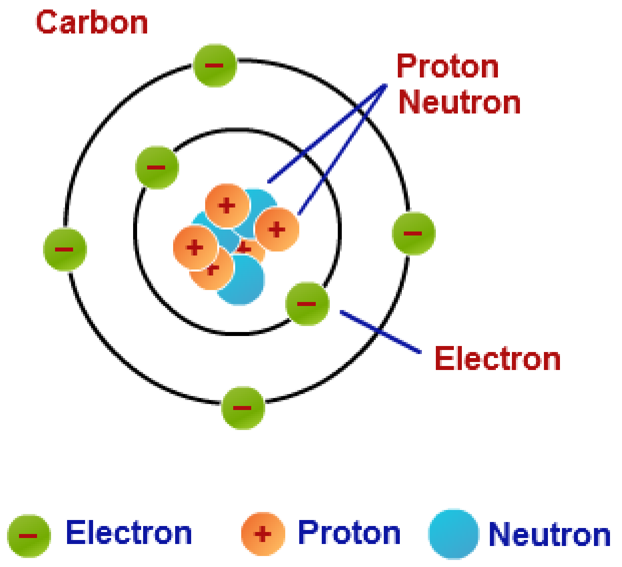
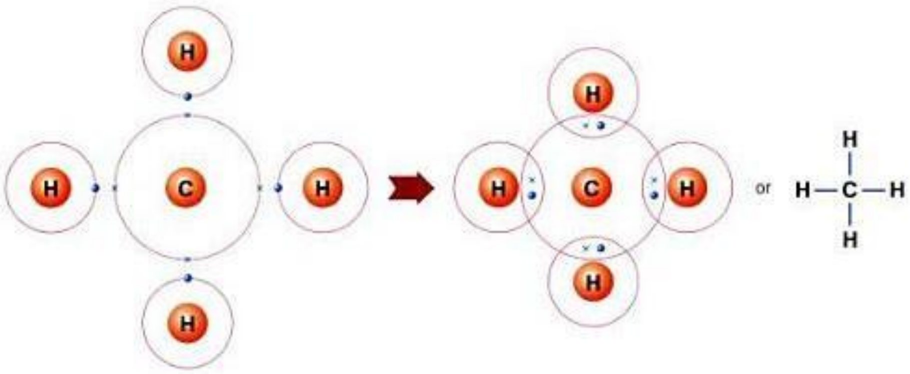
Macromolecules

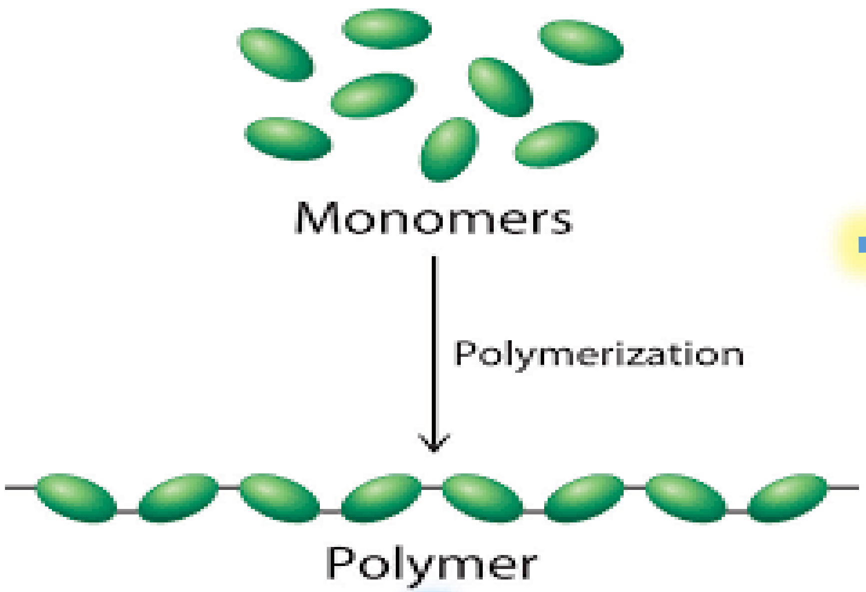
Ach

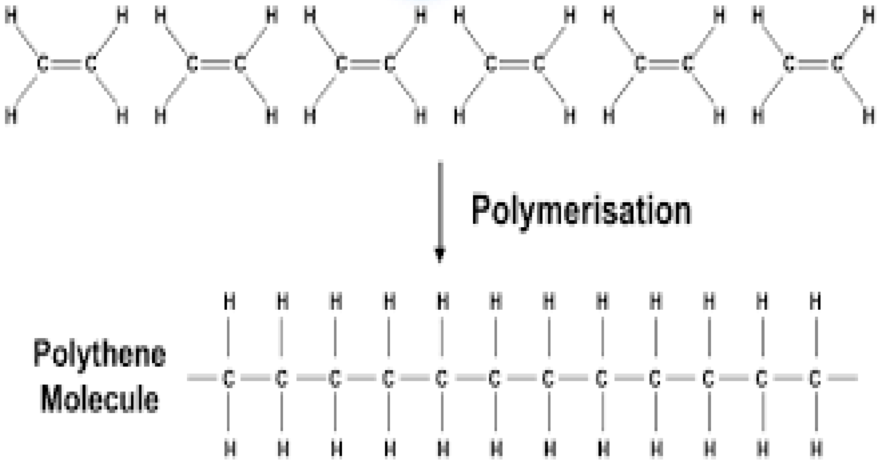
Chemistry of Carbon

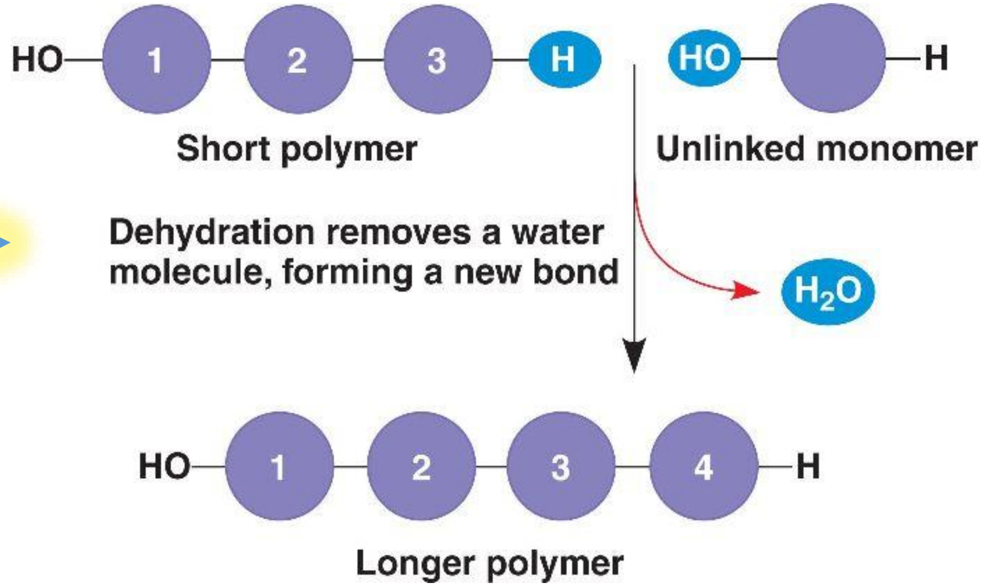


- All living things rely on one particular type of molecule: carbon
- Carbon atom with an outer shell of four electrons can form covalent bonds with four atoms.
- In organic molecules, carbon usually forms single or double covalent bonds. Carbon chains form the skeletons of most organic molecules.
- Each carbon atom acts as an intersection point from which a molecule can branch off in as many as four directions.
- The skeletons vary in:
  - length
  - may be straight or branched
  - arranged in closed rings
  - have double bonds which vary in number and location

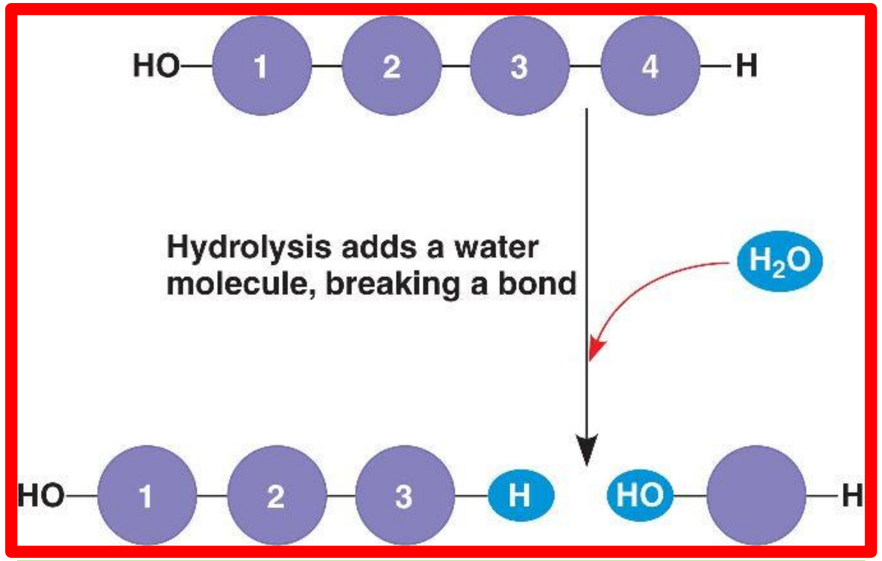








Dehydration / Condensation



Hydrolysis

Terminologies

- **Macromolecule:** Small molecules assemble in different orientation to make large molecule or macromolecules. **Example:** Glucose molecules assemble to make cellulose (a carbohydrate) .
- **Monomers** are small molecules or building blocks which may be joined together in a repeating fashion to form more complex molecules called polymers.
- A **polymer** may be a natural or synthetic macromolecule comprised of repeating units of a smaller molecule (monomers).
- **Polymerization** is the linking together of monomers to form polymers.
- A **dehydration / condensation** reaction occurs via the loss of a small molecule (water) , usually from two different substances, resulting in the formation of a covalent bond.
- **Polymerization** is the linking together of monomers to form polymers.
- **Hydrolysis,** which is the reverse of condensation, breaks apart large organic molecules into smaller ones.
- By breaking the bonds between monomers, hydrolysis liberates the energy that polymers contained during condensation; thus, some of the energy required to polymerize is returned upon hydrolysis.

