Cellular and Molecular Biophysics

Lecture 9

Cells:
Its Organelles and Molecules:
Water, Carbohydrates, Lipids

Cell - is a fundamental unit of life

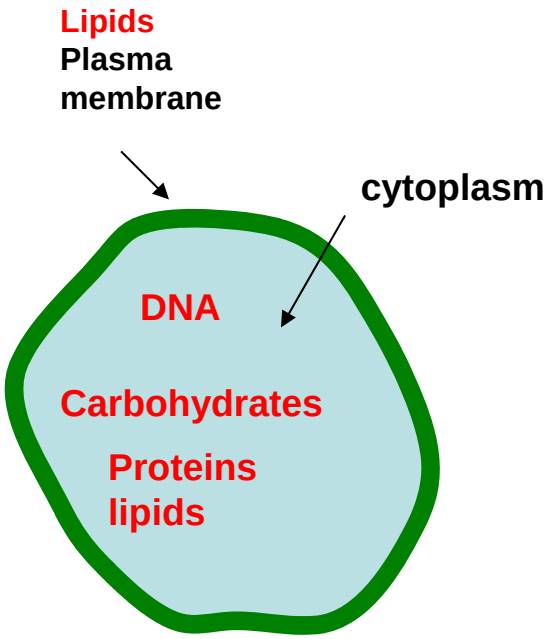
- Basic molecules:

- DNA – the only molecule that duplicate
- Proteins – associate with DNA for various purposes
- Carbohydrates – supply energy
- Lipids – form a membrane to enclose all components of cell
- Water 65-80% of cell by weight, effective solvent

- More complex cells have compartments: organelles

- Nucleus is a central core, membrane bound organelle, stores and transfers genetic information (DNA)

- Prokaryotes – more primitive cells (no nucleus)
- Eukaryotes – have nucleus

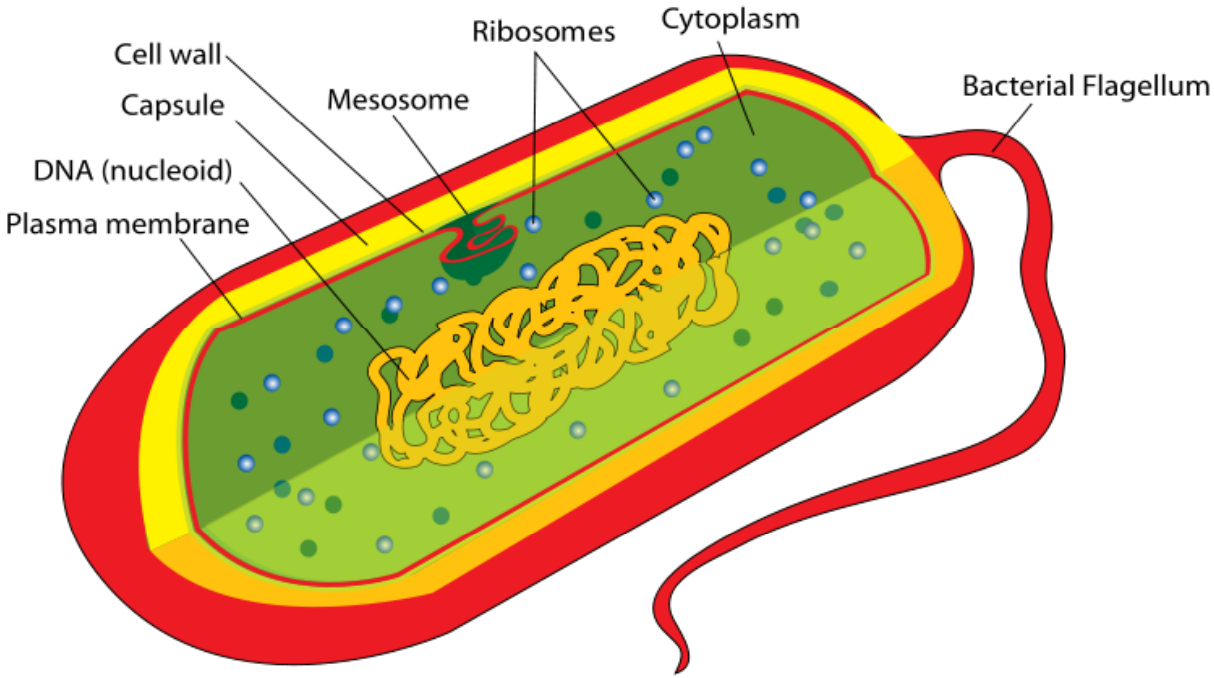


The simplest cell

Structure of Prokaryotes

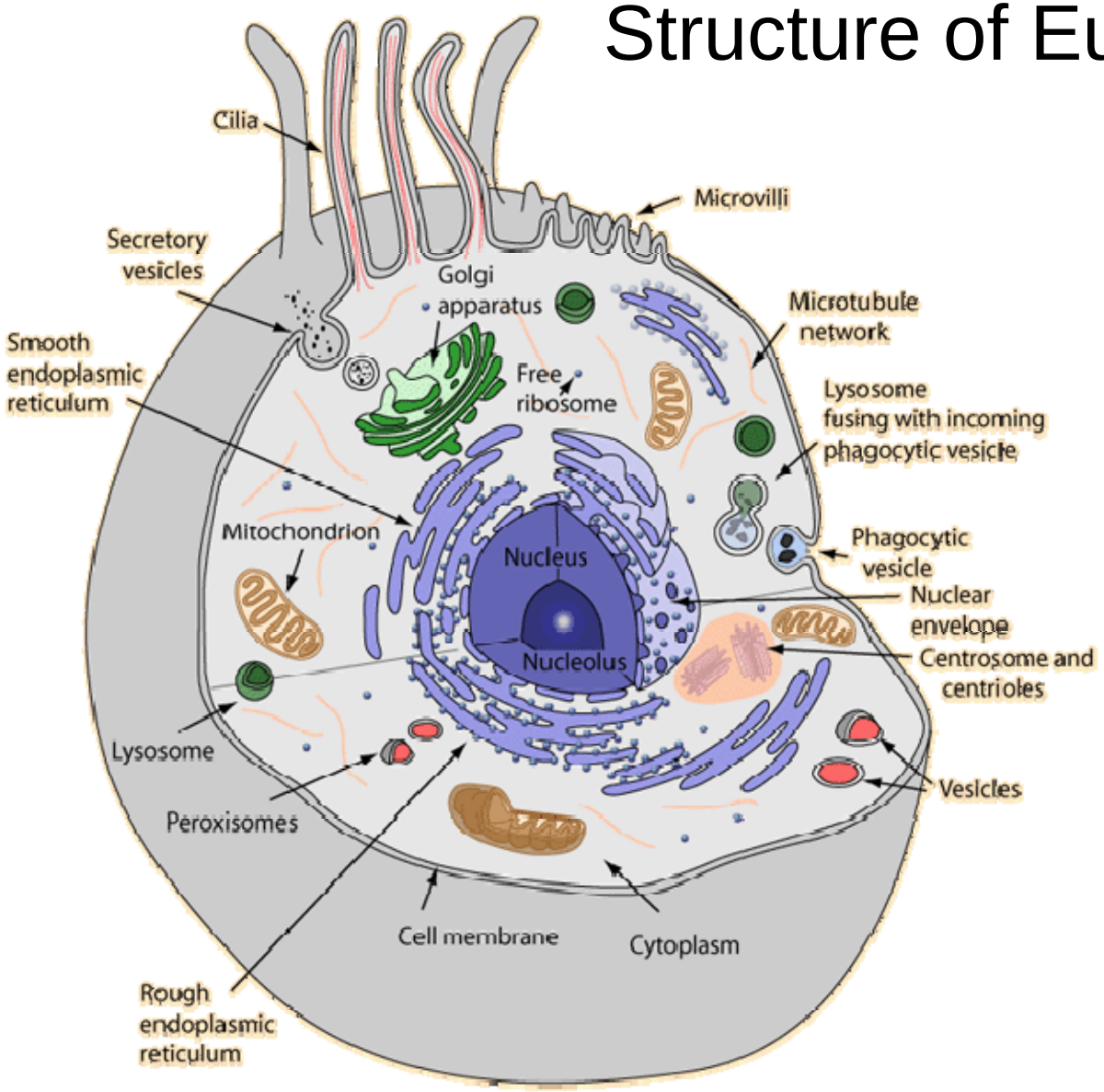
- No nucleus no organelles, prokaryotes are more primitive cells
- **prokaryotes** are a group of organisms that lack a cell nucleous (=karyon).

