Prokaryotic and Eukaryotic Cells

Paper: Cell Biology
Lesson: Prokaryotic and Eukaryotic Cells
Author Name: Dr. Lokesh Chandra Mishra , Dr. Gauri Mishra
College/ Department: Hansraj College, Swami Shraddhanand College
Department of Zoology , University of Delhi

Prokaryotic and Eukaryotic Cells

Table of Contents

Chapter: Prokaryotic and Eukaryotic Cells

PROKARYOTIC AND EUKARYOTIC CELLS

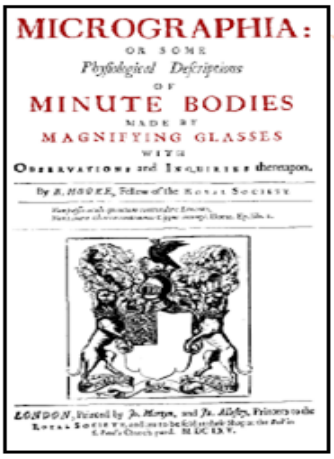
Introduction

The term "**Cell**" (Latin word, *cella*-hollow space) for the first time was coined by Robert Hooke in 1665 to describe the hollow spaces bound by cork in thin slices of cork under the first compound microscope. The cell is the fundamental structural, functional and biological unit of living organism. It is an aqueous compartment bound by cell membrane, which is capable of independent existence and performing the essential functions of life. Thus the study of cells started and the branch was called as Cytology.

Value Addition

Robert Hooke: Discovered first cell (cork) by compound microscope.

Source: http://www.science-of-aging.com/timelines/hooke-history-cell-discovery.php



Micrographia, major publication by Royal Society (1665). Significant historical book, by Robert Hooke. Speaks about his observations through various lenses. It was the first book to illustrate insects, plants etc. as seen through microscopes. First scientific best-seller, inspiring young minds in the new world of science.

Source: http://ocw.mit.edu/ans7870/21l/21l.016/s07/assignments/hooke-cover.html

Prokaryotic and Eukaryotic Cells

All organisms consist of cells, which are more complex than viruses. Viruses are non-cellular as they lack cell or cell like structure. In 1838, Schleiden and Schwann propounded the "**Cell Theory**", according to that; tissues of all living organisms consist of cell. Thus the cells are the smallest unit of life which can replicate independently, and are referred to as "building blocks of life". In 1855, Rudolf Virchow added further by proposing that all living cells arise from pre-existing cells (***omnis cellula e cellula***). The theory, over the time continued to evolve and included the following components:

- All living organisms are made up of cell/cells.
- Cell is the basic structural and functional unit of life.
- Cells come up from pre-existing cells.
- All cells have similar basic chemical composition.
- Cells acquire and utilize energy.
- Cell possesses a genetic program (DNA) and the means to use it.

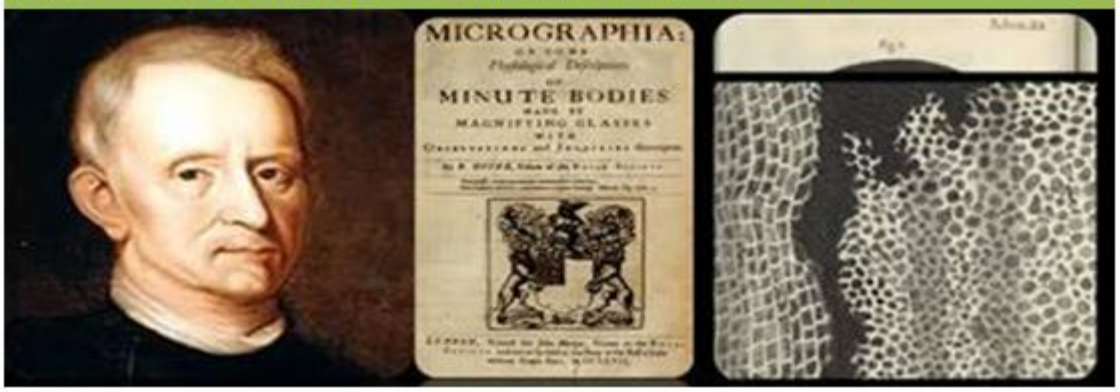
The discovery of electron microscope enabled the biologists to look at the interior organization of an extensive diversity of cells. Now, it turned out to be obvious that there were two fundamental types of cells,—prokaryotic cells (eg. bacteria) which lack a nuclear envelope; and eukaryotic cells which possess a well defined nucleus in which the genetic material or DNA is estranged from the cytoplasm (Figure 1). These could be easily differentiated by their size and internal organization (Figure 2). Prokaryotic cells are typically lesser in size and complexity than eukaryotic cells. The structurally less intricate prokaryotic cells embrace bacteria, while the more complex eukaryotic cells take account of protists, fungi, plants, and animals. The prokaryotic cells have genome which is less complex and lack cytoplasmic organelles unlike eukaryotic cells (Figure 3). All existing cells have come down from a solitary primordial predecessor, and have the same fundamental molecular machinery.

