BIO102-Foundations of Biology (I)

Cell – Structure and chemical composition

INDRAPRASTHA INSTITUTE *of*
INFORMATION TECHNOLOGY **DELHI**

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What does it mean to be living?

- What are the fundamental properties that characterize living things and distinguish them from non-living matter?

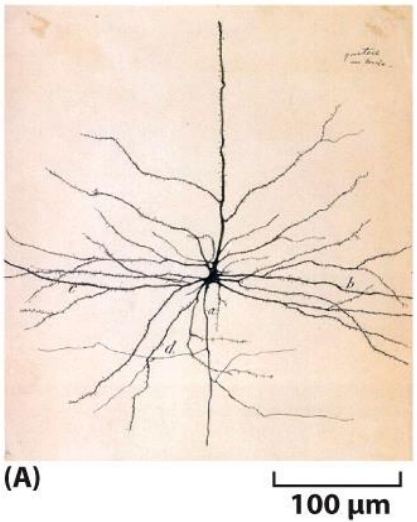
Living things may be distinguished from non-living things in their ability to carry on life processes such as movement, respiration, growth, responsiveness to environmental stimuli and reproduction.

All living things (or organisms) are built from cells: small, membrane enclosed units filled with a concentrated aqueous solution of chemicals and endowed with the extraordinary ability to create copies of themselves by growing and then dividing in two.

Cell, the basic unit of life

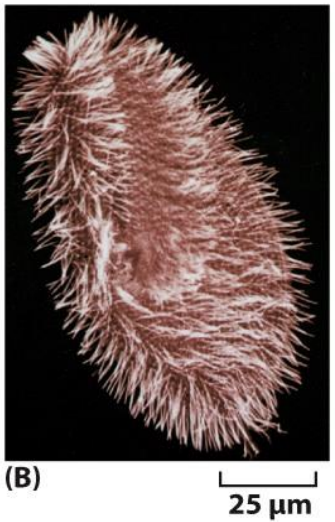
- The simplest forms of life are solitary cells.
- Higher organisms, including ourselves, are communities of cells derived by growth and division from a single founder cell.
- Every animal or plant is a vast colony of individual cells, each of which performs a specialized function that is regulated by intricate systems of cell-to-cell communication.

Cells exist in varied shapes and sizes



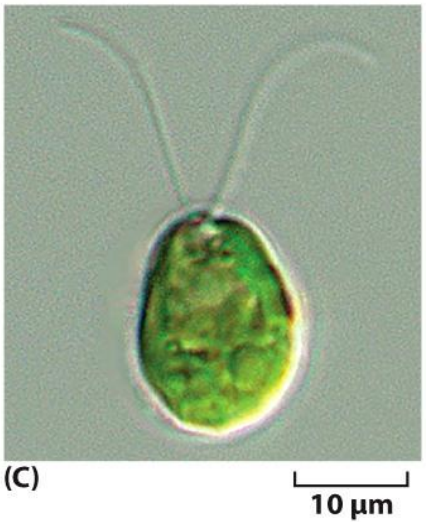
Neuron

Nerve cells from mammalian brain



Paramecium

Protozoan



Chlamydomonas

Single celled green algae

S. cerevisiae

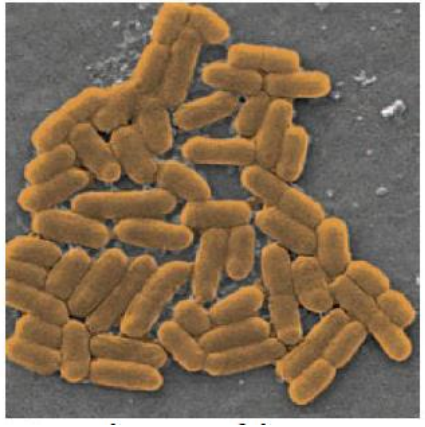
Yeast cell

H. Pylori

Bacteria causes stomach ulcer

Biologists estimate that there may be up to 100 million distinct species of living things on our planet.

All living organisms are made up of cells



A colony of bacteria

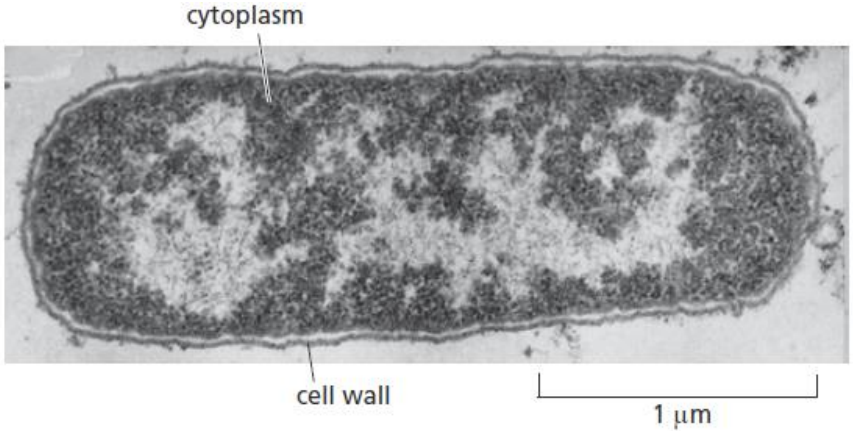
Butterfly

Rose

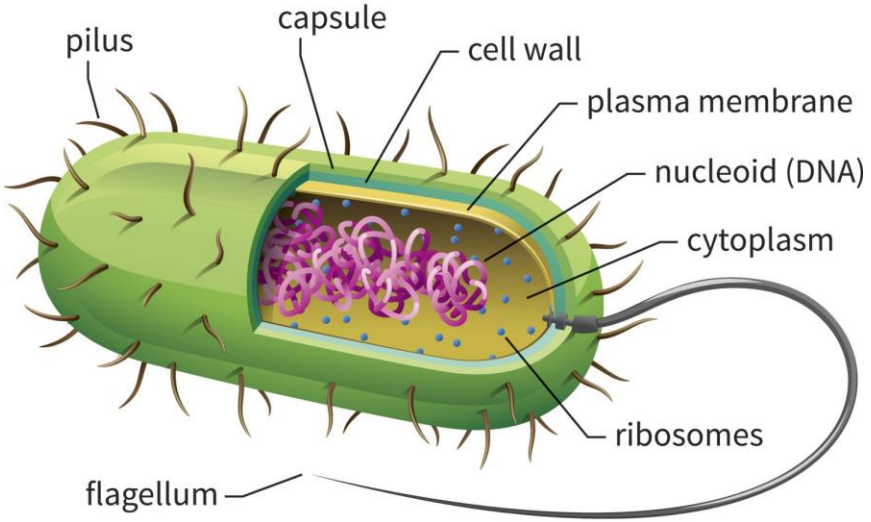
Whale

Prokaryotic cell

Nucleus is not present; eg. bacteria, archaea

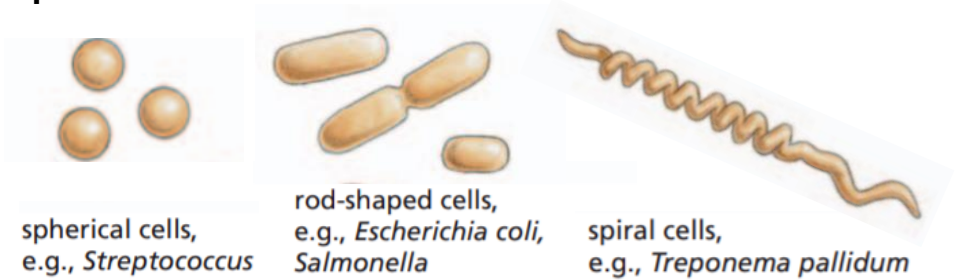


An electron micrograph of a longitudinal section of the bacterium *Escherichia coli* (E. coli). The cell's DNA is concentrated in the lightly stained region.



Prokaryotic cells/organisms

- Single-celled organisms, no nucleus
- Include bacteria and archaea
- Small in size - generally just a few micrometers long (can be 100 times longer as well)
- Plasma membrane encloses a single compartment containing the cytoplasm and the DNA
- Plasma membrane is surrounded by a tough protective coat called cell wall
- Cell interior appears as a matrix of varying texture, without organized internal structures
- Exploit enormous range of habitats - hot puddles of volcanic mud to the interiors of other living cells
- Reproduce quickly by dividing in two
- Evolve rapidly