- 90% water
- rigid cell wall
- Nucleotide–single
- chromosome
- made of DNA



- Example:
- Viruses
- Bacteria
- Blue-green algae

Structure of Eukaryotes

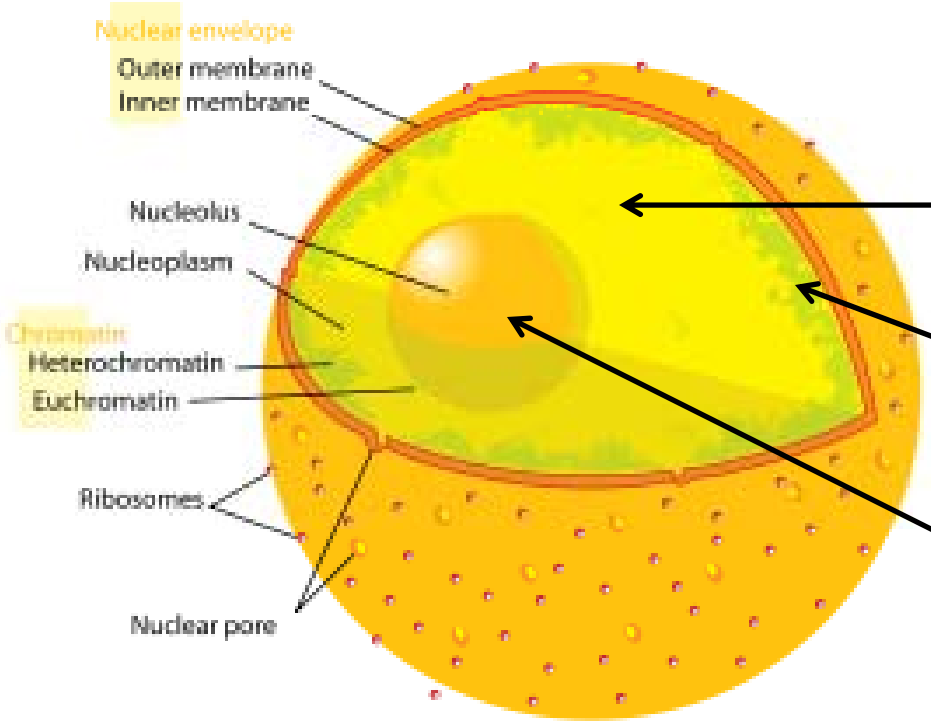


- Cytoplasm-fluid region inside the cell
- Inside the cytoplasm are organelles:
- Nucleus (genetic inform)
- Mitochodria (energy)
- Endoplasmic reticulum (protect and transport)
- Golgi complex (storage and transport)
- Lysosomes (digestion)
- Ribosomes (protein synthesis)
- Vesicles (transport)

- Not all of them are found in every cells

Nucleus

Nucleus – organelle inside the cell, stores genetic information in DNA, transfers genetic information – RNA, initiates cell division (mitosis),
Nucleus is enclosed in membrane with pores and channels – exchange



Inside the nucleus:

Nucleoplasm – jelly like mass – contains:

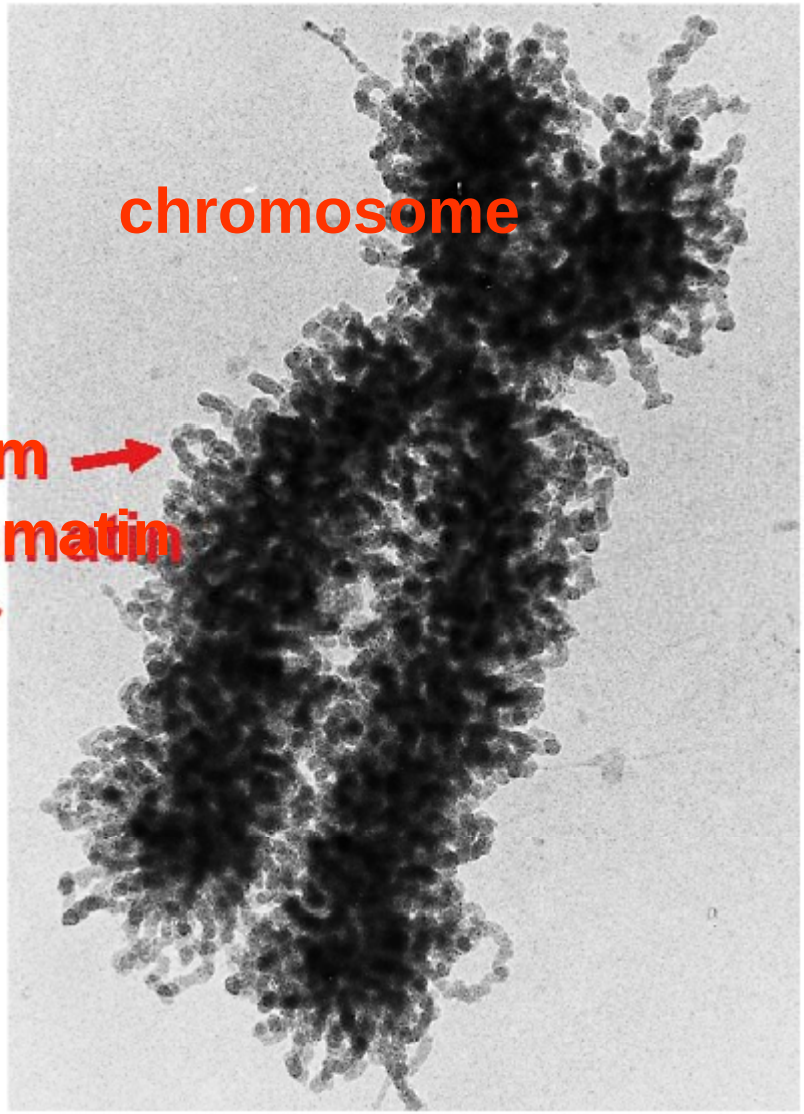
1.nuclear gel (large amount of proteins + small amounts of DNA, RNA, lipids), (replication and transcription)

2.chromatin (large fiber-like body made of large amount of DNA and basic proteins - histones

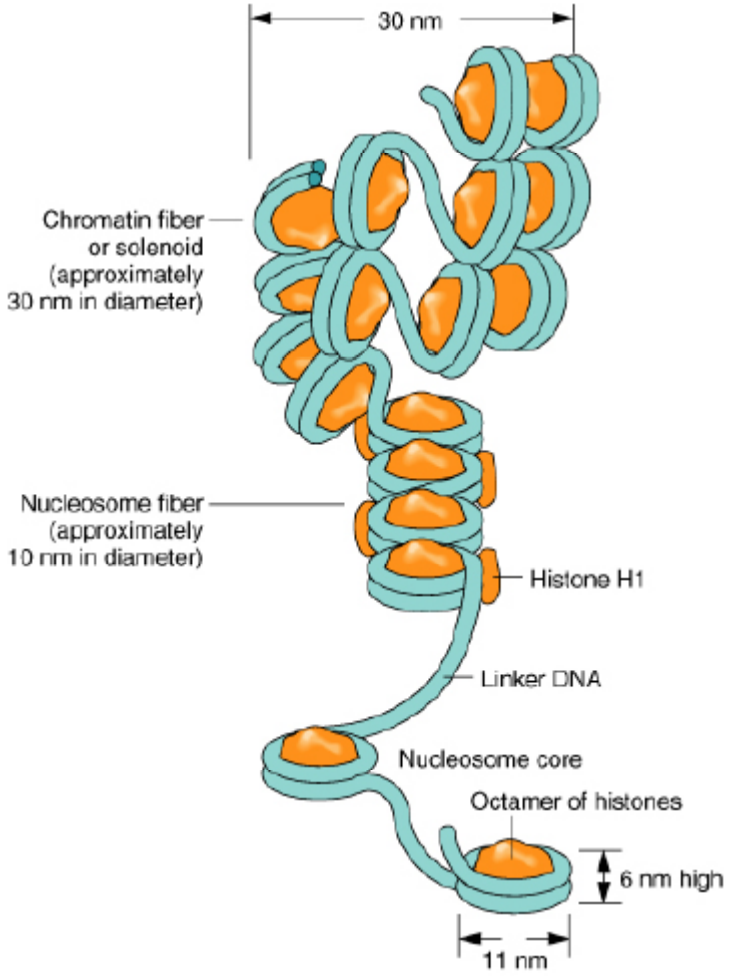
Nucleolus – large ribonucleoprotein

Function of nucleolus - transcription of genes that code for ribosomal RNA– factory of ribosomes

