemical reactions would occur too slowly at the temperatures found in an organism. Higher temperatures would increase the rate of chemical reactions, but they harm or destroy the organism.

Characteristics of enzymes:

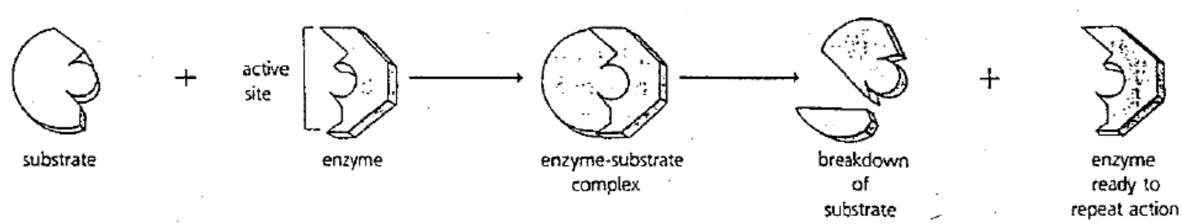
1.____all enzymes ore protein (organic catalysts)___

2.___help to speed reactions. specific to each reaction. one enzyme one reaction. reactions speeded a million to over a trillion times faster.

3.___the 3d shape of an enzyme (tertiary or quaternary struct) is specific for the reactants that are involved in the rxn

Substrate___reactants – temporarily bind to enzyme until reaction takes place

Active Site__the 3D surface on the enzyme that the substrate binds to.



4. Enzymes are often named after the substrate on which they act. Many enzymes also have **–ase** endings.

Examples: If sucrose is the substrate, __sucrase________________________ is the enzyme.

If a peptide were the substrate, the enzyme would be ____peptidase_______________

5. ___Enzymes lower the activation energy (energy required to make rxn go) so rxn is more efficient and doesn't hurt cell. (also – not used upup, like stage in theatre)

6. **How Enzymes Speed Up Chemical Reactions**

Active site - critical. Doesn't actually break bonds. It helps to speed rxn.

Hydrolysis reactions	*Dehydration synthesis reactions*
Enzyme binds to substrates (Polymer + H_2O) and helps to stress or weaken the chemical bonds. Less energy is needed to break the bonds. (ATP, Thermal etc)	Enzyme binds to substrates (monomer + monomer) : once together, helps to weaken bonds so little energy is required to break them & form products (dimer + H_2O)

In cells, enzymes often work in biochemical pathways.

Biochemical pathway ___A series of chemical rxns where the product of one reaction is the reactant of the next etc._

ENERGY

Cells all require energy to stay alive and perform their functions.

Energy can be defined as ____the ability to do work__________________________

FORMS OF ENERGY

Energy cannot be created or destroyed, but energy can and does change form. In photosynthesis and respiration, energy changes from one form into another. Review the energy changes that take place in these two reactions:

these two reactions:

P/S

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

light Solare (radiente) ; Heat (Thermale) ; (chemicale) (FOOD)

C/R

$$C_6H_{12}O_6 + 6O_2 \rightarrow CO_2 + H_2O$$

(Chemical) ; ATP → Cell work (mechanical) ; Heat (Thermal)

1. **Potential energy __stored energy in system______________**

2. **Kinetic energy ___energy of motion________**

Potential energy can be changed into kinetic energy

Examples of potential energy being changed into kinetic energy:

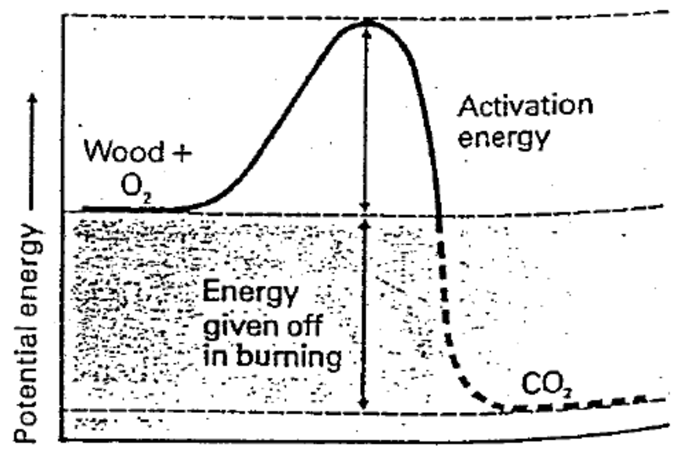
1.___climb a slide (P) → slide down (K)____

