

BCH 201

Cell Biochemistry

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Introduction

- All organisms are composed of structural and functional units of life called 'cells'.
- The body of some organisms like bacteria, protozoans and some algae is made up of a single cell whereas the body of higher fungi, plants and animals are composed of many cells. Human body is built of about one trillion cells.
- Cells vary in size and structure as they are specialized to perform different functions. But the basic components of the cell are common to all biological cells.
- **The cell theory** - In 1838 M.J. Schleiden and Theodore Schwann formulated the "cell theory." Which maintains that:
 - all organisms are composed of cells.
 - cell is the structural and functional unit of life, and
 - cells arise from pre-existing cells.
- The cells vary considerably, in shapes and sizes. *→ Time*
 - Nerve cells of animals have long extensions. They can be several centimeter in length. Muscle cells are elongated in shape. Egg of the ostrich is the largest cell (75 mm). Some plant cells have thick walls. There is also wide variation in the number of cells in different organisms.

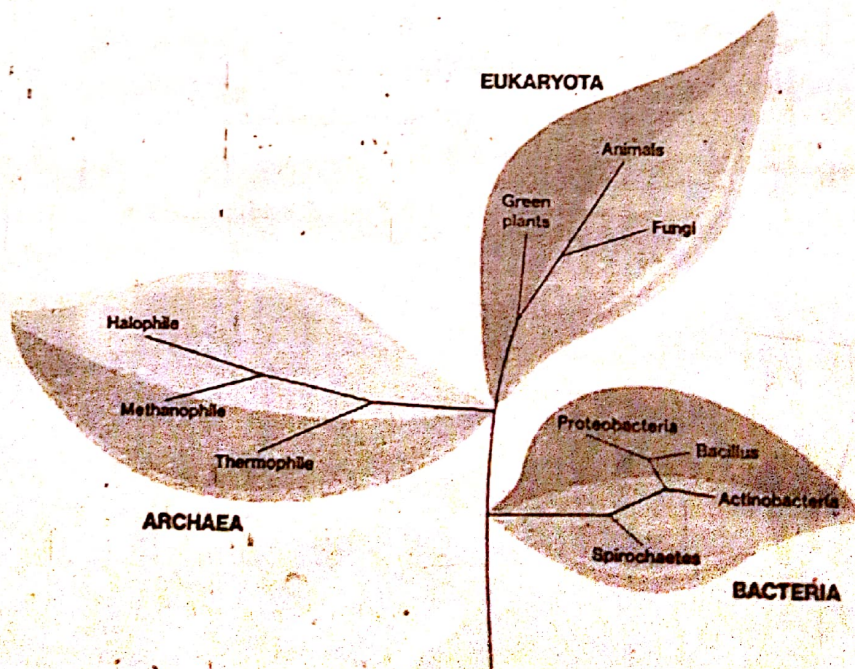
The Cell

- A cell may be defined as a unit of protoplasm bound by a plasma or cell membrane and possessing a nucleus.
- Protoplasm is the life giving substance and includes the cytoplasm and the nucleus.
- The cytoplasm has in it organelles such as ribosomes, mitochondria, golgi bodies, plastids, lysosomes and endoplasmic reticulum.
- Plant cells have in their cytoplasm, large vacuoles containing non-living inclusions like crystals, and pigments. *↓ storage water in the plants*
- The bacteria have neither defined cell organelles nor a well formed nucleus.
- But every cell has three major components:
 - plasma membrane ✓
 - cytoplasm ✓
 - DNA (naked in bacteria) and enclosed by a nuclear membrane in all other organisms

