Organic Chemistry

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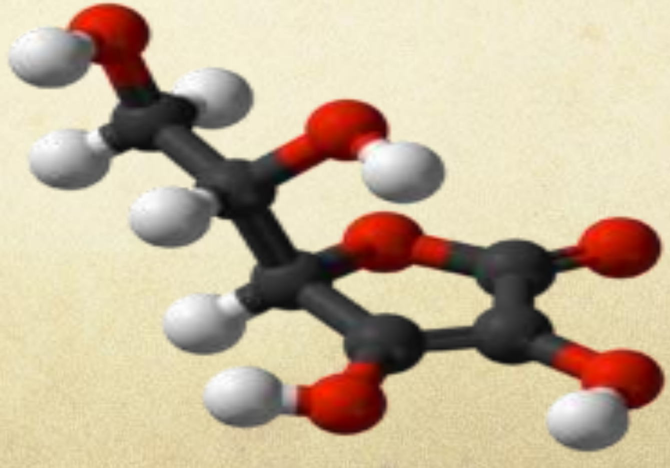
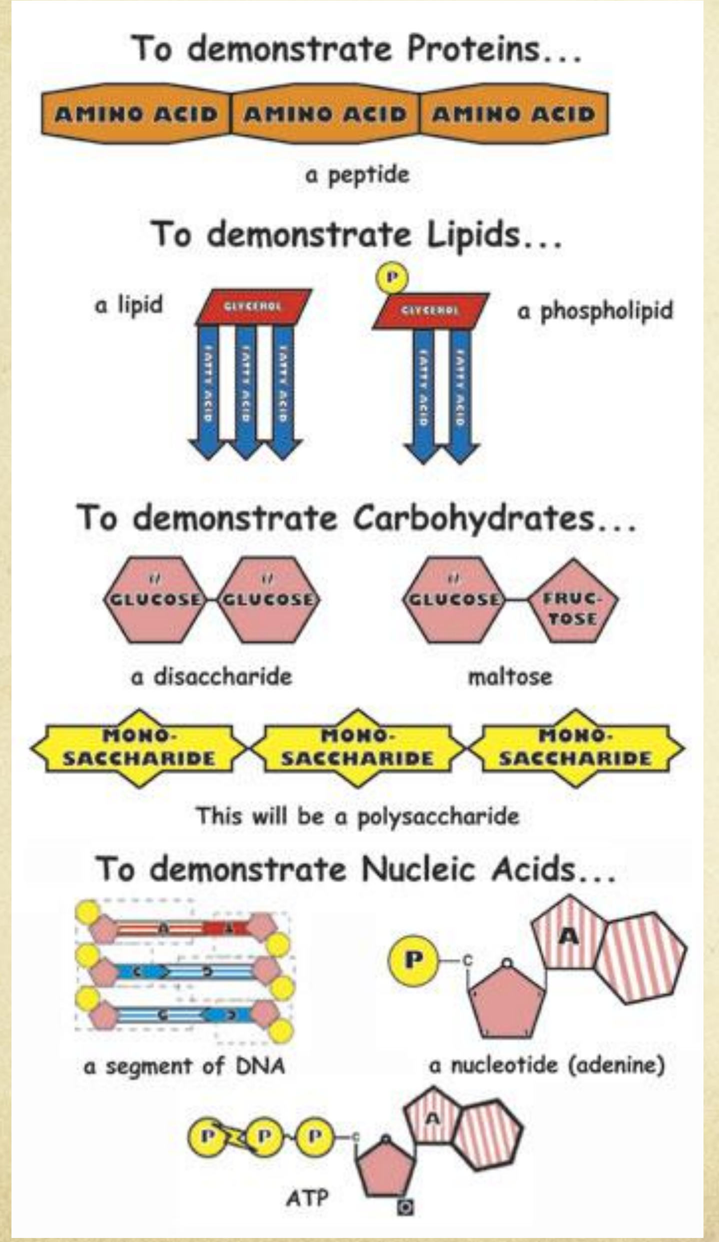
- Organic compounds contain **carbon** atoms bound to (mostly) **hydrogen, oxygen,** and **nitrogen.**
- Most organic compounds contain **rings** or **chains** of C-atoms with **functional groups** attached.
- **Chemical reactions** between organic molecules usually involve the molecules' **functional groups.**



FUNctional Groups

Group	Chemical Formula	Characteristic
Hydroxyl	-OH	Polar
Carboxyl	COOH (COO^-)	Acid
Amino	$-NH_3$ ($-NH_4^+$)	Basic
Sulfhydryl	-SH	Polar
Phosphate	$-PO_4^{-2}$	Acid

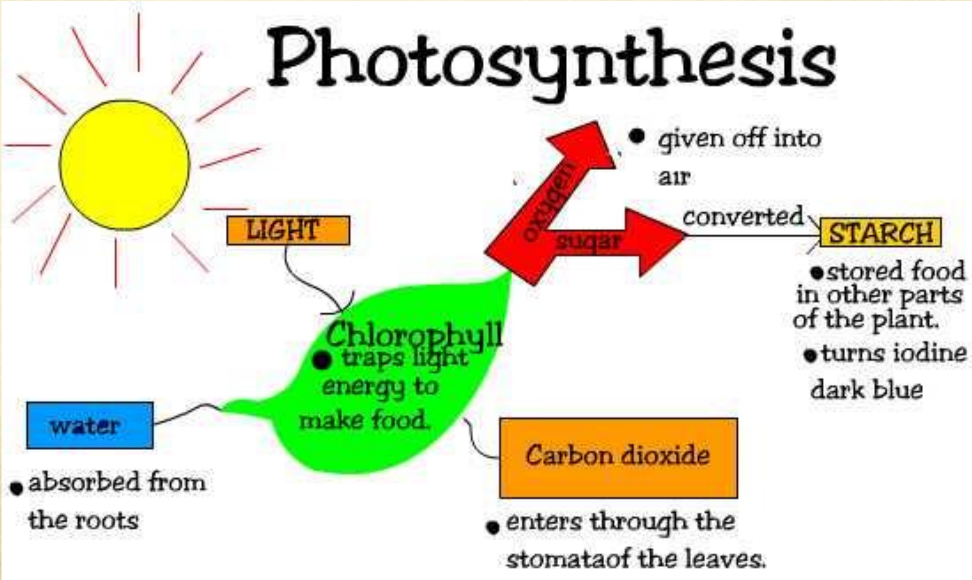
Biological Compounds



- Because of their **large** size, containing several **carbon atoms** and many **functional** groups, organic molecules are called **macromolecules.**
- There are **4** major groups of biologically important molecules: **carbohydrates, lipids, proteins,** and **nucleic acids**

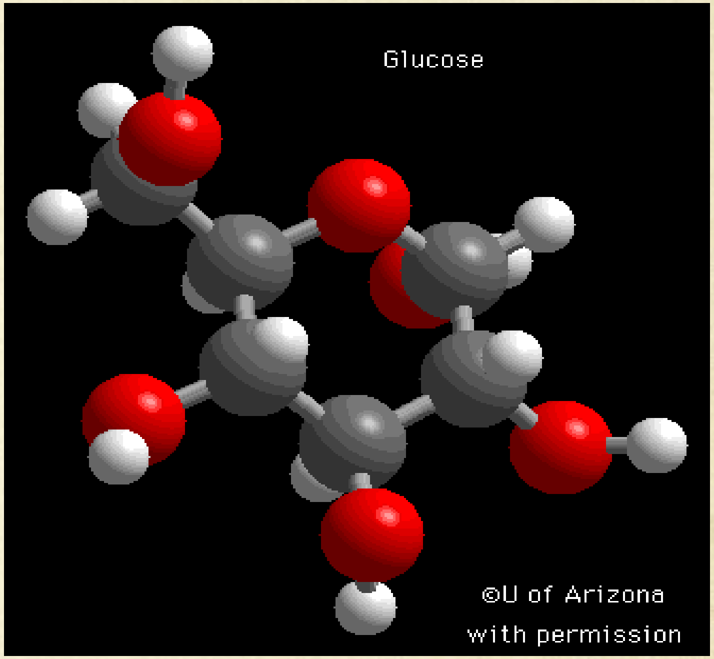
Carbohydrates

- Carbohydrates contain **carbon, hydrogen,** and **oxygen** and are used mainly as a source of **energy.**
- Plants and **cyanobacteria** produce carbohydrates by the process of **photosynthesis**
  - they are mainly *sugars* and *starches* and provide short-term energy to cells.