2.__light energy (K) → glucose (P) → ATP (P) → cell work (K)__________________

3.__wood (P) → burn (K)______________________________

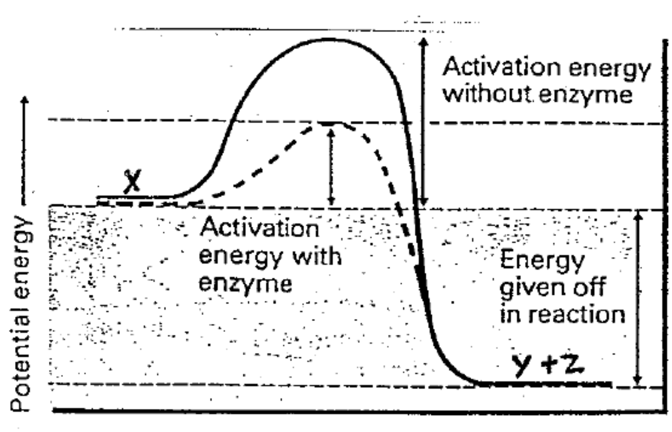
ENERGY IN CHEMICAL REACTIONS

All chemical reactions require **activation energy.**
Activation energy __Energy required to start a reaction – differs from reaction to reaction.



In reactions that do not occur in organisms, activation energy is often in the form of **heat.** Heat makes the molecules move faster, so they have a better chance of colliding and reacting. It helps to destabilize bonds, so they can more easily break, and new bonds in the products can form. If that much heat were added to cells, the cells would die. The chemical reactions in our cells are designed to work best at 98.6^{o}F, body temperature. How can we then overcome the activation energy barrier of chemical reactions so that they can proceed at the relatively low temperature of 98.6^{o}F?

__Enzymes form interactions with substrate(s) at the active site and stress the bonds of the substrate so less activation energy is needed to break bonds.



How do enzymes lower the amount of activation energy needed to start these 2 types of reactions?

Hydrolysis reactions: __Enzymes bind with substrates (ex. Polymers and water) and stresses bonds, so that less A.E. is needed.

Synthesis reactions: _ Enzyme brings substrates close together. Enzyme binds with substrates (dimers or polymers & water) and stresses bonds so that less A.E. is needed.

There are many chemical reactions that take place in cells – as a matter of fact, all cell processes are a result of chemical reactions. Here we will be looking at two basic types of chemical reactions: **exothermic** reactions and **endothermic** reactions. ***Both of these types of reactions require activation energy.***

*Energy absorbed to break old bonds. Energy released when NEW bonds form!!

Characteristics of **exothermic** reactions:

- _ Overall or Net release of energy as reactants become products Ex. $H_2O_2 \rightarrow 2H_2O + O_2$ + heat release__
- __Reactants have more PE than products. Reactants are less stable than products (easy to break bonds). Reactants are more organized (complex than products)
- _Less energy is needed to start rxn (break bonds) (A.E.) than is released when new bonds form in products.

Example: __Cell resp. –or-- $H_2O_2 \rightarrow 2H_2O + O_2$ -or- hydrolysis such as dipeptide → 2 AA's + H_2O_

Note: In organisms, exothermic reactions are also **exergonic.** These 2 terms are related but not exactly the same. The difference will be discussed in chemistry class.

Characteristics of **endothermic** reactions:

- ___Overall or net input of energy needed for reactants
- _Reactants have less PE than products. Reactants are more stable, less complex/organized than products (hard to break bonds).___
- ____More (activation) energy is needed to break bonds in reactants than is released when new bonds form.

Example: __photosynthesis –or- dehydration synth such as amino acid + amino acid → dipeptide + H_2O.

Note: In organisms, endothermic reactions are also **endergonic.** These 2 terms are related but not exactly the same. The difference will be discussed in chemistry class.

Diagram of Exothermic and Endothermic Reactions

(Cell Respiration and Photosynthesis will be used as examples)