The Domains of Life

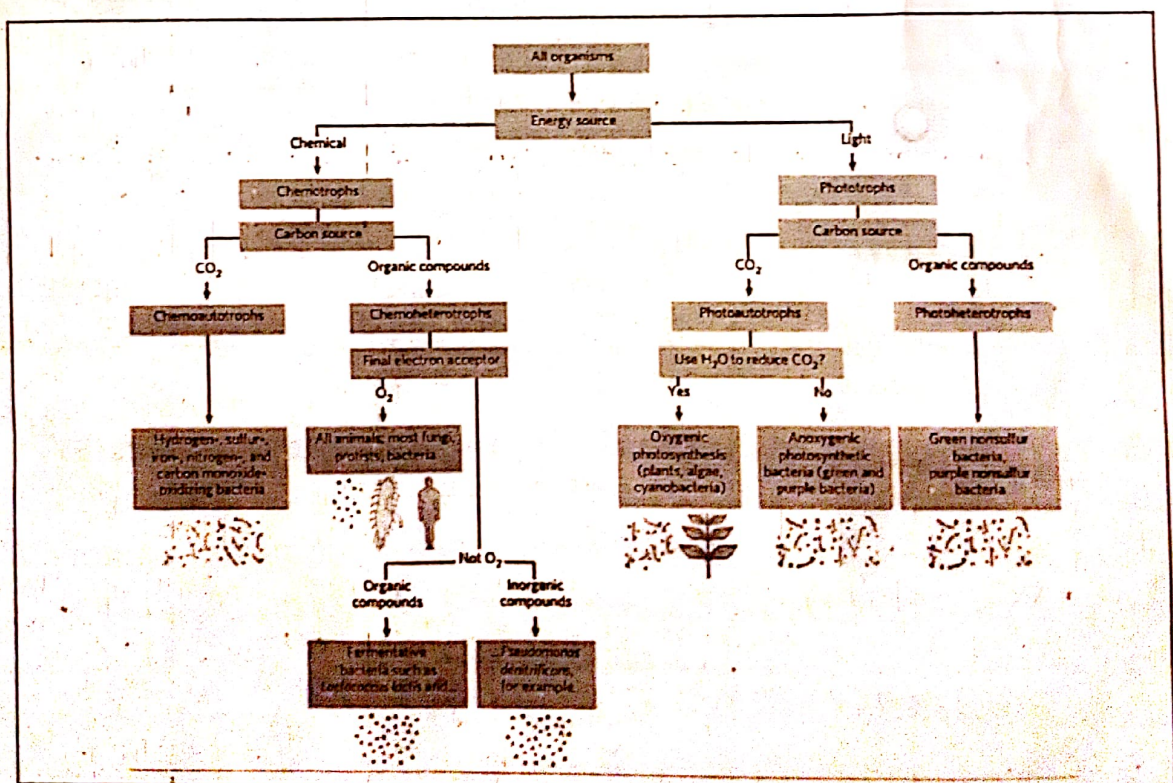
- All living organisms fall into one of three large groups (domains) that define three branches of the evolutionary tree of life originating from a common progenitor.
- Two large groups of single-celled microorganisms can be distinguished on genetic and biochemical grounds: Bacteria and Archaea.
- ✓ ▪ Bacteria inhabit soils, surface waters, and the tissues of other living or decaying organisms.
- ✓ ▪ Many of the Archaea inhabit extreme environments such as salt lakes, hot springs, highly acidic bogs, and the ocean depths.
- ✓ ▪ All eukaryotic organisms, which make up the third domain, Eukarya, evolved from the same branch that gave rise to the Archaea; eukaryotes are therefore more closely related to archaea than to bacteria.
- Within the domains of Archaea and Bacteria are subgroups distinguished by their habitats.
- In aerobic habitats with a plentiful supply of oxygen, some resident organisms derive energy from the transfer of electrons from fuel molecules to oxygen within the cell.
- Other environments are anaerobic, virtually devoid of oxygen, and microorganisms adapted to these environments obtain energy by transferring electrons to nitrate (forming N_2), sulfate (forming H_2S), or CO_2 (forming CH_4).
- Many organisms that have evolved in anaerobic environments are obligate anaerobes: they die when exposed to oxygen. Others are facultative anaerobes, able to live with or without oxygen.

The Three Domains of Life



The Sources of Cellular Energy and Biosynthetic Precursors

- Organisms can be classified according to how they obtain the energy and carbon they need for synthesizing cellular materials.
- There are two broad categories based on energy sources: phototrophs (Greek *trophe*, "nourishment") trap and use sunlight, and chemotrophs derive their energy from oxidation of a chemical fuel.
- Phototrophs and chemotrophs may be further divided into those that can synthesize all of their biomolecules directly from CO_2 (autotrophs) and those that require some preformed organic nutrients made by other organisms (heterotrophs).
- For example, cyanobacteria are photoautotrophs; humans are chemoheterotrophs.
- Many organisms can obtain energy and carbon from more than one source under different environmental or developmental conditions.