Chromatin composes chromosome



From E. DuPraw, *DNA & Chromosomes*, Holt, Rinehart, & Winston, New York, 1970. Original photo courtesy E. DuPraw

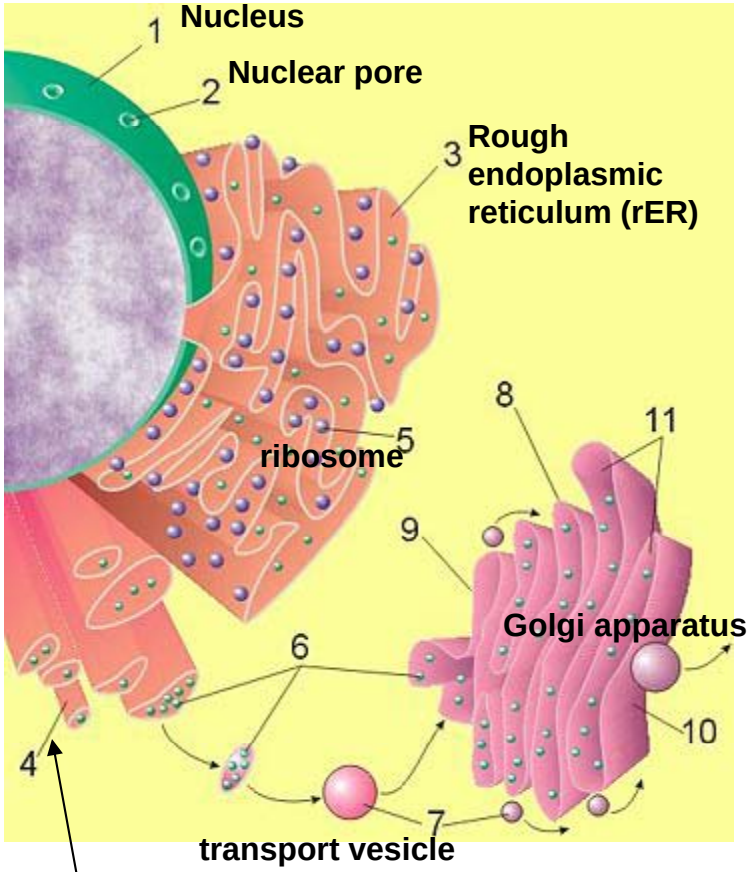


Endoplasmic reticulum, Golgi complex and ribosomes

- Endoplasmic Reticulum is complex membranous structure that serve to separate some of the products of the cell from the synthetic machinery and transport extracellular materials to nucleus.
- Rough ER - lined with ribosomes on their outer surfaces. Smooth ER - no attached ribosomes.

- Ribosomes – large nucleoproteins contain 55-60 different proteins and 3-4 RNA
- Ribosomes are sites for protein synthesis

- Golgi complex:
- synthesis of carbohydrate-rich molecules: polysaccharides and glycoproteins
- storage, transport and release of proteins, lipids, and polysaccharides,



4. Smooth endoplasmic reticulum (sER)

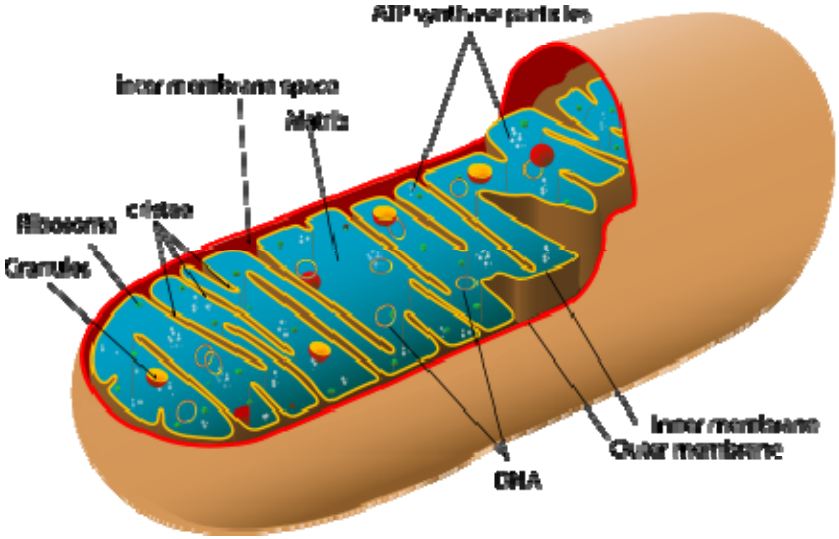
6. transported proteins

Mitochondrion

- Mitochondria are the energy factories of the cells.

- The main function – oxidation of food molecules: proteins, carbohydrates, lipids
- Energy rich molecule adenosine triphosphate (ATP) is produced in the mitochondria using energy stored in food.
- ATP converts to ADP (adenosine diphosphate) and supplies energy

- Mitochodrion has also few DNA and RNA (1:20)
  also participates in
  protein synthesis
- have ribosomes



Mitochodrion

Lysosome

- Lysosome –

- spherical single membrane body, 0.5 microns in diameter
- involved in digestion (hydrolysis of large molecules)

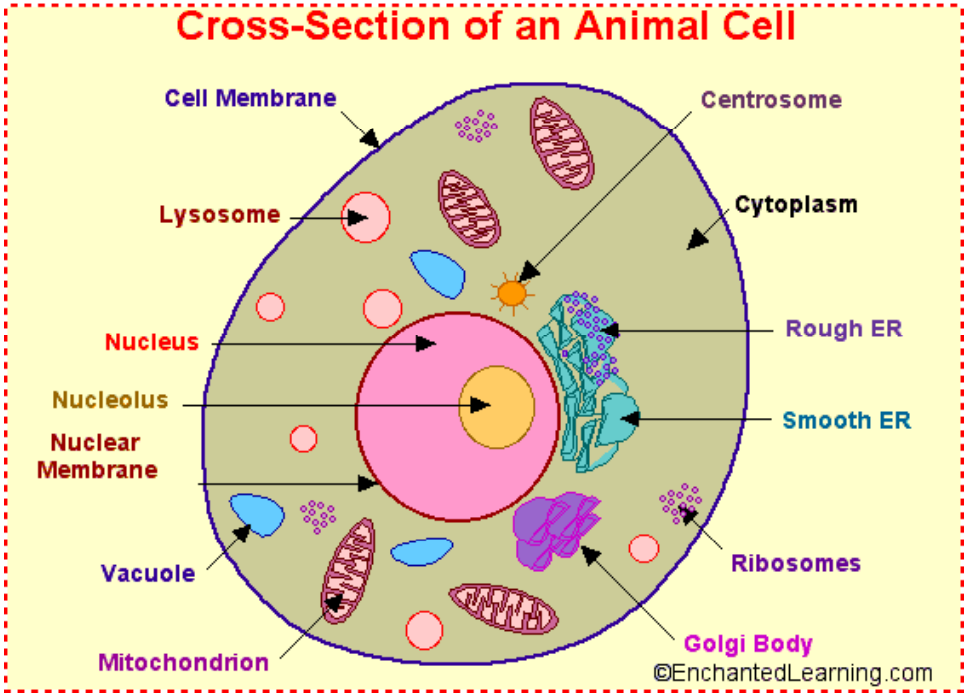
- Various enzymes – are inside the lysosome