Organic and inorganic compounds

Organic
- Carbon-carbon bonds
- With Hydrogen
- LARGE, COMPLEX
  - Ex. Nutrients
- Made in living things

4 Main life molecules
- Carbohydrates
- Lipids (fats)
- Nucleic acids (DNA)
- proteins

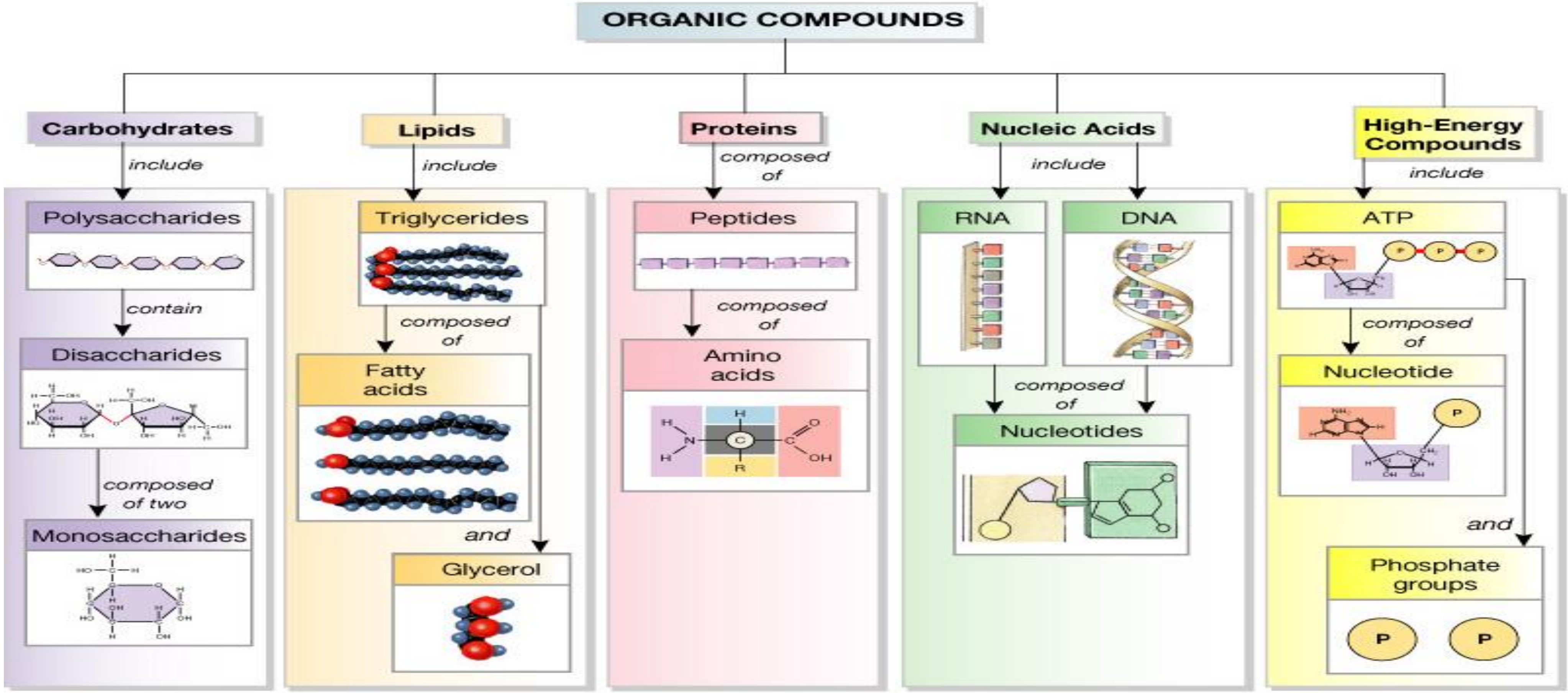
Inorganic
- *Might* have carbon, but NO
  - Hydrogen
  - Carbon-carbon bonds
  - Ex. CO_2 $CaCO_3$
- Small, few atoms
- *Some* are in living things

Inorganics needed for life:
- Water
- Minerals, salts

Vitamins are organic,
need in small amounts

The Four Macromolecules and their Monomers

The Four Major Types of Macromolecules Found in Living Cells				
Macromolecule	Elements	Monomer	Polymer	example
Carbohydrate	C, H, O	Simple sugars	Polysaccharide	Starch
Lipids	C, H, O	Fatty acids and glycerol	Lipid	Fats, oils, waxes
Proteins	C, H, O, N, S	Amino acids	Polypeptides	Insulin
Nucleic acids	C, H, O, P	Nucleotides	Nucleic acids	DNA



Carbohydrates

Carbohydrates are organic compounds made up of the elements carbon, hydrogen & oxygen. The hydrogen and oxygen are present in the same ration as in water 2:1

- **Small sugar molecules** to **large sugar molecules**.
- Consist of carbon, hydrogen and oxygen
- Common formula: $(CH_2O)_n$
- **Examples:**
  - A. **monosaccharide**
  - B. **disaccharide**
  - C. **polysaccharide**

Carbohydrates

Monosaccharide: one sugar unit

Examples: ($C_6H_{12}O_6$)

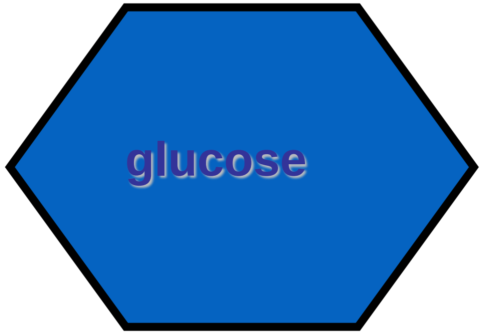
glucose

deoxyribose

ribose

Fructose

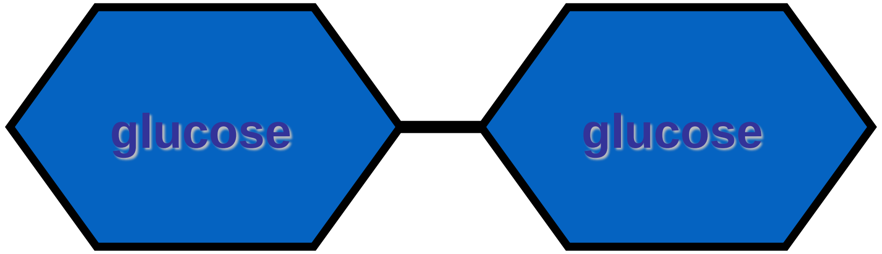
Galactose



Disaccharide: two sugar unit

Examples:

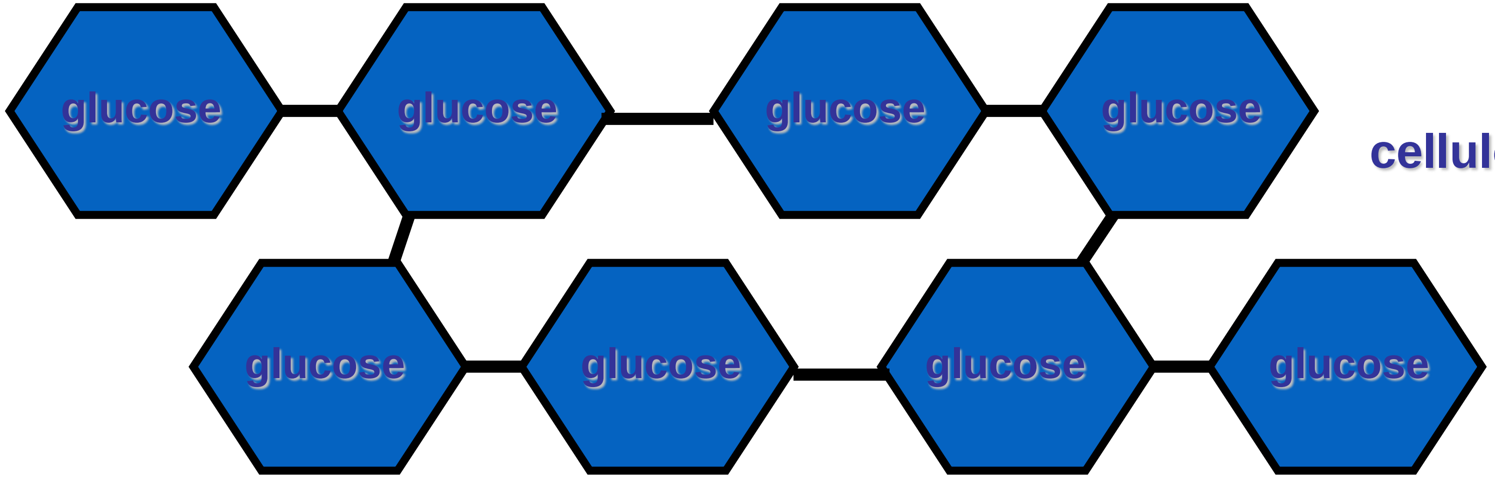
- **Sucrose;** cane sugar (glucose+fructose)
- **Lactose;** milk sugar (glucose+galactose)
- **Maltose:** malt sugar (glucose+glucose)



Carbohydrates

Polysaccharide: many sugar units

Examples: starch (bread, potatoes)
glycogen (beef muscle)
cellulose (lettuce, corn)



cellulose

Starch and Glycogen	Cellulose
• Starch is energy storage molecule in plants • Glycogen is energy storage molecule in animals. • Starch and glycogen can be digested by animals.	• Different bond formed than starch • Structural component in plants • Cannot be digested by animals – forms dietary fibers

CARBOHYDRATE

Functions of Carbohydrates

Carbohydrate's main function is to provide and store energy

1. Providing energy – carbohydrates are the preferred fuel source of our body.

Carbohydrate -> glucose -> energy

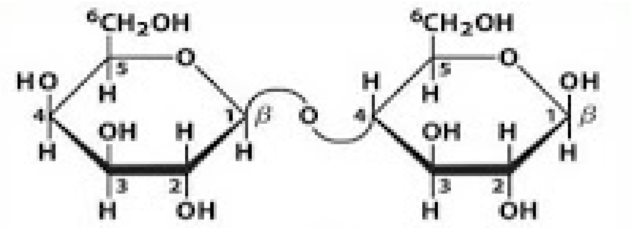
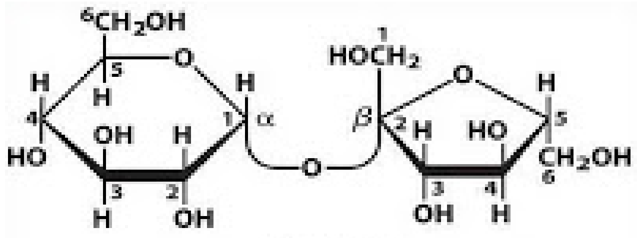
2. Store energy – excess glucose is stored as glycogen in muscles and liver of animals (or starch in plants).