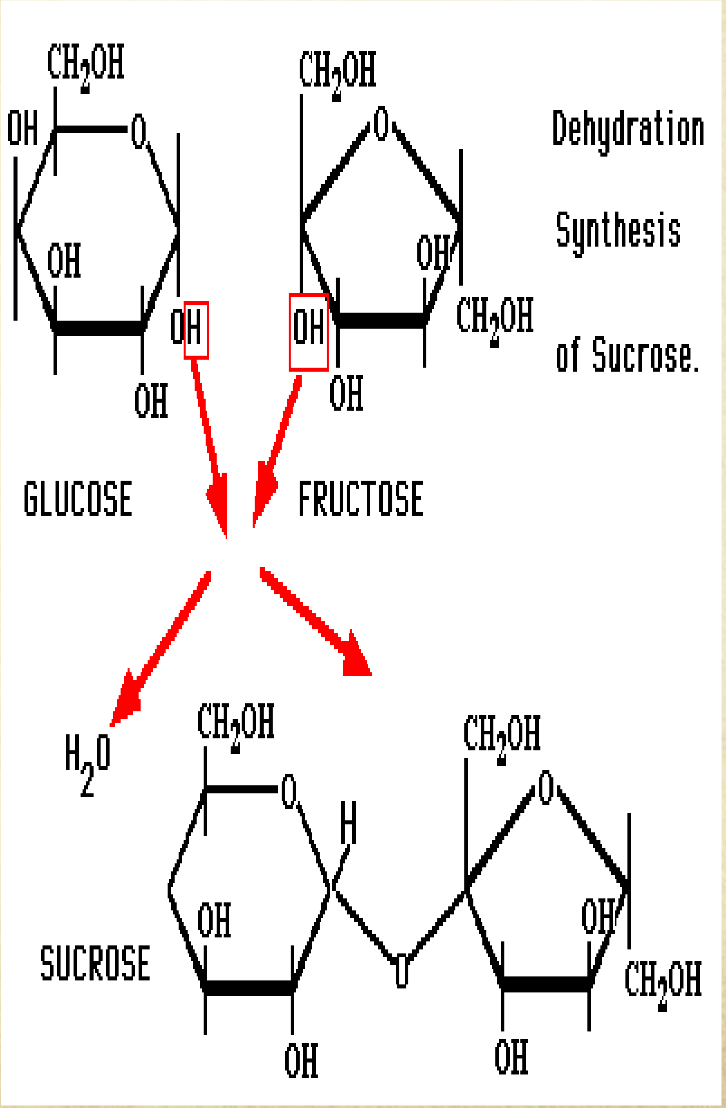
Monosaccharides (Simple Sugars)

- The simplest sugars are **sweet-tasting** and the name comes from the Greek for **"single"** and **"sweet thing"**.
- The most important monosaccharides have **6** carbon atoms and a number of **hydroxyl** groups.
- Glucose has the chemical formula $\mathbf{C_6H_{12}O_6}$
  - **fructose** and **galactose** are examples of other simple sugars.

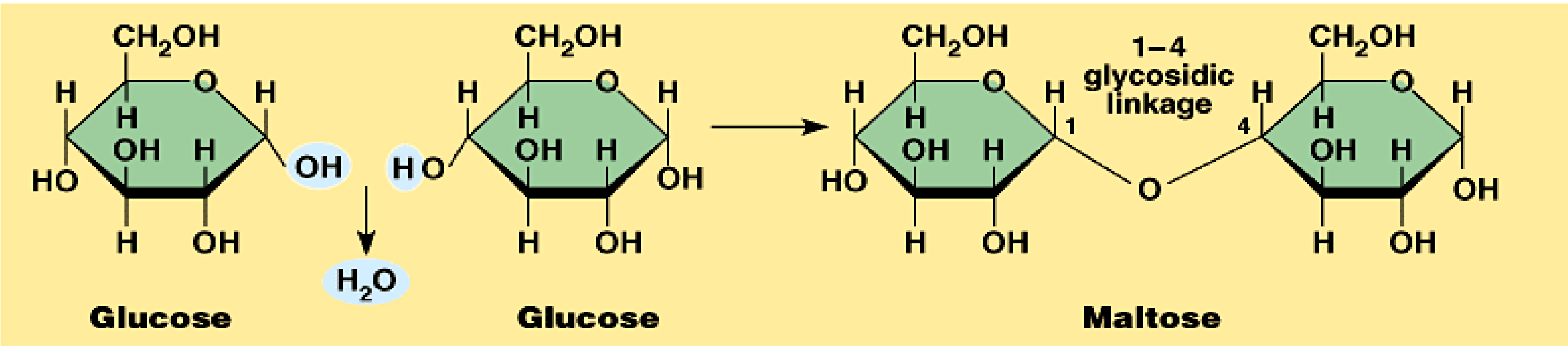


Disaccharides (Double Sugars)

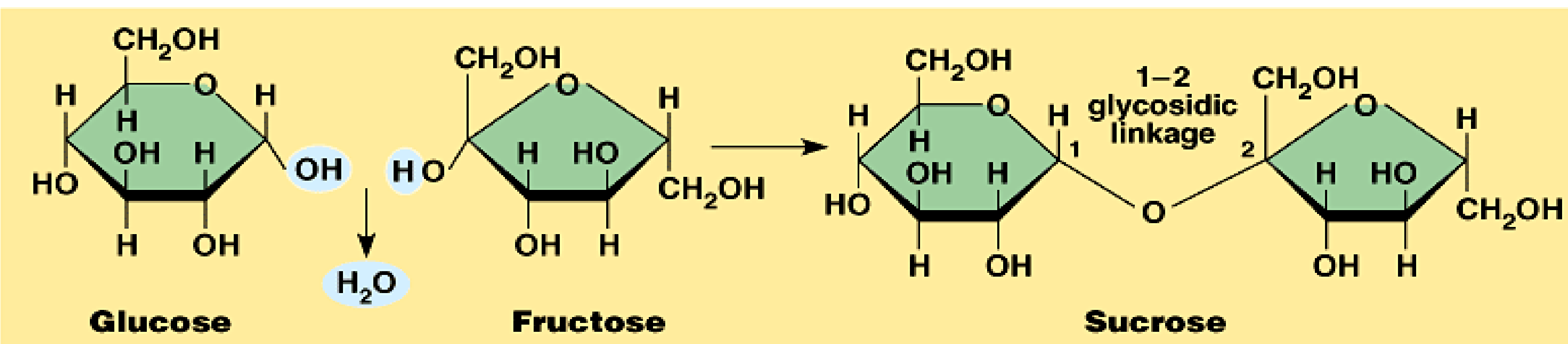
- Two simple sugars may link together to form a **disaccharide**
- Sucrose **(table sugar)** is formed when a molecule of **glucose** links to a molecule of **fructose** in a process called **dehydration synthesis**
- **Hydroxyl** groups of glucose and fructose react, leaving an **oxygen** link and creating a **water** molecule