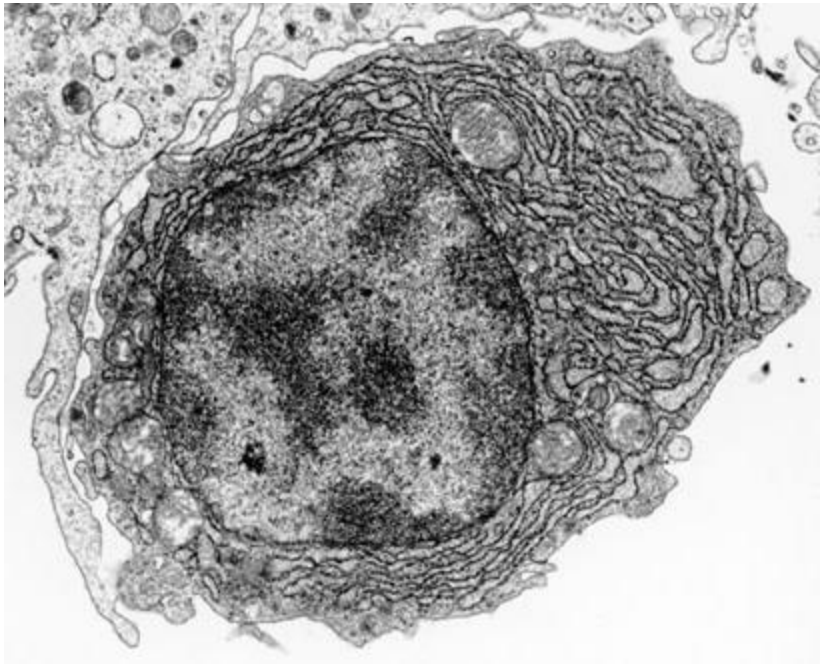


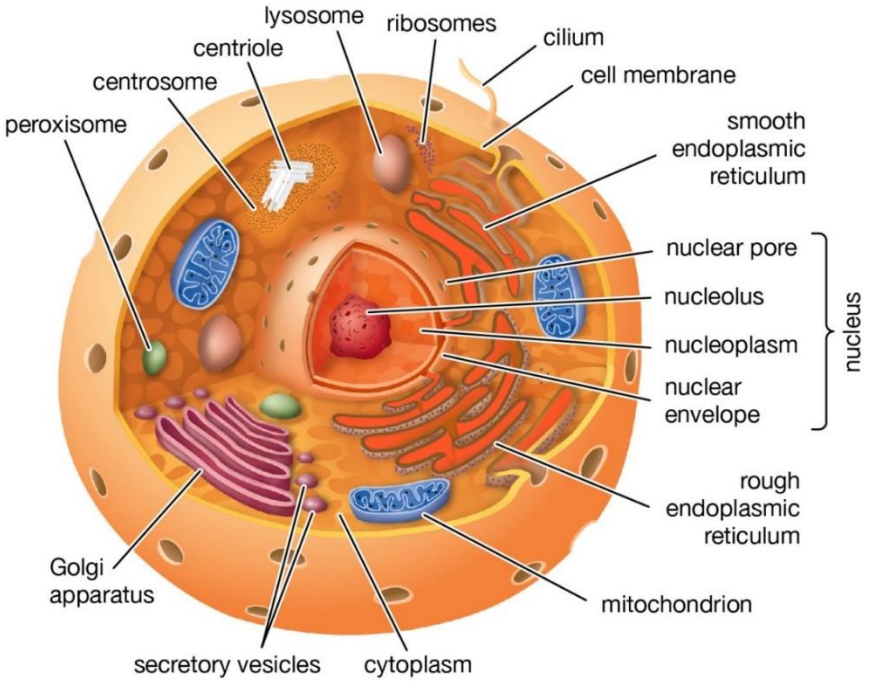
Prokaryotic cells/organisms

- Aerobic or anaerobic
- Varied food sources – organic matter, inorganic material, photosynthetic
- Archaea live in environments that are too hostile for most other cells - concentrated brine, the hot acid of volcanic springs, the airless depths of marine sediments, the sludge of sewage treatment plants, pools beneath the frozen surface of Antarctica, and in the acidic, oxygen-free environment of a cow's stomach where they break down cellulose and generate methane gas

Eukaryotic cell

Well defined nucleus is present; eg. yeast, plants, animals



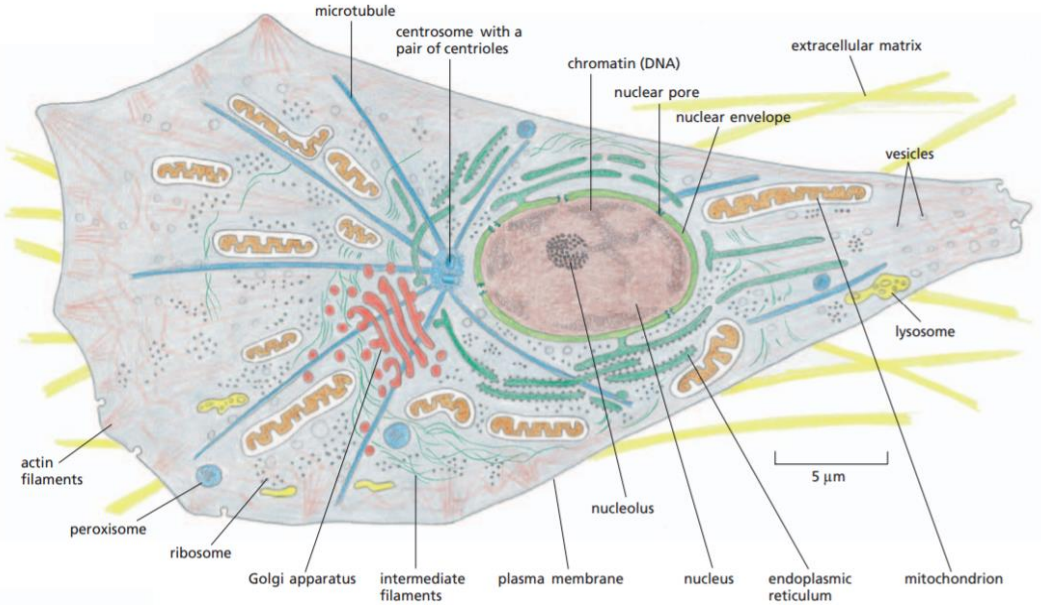


Eukaryotic cells/organisms

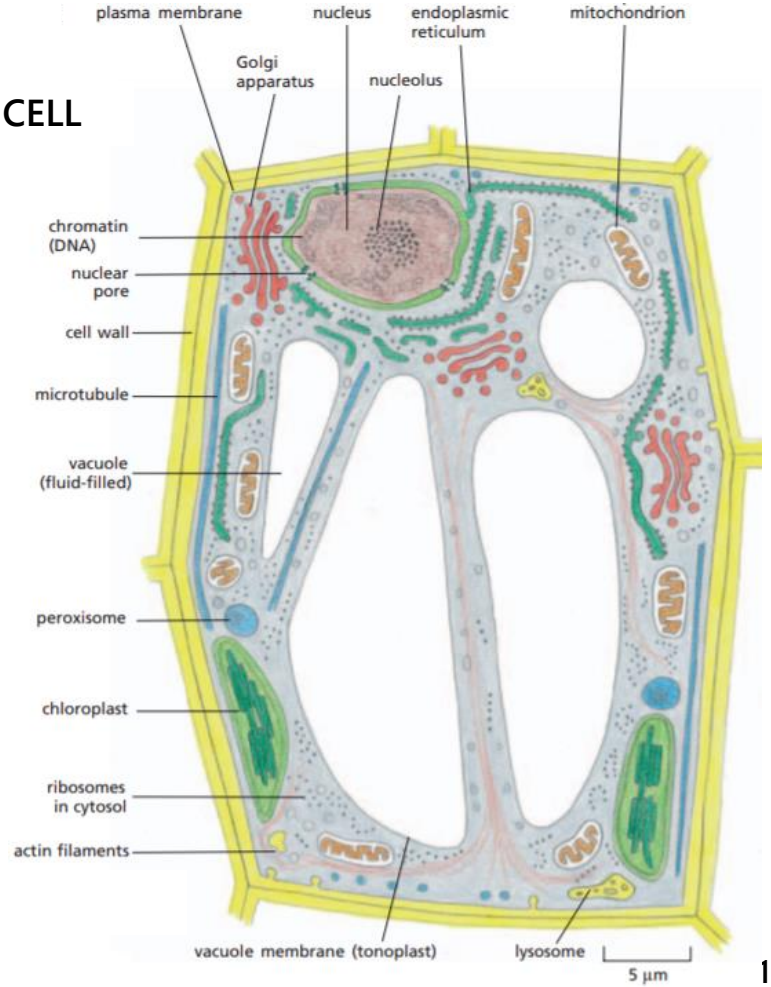
- Single-celled organisms, such as amoebae and yeasts
- More complex multicellular organisms, such as plants, animals, and fungi
- Contain nucleus and a variety of other organelles which are membrane-enclosed
- The main organelles include nucleus, mitochondria, chloroplast, endoplasmic reticulum, golgi apparatus, lysosome
- Some can prepare their own food, while others depend on the organic compounds prepared by other organisms
- Mostly aerobic, however some eukaryotic cells turn to anaerobic respiration when oxygen is unavailable