3. Build macromolecules – some sugar is used to make cell components such as DNA, RNA and ATP

4. Spare protein and fat for other uses – when energy demands cannot be met by carbohydrates, body starts breaking down proteins from muscles an other tissues

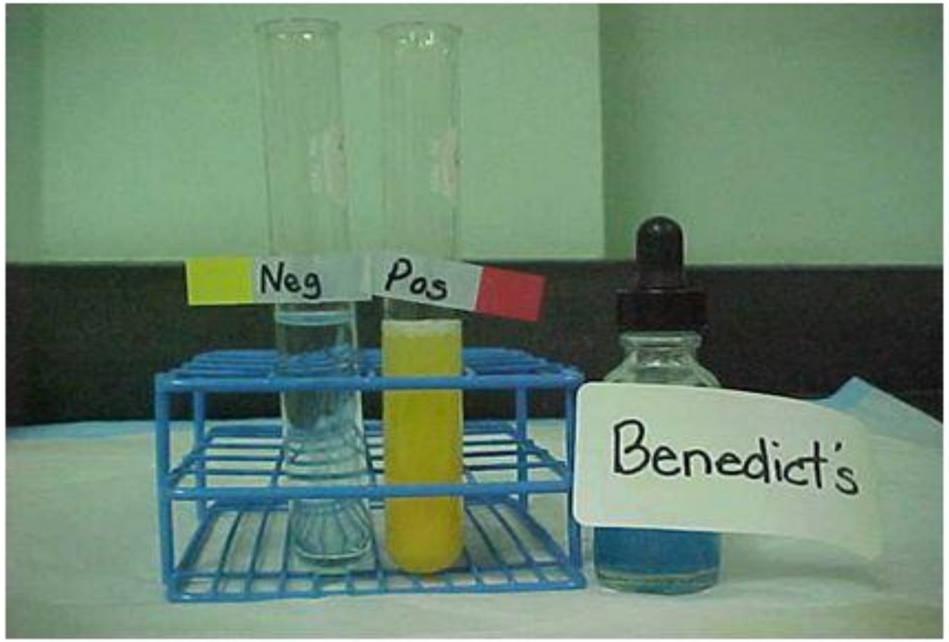
5. Dietary fiber – essential for the elimination of waste materials from the body and prevents constipation

Reducing and Non-reducing sugars

No	Reducing Sugars	Non-reducing Sugars
1	Such sugar bear a free aldehyde (-CHO) or ketonic (-CO) group.	These sugars do not have such groups
2	Reducing sugars have the capacity to reduce cupric ions of Benedict's or Fehling solution to cuprous ions.	Non reducing sugar fail to reduce the cupric ions of Benedict's solution to cuprous ions.
3.	**Examples:** Maltose, Lactose, Melibiose, Cellobiose, Gentiobiose  Lactose (β form) β-D-galactopyranosyl-(1→4)-β-D-glucopyranose Gal(β1→4)Glc Lactose	**Examples:** Sucrose, Trehalose  Sucrose α-D-glucopyranosyl β-D-fructofuranoside Glc(α1↔2β)Fru Sucrose

Test for Simple Carbohydrates
Benedict's solution

- Benedict's solution is a chemical indicator for simple sugars such as glucose: $C_6H_{12}O_6$.
- Aqua blue: negative test; yellow/green/brick red, etc.: positive test



Fats & Lipids

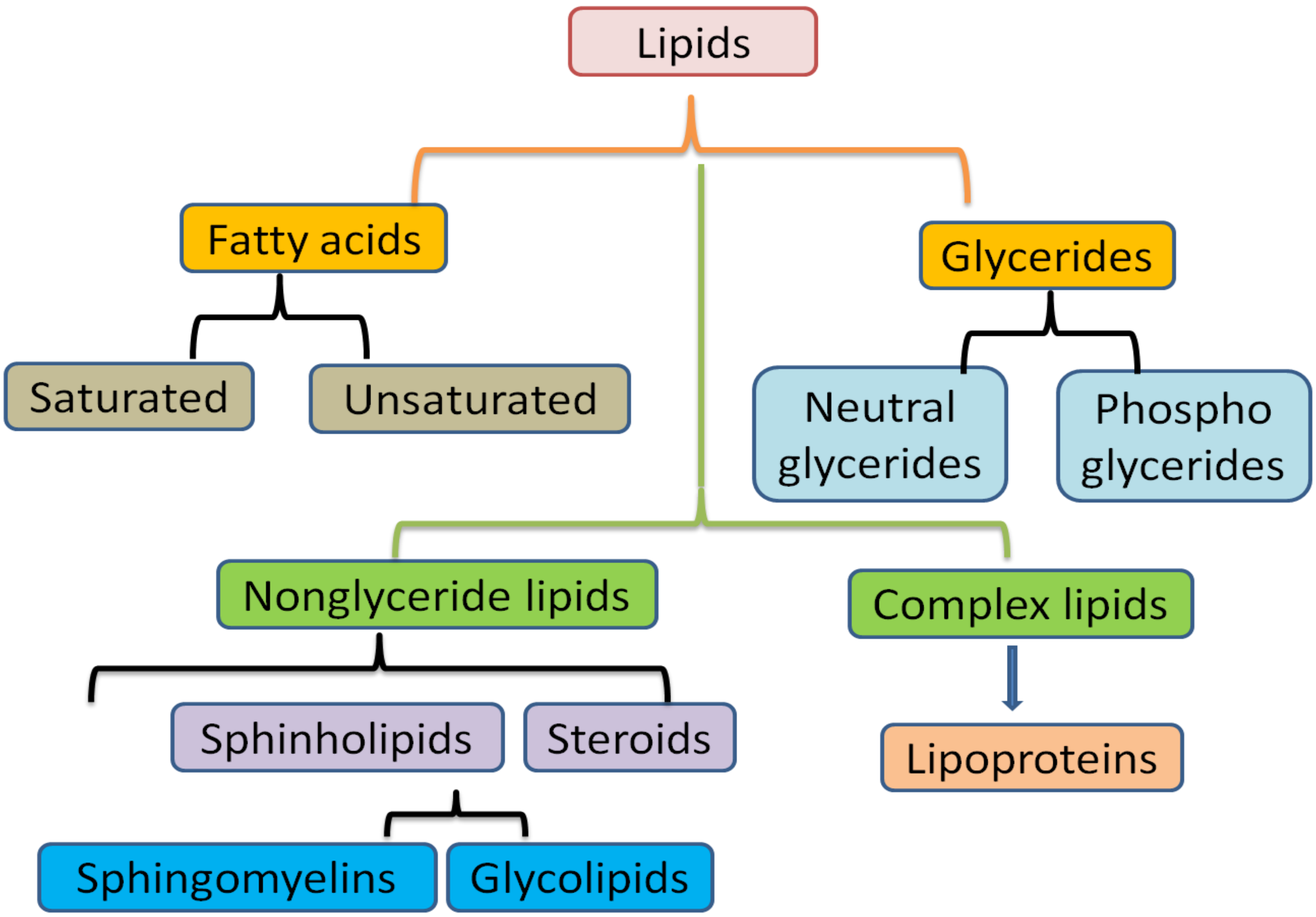
Lipids / Fats

Fats are organic compounds made up of the elements carbon, hydrogen & oxygen. But contains less oxygen in proportion to hydrogen.

- General term for compounds which are not soluble in water.
- Lipids are soluble in hydrophobic solvents.
- Remember: "stores the most energy"
- Examples:
  1. Fats
  2. Phospholipids
  3. Oils
  4. Waxes
  5. Steroid hormones
  6. Triglycerides

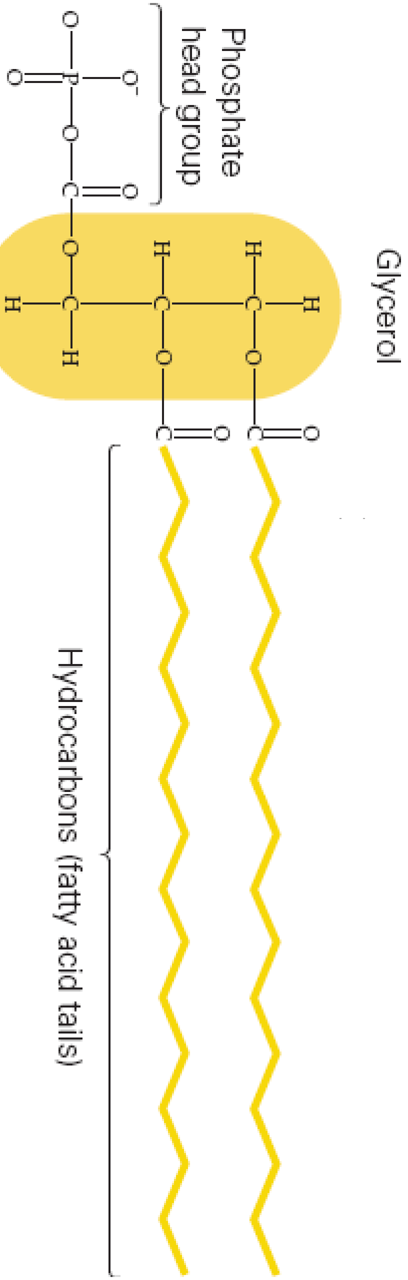
Six functions of lipids:

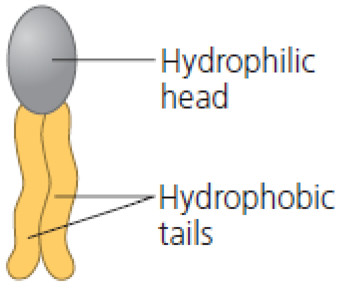
1. Long term energy storage
2. Protection against heat loss (insulation)
3. Protection against physical shock
4. Protection against water loss
5. Chemical messengers (hormones)
6. Major component of membranes (phospholipids)


Lipids
Fatty acids
Glycerides
Saturated
Unsaturated
Neutral glycerides
Phospho glycerides
Nonglyceride lipids
Complex lipids
Sphinholipids
Steroids
Lipoproteins
Sphingomyelins
Glycolipids

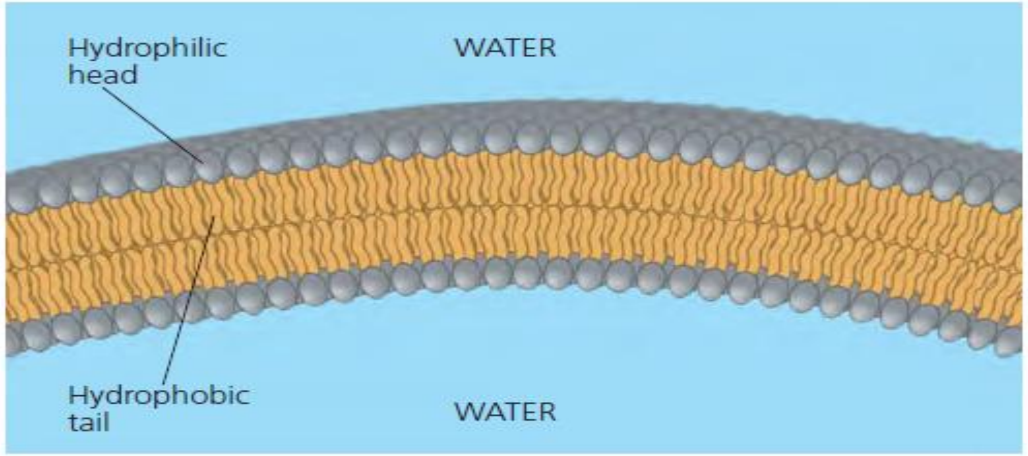
Phospholipid

- Made up of two fatty acids and a phosphate group
- Has both hydrophobic (fatty acid tail) and hydrophilic (phosphate head) regions
- **Function:** Forms part of cell membranes