Dehydration Synthesis

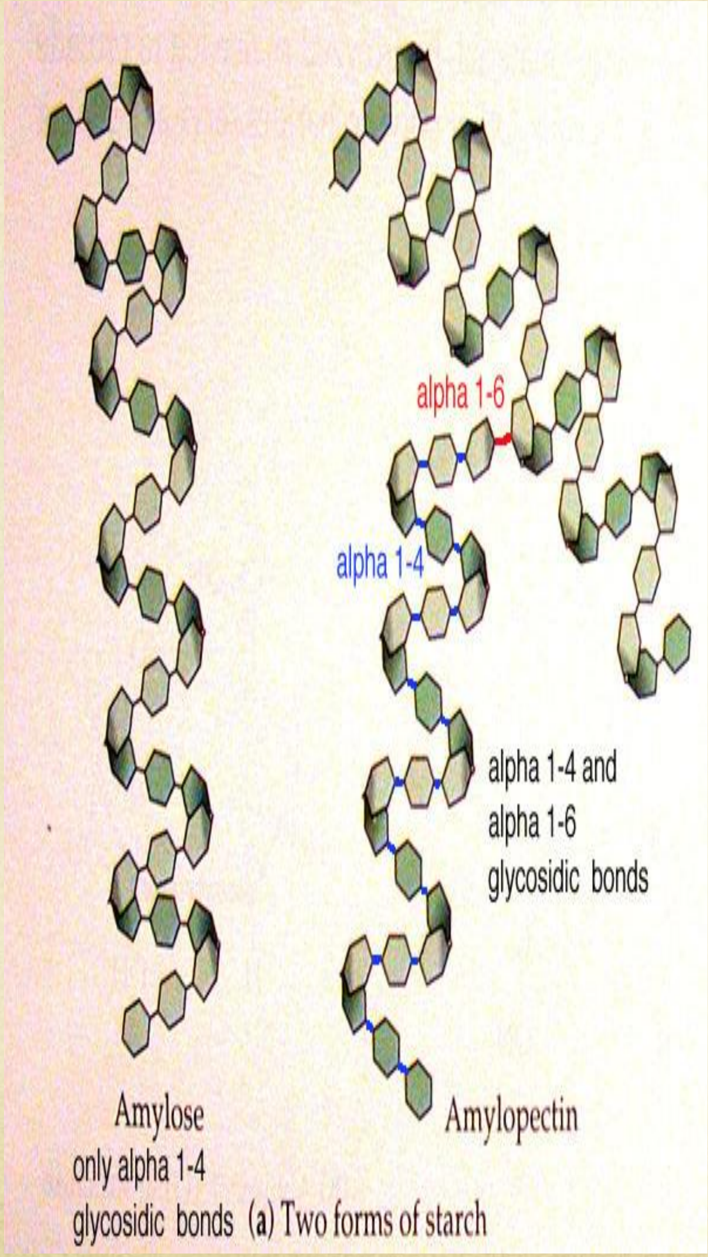


(a) Dehydration synthesis of maltose



(b) Dehydration synthesis of sucrose

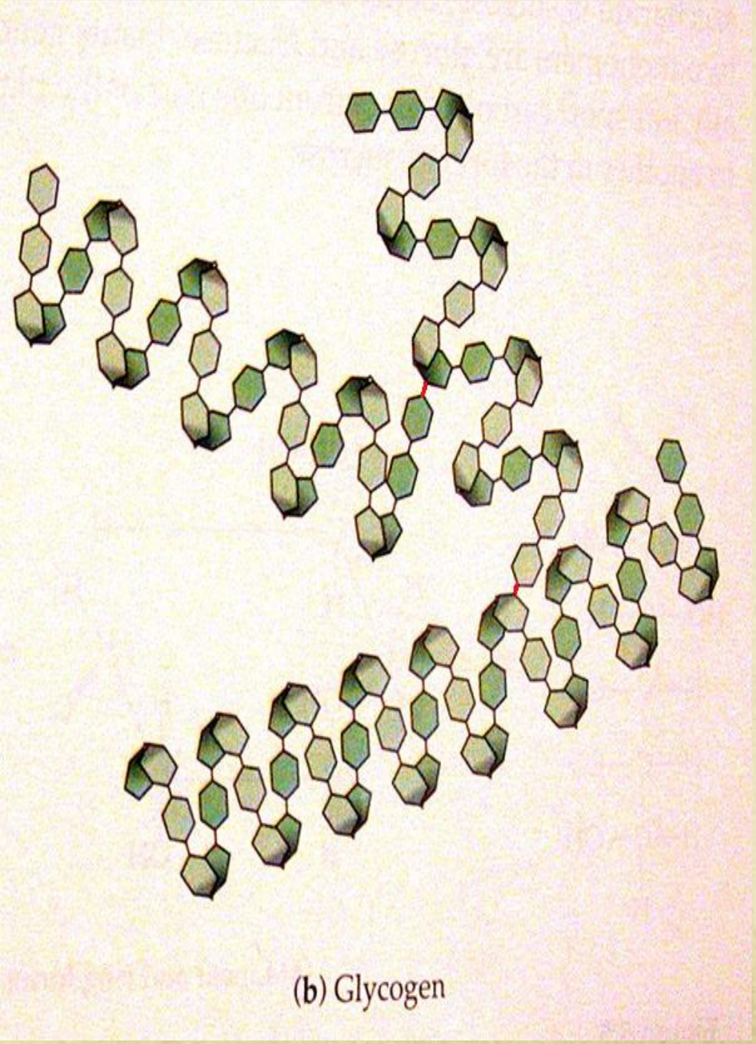
Polysaccharides (Complex Carbohydrates)

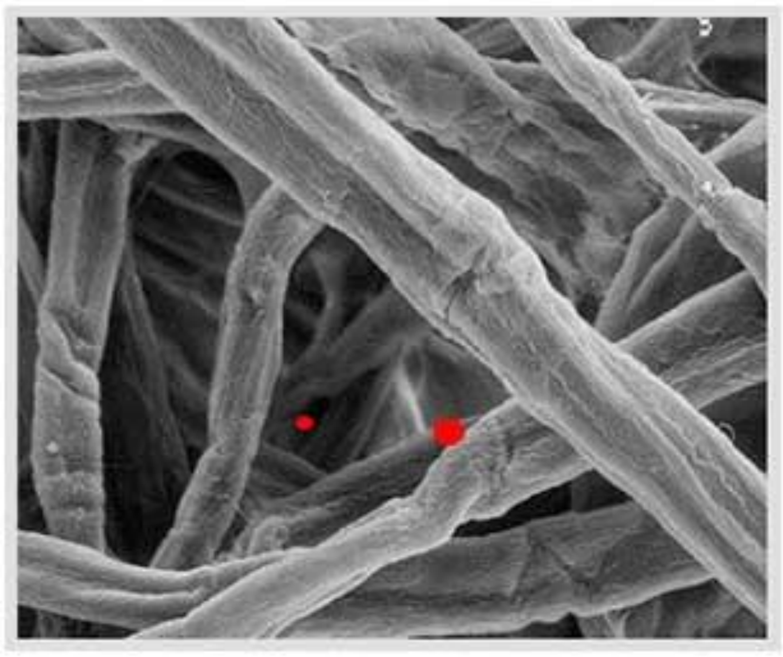


- Monosaccharides and disaccharides are **soluble** in water because their hydroxyl groups form **hydrogen** bonds with the **hydrogen** and **oxygen** atoms of water

Starch

- Animal starch
  - Is called **glycogen,** formed from chains of glucose that are highly **branched.**
  - Starch is a common component of **food,** found in large quantities in **rice, wheat flour, cornstarch,** and **potatoes**