Prokaryotic and Eukaryotic Cells

Value Addition: Robert Hooke's statement

"I could exceedingly plainly perceive it to be all perforated and porous, much like a Honey-comb, but that the porous of it were not regular....these pores, or cells.....were indeed the first microscopical pores I ever saw, and perhaps, that were ever seen, for I had not met with any writer or person, that had made any mention of them before this"

(Source: Micrographia, by R. Hooke, Fellow of Royal Society, 1964)



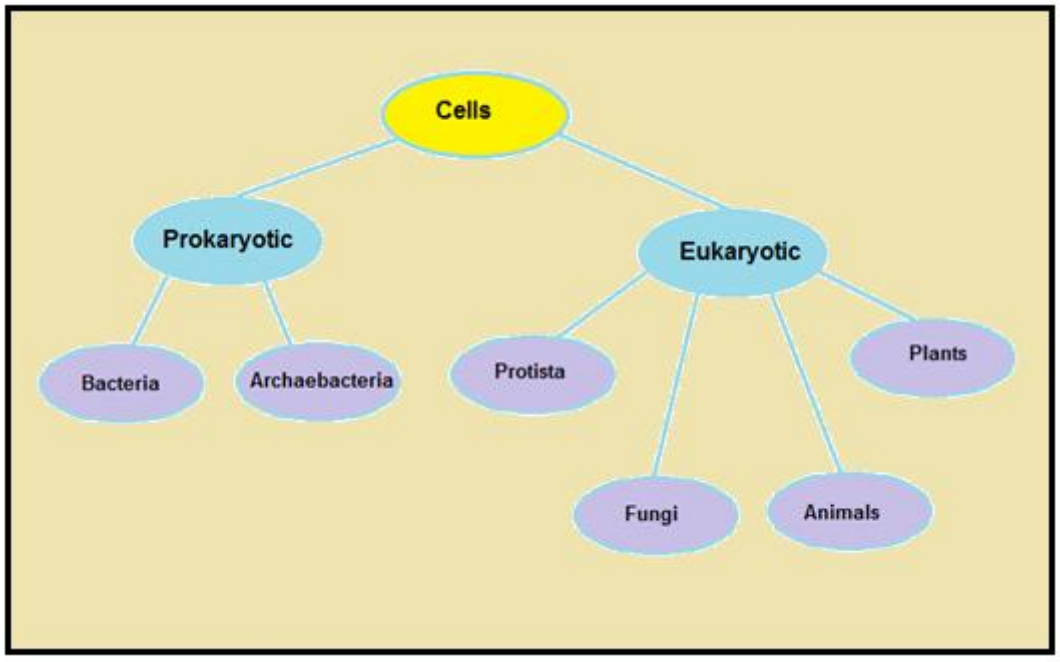


Figure 1: Illustration showing types of cells forming an entity.

Prokaryotic and Eukaryotic Cells

Prokaryotes include a variety of bacteria, which can be divided in archaebacteria and the eubacteria. Archaea, have no nucleus and cell organelle, and were considered as extremophiles living in severe environments, for instance hot springs and salt lakes. The eubacteria embrace the general forms of bacteria which is a huge cluster of organisms that exist in an extensive range of environments like water, soil, and other organisms (e.g., human pathogens). The largest and most complex prokaryotes are the cyanobacteria, in which photosynthesis evolved.

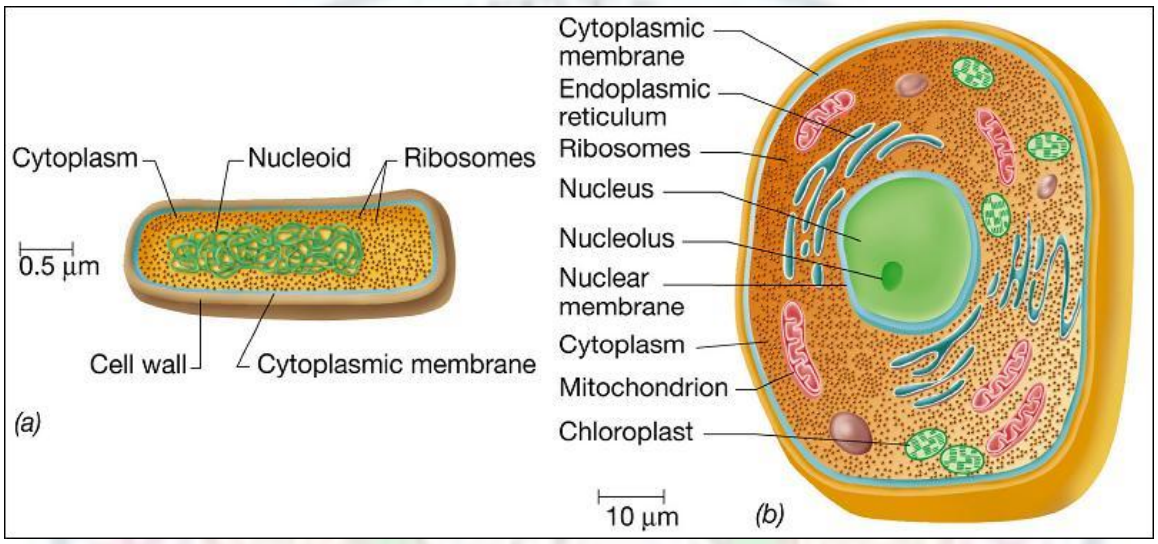


Figure 2: Diagrammatic view Prokaryotic and Eukaryotic cell.