(c) Phospholipid symbol



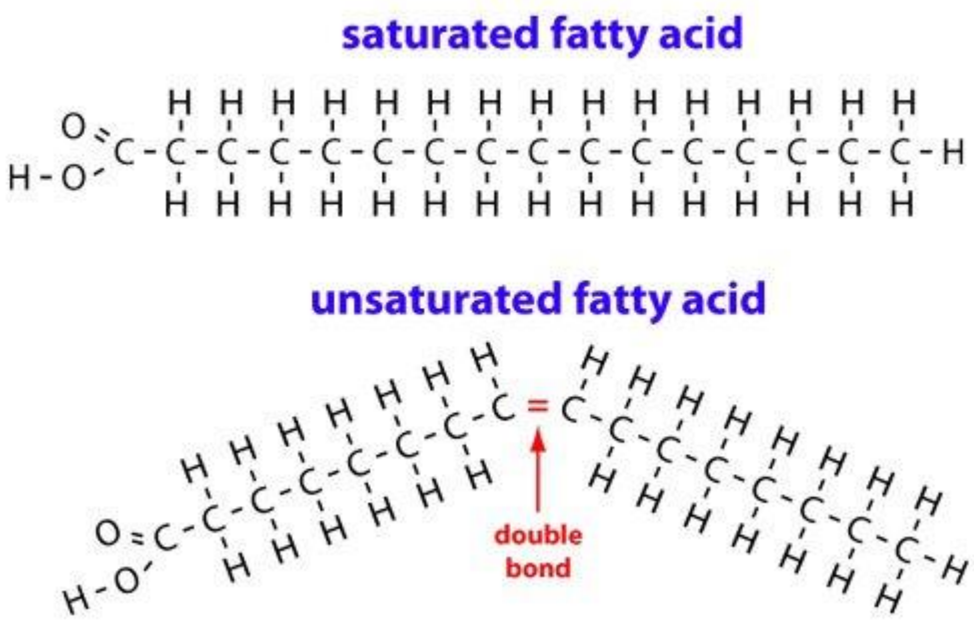
Lipid bilayer structure in biological membranes

Fatty Acids

There are two kinds of **fatty acids** you may see these on food labels:

1. **<u>Saturated fatty acids:</u> no double bonds (bad)**

2. **<u>Unsaturated fatty acids:</u> double bonds (good)**

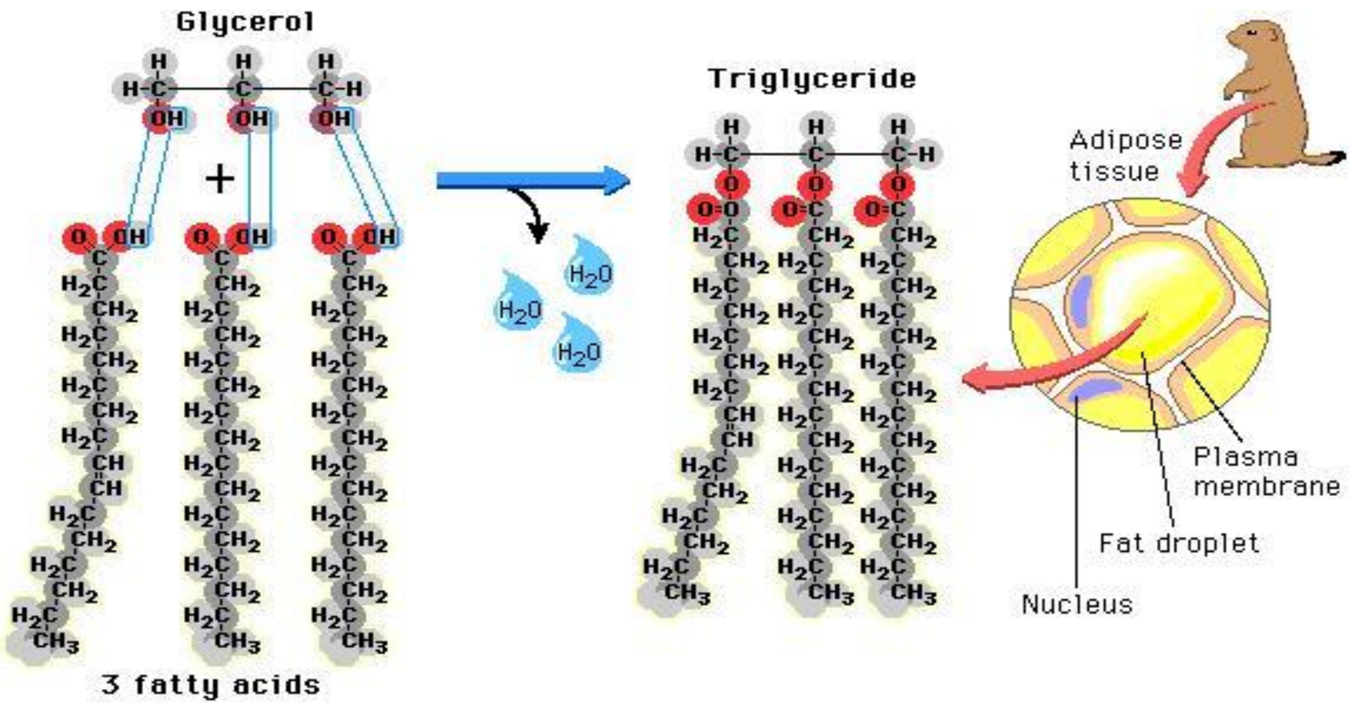


	Saturated Fats	Unsaturated Fats
Type of bonds	Consist of SINGLE bond	Consist of at least 1 DOUBLE bond
Recommended consumption	Not more than 10% of total calories per day	Not more than 30% of total calories per day
Health Effects	Excessive consumption is not good because of their association with atherosclerosis and heart diseases.	Unsaturated fats are considered good to eat if you are watching your cholesterol. Also high in antioxidants.
Cholesterol	Saturated fats increase Low Density Lipoproteins (LDL or bad cholesterol) & Very Low Density Lipoproteins (VLDL's).Sources of bad cholesterol are foods rich in trans fatty acids, refined carbohydrates, such as white sugar, and flour.	Unsaturated fats increase High-Density Lipoprotein (HDL or good cholesterol) and decrease Low Density Lipoproteins (LDL or bad cholesterol). Sources of HDL include onions and Omega-3 fatty acids like flax oil, fish, foods rich in fiber like grains.
Commonly found in	Butter, coconut oil, whole milk, meat, peanut, butter, margarine, cheese, vegetable oil, fried foods, & frozen dinners	Avocado, soybean oil, canola oil and olive oil, sunflower oil, fish oils walnuts, flax, & red meats

Triglycerides: Triglycerides are a type of fat (lipid) found in your blood. When you eat, your body converts any calories it doesn't need to use right away into triglycerides. The triglycerides are stored in your fat cells. Later, hormones release triglycerides for energy between meals. If you regularly eat more calories than you burn, particularly "easy" calories like carbohydrates and fats, you may have high triglycerides (hypertriglyceridemia).

A simple blood test can reveal whether your triglycerides fall into a healthy range.

- Normal — Less than 150 milligrams per deciliter (mg/dL), or less than 1.7 millimoles per liter (mmol/L)
- Borderline high — 150 to 199 mg/dL (1.8 to 2.2 mmol/L)
- High — 200 to 499 mg/dL (2.3 to 5.6 mmol/L)
- Very high — 500 mg/dL or above (5.7 mmol/L or above)



Test for Fat

- Fats go cloudy white when they are mixed with ethanol and water.

Now see if you can use these tests to identify the food chemicals on the next slides.

Proteins

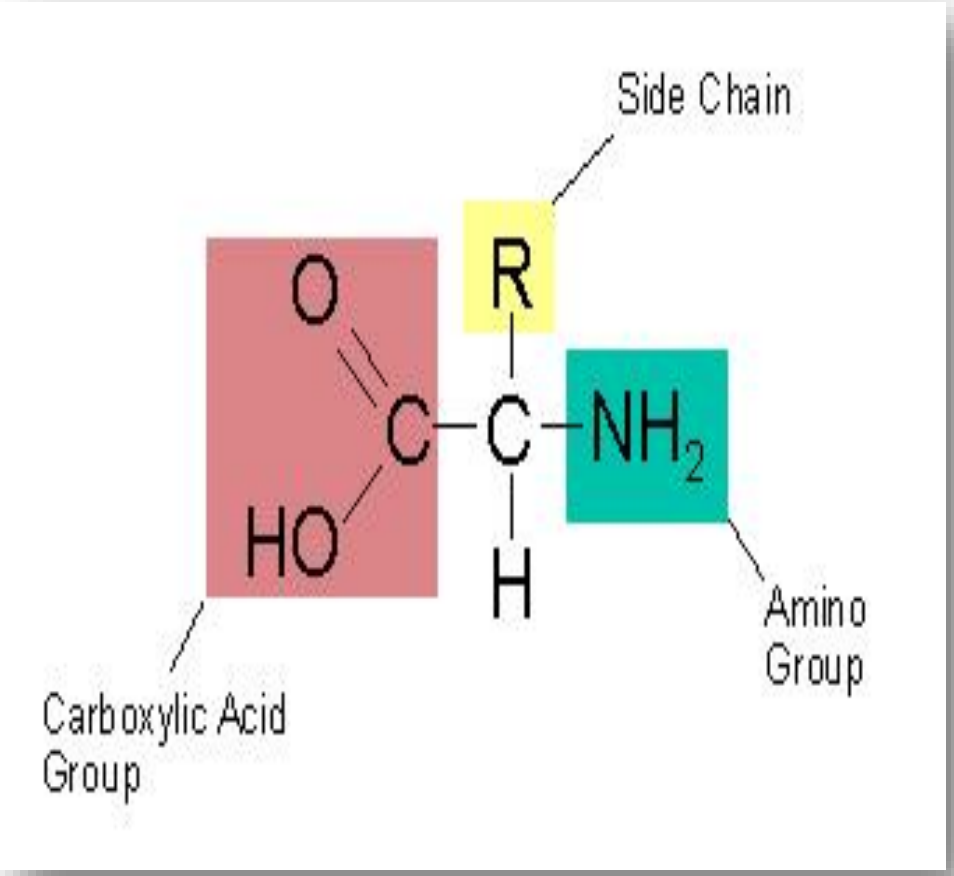
Amino Acids

Monomers of proteins

<u>Structure:</u>

- Contains an amino group (NH_2)
- A carboxyl group (COOH)
- One or more atoms called an "R group"
- All three groups are attached to the same carbon atom

There are 20 types of "R" groups and name of each amino acid depends on the R group.