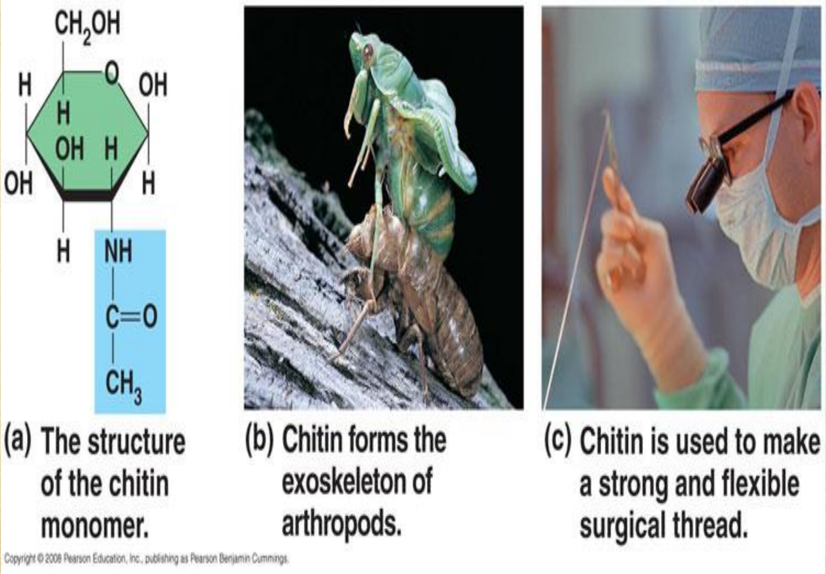




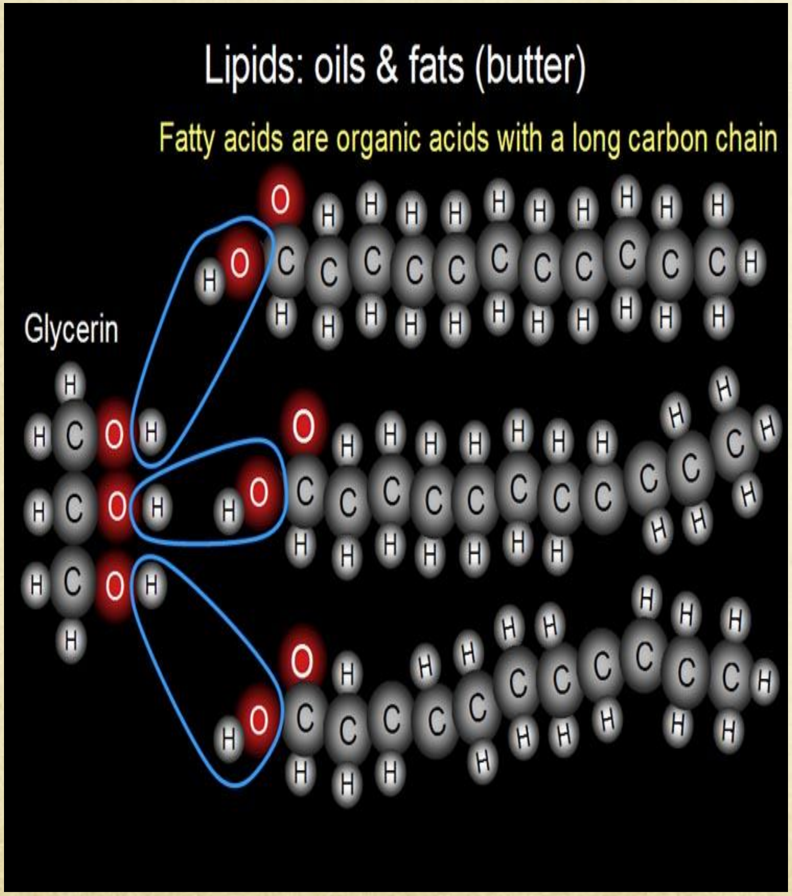
Starch

- **Cellulose** makes up plant **cell walls**
  - Humans cannot **digest**
  - The major component of **wood, paper,** and **cotton** (for clothing).
  - Cellulose is important for human health because it attracts **water** and **mucus** in the digestive system, and aids in the elimination of **solid waste**, helping to prevent **constipation.**

- **Chitin** is a modified form of **cellulose** found in **insect** and **crustacean** exoskeletons as well as **mushrooms**



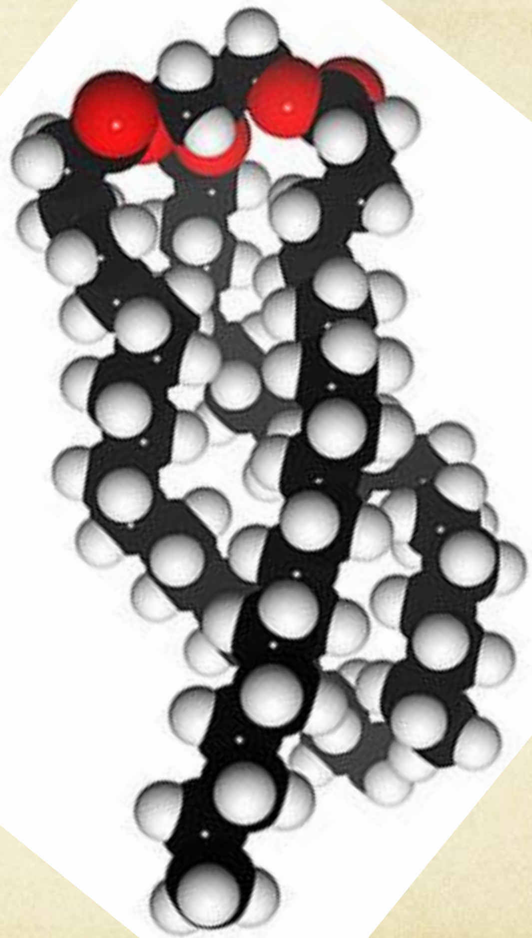
Lipids



- Lipids are also molecules made up of carbon, hydrogen, and oxygen, but have a higher proportion of **hydrogen** atoms
  - They store more chemical energy than **carbohydrates** and are used by **animals** as major **energy-storage** molecules (cells in **fat** tissue are full of lipid molecules).
  - Lipids are soluble in **oils and other nonpolar sovents**, but are insoluble in **water** and **aqueous** solutions.
  - Lipids include **oils, fats, waxes, phospholipids,** and **steroids**
- Oils and fats are composed of lipid molecules called **triglycerides**

Triglyceride

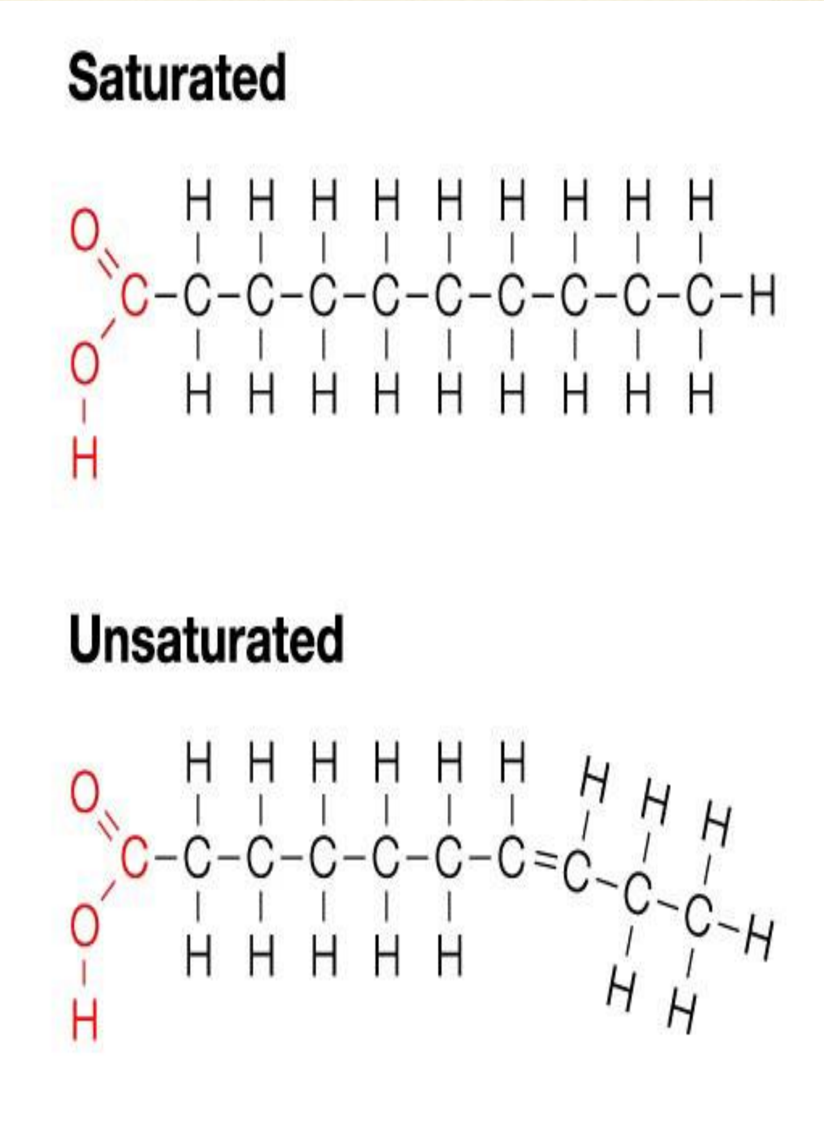
- A triglyceride contains **4** subunits: **glycerol** and **three fatty acids**
- Glycerol is a three carbon molecule with a hydroxyl group attached to each carbon atom.
- Fatty acids are long-chain of carbon and hydrogen with a carboxyl group at one end.
- To form a triglyceride, a **fatty acid** is attached to each of the **three hydroxyl groups** of glycerol