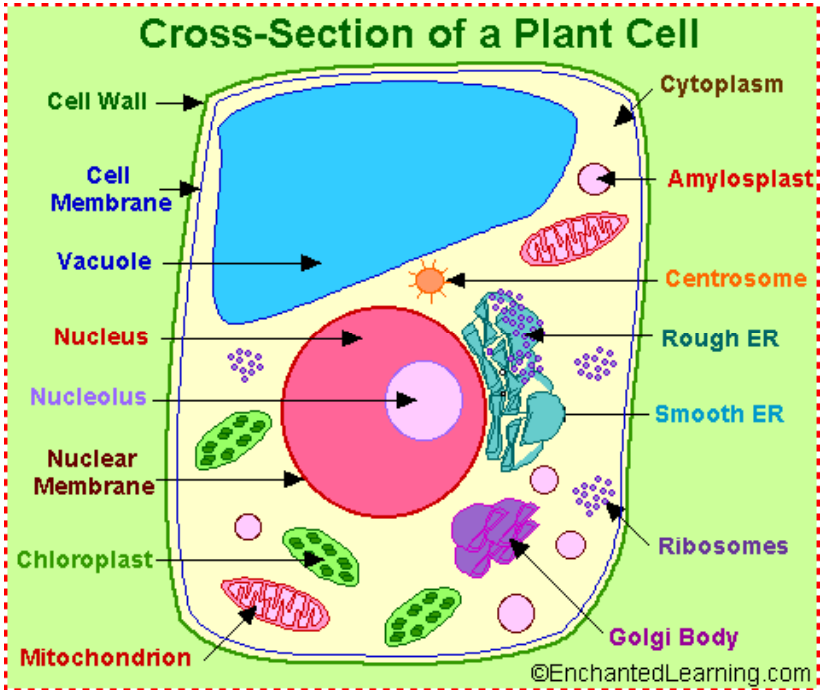
- Enzymes can digest the cell itself,
- but they are enclosed in lysosome membrane

Summary on cell organelles:
http://www.youtube.com/watch?v=LP7xAr2FDFU&feature=related

Animal and Plant cells

- Common: nucleus, mitochondria, Golgi complex, ribosomes, cell membrane
- Only in plants:
- Thick cellulose cell wall outside cell membrane, criss-cross cellulose fiber- layers
- Plastids :
- Leucoplasts (no pigment) – storage of starch, oil, proteins
- Chromoplasts (contain pigments), most common - chloroplasts (with pigment - chlorophyl) – synthesize food and produce oxygen,
- Large vacuole filled with fluid in all plant cells– shape the plant cell



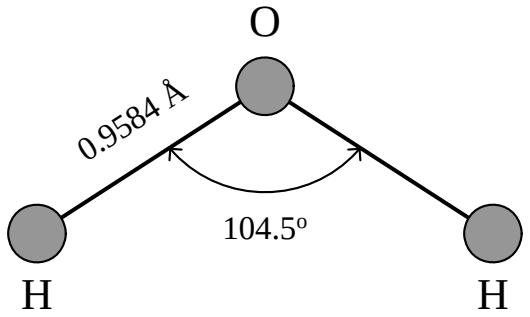


Molecular components of cell:

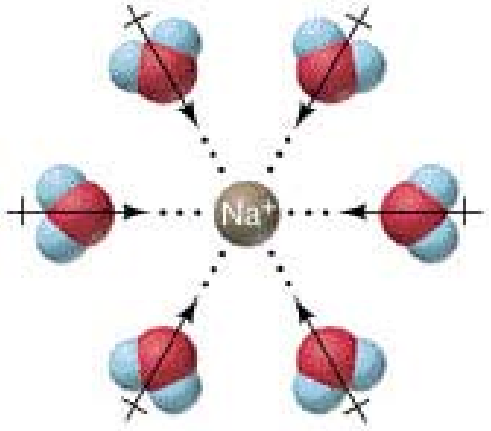
- DNA – the only molecule that duplicates
- Proteins – associate with DNA for various purposes
- Carbohydrates – supply energy
- Lipids – form a membrane to enclose all components of cell
- Water - solvent
- Heteromacromolecules – complexes of two different types of molecules

Water

- Amount of water in cell in average 65%
- Blood - 80%, Fat cells – 10-20%
- Most water 30-45% inside the cell
- 12-16% in intracellular fluids,
- 5% in blood plasma, and 2% lymph

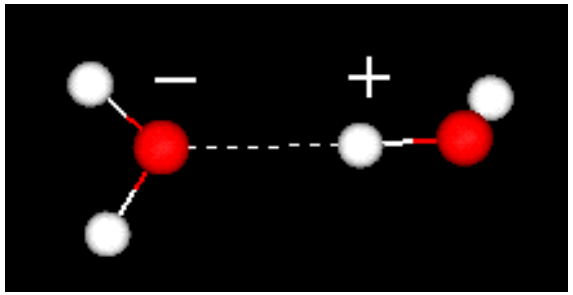


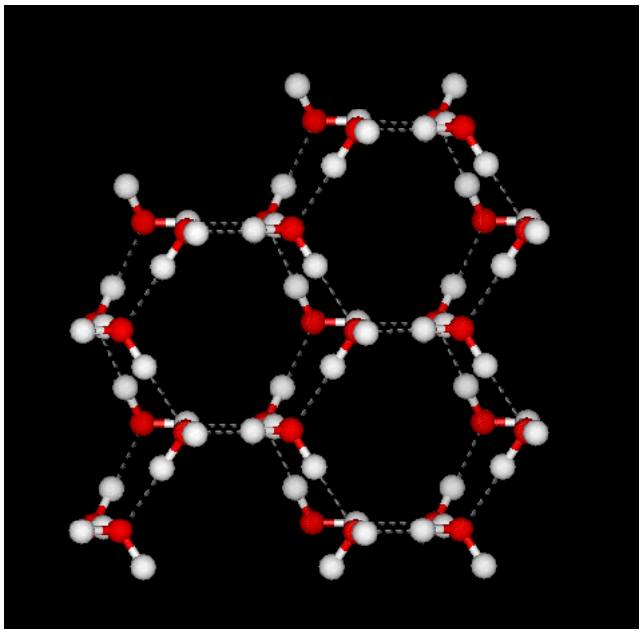
- Water has unique physical and chemical properties:
- is polar molecule, dielectric constant 80, water is very effective solvent, dissolves other substances due to electrostatic interactions



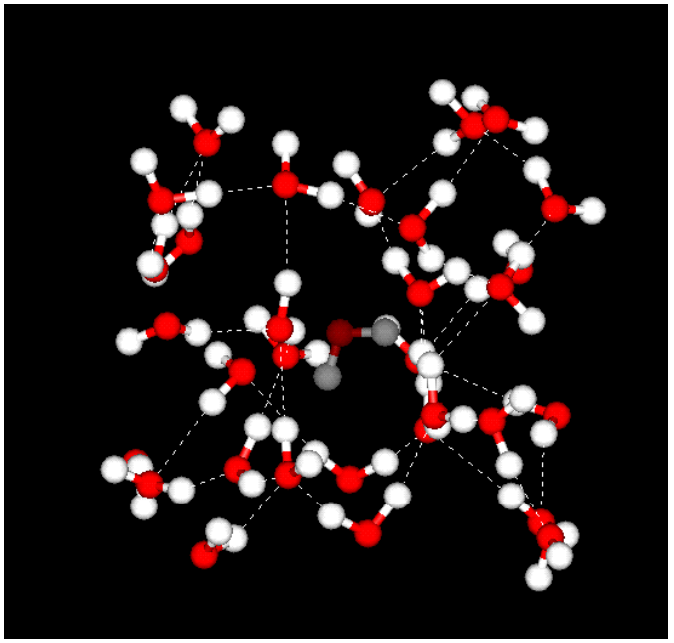
- Water is stable substance,
- boiling T 100 C
- Reactions, T balance