Source: http://www.socratic.org

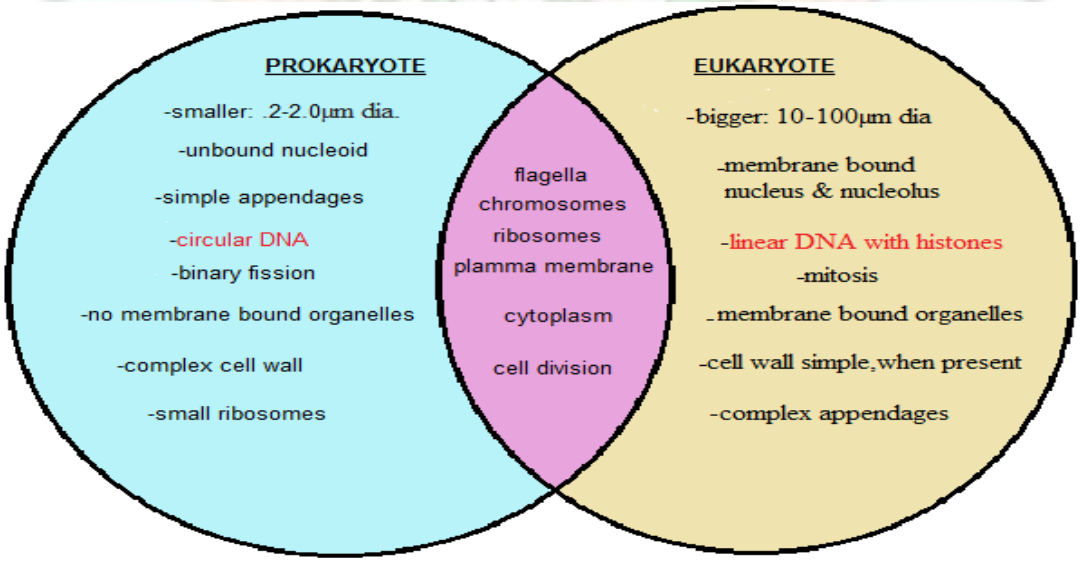


Figure 3: Comparative view of a Prokaryotic and Eukaryotic cell

Source: Author

Prokaryotic and Eukaryotic Cells

Prokaryotic Cell Structure

Prokaryotic cells do not possess a defined nucleus; instead, a nucleoid (incipient nucleus) is present. In this Nucleoid a single chromosomal, circular, double-stranded DNA molecule is located. The structure of a typical prokaryotic cell is illustrated in Figure 4. **Capsule**, a slimy and gummy covering, is the outer layer of prokaryotic cell. Sometimes, it is labeled as the "**Slime capsule**". It enables the bacteria to live together and also provide protection to the cell. Prokaryotic cells are generally bounded by a **cell wall** which is a stiff scaffold of **murein** (polysaccharide cross-linked by peptide chains). Beneath the cell wall is the **plasma membrane** (also referred as cell membrane), which is a double layer formed by phospholipids and proteins. It is flexible while the cell wall is porous and rigid structure. The plasma membrane works as a functional divider between the cell's internal and external environment.

Most prokaryotes are bounded by a cell wall with the exceptions of *Mycoplasma* (bacteria) and *Thermoplasma* (archaea).

Value Addition: Screenshot of article published by Carl R. Woese on prokaryotic domain

Proc. Natl. Acad. Sci. USA
Vol. 74, No. 11, pp. 5088–5090, November 1977
Evolution

Phylogenetic structure of the prokaryotic domain: The primary kingdoms

(archaebacteria/eubacteria/urkaryote/16S ribosomal RNA/molecular phylogeny)

CARL R. WOESE AND GEORGE E. FOX*

Department of Genetics and Development, University of Illinois, Urbana, Illinois 61801

Communicated by T. M. Sonneborn, August 18, 1977

ABSTRACT **A phylogenetic analysis based upon ribosomal RNA sequence characterization reveals that living systems represent one of three aboriginal lines of descent: (*i*) the eubacteria, comprising all typical bacteria; (*ii*) the archaebacteria, containing methanogenic bacteria; and (*iii*) the urkaryotes, now represented in the cytoplasmic component of eukaryotic cells.**

The biologist has customarily structured his world in terms of certain basic dichotomies. Classically, what was not plant was animal. The discovery that bacteria, which initially had been considered plants, resembled both plants and animals less than plants and animals resembled one another led to a reformulation of the issue in terms of a yet more basic dichotomy, that of eukaryote versus prokaryote. The striking differences between eukaryotic and prokaryotic cells have now been documented in endless molecular detail. As a result, it is generally taken for granted that all extant life must be of these two basic types.

Thus, it appears that the biologist has solved the problem of the primary phylogenetic groupings. However, this is not the to construct phylogenetic classifications between domains: Prokaryotic kingdoms are not comparable to eukaryotic ones. This should be recognized by an appropriate terminology. The highest phylogenetic unit in the prokaryotic domain we think should be called an "urkingdom"—or perhaps "primary kingdom." This would recognize the qualitative distinction between prokaryotic and eukaryotic kingdoms and emphasize that the former have primary evolutionary status.

The passage from one domain to a higher one then becomes a central problem. Initially one would like to know whether this is a frequent or a rare (unique) evolutionary event. It is traditionally assumed—without evidence—that the eukaryotic domain has arisen but once; all extant eukaryotes stem from a common ancestor, itself eukaryotic (2). A similar prejudice holds for the prokaryotic domain (2). [We elsewhere argue (6) that a hypothetical domain of lower complexity, that of "progenotes," may have preceded and given rise to the prokaryotes.] The present communication is a discussion of recent findings that relate to the urkingdom structure of the prokaryotic do-

The genetic material consists of a single circular molecule in the **nucleoid**. The nucleus (known as nucleoid) of prokaryotic cells varies from that of eukaryotic cells. The eukaryotic cell nucleus is enclosed by a nuclear membrane and inside there is DNA with histone protein while prokaryotes have incipient nucleus without nuclear membrane and histone. The cytoplasm is granular in appearance due to the presence of approximately 30,000 ribosomes which is also the site of protein synthesis. The ribosomes in prokaryotic cells are of 70S type. Plasmid, short circular DNA, is also present which can replicate independently due to the presence of origin of replication.