Saturated and Unsaturated Fats

- Fatty acids with only single bonds between carbons are called **saturated** and form a **straight chain**

- Fatty acids with at least one double-C bond are called **unsaturated** and produces a "kink" that prevents molecules from packing together, so they are **liquid** at room temperature and have a **low** melting point

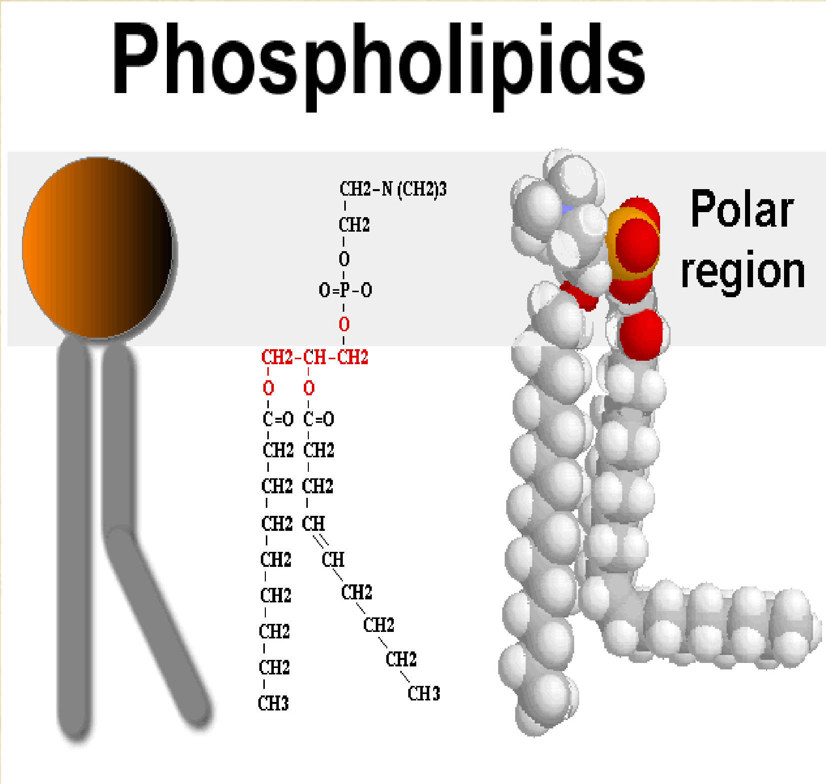


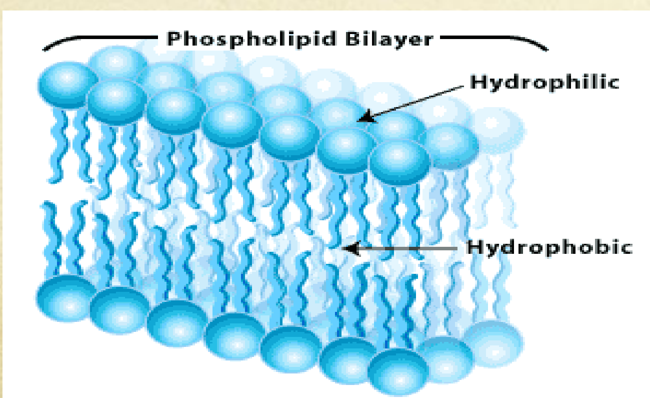
Fats

- Plants produce large numbers of **polyunsaturated** fats which are used in **cooking**
- Margarine is a **solid** fat produced from plant oils
  - **hydrogenation** adds **hydrogen** gas, reducing the number of double C-bonds and making the fatty acids more **saturated** which makes them **solid** at room temperature
  - These so-called **trans-fatty acids** have been shown to affect health, and other **saturated** (i.e. animal) fats may contribute to clogged arteries leading to **heart attack** and **stroke**

Waxes, Phospholipids and Steroids

- **Waxes** are commonly used by **plants** and sometimes by **animals** as **waterproof** coatings .



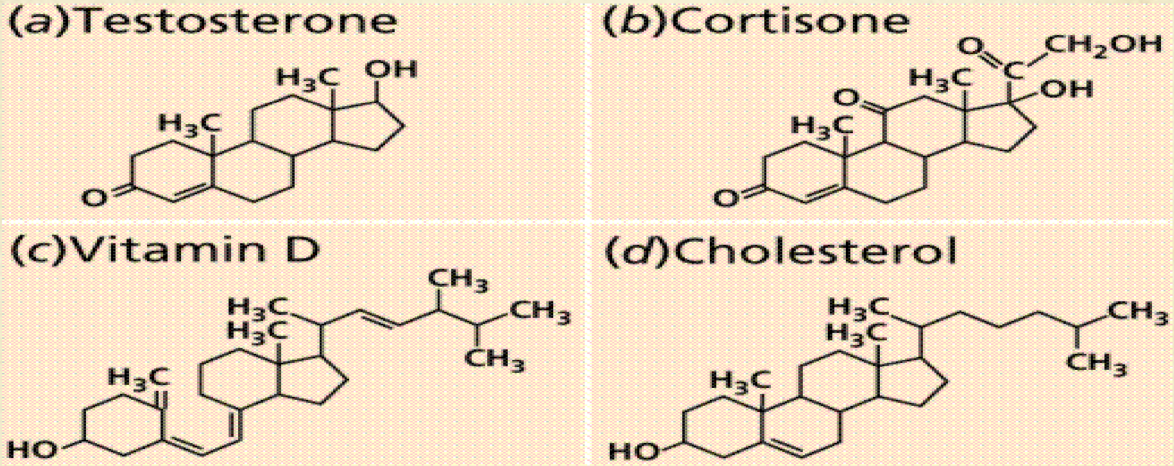


Phospholipids

- **Phospholipids** are similar to **triglycerides,** except it has a **phosphate** group
  - → Their polar head is **hydrophilic** ("water-loving"), dissolving in water, while the non-polar fatty acid tails are **hydrophobic** ("water-fearing"), so they play a key role in the structure of **cell membranes**
  - → Phospholipids allow for cell membranes to **regulate passage of fat-soluble or small molecules** in and out of the cell.