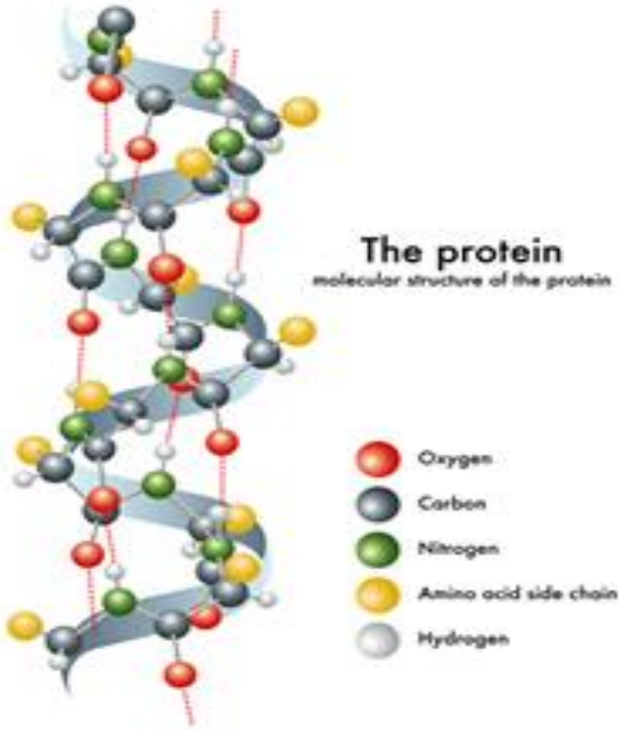


Proteins (Polypeptides)

Proteins are very complex organic compounds made up of the elements carbon, hydrogen, oxygen & nitrogen . Sulphur and Phosphorus are often present.

- **Amino acids (20 different kinds of aa)** bonded together by **peptide bonds** (polypeptides).

- **Six functions of proteins:**
  1. **Storage:** albumin (egg white)
  2. **Transport:** hemoglobin
  3. **Regulatory:** hormones
  4. **Movement:** muscles
  5. **Structural:** membranes, hair, nails
  6. **Enzymes:** cellular reactions



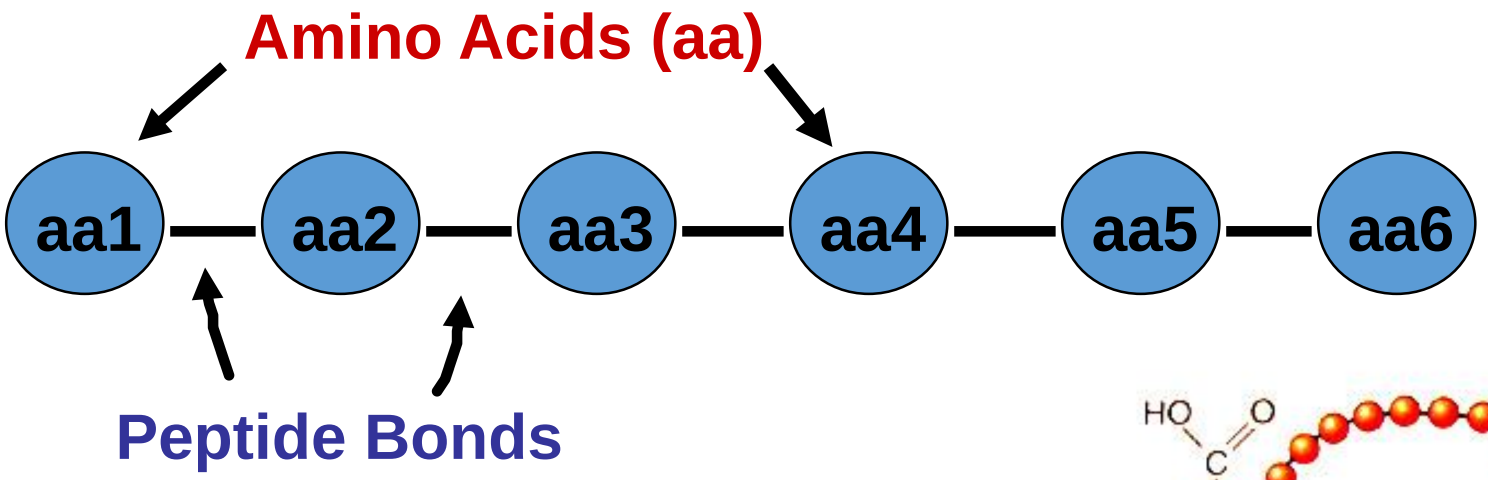
Proteins (Polypeptides)

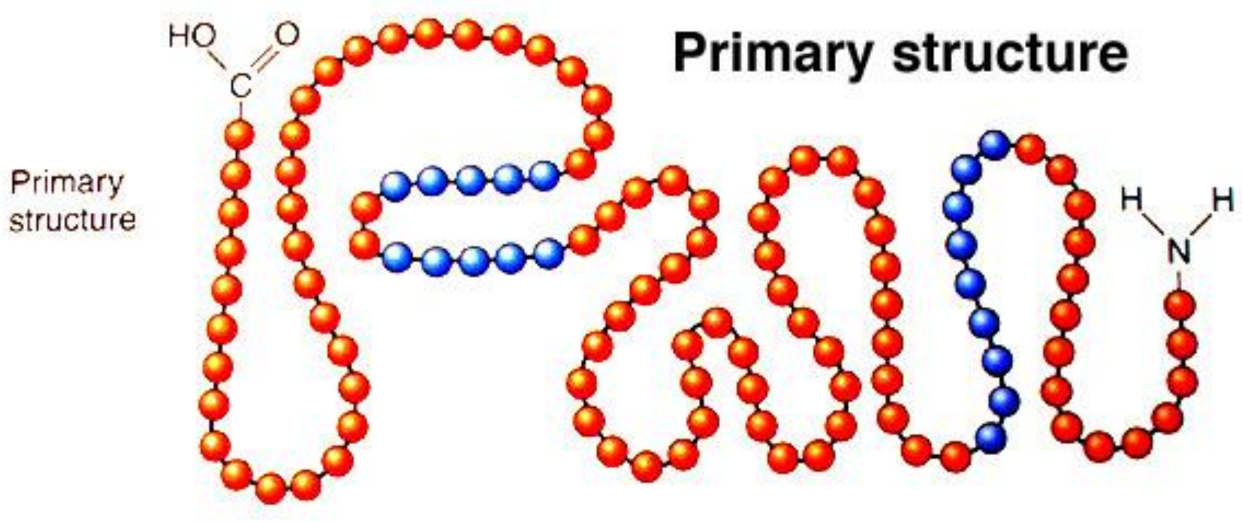
Four levels of protein structure:

A. Primary Structure
B. Secondary Structure
C. Tertiary Structure
D. Quaternary Structure

Primary Structure

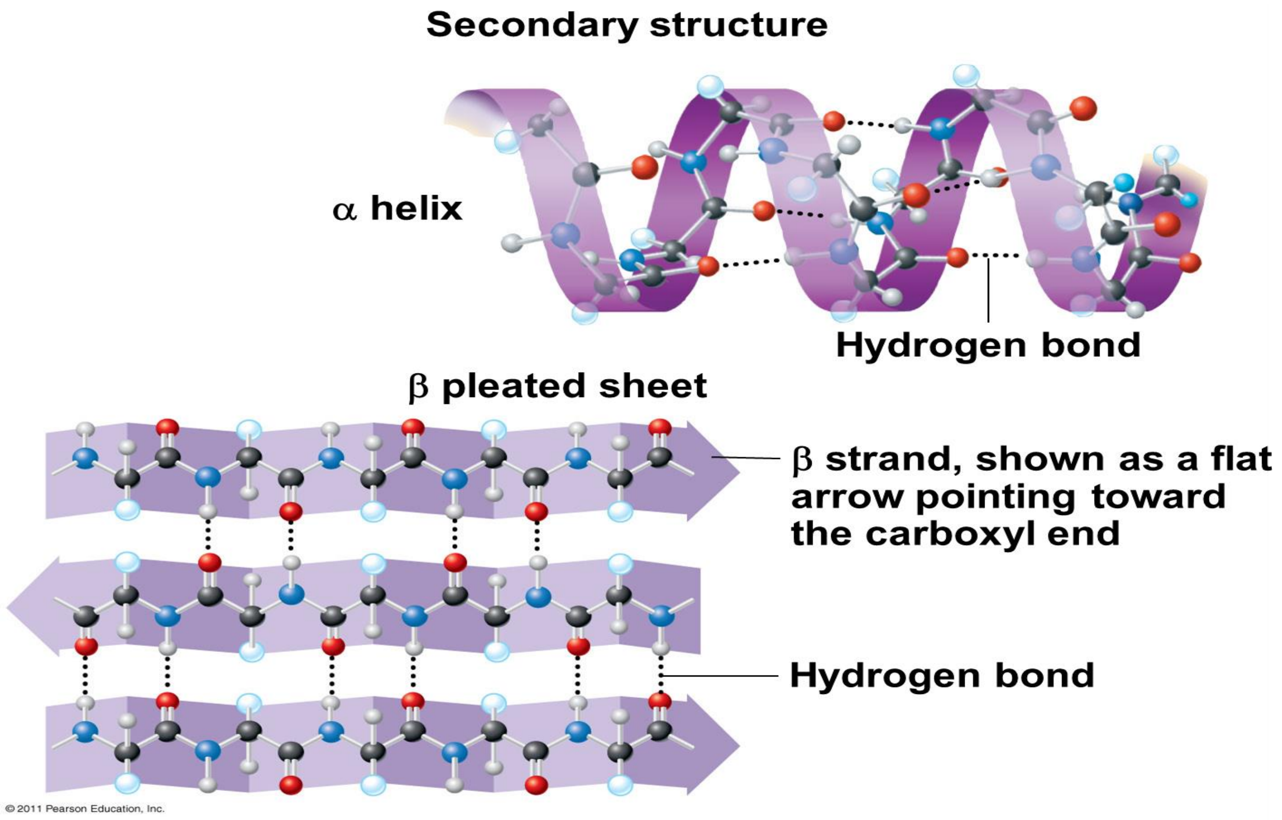
Amino acids bonded together by peptide bonds (straight chains)





Secondary Structure

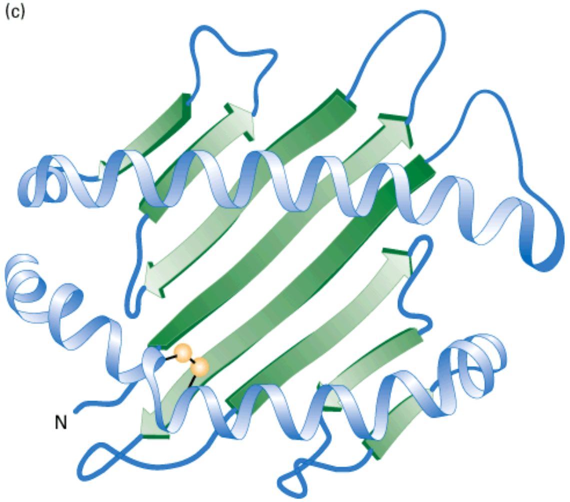
- 3-dimensional folding arrangement of a **primary structure** into **coils** and **pleats** held together by **hydrogen bonds**.