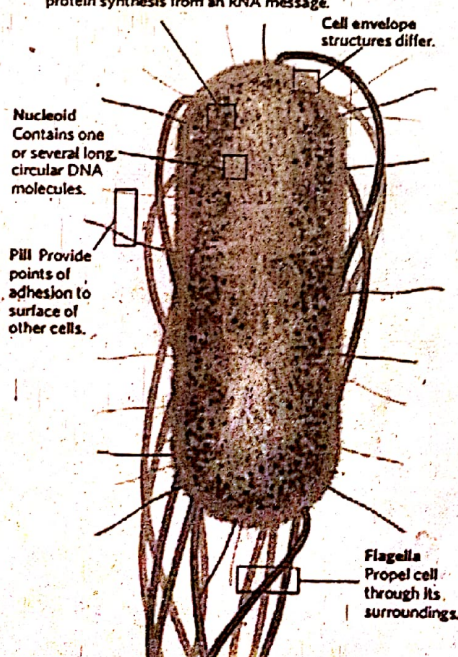


Similarities and Differences Between Bacterial and Archaeal cells

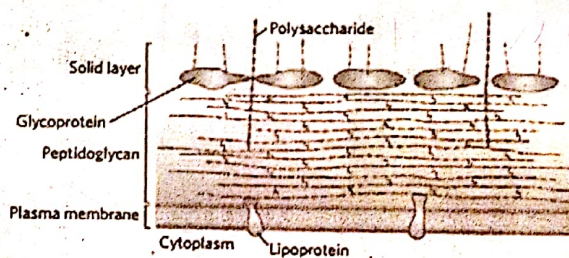
- The cell envelope of gram-positive bacteria is a single membrane with a thick, rigid layer of peptidoglycan on its outside surface. A variety of polysaccharides and other complex polymers are interwoven with the peptidoglycan, and surrounding the whole is a porous "solid layer" composed of glycoproteins.
- *E. coli* is gram-negative and has a double membrane. Its outer membrane has a lipopolysaccharide (LPS) on the outer surface and phospholipids on the inner surface. This outer membrane is studded with protein channels (porins) that allow small molecules, but not proteins, to diffuse through. The inner (plasma) membrane, made of phospholipids and proteins, is impermeant to both large and small molecules. Between the inner and outer membranes, in the periplasm, is a thin layer of peptidoglycan, which gives the cell shape and rigidity, but does not retain Gram's stain.
- Archaeal membranes vary in structure and composition, but all have a single membrane surrounded by an outer layer that includes either a peptidoglycanlike structure, a porous protein shell (solid layer), or both.

Some common structural features of bacterial and archaeal cells

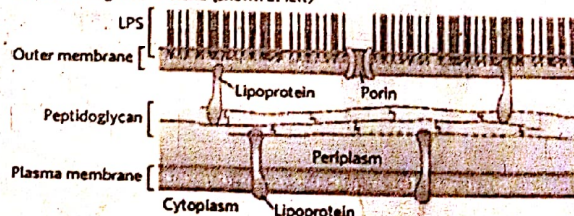
(a) Ribosomes Bacterial and archaeal ribosomes are smaller than eukaryotic ribosomes, but serve the same function—protein synthesis from an RNA message.



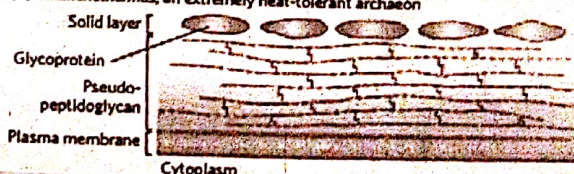
(b) Gram-positive bacteria



(c) Gram-negative bacteria (shown at left)



(d) *Methanothermus*, an extremely heat-tolerant archaeon

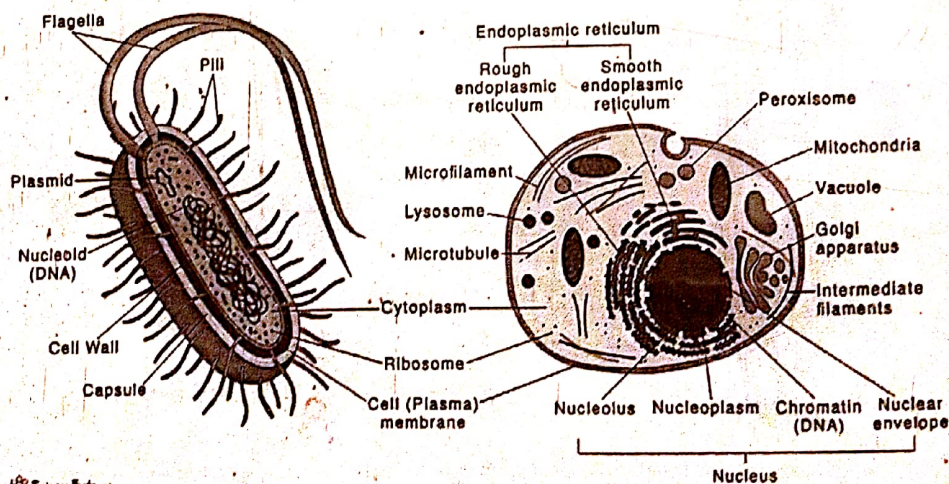


The Two Basic Type of Cells

- There are two basic type of cells:
 - Organisms which do not possess a well formed nucleus are prokaryotes such as the bacteria.
 - All others possess a well defined nucleus, covered by a nuclear membrane and they are referred to as eukaryotes.
- Prokaryotes are usually single-celled organisms. The best studied of all living organisms is the bacterium *Escherichia coli*. This organism has served for half a century as a model biological system.
- Eukaryotes include plants, animals, and fungi. Eukaryotic cells are much larger than bacteria with cell volumes a thousand to a million times larger than those of bacteria. The distinguishing characteristics of eukaryotes are the nucleus and a variety of membrane-enclosed organelles with specific functions.