Hydrogen bonding in water



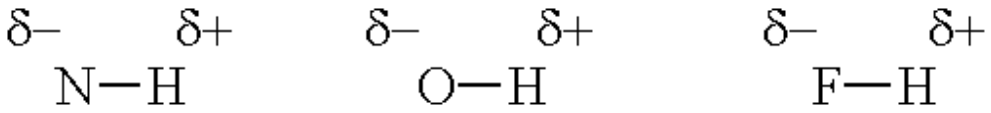


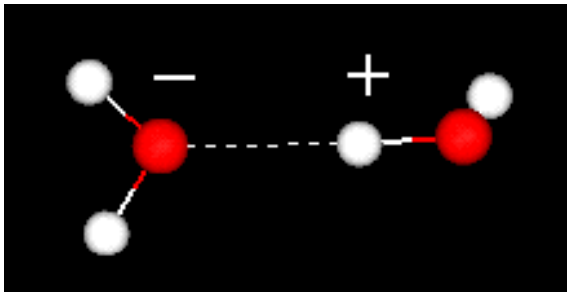
Ice



Water

- **Hydrophilic** – water soluble molecules
- Ionic substances (charged groups)
- Contain polar groups, can form hydrogen bonds with water





- **Hydrophobic** – insoluble – no polar groups - no hydrogen bonds with water
- **Amphiphilic** – both polar and non-polar groups (phospholipids)

Hydrophilic **Hydrophobic**

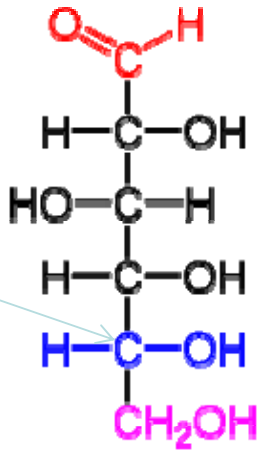
Important biological functions of water

- 1. dissolves and stabilizes biological molecules and ions
- 2. controls T balance in organism by absorbing and releasing heat energy
- 3. maintains shape of cell by adjusting intracellular pressure
- 4. helps in forming structural layers between polar end of proteins and lipids in biomembranes
- 5. helps supply of nutrients to plants (xylem and phloem transport)
- 6. participates in photosynthesis (oxidizes into oxygen and donates electrons)
- 7. participates in many reactions synthesizing and breaking biomolecules

Carbohydrates

- Carbohydrates or saccharides $(C{\cdot}H_2O)_n$

- have carbonyl group –CO and
- at least 2 hydroxyl groups –OH and
- asymmetric C atom between them



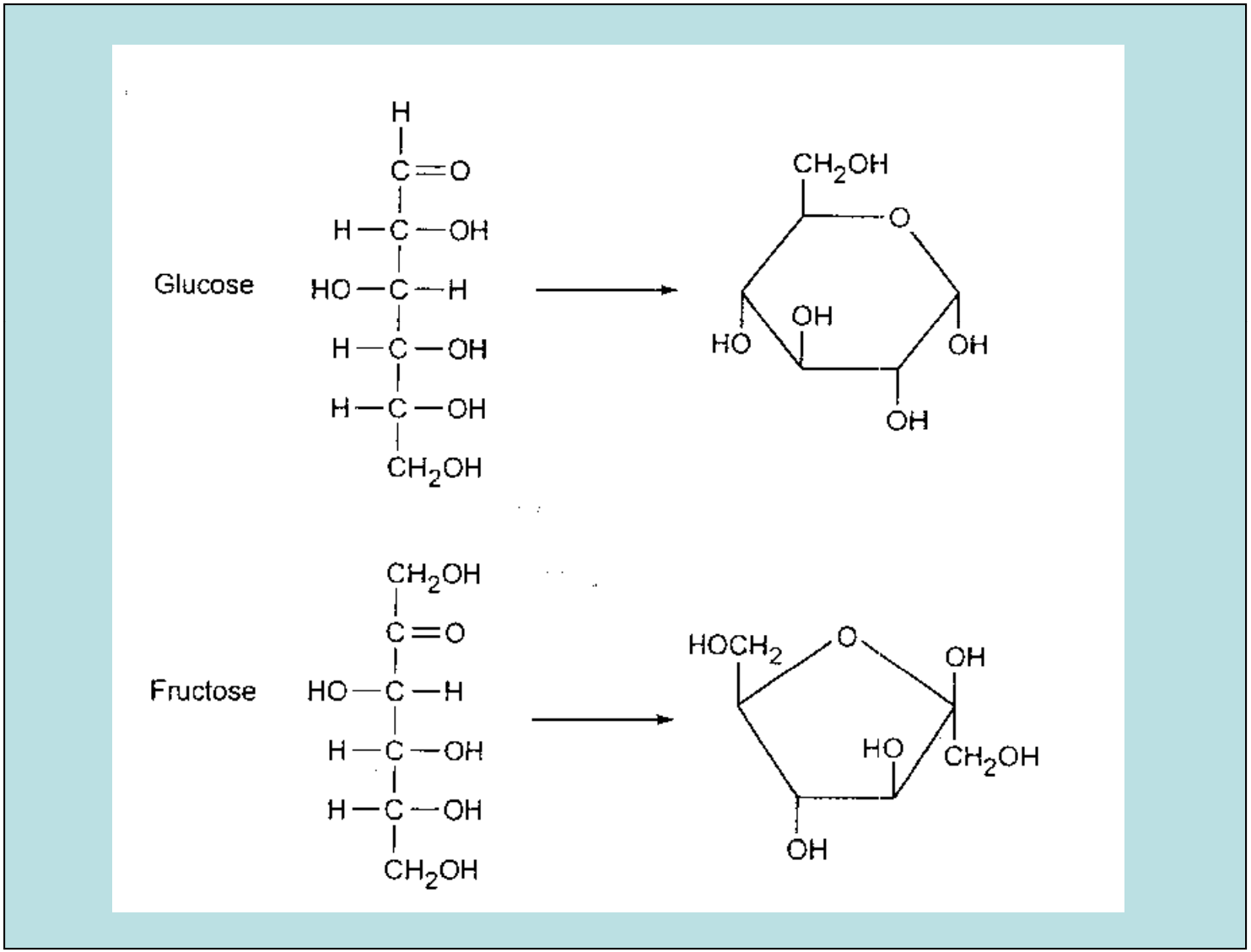
D-glucose, $(CH_2O)6$

- Pentose (5 C)
- Hexose (6 C)
- Glucose, mannose, galactose
- fructose (keto-hexose)

- Can be monosaccharides, disaccharides, and poly-saccharides

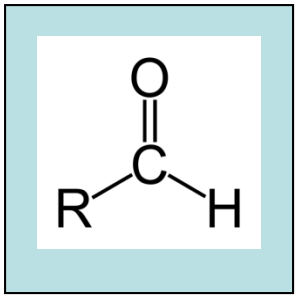
- Carbohydrates are sources of energy and structural support

Monosaccharides are cyclic in aqueous solution

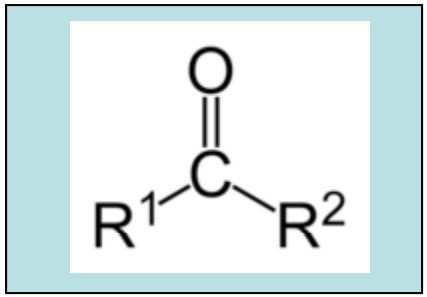


Carbohydrates

- Carbohydrates
- have carbonyl group –CO and at least 2 hydroxyl groups –OH and asymmetric C atom between them
- Carbonyl group –CO can be - in aldehyde form or keton form
- Pentose (5 C)- keto or aldo
- Hexose (6 C) - keto or aldo
- Aldo:
- Glucose, mannose, galactose
- Keto: fructose (keto-hexose)