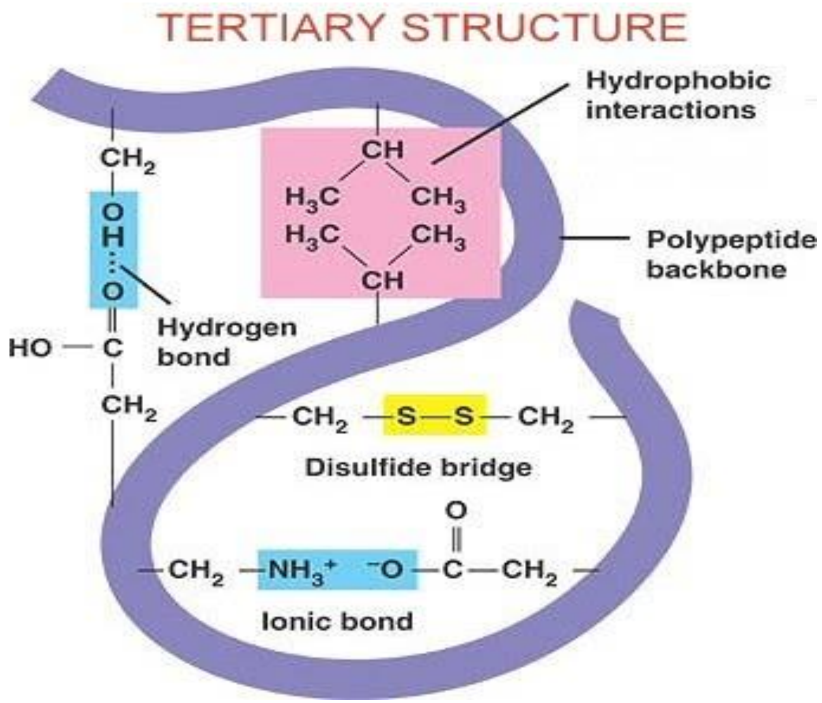


Tertiary Structure

- The third type of structure found in proteins is called tertiary protein structure.
- The tertiary structure is the final specific geometric shape that a protein assumes.
- This final shape is determined by a variety of bonding interactions between the "side chains" on the amino acids.
- These bonding interactions may be stronger than the hydrogen bonds between amide groups holding the helical structure.
- Bonds: H-bonds, ionic, disulfide bridges (S-S)

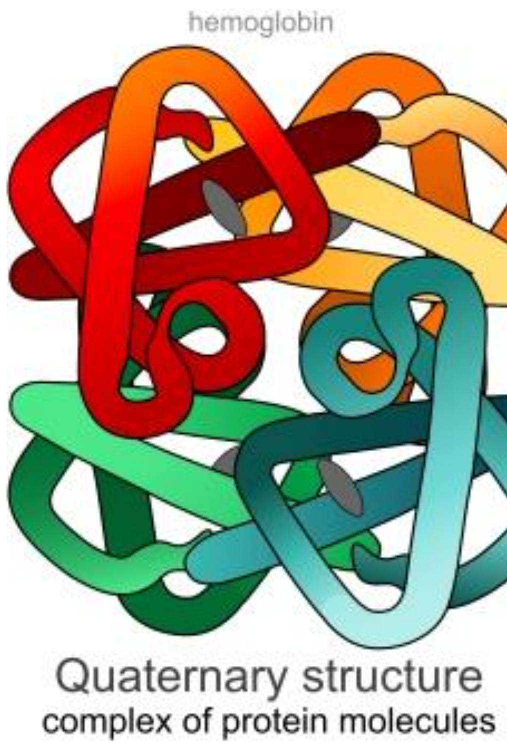
(c)

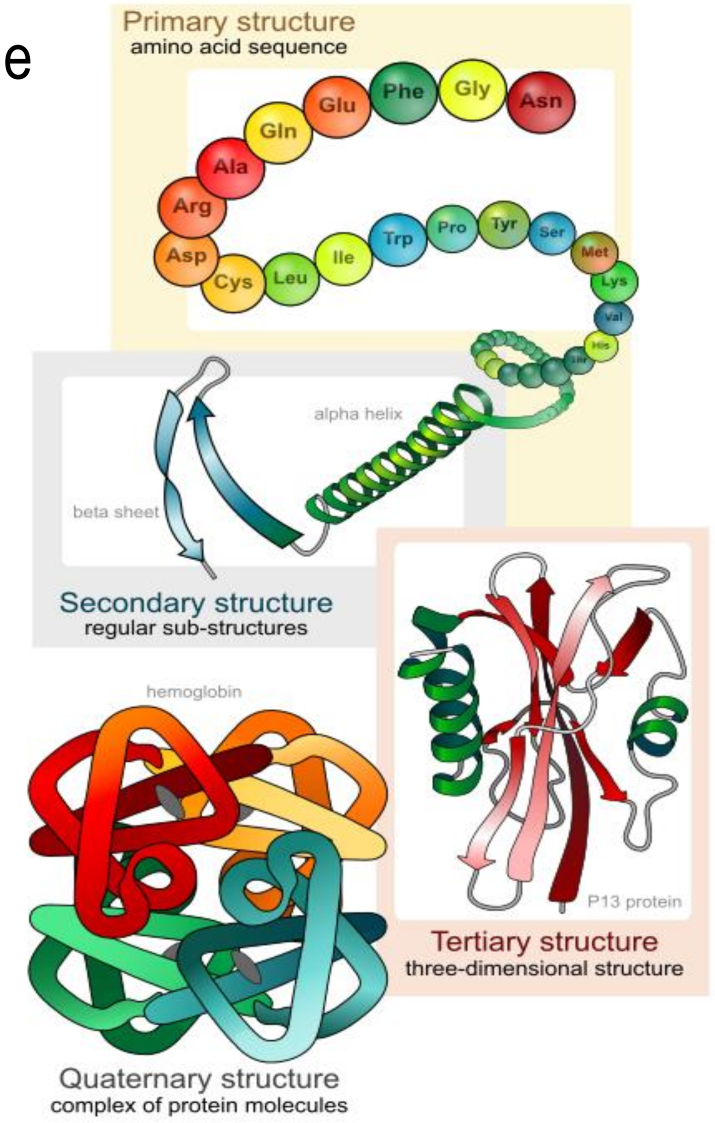




Quaternary Structure

Quaternary Structure: The structure formed when two or more polypeptide chains join together, sometimes with an inorganic component, to form a protein.





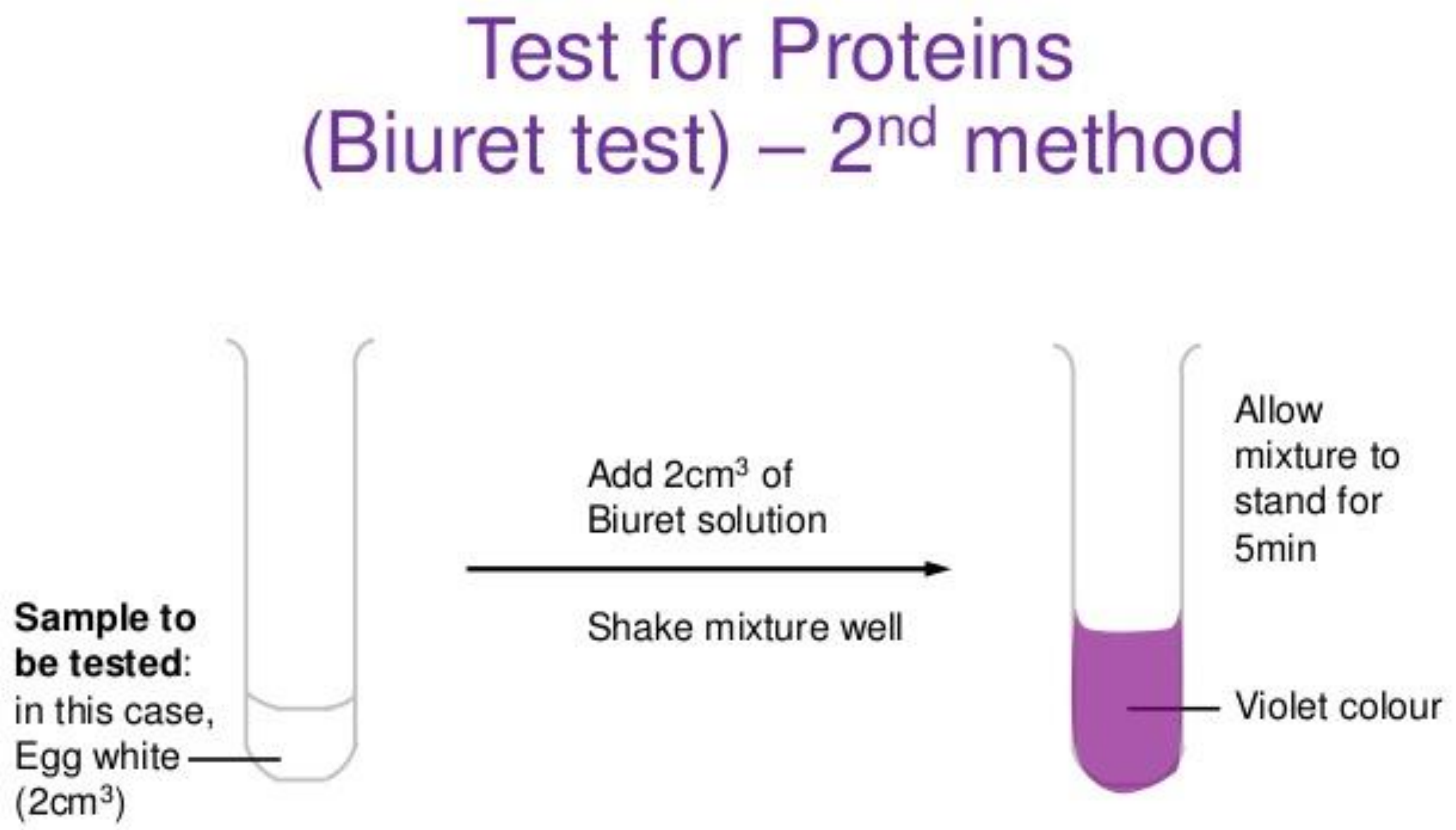
PROTEINS

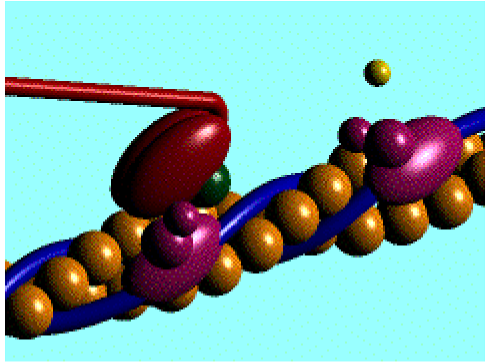
Functions of proteins

Protein's main function is to build, maintain and repair all our body tissues

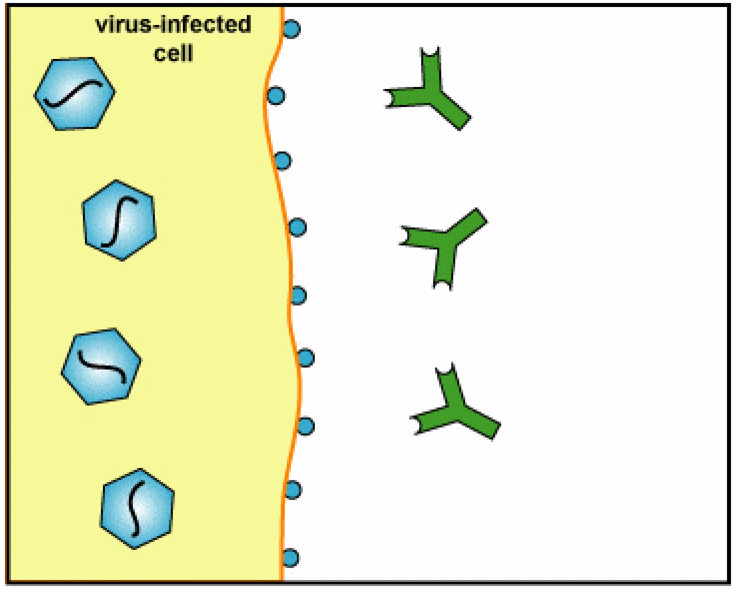
Type	Function	Example
Enzymes	Increases rate of chemical reaction	Digestive enzymes
Structural proteins	Give shape and support to cell	Keratin in hair and nails
Defensive proteins	Protection against diseases	Antibodies
Transport proteins	Transport of substances	Hemoglobin (transports oxygen from lungs to different parts of body)
Hormonal proteins	Coordination of organism's activities	Insulin
Motor proteins	Movement	Actin and myosin for muscle movement