The invaginations of the plasma membrane forms structure known as Mesosome. Enzymes associated with respiration are located on these infoldings. Mesosomes are not present in all the prokaryotic cells. Prokaryotic cells store lipid globules or glycogen granules as reserve food materials. Prokaryotic cell (e.g. a bacterium) also shows movement with the help of flagella. Motility is spontaneous and active by consuming energy. The flagellum of a prokaryotic cell rotates on a "bearing" in the cell wall which results in curved motion which

resembles a propeller of some ships. Pili are hair like appendages present on the surface of many bacteria. It is a protein rod, shorter and thinner than flagellum. It helps in adherence with each another.

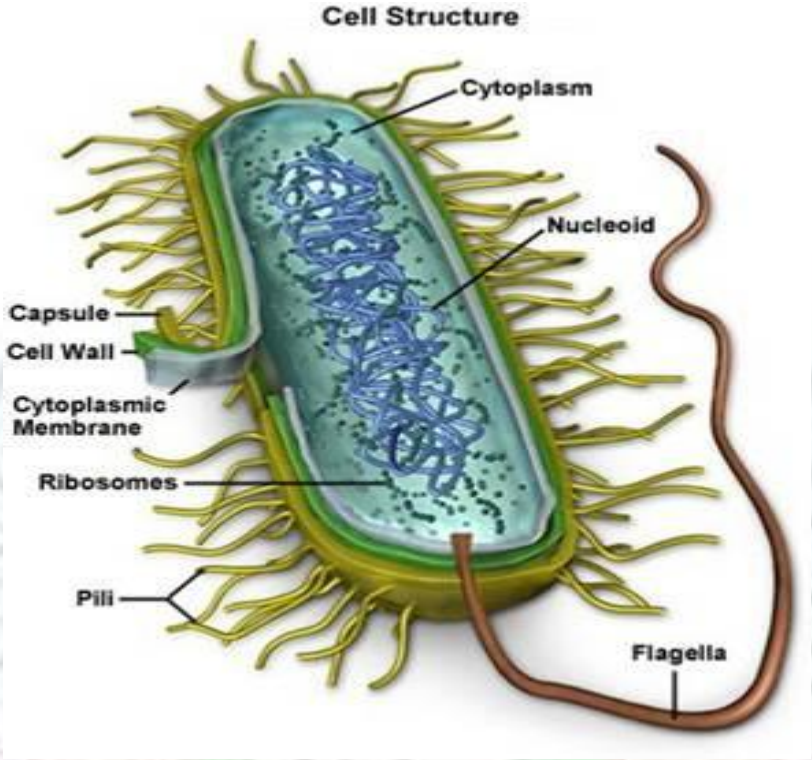
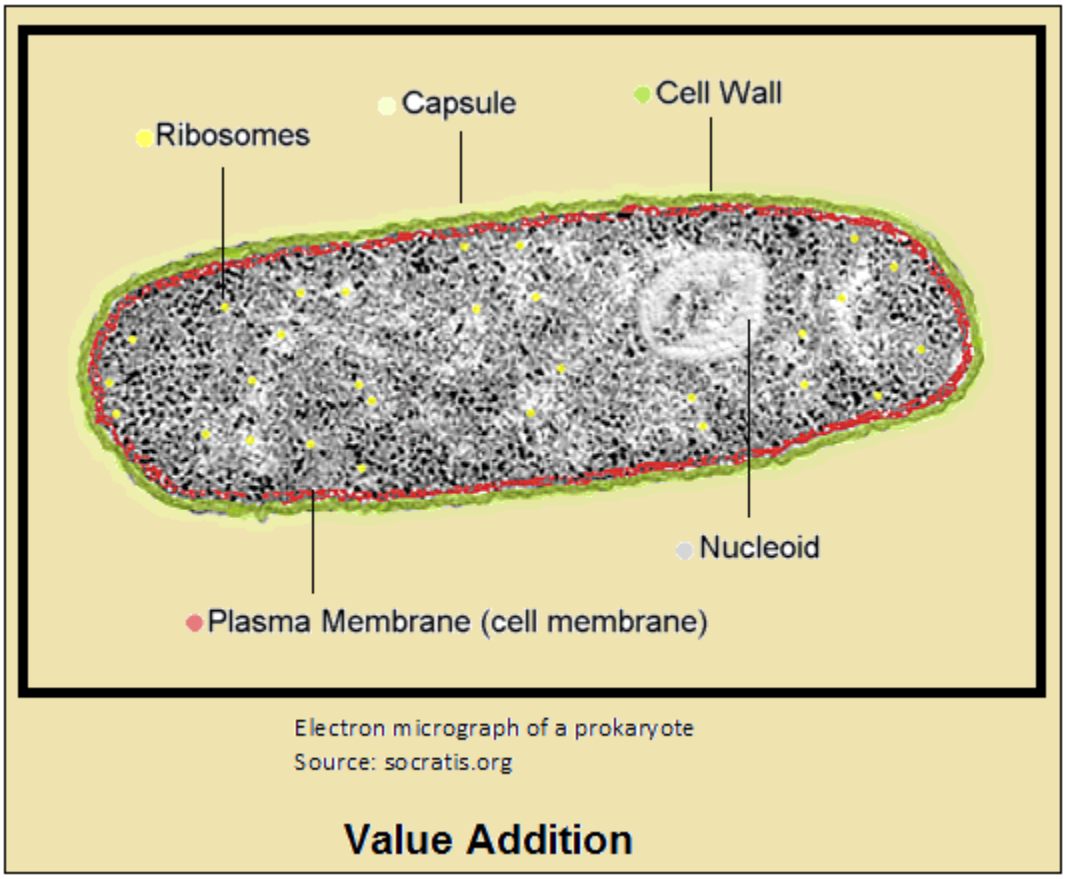