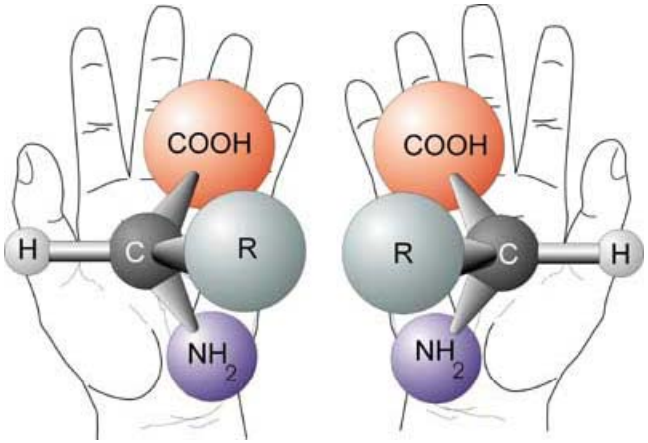
aldo



keto

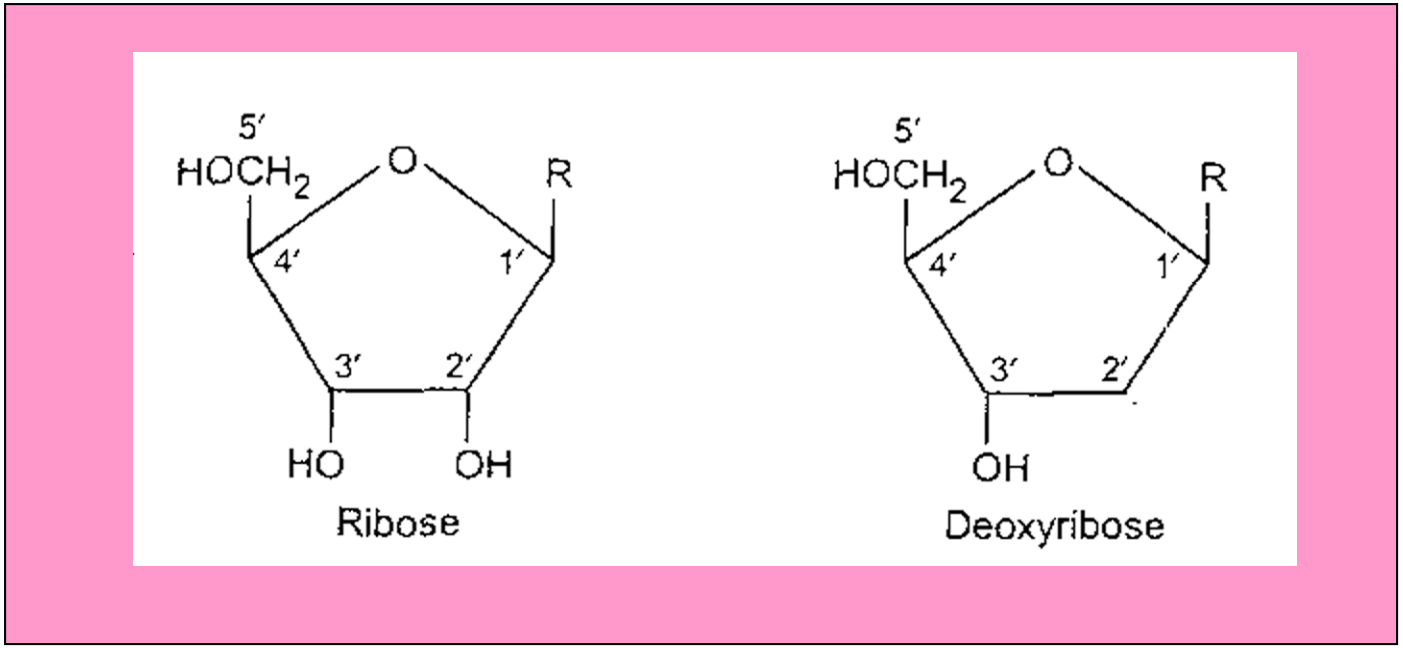
Carbohydrates

- Saccharides have
- stereo-isomers:



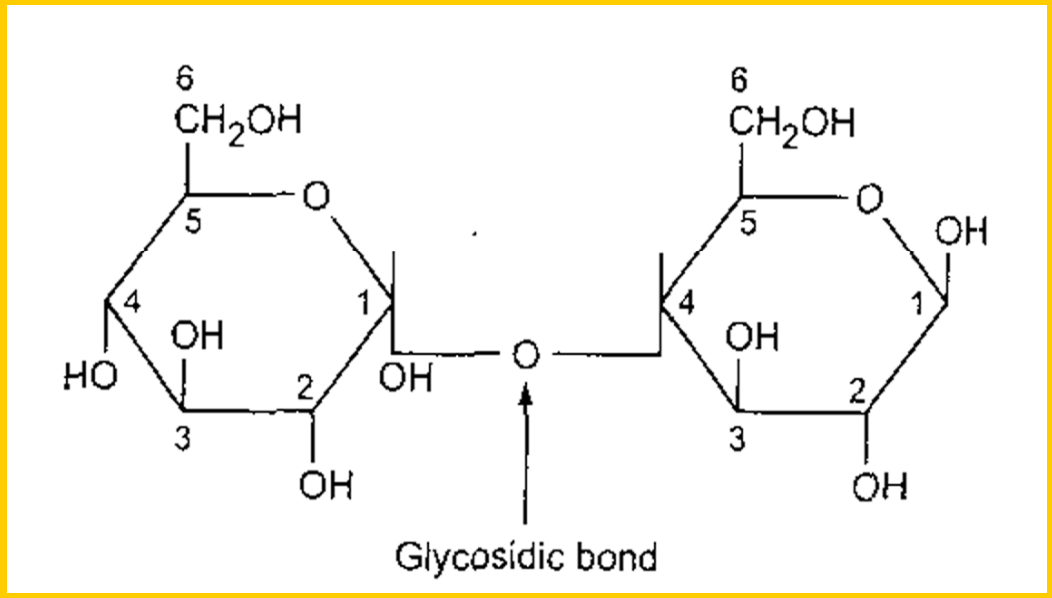
Carbohydrates - Pentose sugars

- Important derivative – deoxyribose sugar – constituent of DNA



Disaccharides

- Condensation of two monosaccharides molecules



Biologically important:

Sucrose (cane and beet sugar): Glucose + Fructose

Maltose (malt sugar)

Cellulose – steroisomer of maltose

Lactose (milk sugar)

Additional information - Glucose

- Our body's primary source of energy takes the form of glucose. This type of sugar comes from digesting carbohydrates into a chemical that we can easily convert to energy. When glucose levels in the bloodstream aren't properly regulated, one can develop a serious condition, such as diabetes.

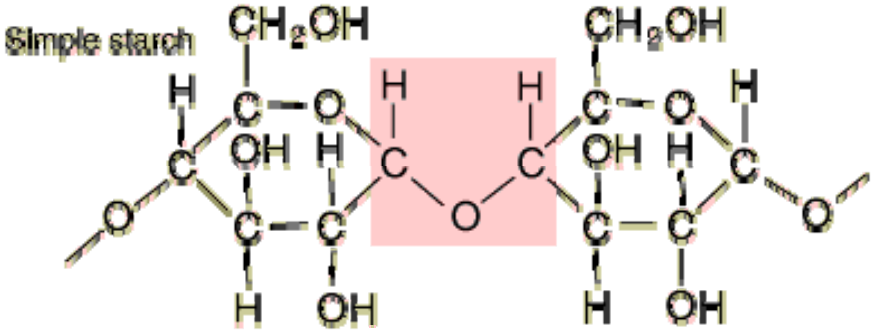
- We get most of our glucose from digesting the sugar and starch in carbohydrates. Foods like rice, pasta, grain, potatoes, fruits, a few vegetables, and processed sweets qualify as carbohydrates. Our digestive system, using bile and enzymes, breaks down the starch and sugar in these foods into glucose. This functional form of energy then gets absorbed through the small intestine into the bloodstream. There, a chemical known as insulin, excreted by the pancreas, meets the glucose. Together, they can enter cells in muscles and the brain, allowing glucose to power activities like lifting a book or remembering a phone number.