Eukaryotic cells

ANIMAL CELL



PLANT CELL

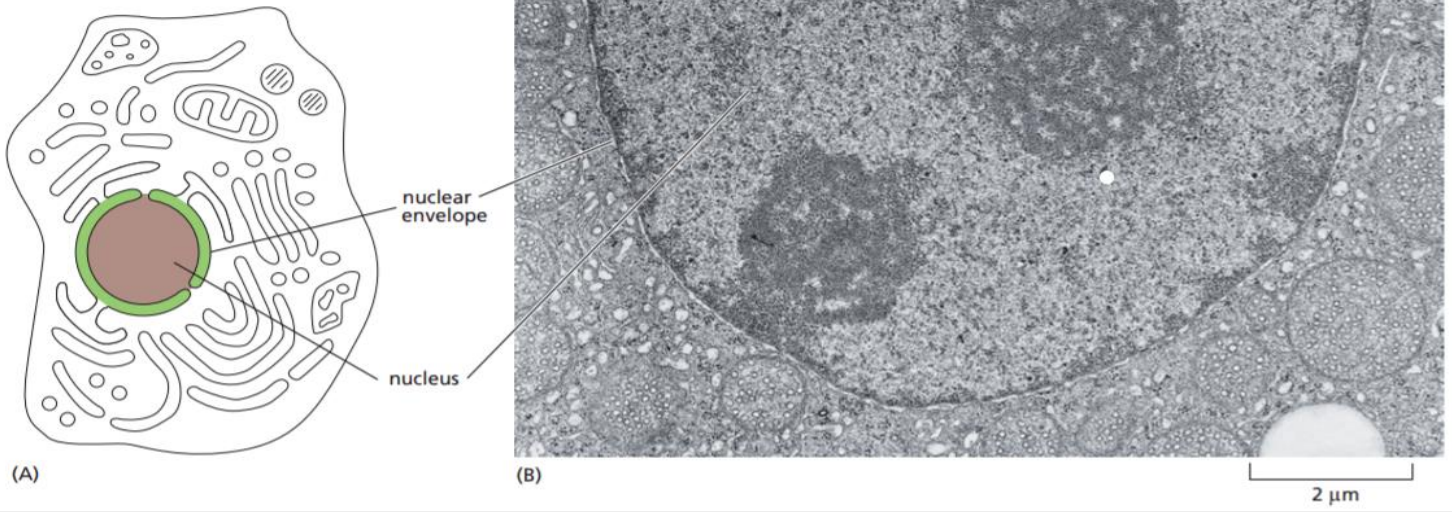


Nucleus contains all the information required by a cell

Most prominent organelle in a eukaryotic cell

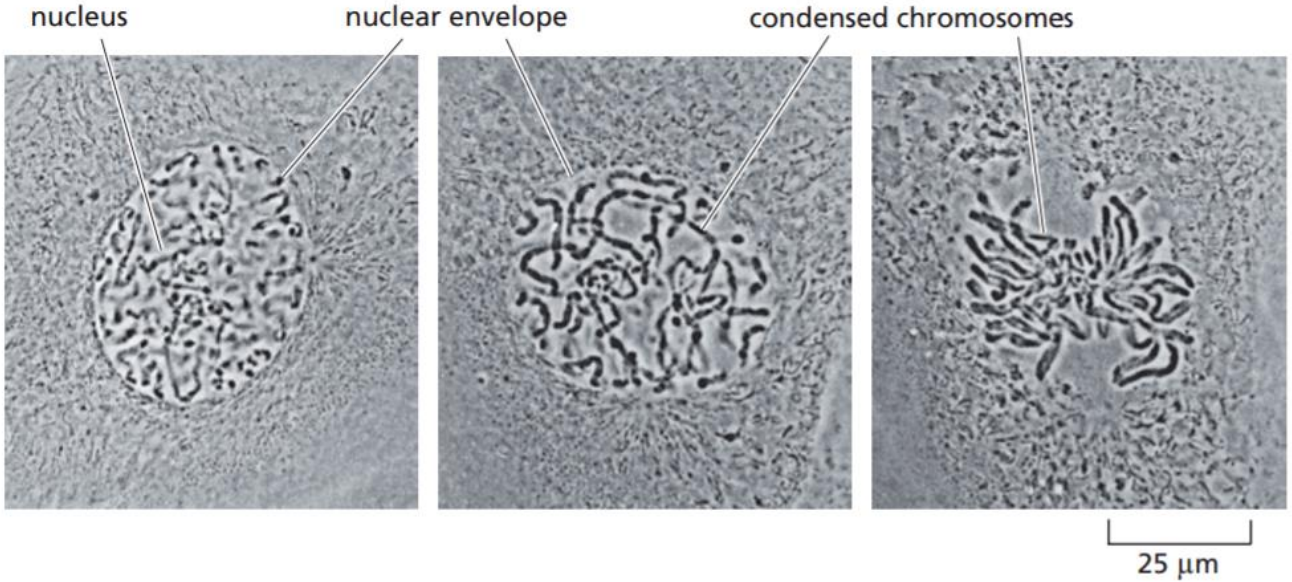
Nuclear envelope

Contains DNA, the genetic information of the organism



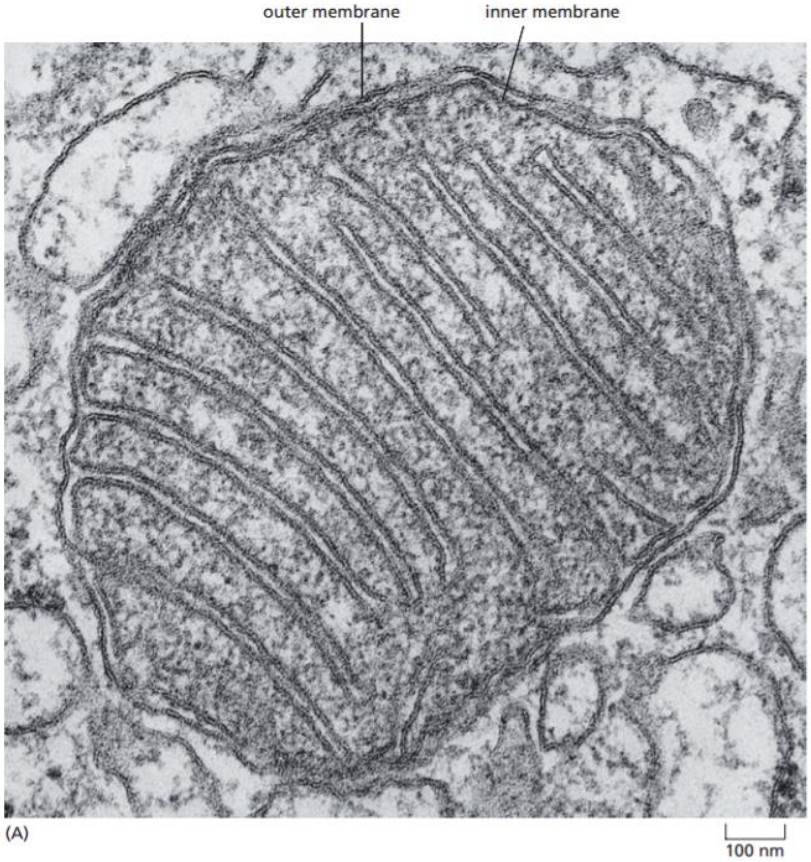
Nucleuse contains all the information required by a cell

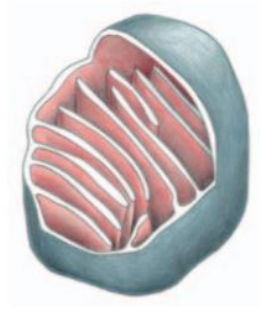
As a eukaryotic cell prepares to divide, its DNA molecules become progressively more compacted (condensed), forming wormlike chromosomes that can be distinguished in the light microscope.



Mitochondria, the power house of cells

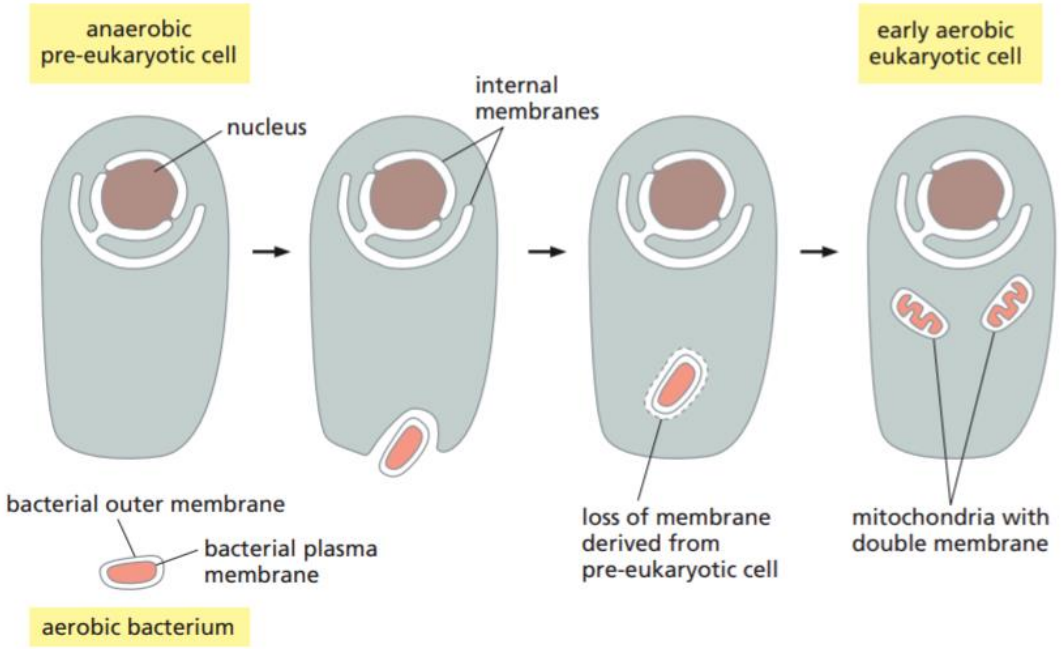
- Double membraned organelle
- The inner membrane of the mitochondrion folds inwards, forming the cristae
- Generate chemical energy for the cell
- Harness the energy from the oxidation of food molecules, such as sugars, to produce adenosine triphosphate, or ATP
- Consumes oxygen and releases carbon dioxide, therefore process is cellular respiration





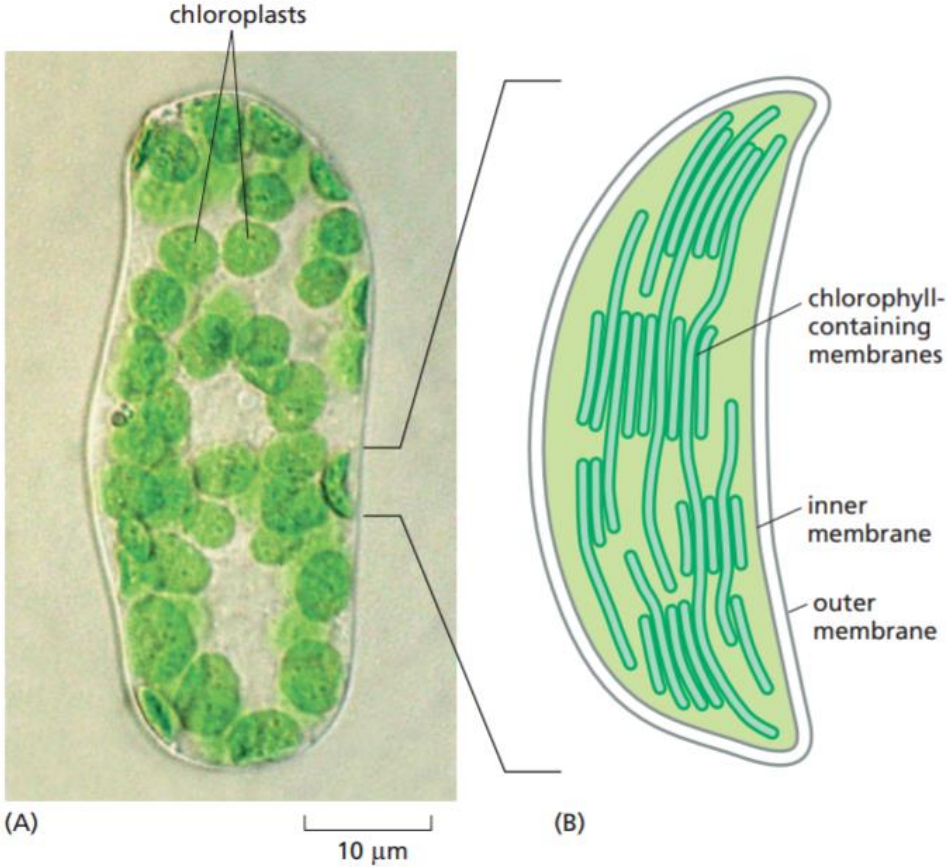
Mitochondria, the power house of cells

- Contain their own DNA and reproduce by dividing in two
- Mitochondria have been thought to originate from bacteria that were engulfed by an ancestral pre-eukaryotic cell and survived inside it, living in symbiosis with their host