Figure 4: Prokaryotic Cell

Source: http://www.cellspd5spering.wikispaces.com



Electron micrograph of a prokaryote
Source: socratis.org

Value Addition

Eukaryotic Cell Structure

The name Eukaryote comes from the Greek ευ (*eu*, "well") and κάρυον (*karyon*, "nut" or "kernel") which means a true or well developed nucleus. Structure of eukaryotic cells is more complex. Eukaryotic cells have membrane-bound organelles. The nucleus, enclosed by a nuclear membrane, contains genetic material which which is different from prokaryotic cells (Bacteria and Archaea). Eukaryotic cells have a variety of cytoplasmic organelles and cytoskeleton (Figure 4). In eukaryotes, the genetic information (contained in nucleus) is structured in a linear rather than circular pattern of DNA molecules. Nucleus is the place of DNA replication and synthesis of RNA. This is also the largest organelle of the cell. Eukaryote cells comprise a diversity of membrane-bound structures (Figure 7) which is cooperatively referred to as the endomembrane system for example mitochondria, endoplasmic reticulum, vacuole, the Golgi apparatus etc. (Figure 5) in cytoplasm. In addition, plants and algae contain chloroplasts. These organelles are like specialized booths for

diverse metabolic activities and also compartmentalization permits eukaryotic cells to work proficiently.

Mitochondria and chloroplasts are very important organelles as these participate in energy metabolism gravely. Mitochondria are present universally in all eukaryotic cells. It is surrounded by phospholipid bi-layer double membranes. The inner membrane is folded into invaginations called cristae. Cristae are the site of aerobic respiration where oxidative metabolism takes place. Mitochondria generate most of the ATP by the breakdown of organic molecules. For the same reason, Mitochondria are referred to as "**power bank**" or "**power house**" of the cell. Digestion of macromolecules and diverse oxidative reactions takes place in Lysosomes and Peroxisomes respectively which provide dedicated metabolic booths for the same. Plant cells generally contain large vacuoles that execute variety of functions which include the digestion of macromolecules and providing cargo space for waste products and nutrients. Chloroplasts contain stacked thyllakoids and are bounded by a double membrane. This is the organelle responsible for photosynthesis in plant cells and green algae. This contains a green colour pigment called as chlorophyll. Both mitochondria and chloroplast have their own DNA. Therefore, both are referred as "**semi autonomous replicating organelle**".

Prokaryotic and Eukaryotic Cells

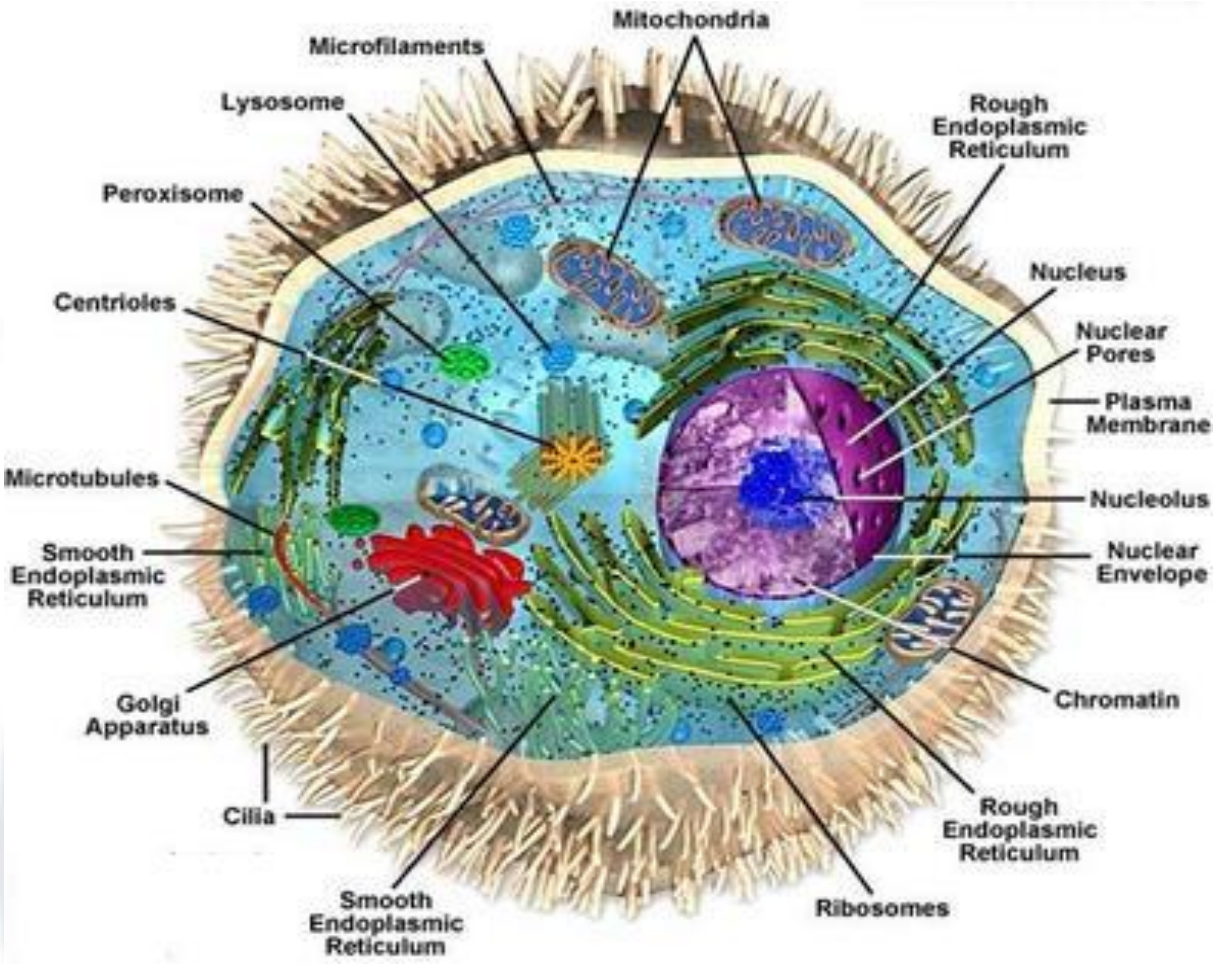
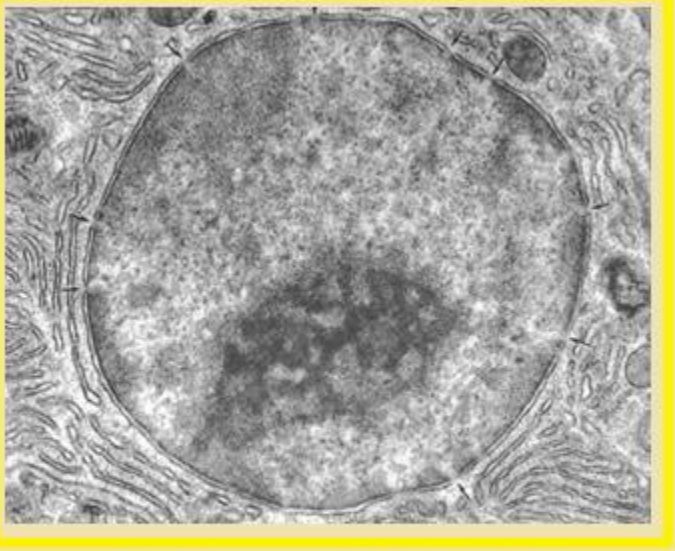