Polysaccharides

- More than 10 monosaccharides, high moleuclar weigth
- Homopolysaccharides – only one type of monosaccharide
- Heteropolysaccharides – different types of monosaccharides

- Starch chemical formula $(C_6H_{10}O_5)n$ is a mixture of two polysaccharides:
- amylose and amylopectin (usually in 20:80 or 30:70 ratios).

Starch is important source of carbohydrates in human diet, found in grains with an insoluble outer layer, remains in the cell where it is formed until the energy is needed. Human digestive process breaks down the starches into glucose units with the aid of enzymes, and glucose molecules circulate in blood stream as an energy source.

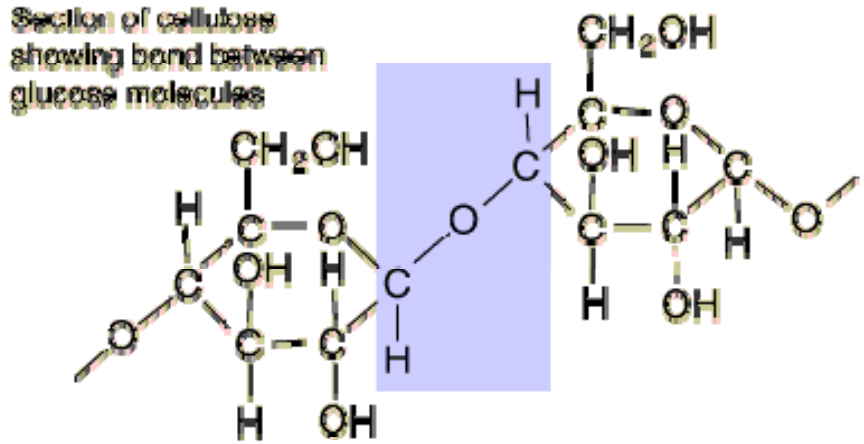


Foods - potatoes, rice, corn and wheat contain starch granules. If you chew on a piece of bread for a while, it will begin to taste sweet because the enzymes in saliva are already beginning to break down the starch into glucose, a sugar.

Polysaccharides

- Glycogen – animal starch – in human and animal tissues, skeletal muscles and liver, energy source
- Cellulose - main constituent of cell walls in living organisms. Wood is mostly cellulose. Homopolysaccharide made of glucose units

Cellulose molecules - straight chains, form fibers to support structures of plants.
animals such as cattle and termites rely on the energy content of cellulose. They have protozoa and bacteria with the necessary enzymes in their digestive systems. Cellulose in the human diet is needed for fiber.



- Hyaluronic acid – heteropolysaccharide – biological cement filling intracellular space, gel-like structure – works as filter, and support, found in skin, cartilage, eye.

- All polysaccharides - high molecular weight compounds with polar groups,
- In water swell and partially dissolve – form viscous colloidal solutions capable of gelation

Lipids

- Lipids are compounds of biological origin, insoluble in water, soluble in non-polar solvents.

- Fats, oils, waxes, sterols are lipids.
- Like the carbohydrates the true fats contain only carbon, hydrogen, and oxygen.

- Phospholipids make up cell membrane

- Lipids are classified:

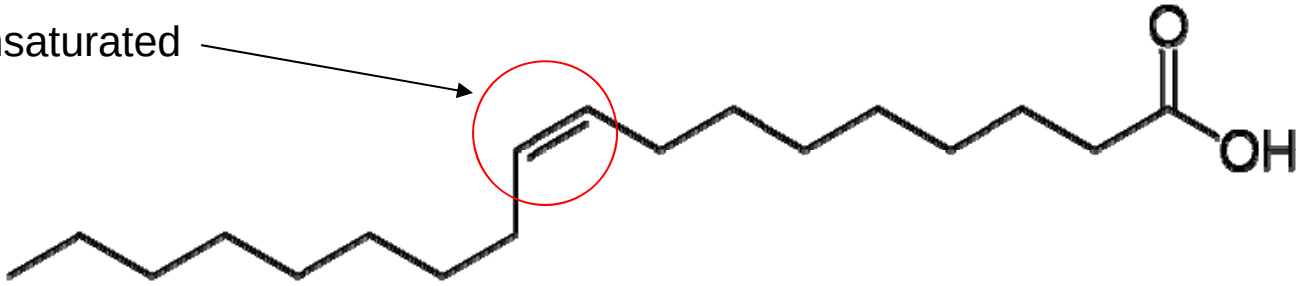
- 1. one-component lipids (lipid monomers)
- 2. multi-component lipids

Lipid monomers

- Fatty acids – rarely as free molecules
- are obtained by hydrolysis of lipids

fatty acids: R-COOH

- saturated or unsaturated

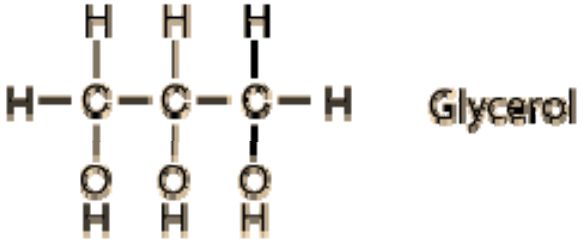


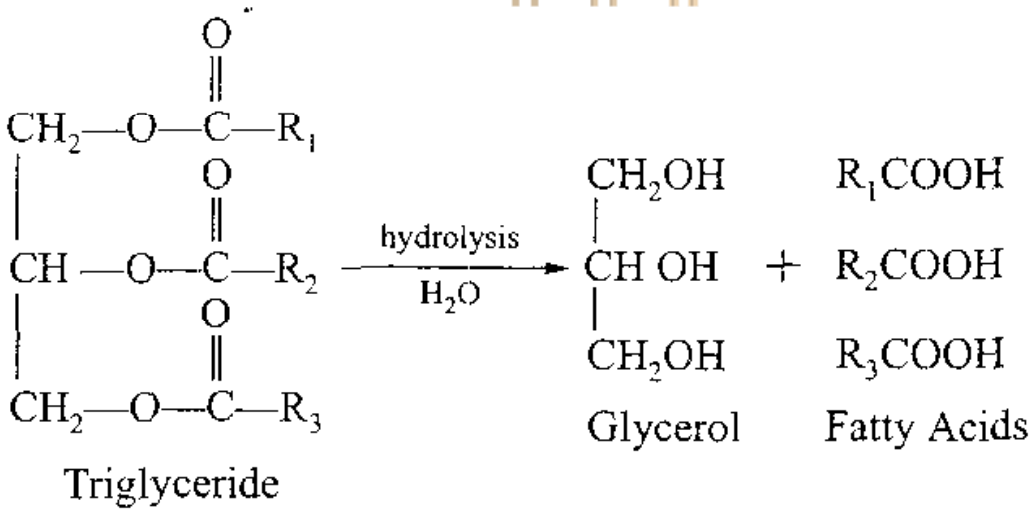
- 200 are known :
- saturated: palmitic and stearic acids are more prevalent
- unsaturated: oleic (vegetable oil), linoic (soybean oil)
- Cholesterol – structural lipid – large amount in nervous tissues, adrenalin glands and liver
- Other: steroids, vitamin A, D, E, K

Multi-component Lipids: triglycerides

- Simple lipids – monomers of fatty acids linked to alcohols,
- (fatty acids: R-COOH)