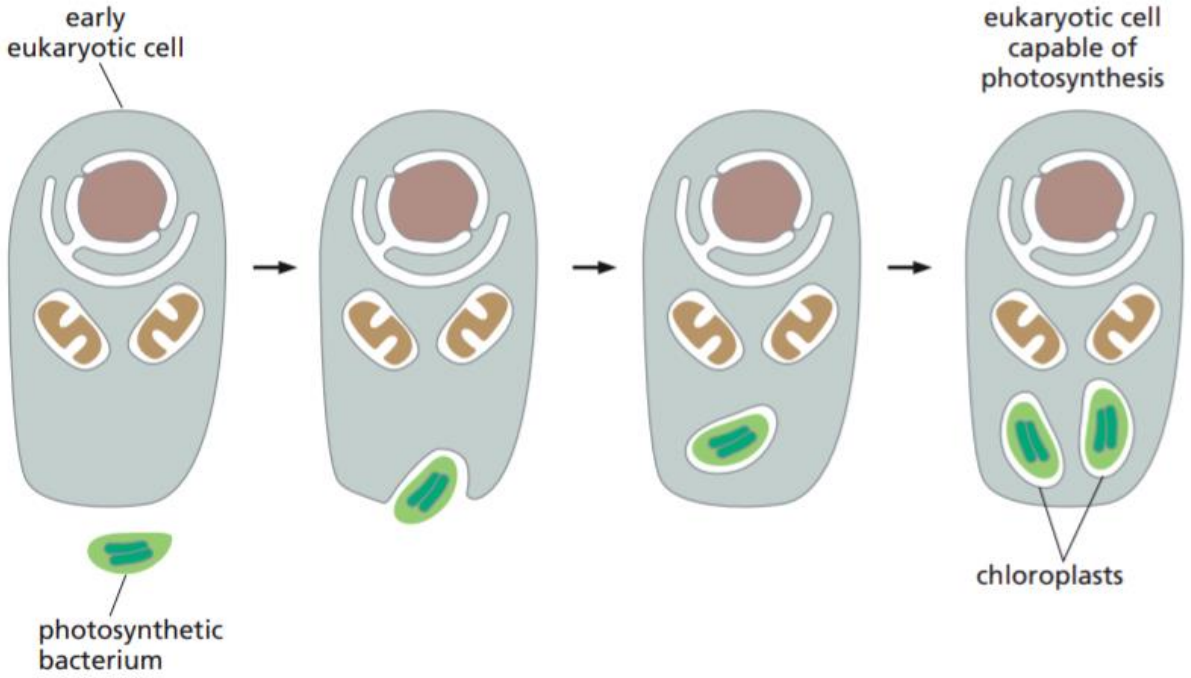
Chloroplasts capture energy from sunlight

- Large, green organelles found only in the cells of plants and algae, not in the cells of animals or fungi
- Double membraned organelle
- Possess internal stacks of membranes containing the green pigment chlorophyll, which helps in the process of photosynthesis
- Energy of sunlight is used to drive the manufacture of energy-rich sugar molecules, oxygen is released as a molecular by-product
- Oxidizing these sugars in mitochondria, plants can derive energy when needed

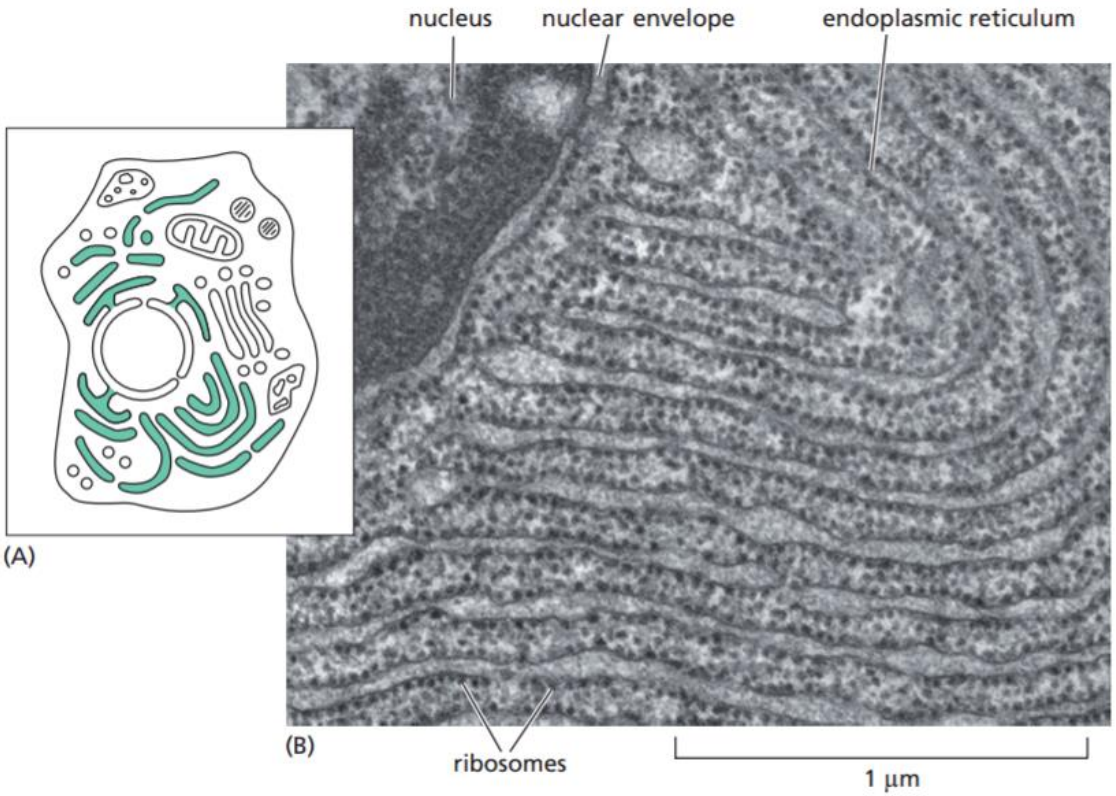


Chloroplasts capture energy from sunlight

Like mitochondria, chloroplasts contain their own DNA, reproduce by dividing in two, and are thought to have evolved from bacteria



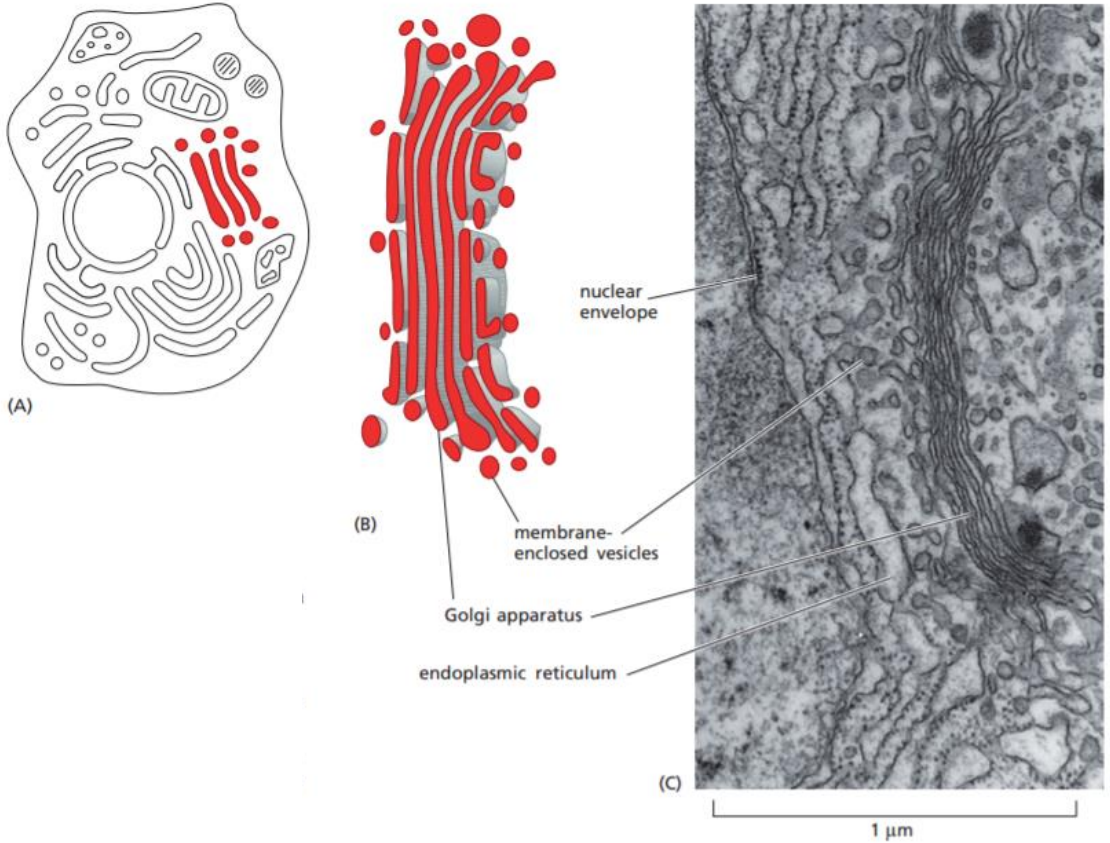
Endoplasmic reticulum helps in secretion of protein



- It is an irregular maze of interconnected spaces enclosed by a membrane
- Enormously enlarged in cells
- Specialized for the secretion of proteins
- Site for preparation of cell-membrane components and other material for export