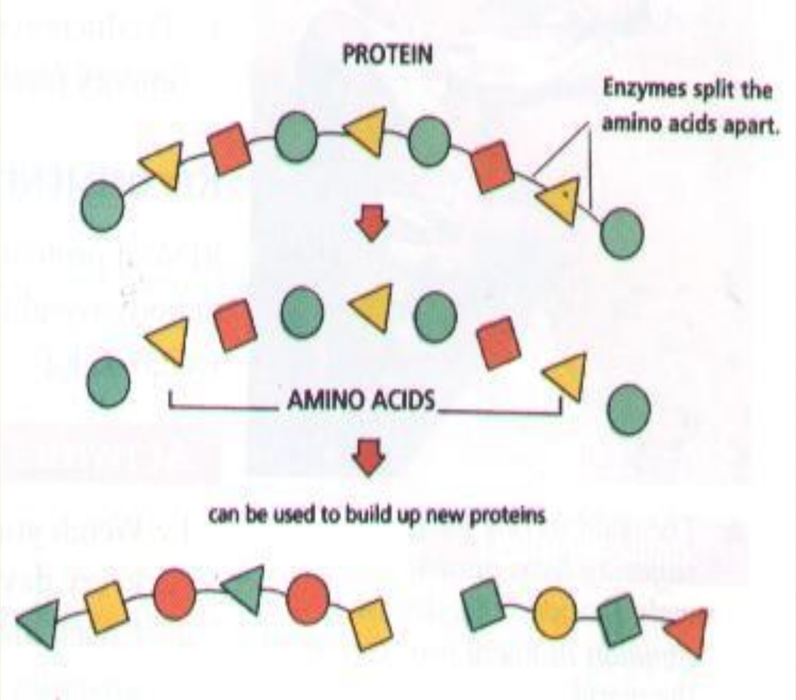
Steroids

- **Steroids** are composed of 4 **carbon rings** + side chains
  - **Cholesterol** (formation of cell membrane, breakdown of fats), **testosterone,** and **estradiol** are all steroids.
  - **Anabolic steroids** are artificial testosterones which increases strength and muscle mass, but also has severe side effects.

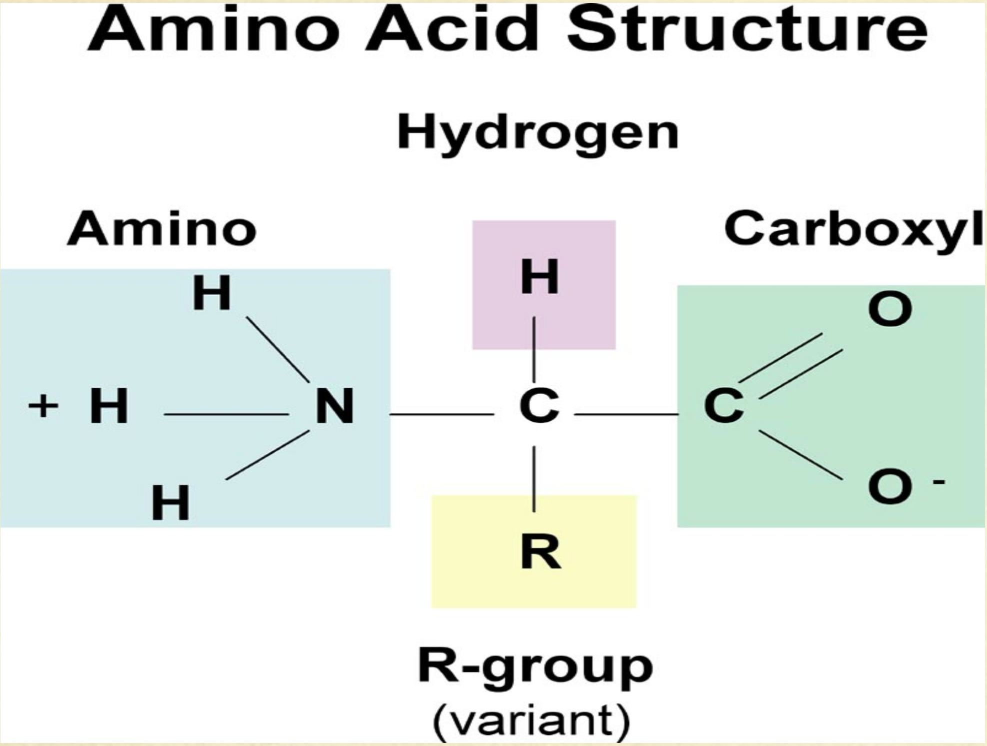


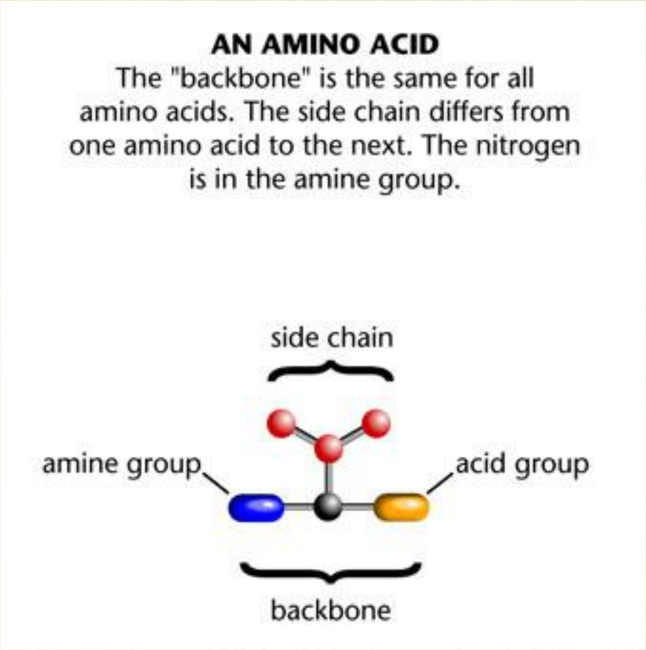
Proteins

- Proteins are the most **diverse** and among the most **important** molecules, essential to the structures and activities of living organisms.
  - Proteins are unbranched **polymers** of **amino acids**
  - **amino acids** contain a **central carbon atom** to which is attached an **amino** group (NH_2), a **carboxyl** group (COOH), a **hydrogen atom** and a **side chain**