Figure 5: Eukaryotic Cell

Source: http://www.smokahauntes.wikispaces.com



Electron micrograph showing nucleus
Source: binoculas.net

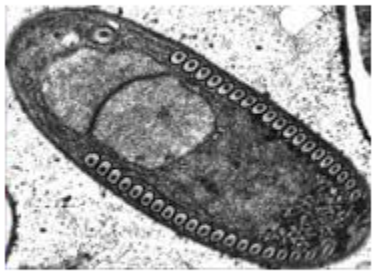
Value Addition

The endoplasmic reticulum and the Golgi apparatus are engaged in the categorization and transport of proteins which are destined for various purposes like secretion, integration in plasma membrane and inclusion into lysosomes. Endoplasmic reticulum (ER) is a network of membrane enclosed tubules and sacs (cisternae) that extends from the nuclear membrane all through the cytoplasm. ER helps in intracellular transport of materials and also provides mechanical support to cytoplasm. Endoplasmic reticulum is of two types–Smooth endoplasmic reticulum (SER) and Rough endoplasmic reticulum (RER). RER arises from nuclear membrane. SER consists of tubules studded with ribosomes and is associated with protein modification and trafficking. SER (without ribosomes) is primarily associated with synthesis of lipids and helps in detoxification (Figure 7). Proteins from RER are transferred inside small membrane vesicles to the Golgi apparatus (series of stacked membranes). Within the Golgi body, further modification and sorting takes place for transport to concluding destinations.

The structural framework of the cell is provided by cytoskeleton which is a network of protein filaments and extends all through the cytoplasm. The shape and the general organization of the cell is determined by the cytoplasm. Cytoskeleton

includes three key filaments; **microfilaments** composed of actin, **intermediate filaments** made up of approximately 70 dissimilar proteins, and **microtubules** have tubulin as a basic subunit. The movement of cell is also the activity of cytoskeleton along with intracellular transportation, placing of organelles and components movements like chromosomes during cell division.

Value Addition



Microsporidia are intracellular parasites that infect other eukaryotic cells, commonly arthropods. They are the **simplest** and **smallest** eukaryotic cells and thus represent an example of reductive evolution

Source: https://www.en.wikipedia.org/wiki/Microsporidia

Plant and animal cells are eukaryotic. Both share common features but on the same time have several differences too (Figure 6). For instance, plant cells differ in having a cell wall and chloroplasts from animal cell. Shape of animal cells varies from round to irregular while plant cells have more or less fixed rectangular shapes. Table 1 shows the point of differences between the animal and plant cell.

Prokaryotic and Eukaryotic Cells

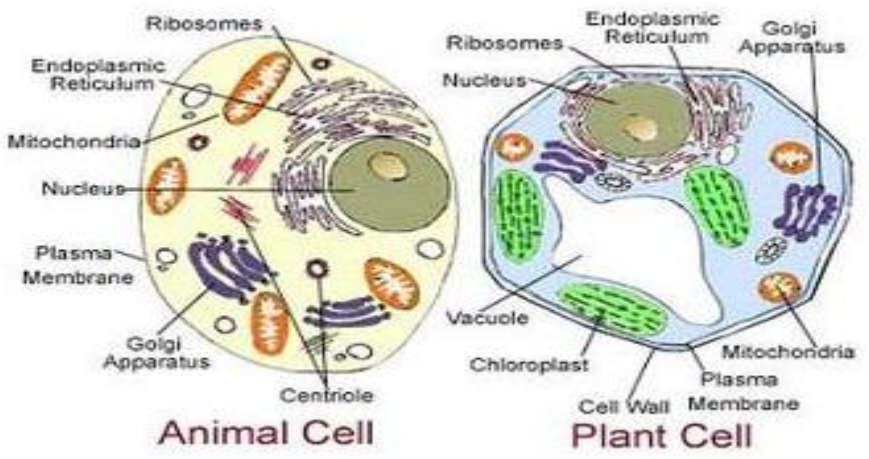


Figure 6: Diagrammatic view of Animal and Plant cell.