Golgi apparatus helps in packaging

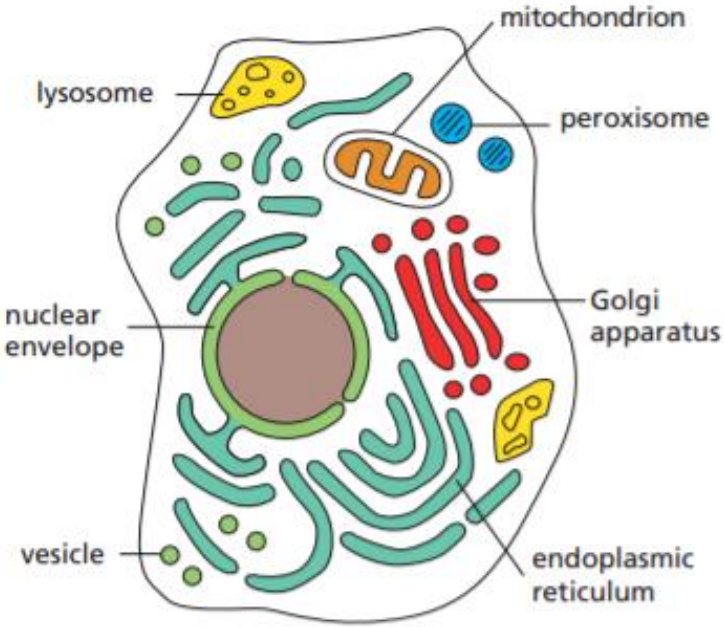
- Stacks of flattened, membrane-enclosed sacs
- Modifies and packages molecules made in the endoplasmic reticulum that are destined to be either secreted from the cell or transported to another cell compartment



Lysosomes and Peroxisomes

Lysosomes

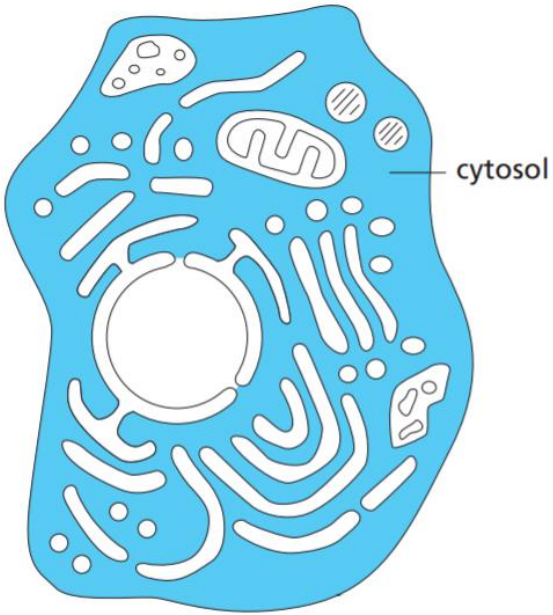
- Small, irregularly shaped organelles
- Intracellular digestion occurs releasing nutrients from ingested food particles
- Unwanted molecules are also broken down here for either recycling within the cell or excretion from the cell
- Many of the large and small molecules within the cell are constantly being broken down and remade



Peroxisomes

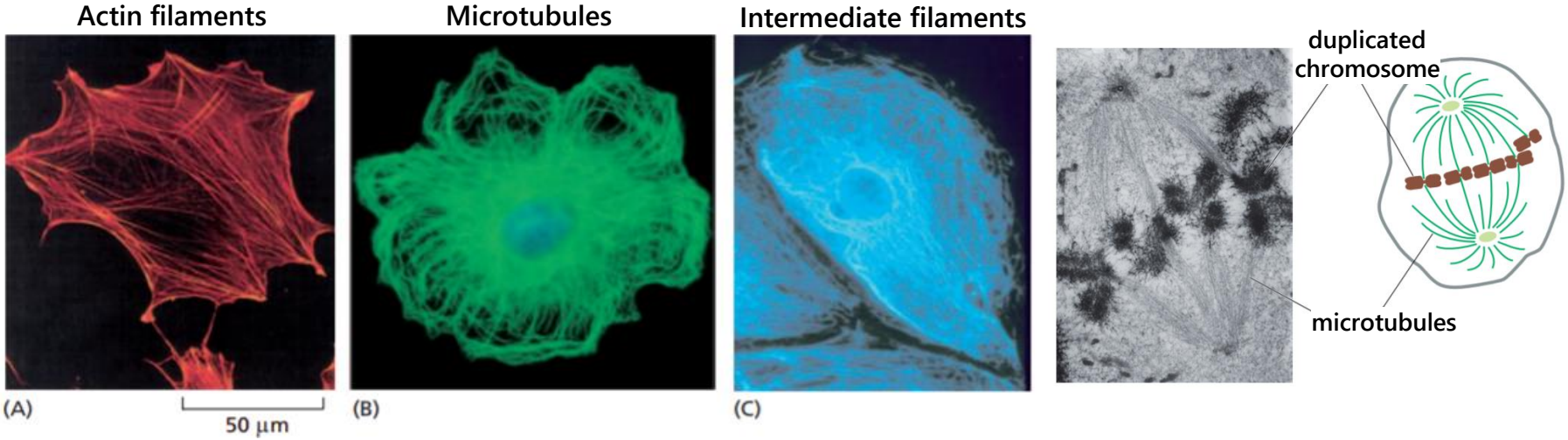
- Small, membrane-enclosed vesicles
- Provide a safe environment for a variety of reactions in which hydrogen peroxide is used to inactivate toxic molecules.

Cytosol or Cytoplasm



- Cytosol is the part of the cytoplasm that is not contained within intracellular membranes
- Contains a host of large and small molecules, crowded
- together so closely that it behaves more like a water-based gel than a liquid solution
- Site of many chemical reactions
- Cytosol is crisscrossed by long and fine filaments, anchored at one end to the plasma membrane or radiating out from a central site adjacent to the nucleus. This network of proteins is called cytoskeleton

Cytoskeleton



Provide strength to the cell and help in the movement of cargo across the cell

Actin filaments

- Thinnest & abundant
- More in muscle cells
- Help in muscle contraction

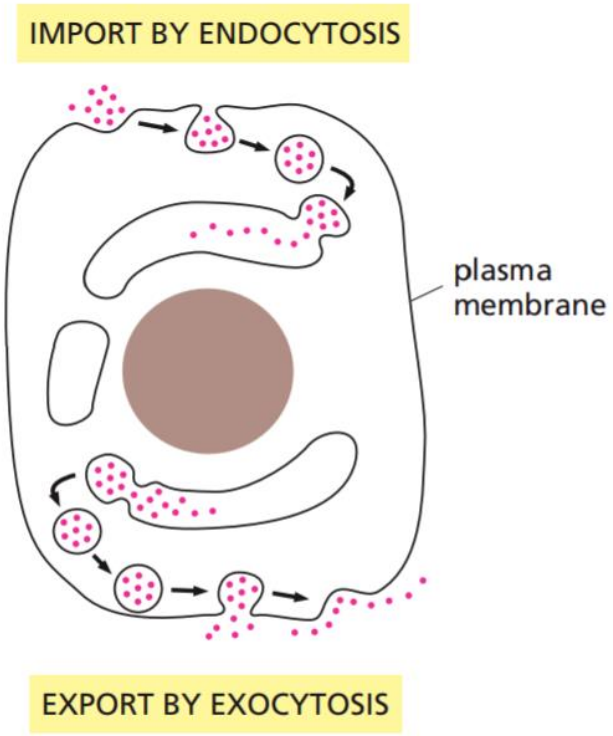
Microtubules

- Thickest
- Help in segregation of duplicated chromosomes during cell division

Intermediate filaments

- Intermediate in thickness
- Gives strength to cell

Endocytosis and Exocytosis

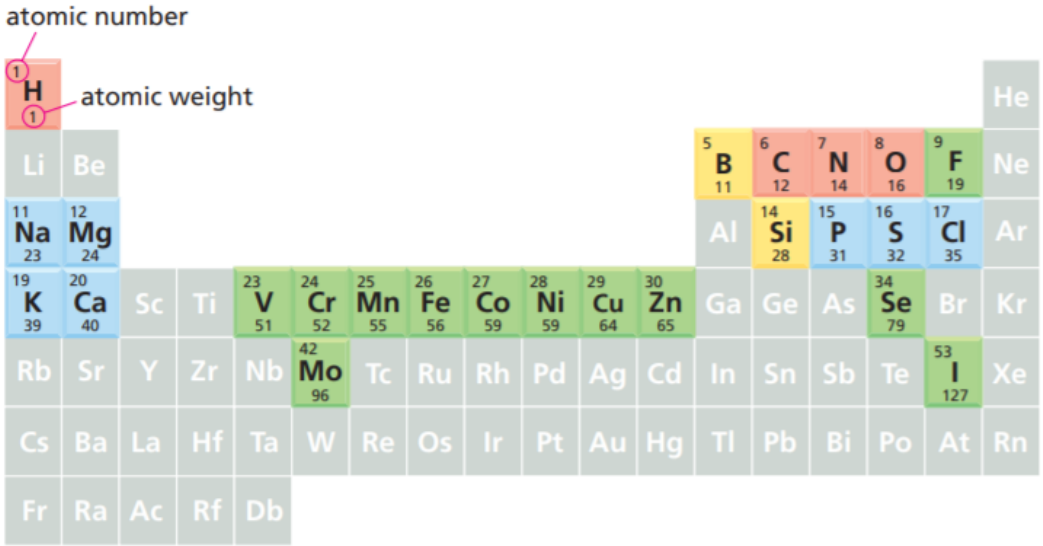


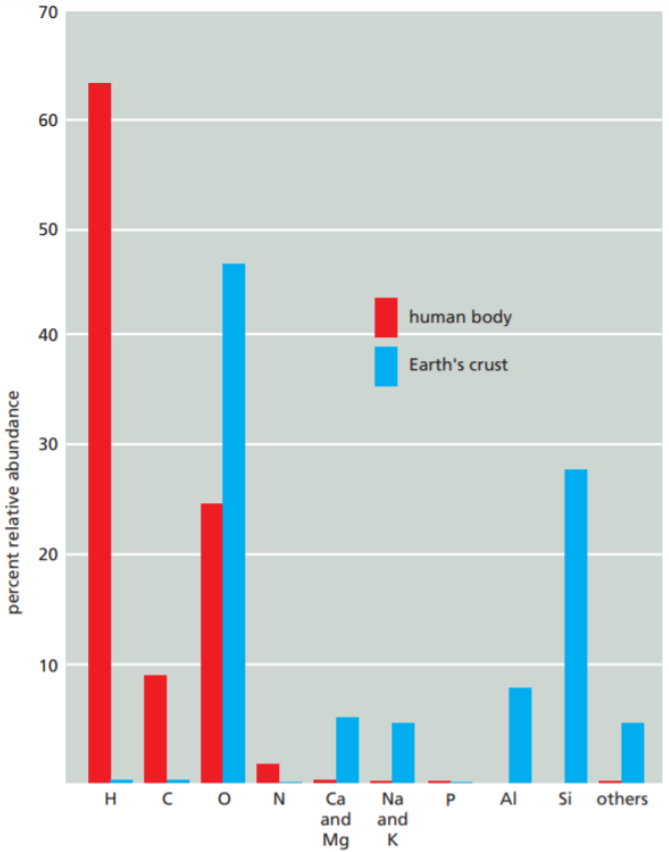
Endocytosis: Plasma membrane at the cell surface tuck inward and pinch off to form vesicles that carry material captured from the external medium into the cell