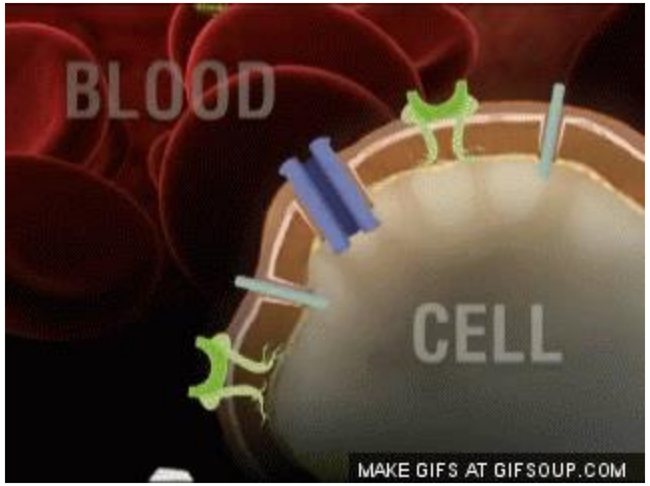
Test for proteins





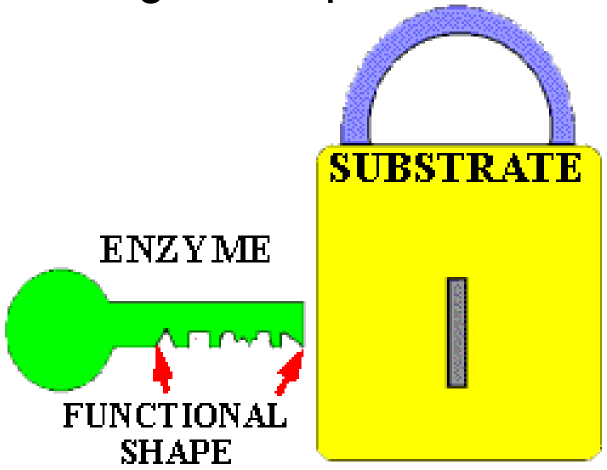

MAKE GIFS AT GIFSOUP.COM

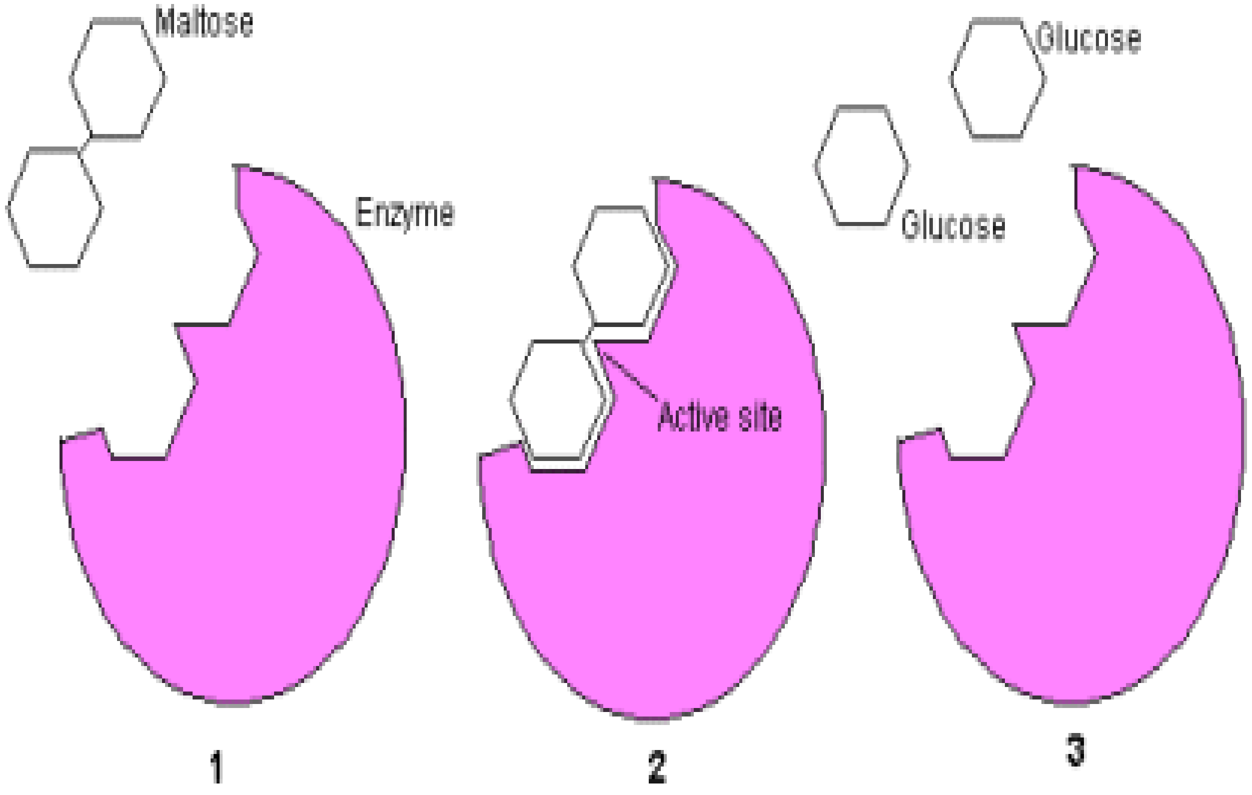

virus-infected
cell

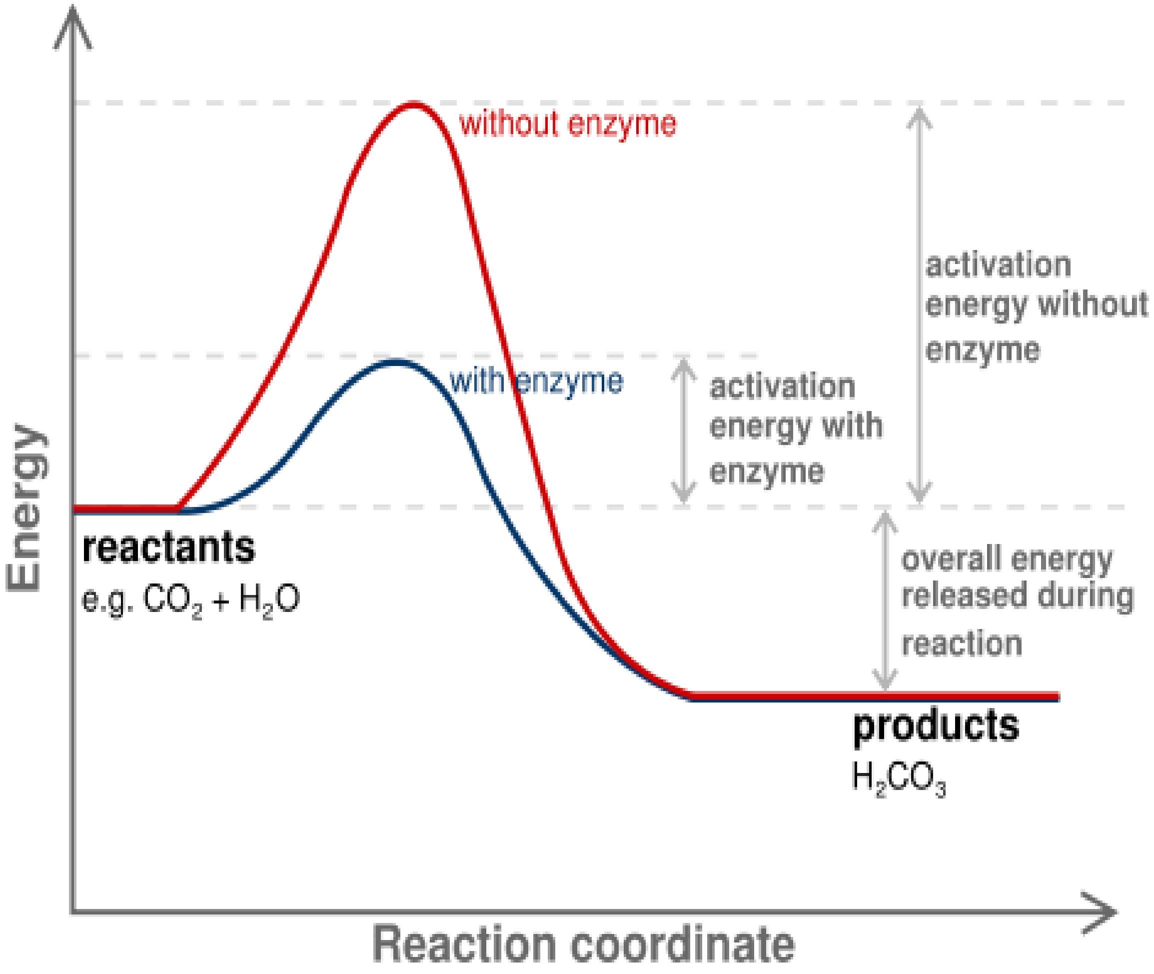

BLOOD
CELL
MAKE GIFS AT GIFSOUP.COM

Enzymes

- Enzymes are **biological catalysts** - substances that increase the rate of chemical reactions without being used up.
- The molecules that an enzyme works with are called substrates.
- **Enzymes are proteins** folded into complex shapes that allow smaller molecules to fit into them. The place where these substrate molecules fit is called the **active site**.
- If the shape of the enzyme (protein) changes, its active site may no longer work. We say the enzyme has been '**denatured**'.
- Enzymes can be denatured by high temperatures or extremes of pH.
- They are vital for life and serve a wide range of important functions in the body, such as aiding in digestion and metabolism.