The Two Basic Type of Cells

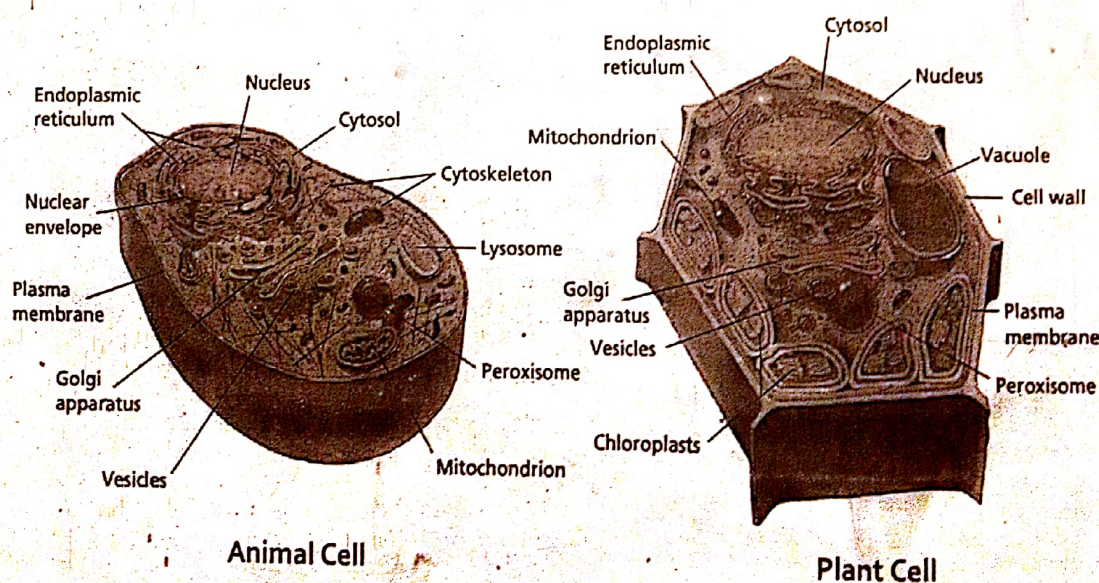
Prokaryotic Cells VS Eukaryotic Cells



Membranous Organelles in Eukaryotic Cells

- The distinguishing characteristics of eukaryotes are the nucleus and a variety of membrane-enclosed organelles with specific functions.
- These organelles include mitochondria, the site of most of the energy extracting reactions of the cell;
- The endoplasmic reticulum and Golgi complexes, which play central roles in the synthesis and processing of lipids and membrane proteins;
- Peroxisomes, in which very long-chain fatty acids are oxidized; and lysosomes, filled with digestive enzymes to degrade unneeded cellular debris.
- In addition to these, plant cells also contain vacuoles (which store large quantities of organic acids) and chloroplasts (in which sunlight drives the synthesis of ATP in the process of photosynthesis).
- Also present in the cytoplasm of many cells are granules or droplets containing stored nutrients such as starch and fat.

Eukaryotic cell structures



Methods of isolation and study of cell organelles

- Under centrifugal force generated in a spinning centrifuge rotor, subcellular structures separate by differences in mass.
- Structures that are more massive reach the bottom of the centrifuge tube before less massive ones. Biochemical analysis of the isolated cell fractions can reveal what different organelles and cellular substructures do.
- Cell fractionation separates cells into their constituent parts.
- The first step is to break open the cells and release their contents. This can be done by physical means such as grinding in a mortar and pestle, tissue grinder or similar device; exposure to ultrasound or high pressure; or exposure to enzymes or other chemicals that can selectively degrade the plasma membrane.
- The next step is to isolate the subcellular organelles and particles from the cytoplasm by **differential centrifugation**. The centrifugation of broken cells at progressively higher centrifugal force separates particulate cell components based on their mass.
- At the end of this process, a researcher will have isolated ribosomes, mitochondria, chloroplasts, nuclei, and other subcellular structures. After re-suspension, each pellet can be prepared for microscopy.

Methods of isolation and study of cell organelles