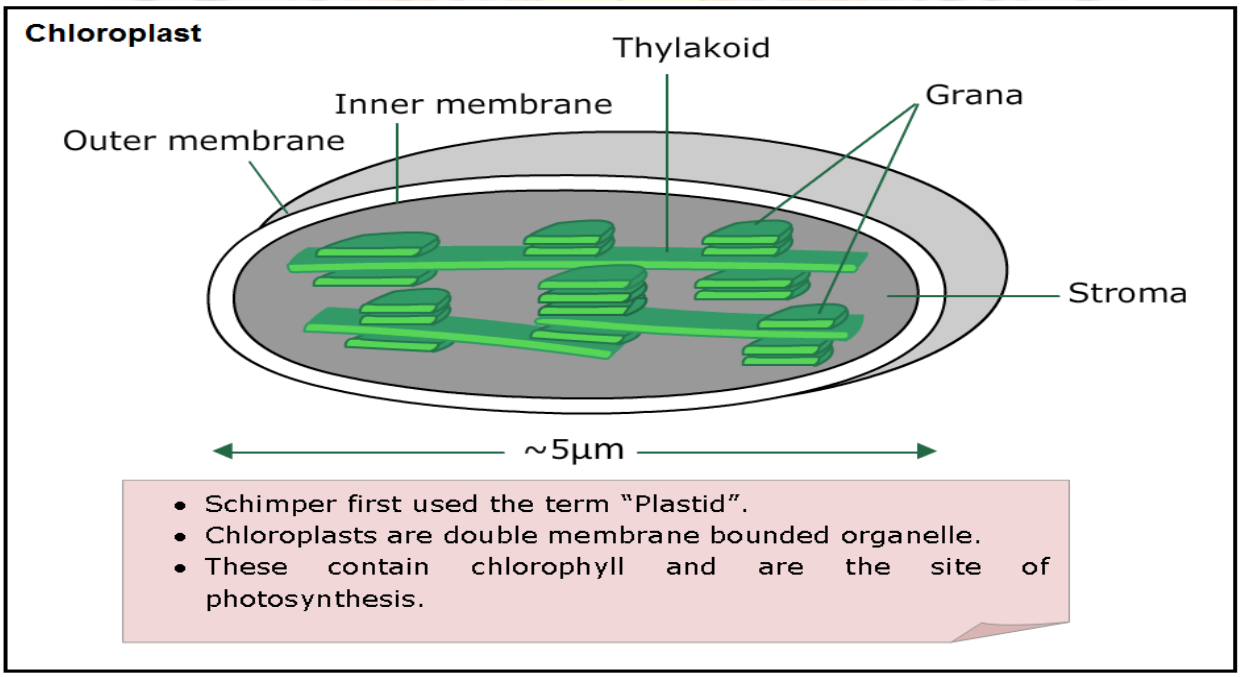
Source: http:// envorganelles.wikispaces.com

Sl.No.	Animal Cell	Plant Cell
1	Comparatively smaller in size	Usually larger in size
2	Enclosed by a thin, flexible plasma membrane	Plasma membrane enclosed by a rigid cellulose cell wall
3	Can often change its shape	Cannot change its shape.
4	Plastids are usually absent	Plastids are present. Cells exposed to sunlight possess chloroplast.
5	Possesses many small vacuoles	Contains a large vacuole.
6	Nucleus usually lies in the center	Nucleus lies on one side in the peripheral cytoplasm.
7	Centrioles present	Centerioles are usually absent except in motile cells of lower plants.
8	Lysosomes are always present	Lysosomes are rare
9	Glyoxysomes are absent	Glyoxysomes may be present
10	Tight junctions and desmosomes present between the cells. Plasmodesmata are usually absent.	Tight junctions and desmosomes lacking. Plasmodesmata present.