Exocytosis: Vesicles from inside the cell fuse with the plasma membrane and release their contents into the external medium

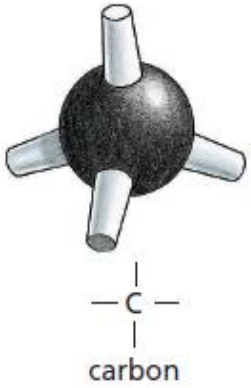
Chemical Components of Cells

- Living organisms obey all the chemical/physical laws
- Chemistry lies at the heart of all biology
- Matter is made of combinations of elements

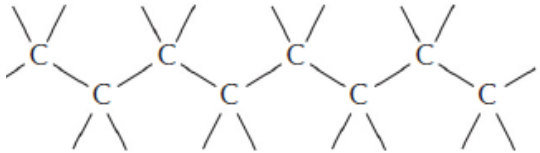




A cell is formed of carbon compounds

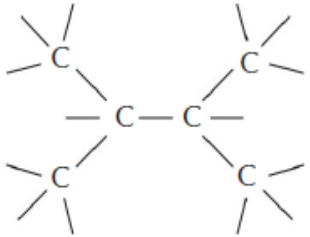


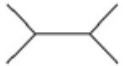
chains



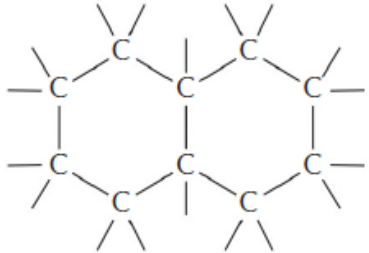
also written as 

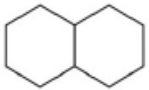
branched trees



also written as 

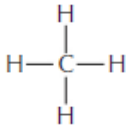
rings



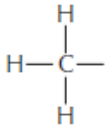
also written as 

Organic compounds

Chemical groups in carbon compounds

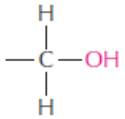


methane



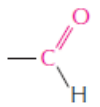
methyl group

alcohol

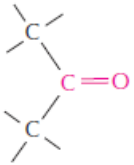


The –OH is called a hydroxyl group.

aldehyde

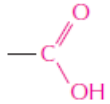


ketone



The C=O is called a carbonyl group.

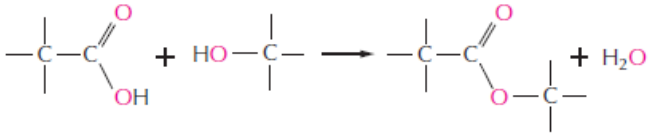
carboxylic acid



The –COOH is called a carboxyl group. In water, this loses an H^+ ion to become $–COO^–$.

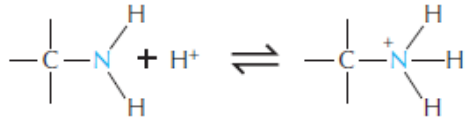
esters

Esters are formed by combining an acid and an alcohol.