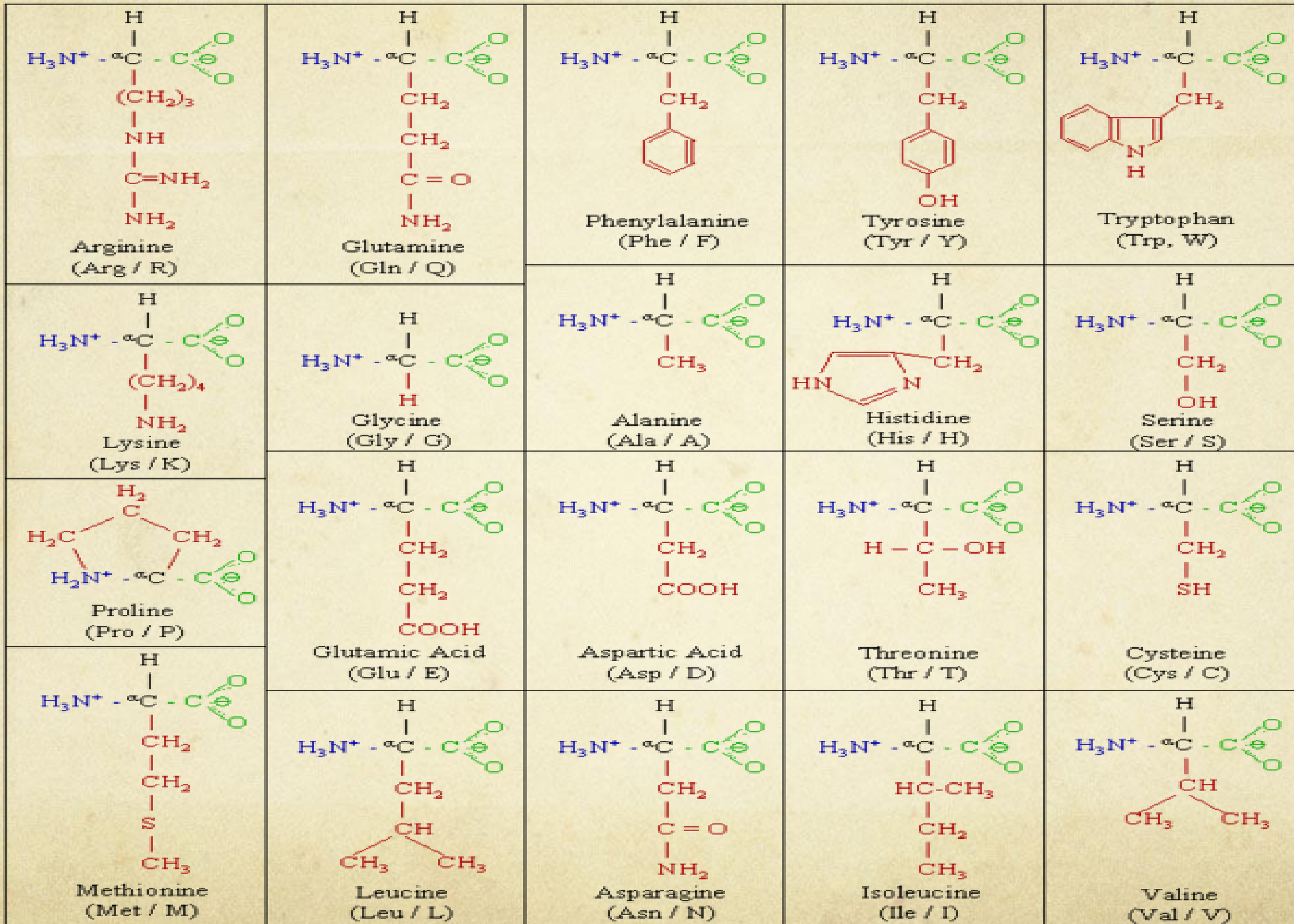


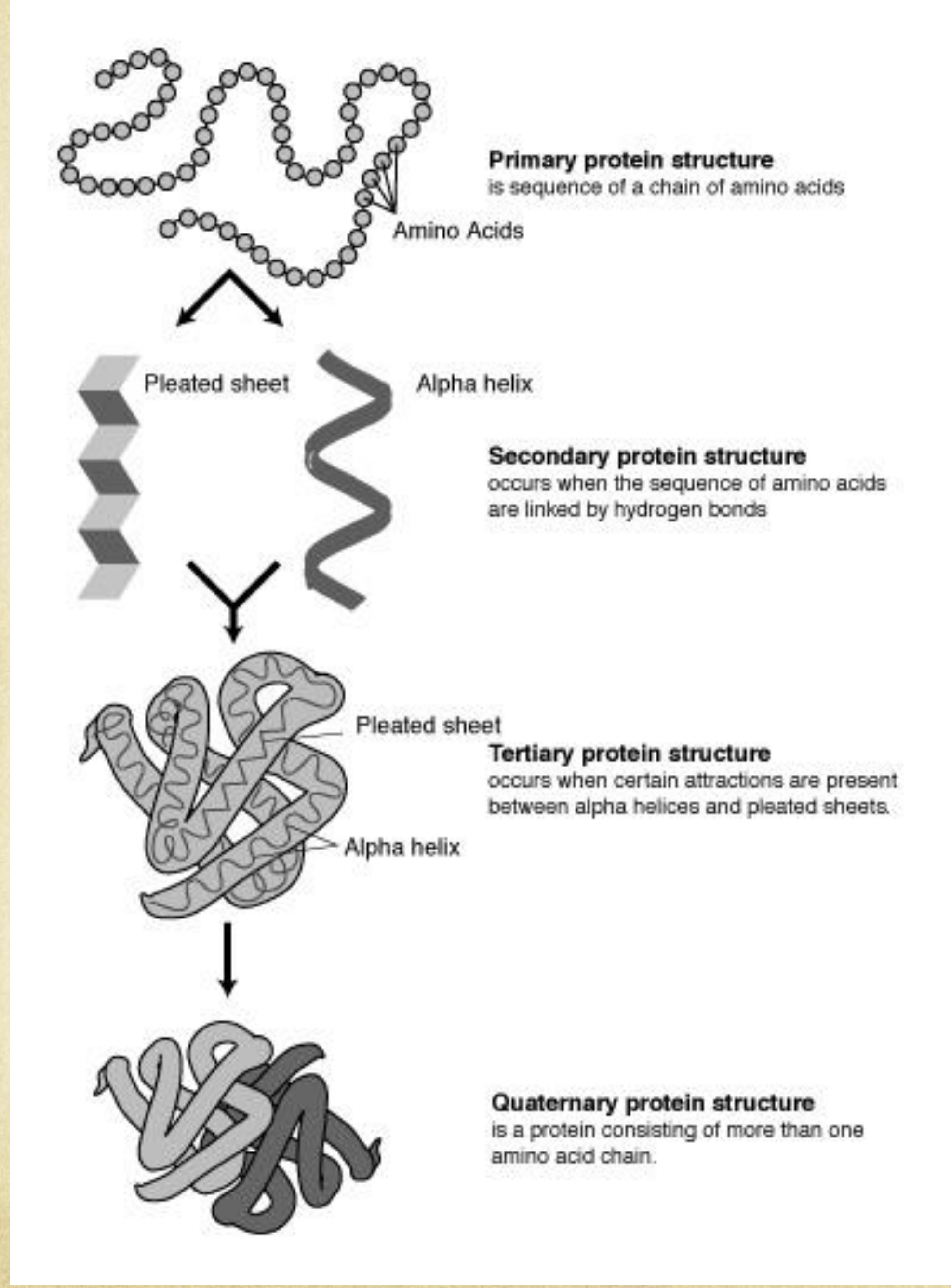
- **Twenty** different side chains determines the structure and function of each amino acid and **eight** of them are called **essential** because they can only be obtained in **food**





Amino Acids


Arginine
(Arg / R)
Glutamine
(Gln / Q)
Phenylalanine
(Phe / F)
Tyrosine
(Tyr / Y)
Tryptophan
(Trp, W)
Lysine
(Lys / K)
Glycine
(Gly / G)
Alanine
(Ala / A)
Histidine
(His / H)
Serine
(Ser / S)
Proline
(Pro / P)
Glutamic Acid
(Glu / E)
Aspartic Acid
(Asp / D)
Threonine
(Thr / T)
Cysteine
(Cys / C)
Methionine
(Met / M)
Leucine
(Leu / L)
Asparagine
(Asn / N)
Isoleucine
(Ile / I)
Valine
(Val / V)



- Protein structure production

- The **number** and **sequence** of amino acids produce many different **polypeptides** (amino acid chains), formed by a link between the **carboxyl** and **amino** groups of amino acids to form a **polypeptide** bond (Fig. 18) during the process of **protein** synthesis. As the polypeptide gets longer, forces of **attraction** and **repulsion** between **functional** groups cause it to fold into **sheets** like keratin and **silk**, and wrap into **coils**, which form globular proteins like **haemoglobin** in RBC. Proteins with the same **sequence** will fold into the same **shape** and therefore have the same function, which can be altered by a single misplaced **amino acid**.