Maltose
Enzyme
Active site
Glucose
Glucose
1
2
3


without enzyme
with enzyme
activation energy without enzyme
activation energy with enzyme
overall energy released during reaction
Energy
reactants
e.g. $CO_2 + H_2O$
products
H_2CO_3
Reaction coordinate

Enzymes

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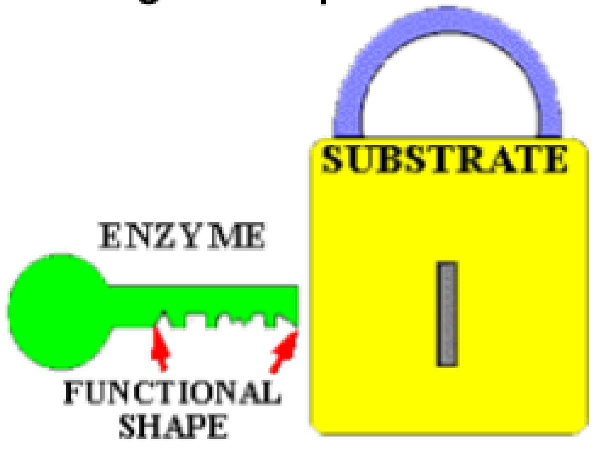


Enzymes

Properties of enzymes

1. Enzymes are **specific:** each enzyme usually **catalyses only one reaction**.

2. Enzymes combine with their substrates to form temporary **enzyme-substrate** complex.

3. Enzymes are **not altered or used up** by the reactions they catalyze, so can be used again and again.

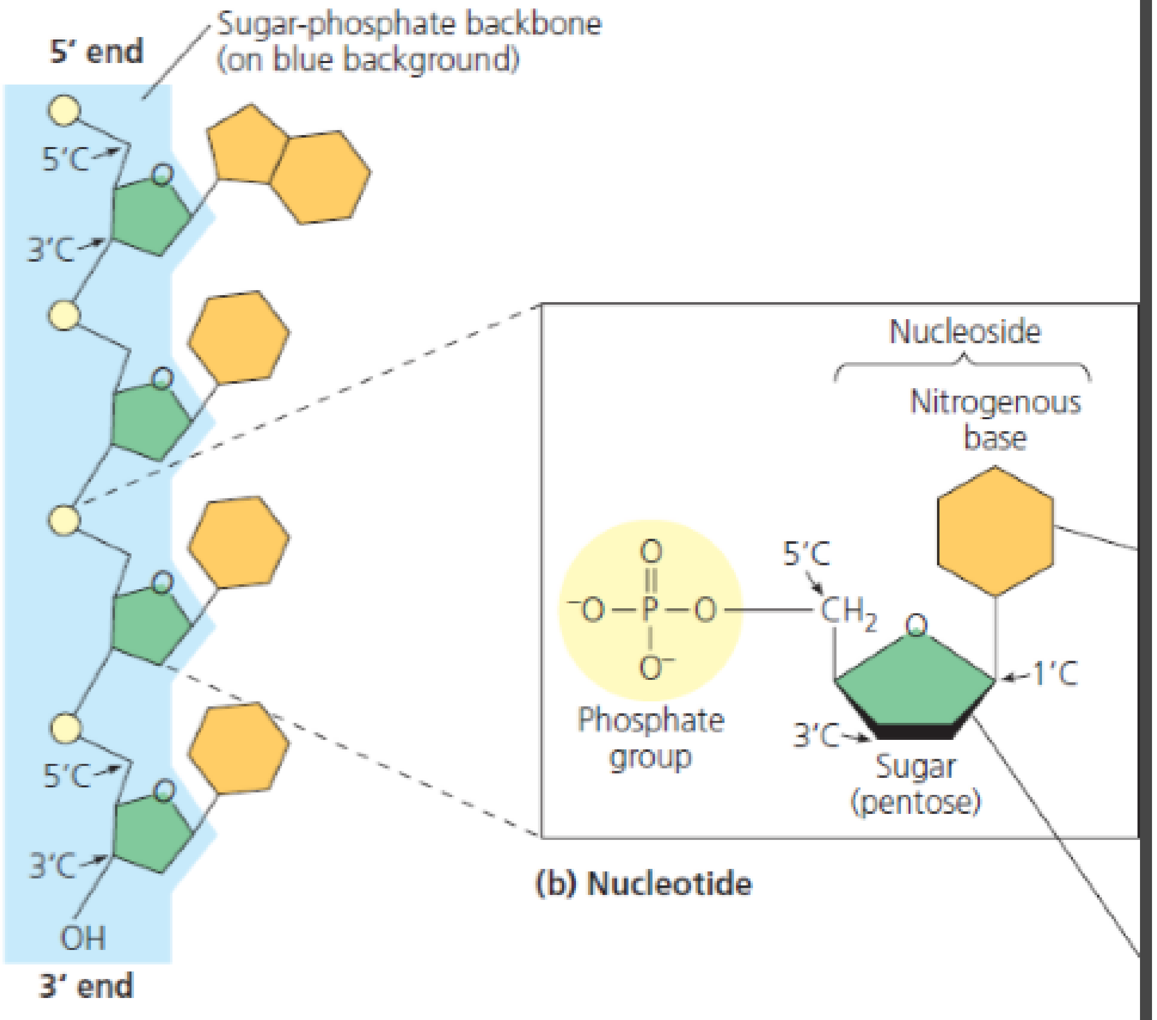
4. Enzymes are **sensitive** to **temperature and pH**.

5. Many enzymes need **cofactors** in order to function.

6. Enzyme function may be slowed down or stopped by **inhibitors**.

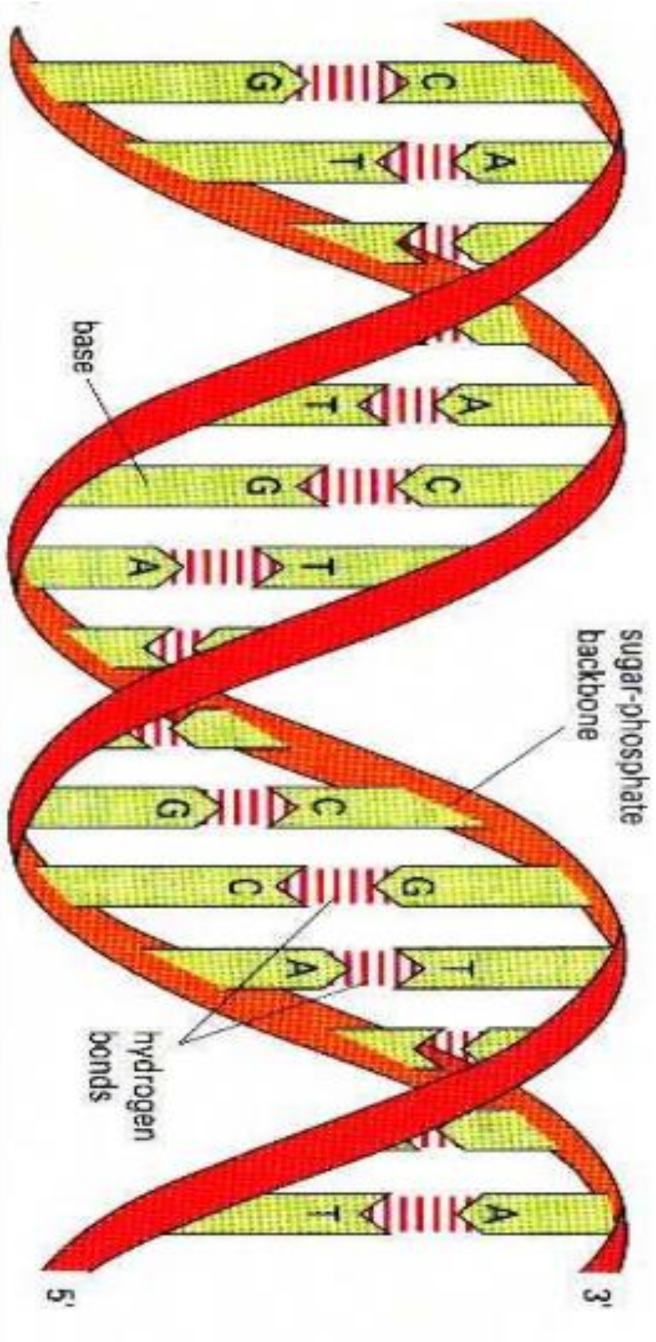
Nucleic Acids

- Nucleic acids carry genetic information of an organism and forms the chemical link between generations. It dictates amino-acid sequence in proteins
- Two types of nucleic acids: DNA and RNA
- Made of strands of nucleotides linked together
  - Polymer – polynucleotides (nucleic acids)
  - Monomer – nucleotides
- Each nucleotide has three components:
  1. Nitrogenous base
  2. Sugar (contains 5 carbon)
  3. Phosphate group



(a) Polynucleotide, or nucleic acid

(b) Nucleotide



Nucleic Acids

Deoxyribonucleic Acid (DNA)

Structure:

- Double stranded polynucleotide made up of phosphate, sugar (Deoxyribose) and bases (Adenine, Thymine, Guanine and Cytosine)
  - A pairs with T
  - G pairs with C

Certain sections of DNA makes up a gene

Functions:

1. Codes for proteins
2. Stores hereditary information

Nucleic Acids

Ribonucleic Acid (RNA)

RNA is a chain of nucleotides that serves as an important information molecule.

Structure:

The structure of RNA is slightly different from that of DNA.

- The sugar in RNA is ribose (not deoxyribose).
- RNA molecules have only one strand of nucleotides.
- The nitrogenous bases used are adenine, guanine, cytosine, and uracil

(rather than thymine).

Function:

Plays an important role in the creation of new proteins

Nucleic Acids

Comparison of DNA and RNA

	DNA	RNA
Structural Name:	Deoxyribonucleic Acid	Ribonucleic Acid
Function:	Codes for proteins and stores hereditary information	Plays an important role in the creation of new proteins
Structure:	Double- stranded molecule	Single-stranded molecule
Sugars:	Deoxyribose	Ribose
Base Pairing:	A-T (Adenine-Thymine), G-C (Guanine-Cytosine)	A-U (Adenine-Uracil), G-C (Guanine-Cytosine)

Summary

	Protein	Nucleic Acid	Lipid	Carbohydrates	Small molecules
Made of	Long chains of 20 kinds of amino acids	Long & short chains of nucleic acid bases form DNA, RNA, also ATP, GTP, ...	Phosphate or or other charged "head" with long hydro-carbon tail	Long & short chains of sugar molecules like glucose, fructose.	Various molecules such as hormones, vitamins, neurotransmitters, porphyrins
Functions	Most of the structure and function of living things; enzymes	Information storage (RNA, DNA), structure, enzymes, energy transfer	Energy storage Insulation Cushioning Membranes	Energy source Energy storage Structure	Mostly sending signals

"You have to realise that as a potato
you are a very complex carbohydrate."