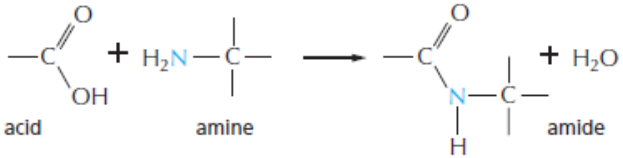


acid alcohol ester

Amines

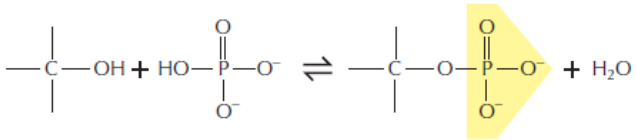


Amides

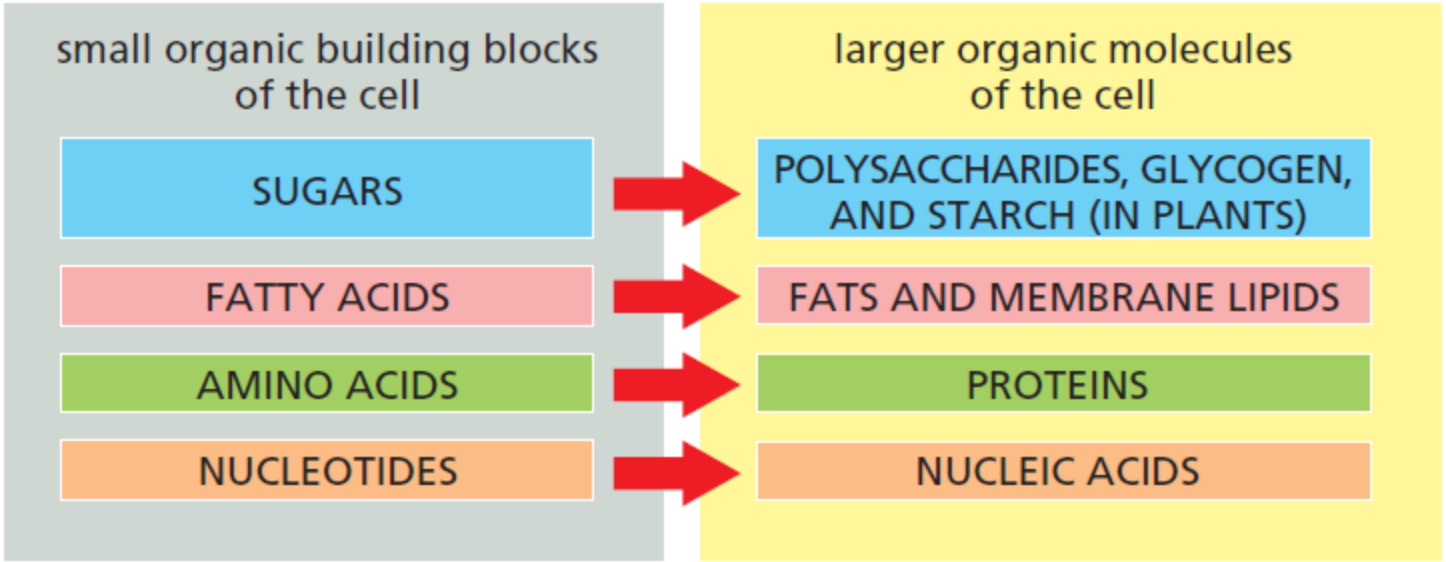


acid amine amide

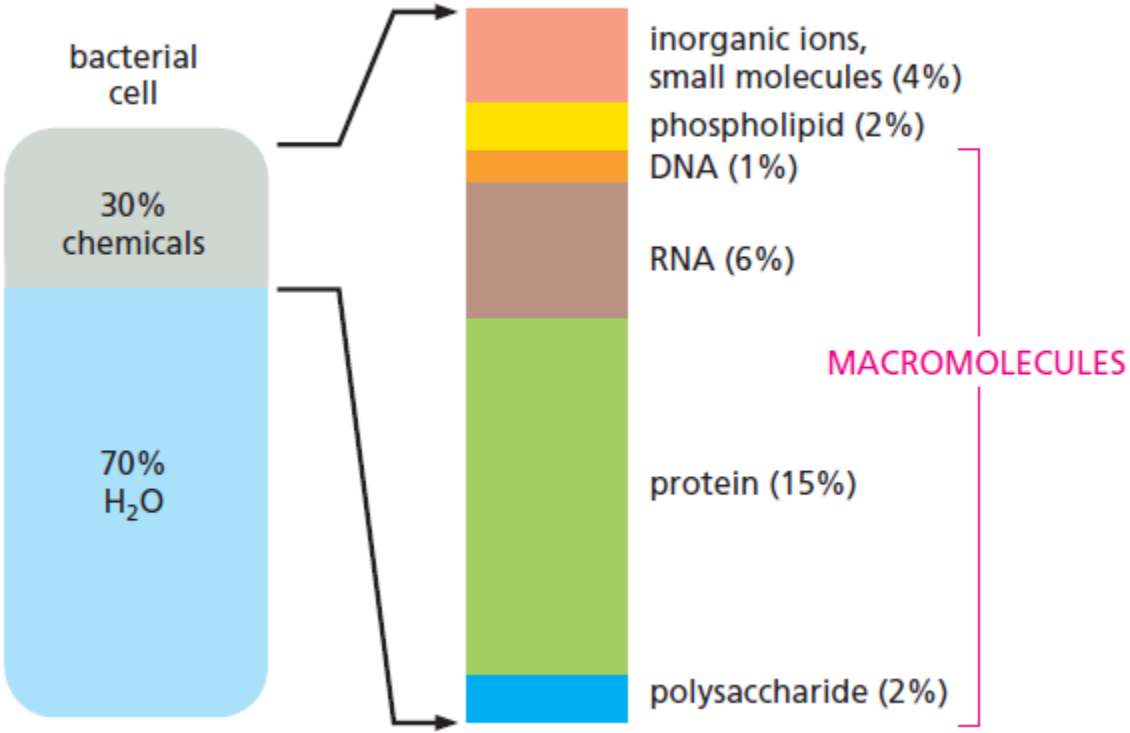
Phosphate groups



Major families of small organic molecules



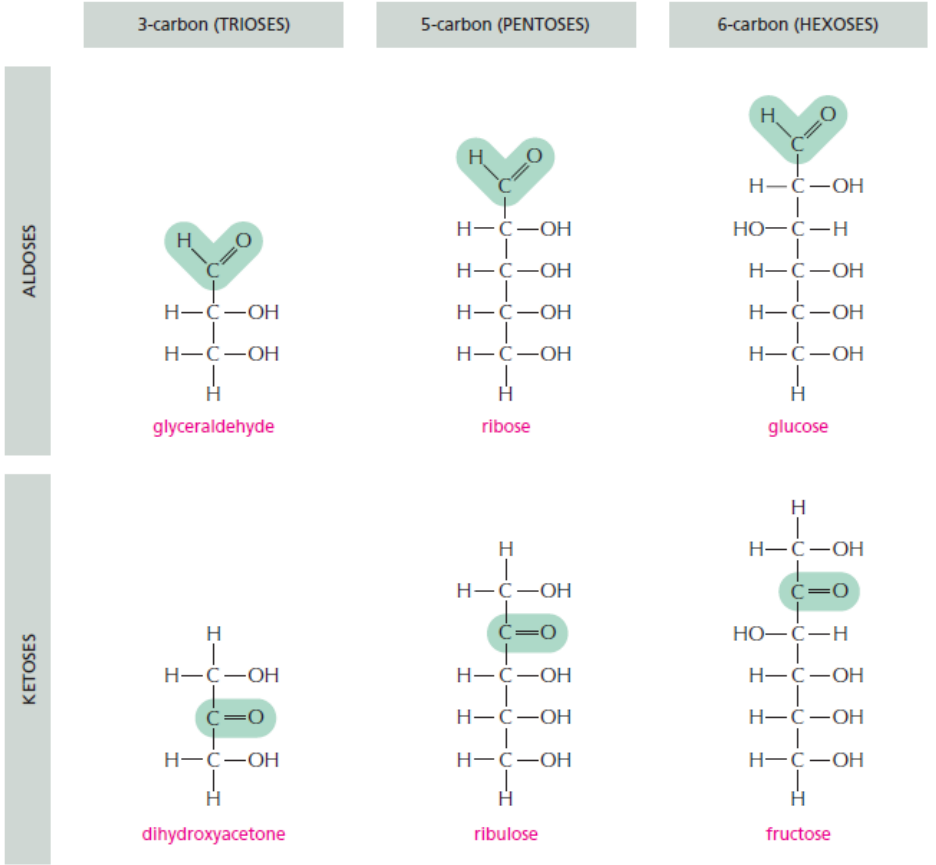
Major families of small organic molecules



Sugars/carbohydrates

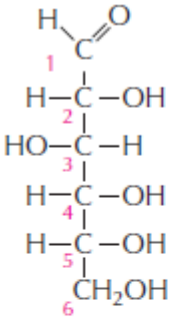
Monosaccharides:

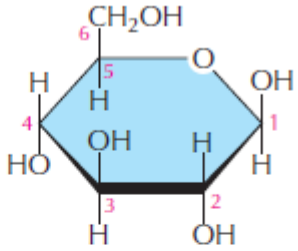
- general formula $(CH_2O)_n$, where n can be 3, 4, 5, or 6
- have two or more hydroxyl groups
- when aldehyde group is present called aldoses, if ketone group is present called ketoses

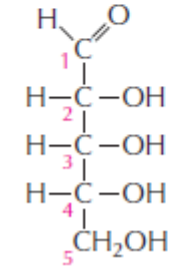


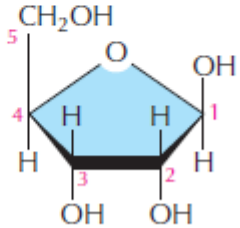
Sugars/carbohydrates

Ring formation

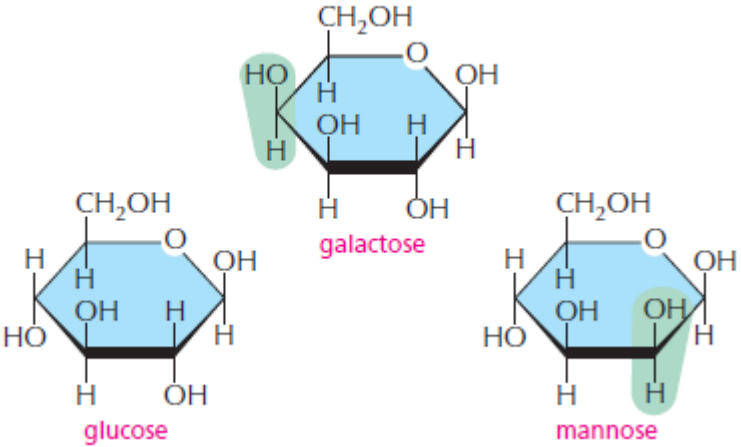






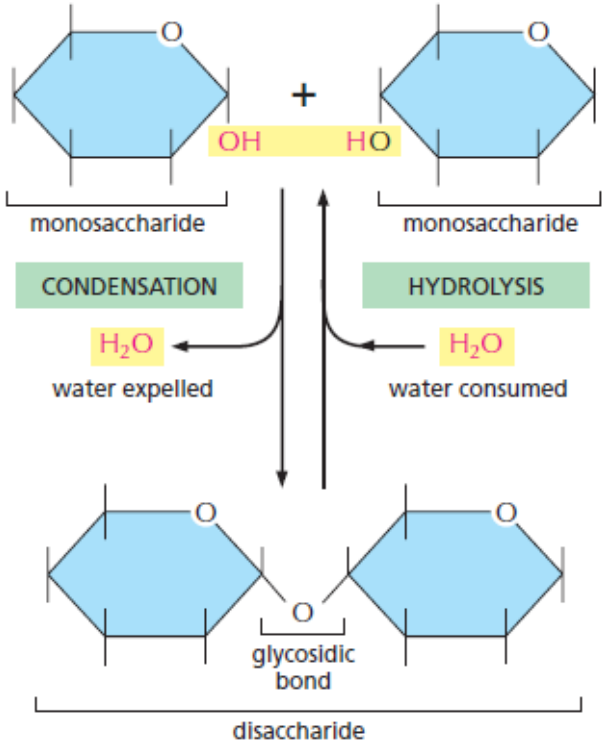


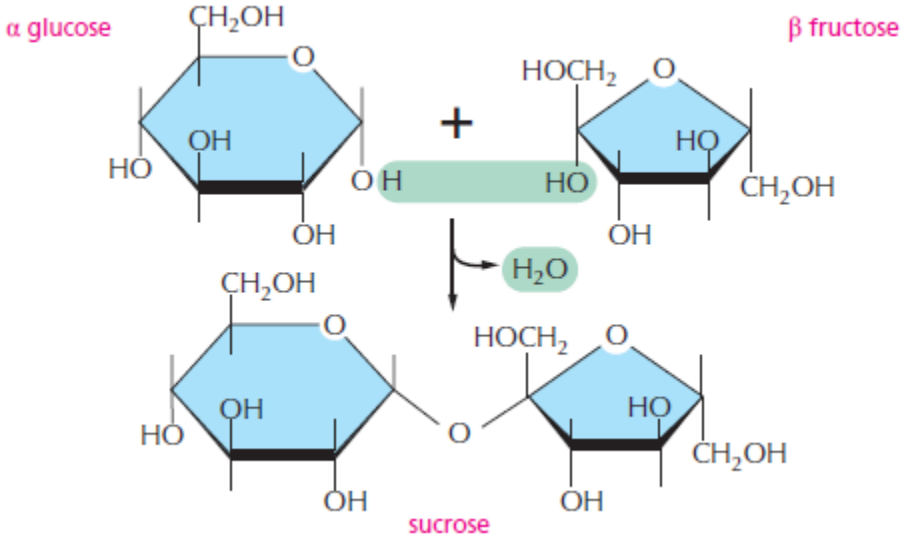
Isomers



Sugars/carbohydrates

Disaccharides: Two monosaccharides linked together by a covalent glycosidic bond





Oligosaccharides: 2-10 monosaccharides

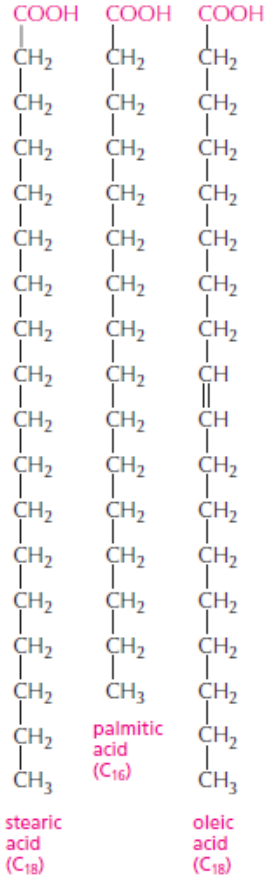
Polysaccharides: 100-1000 monosaccharides

Sugars/carbohydrates

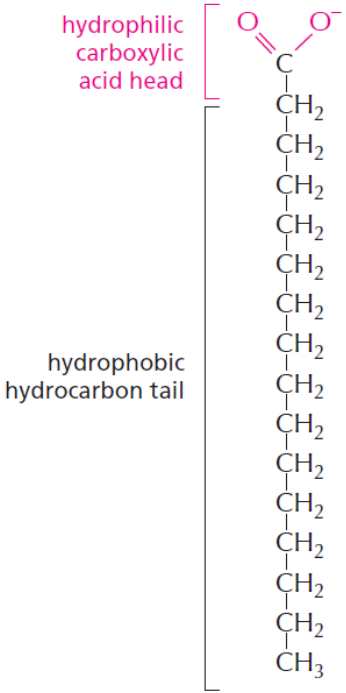
Sugars are both energy source and building blocks for polysaccharides.