Enzymes and other Specialized proteins

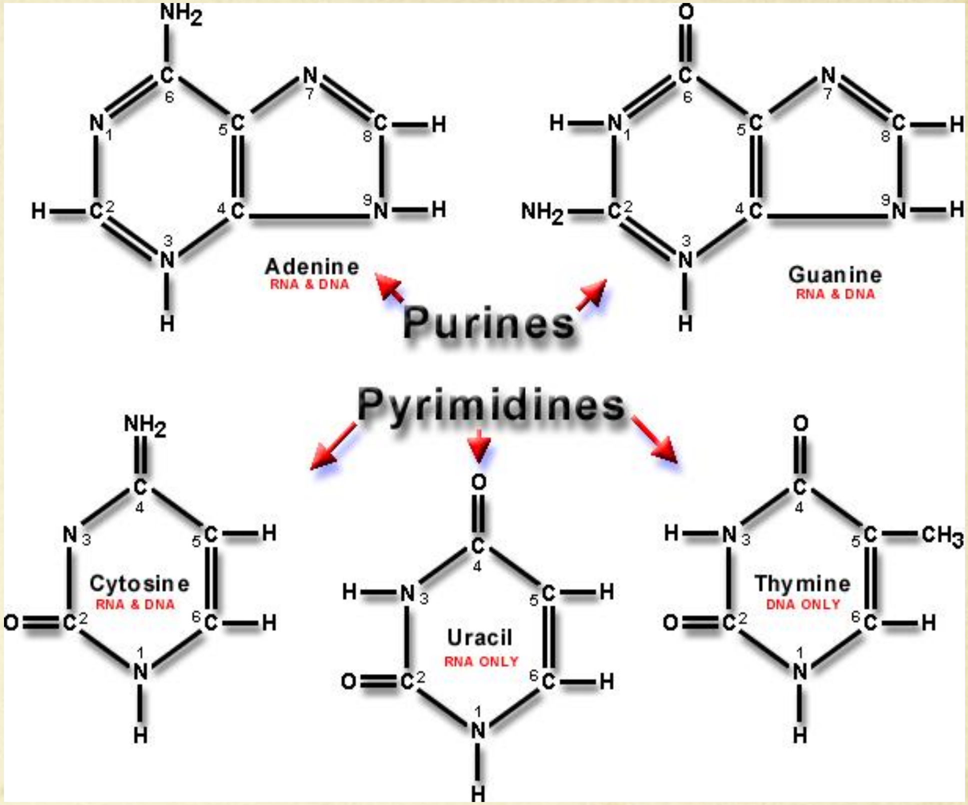
- **Enzymes** are biological **catalysts** that speed up chemical reactions
- Other proteins (i.e. hormones like insulin) act as chemical **messengers**
- Or proteins like collagen give structural **support** to **bones, cartilage,** and **tendons**
- The **chains** of amino acids in functional proteins are separated during food **digestion**

Denaturation

- Denaturation of protein in the body can be dangerous, while pickling foods in vinegar denatures **the enzymes** in food spoilage **bacteria**.
- Protein in **hair** can be denatured to curl or straighten it, and the denaturation of **fibrous** protein in meat makes it easier to chew

Nucleic Acids

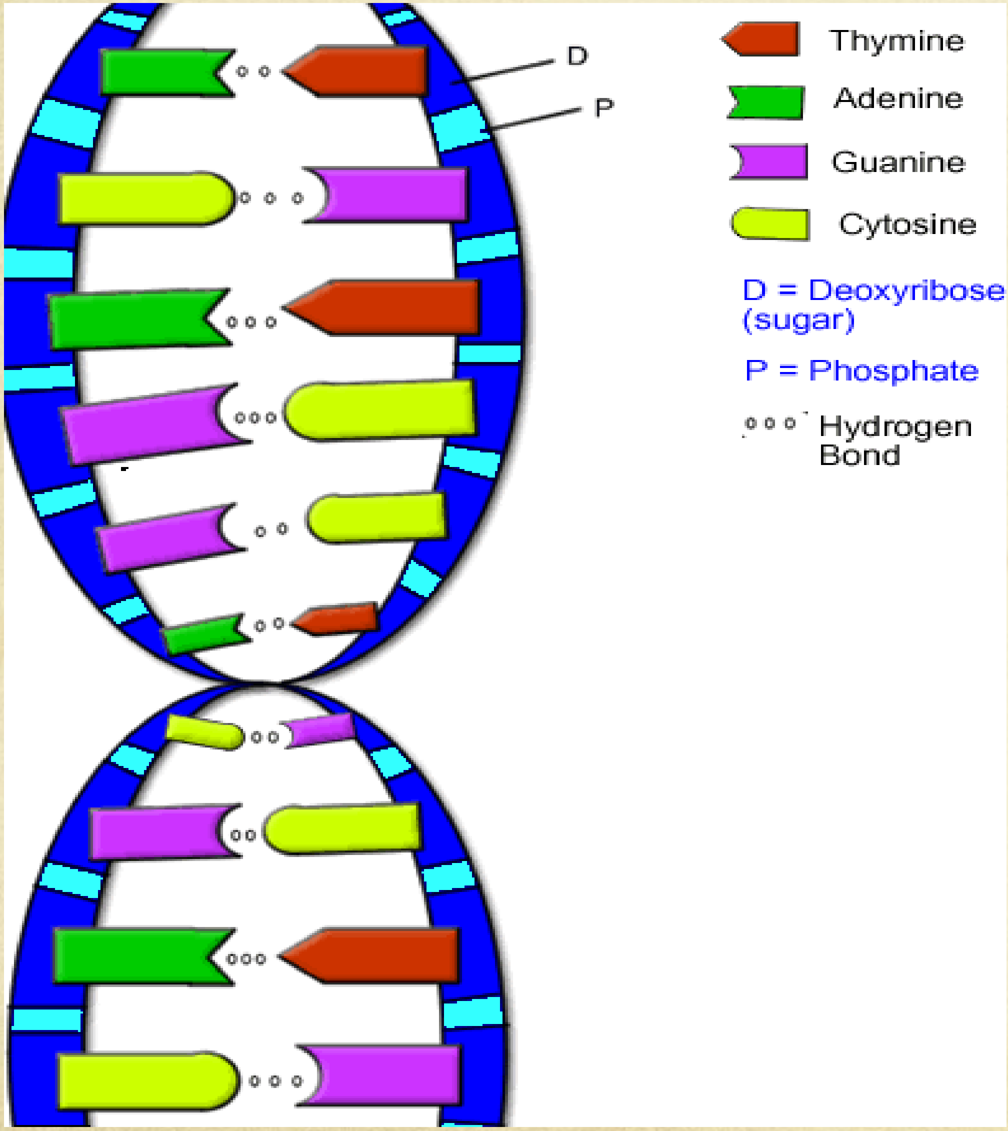
- Nucleic acids form **DNA, RNA**
- They are **polymers** formed from **nucleotide** monomers
- Each nucleotide is formed from 3 subunits: a **five-carbon pentose sugar,** a **phosphate** group, and a **nitrogenous** base.



DNA

- Polymers of nucleic acids form by **dehydration synthesis**, sugar-phosphate groups forming sides of "ladder", **nucleic acid** ('rungs") facing inwards, linked to each other by formation of weak **hydrogen** bonds so that only specific pairings are possible (**complementary base pairs**).
- **DNA** is always **double** -stranded; "unzipping" and rebuilding by attachment of **complementary nucleotides** allows for exact **replication** of molecule (i.e. reproduction).
- DNA stores the information for making **proteins**. The set of instructions in DNA that codes for a complete protein is called a **gene**. The Human **Genome** Project, which sequenced all the nucleotides in all 46 chromosomes, showed there are **3 billion** base pairs, and between **30000** and **35000** genes in the human genome.

DNA



- DNA stores the information for making **proteins**
  - The set of instructions in DNA that codes for a complete protein is called a **gene**

RNA

- **RNA** is usually **single -** stranded, but can form H-bonds and a **double helix. messenger** RNA (mRNA) take the genetic information in DNA out of the **nucleus** to **ribosomes** in the **cytoplasm** where **proteins** are produced.
- DNA stays **place** in the nucleus