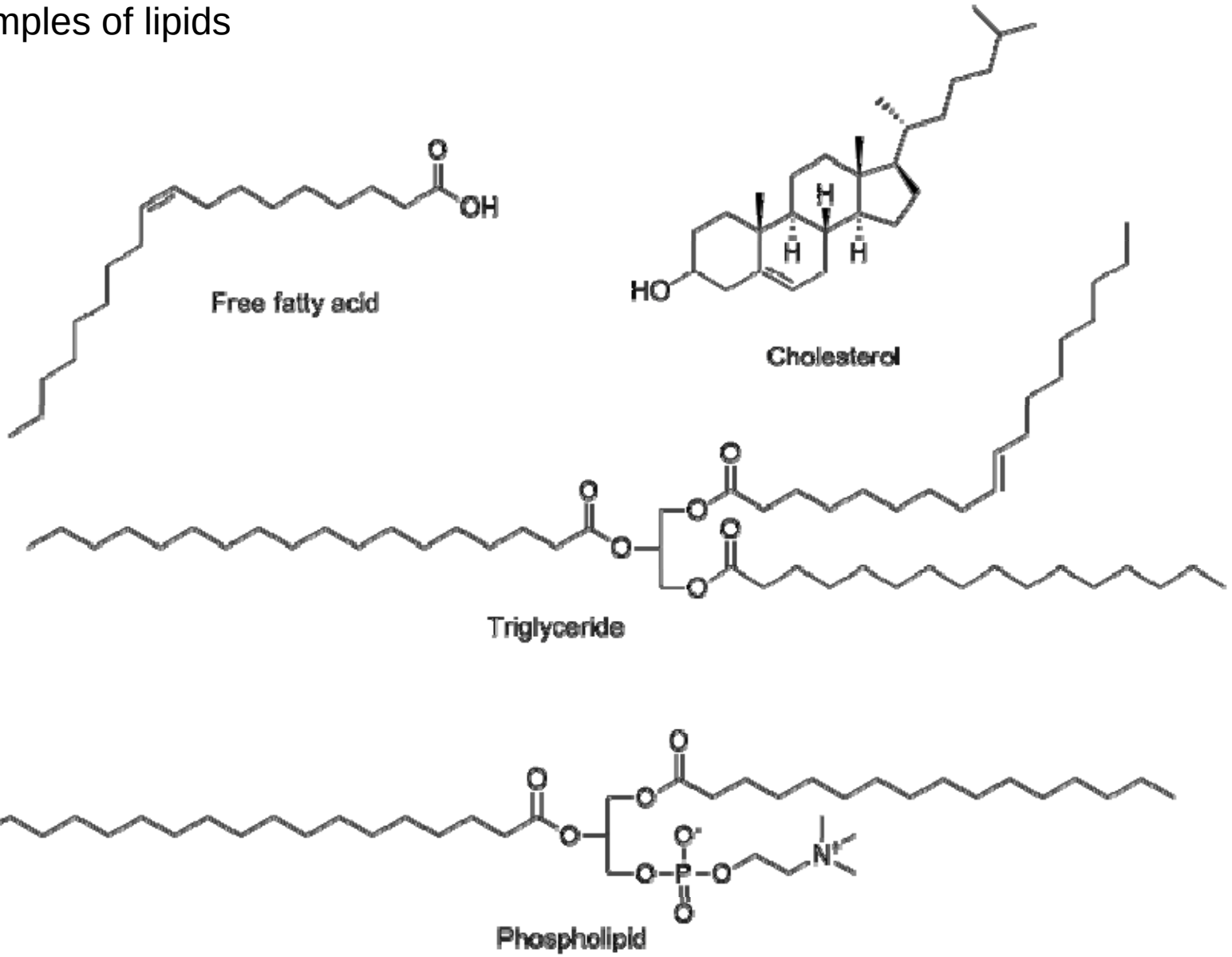
- Example - **Triglycerides** –
- inert lipids - energy storage





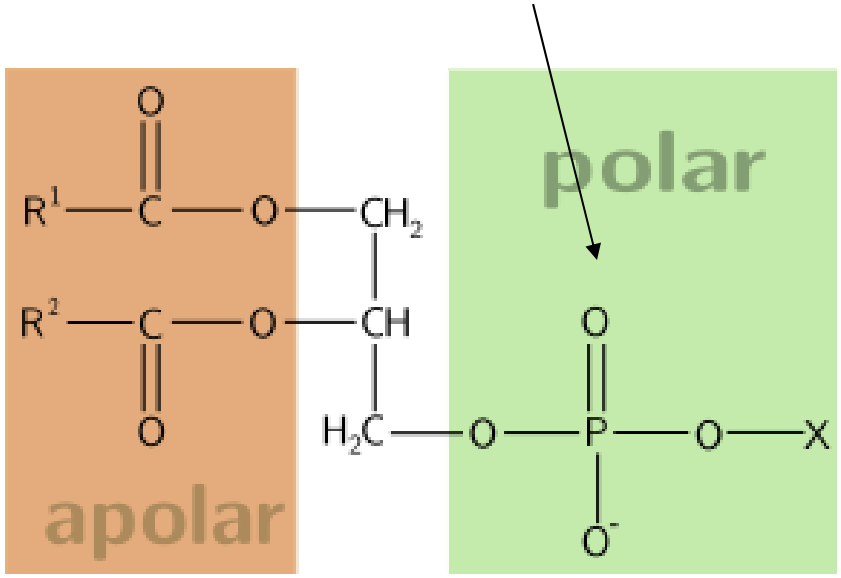
- Complex lipids

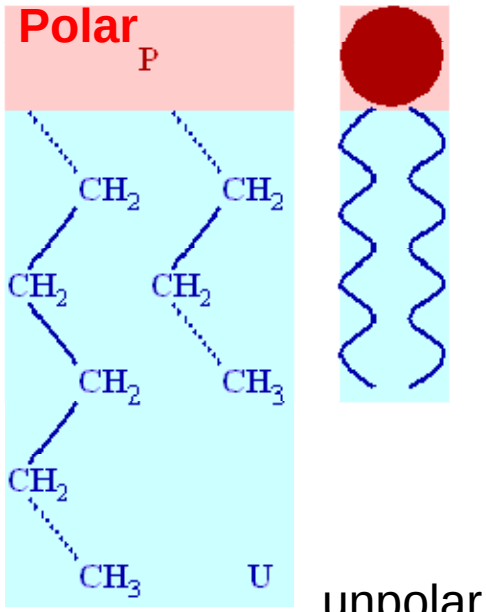
Examples of lipids



Multi-component Lipids: phospholipids

- Complex lipids – contain non-lipid component: phosphate or carbohydrate
- Complex lipids with phosphate group – **phospholipids**





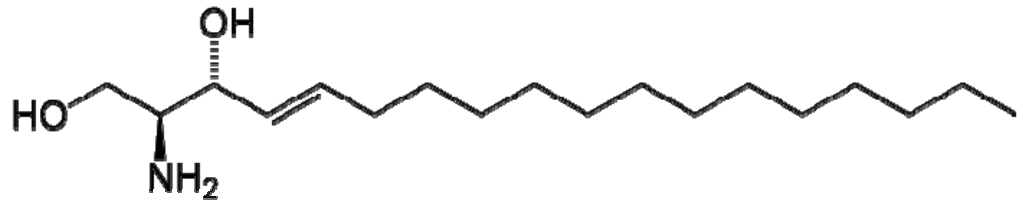
unpolar

- Phospholipids are **Amphi**philic – both polar and non-polar groups

- Constitute biological membrane, found in liver, brain, spinal tissues

Multi-component Lipids: glycolipids

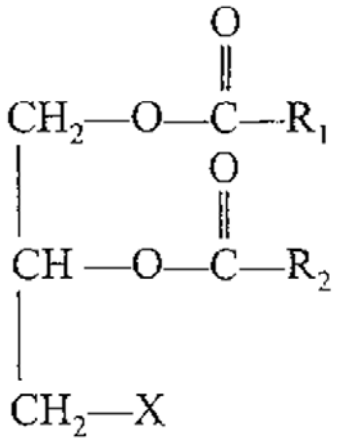
- **Glycolipids** are carbohydrate-attached lipids. Their role is to provide energy and participate in transmission of nerve signals.
- Glycosphigolipids are a subtype of glycolipids containing the amino alcohol sphingosine



sphigolipid

- Glycosphigolipids:
- Cerebrosides found in nerve cells in brain (cerebrum)
- Gangliosides immunology
- Sphingomyelin in neuron cells

General formula glycolipid



X- a monosaccharide