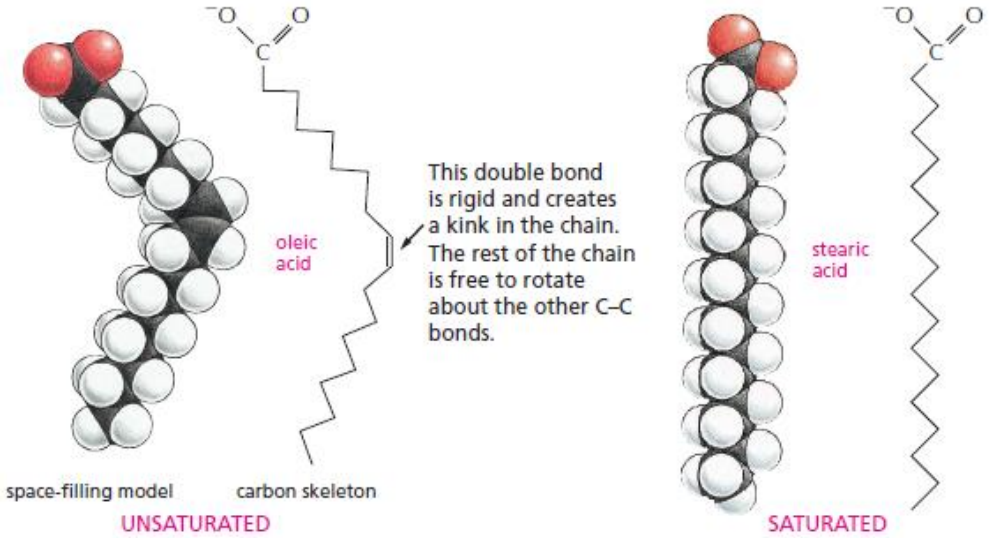
- Glucose (a monosaccharide) has a central role as an energy source for cells. It is broken down to smaller molecules in a series of reactions, releasing energy that the cell can harness to do useful work.
- Glycogen (in animals) and starch (in plants) are polysaccharides made up of glucose, and are reserved for energy production.
- Cellulose (a polysaccharide) that forms plant cell walls provides mechanical support.
- Chitin (also a polysaccharide made of a sugar derivative called N-acetylglucosamine) is present in the insect exoskeletons and fungal cell walls.
- Other polysaccharides components of slime, mucus, and gristle become slippery when wet.

Fatty acids/Lipids



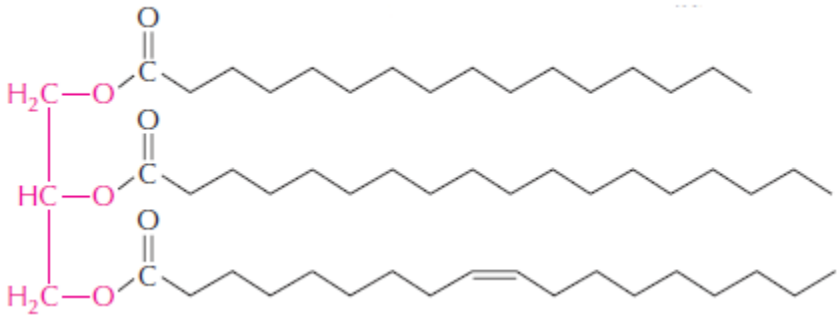
Fatty acids: Long hydrocarbon tails have carboxyl groups at one end.



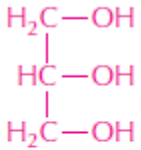


Fatty acids/Lipids

Triacylglycerol: Fatty acids serve as concentrated food reserve in cells. Produce almost 6 times the energy obtained from glucose.

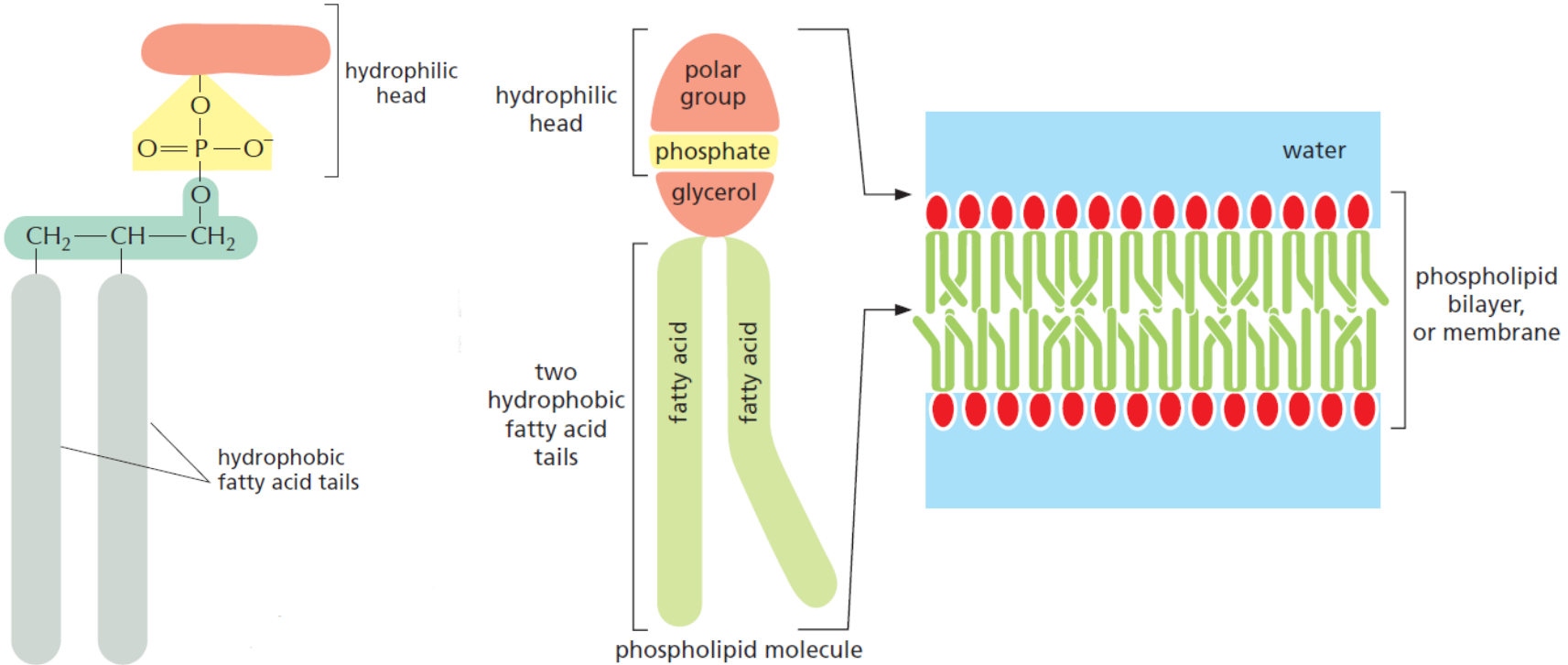


Triacylglycerol molecule



Fatty acids/Lipids

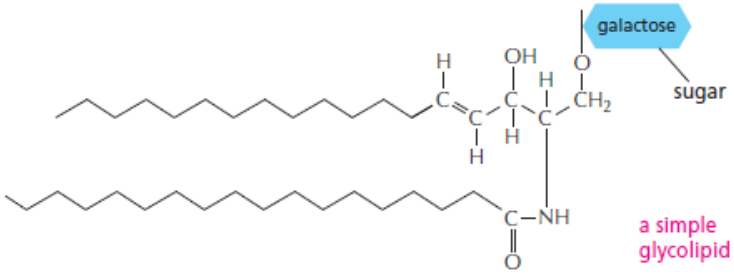
Phospholipids help in the formation of lipid bilayer.

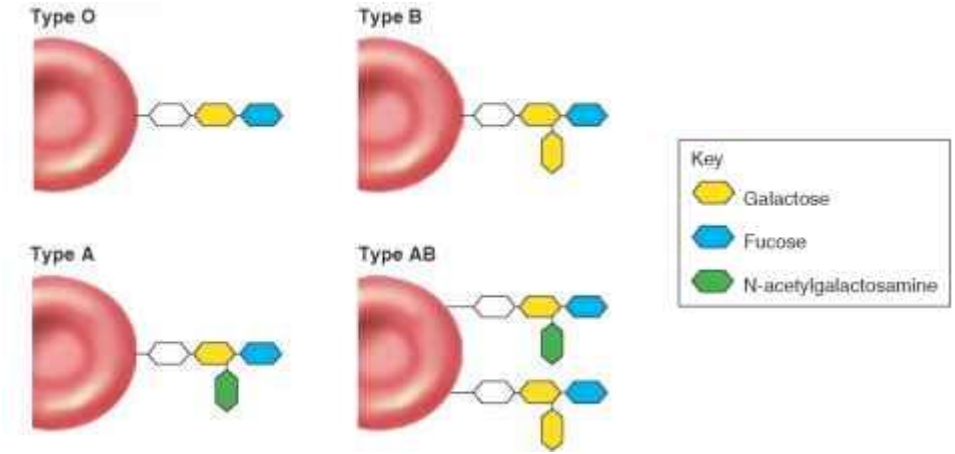


Phosphatidylcholine, Phosphatidylserine, Phosphatidylethanolamine and Sphingomyelin

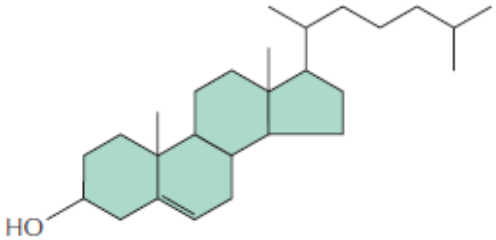
Fatty acids/Lipids

Glycolipids: Have sugars instead of phosphate group.

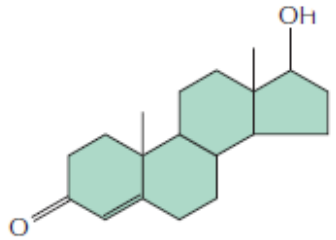




Steroids: Lipids with a common multiple-ring structure.



cholesterol—found in many cell membranes



testosterone—male sex hormone