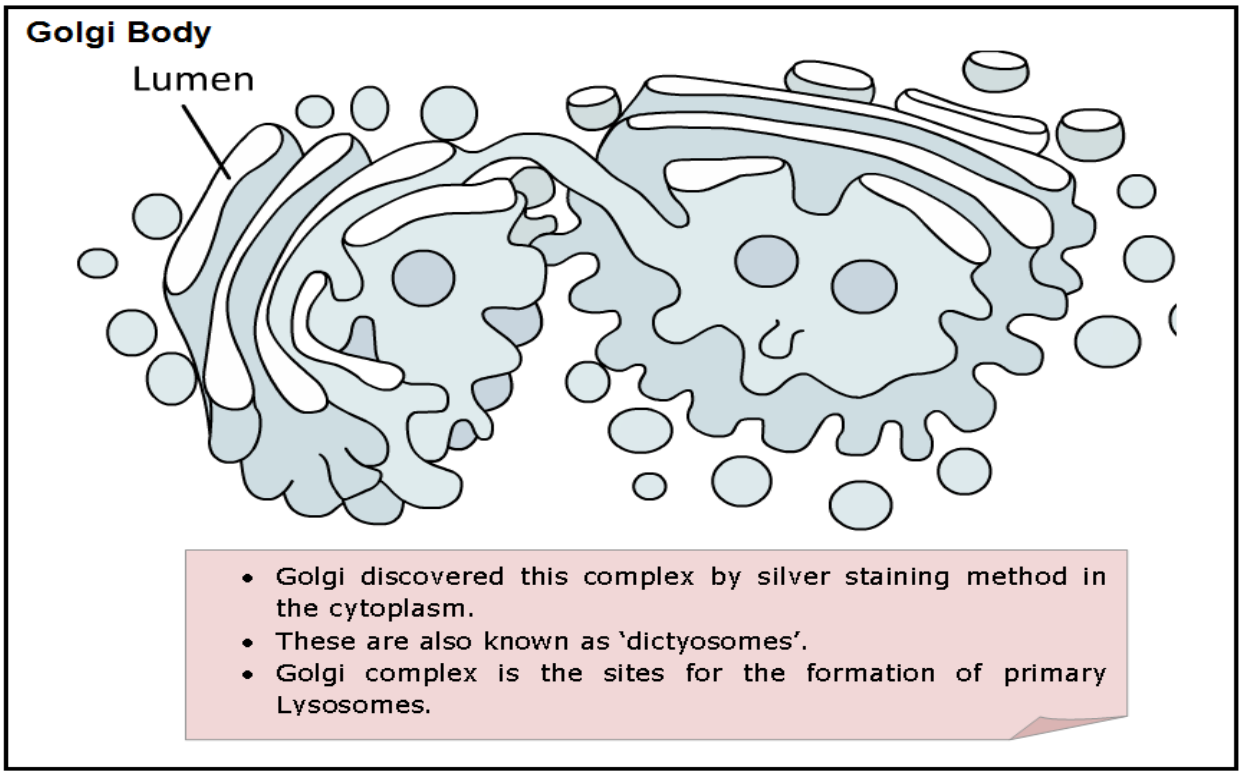
11	Reserve food is usually glycogen	Reserve food generally in form of starch.
12	Cannot synthesize all the amino acids, co-enzymes and vitamins required by them.	Can synthesize all the amino acids, co-enzymes and vitamins required by them.
13	Spindle formed during cell division is amphiastral i.e. has an aster at each pole.	Spindle formed during cell division is anastral i.e. without aster at opposite pole.
14	Cytokinesis occurs by constriction or furrowing	Cytokinesis occurs by cell plate method.

Table 1: Differences between Animal and Plant cell.

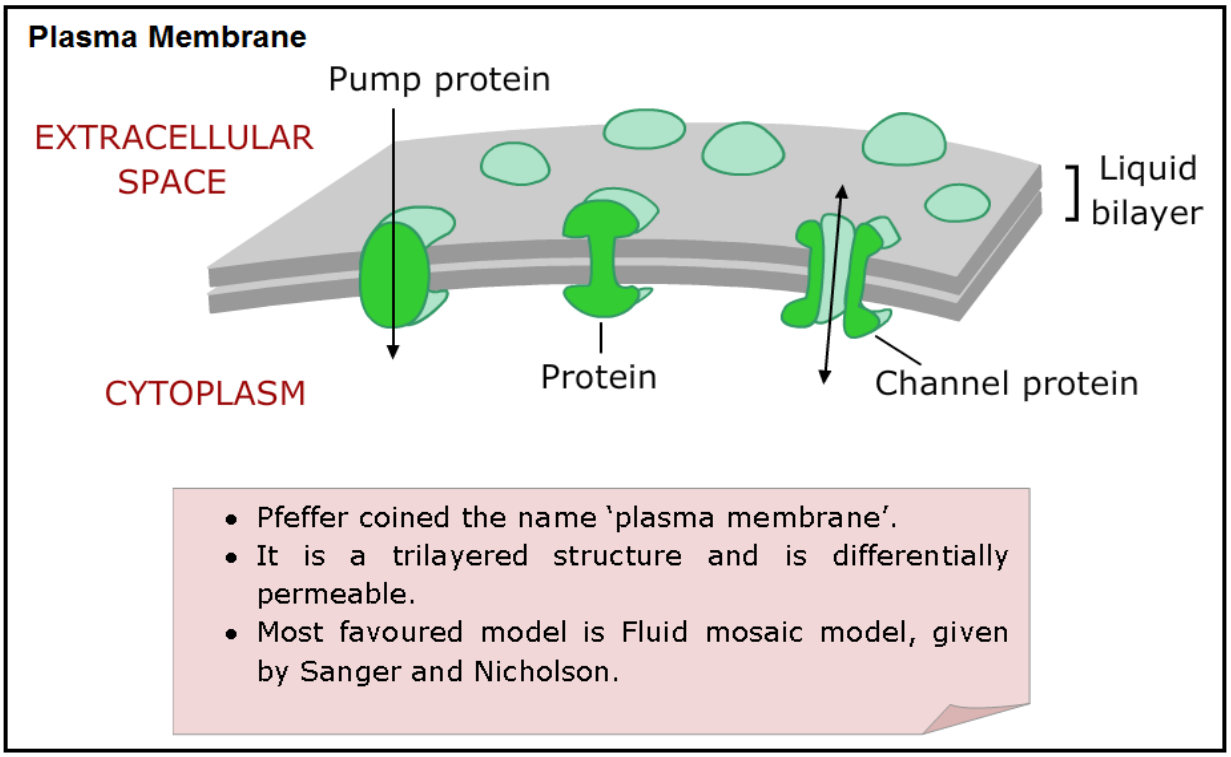
(A)



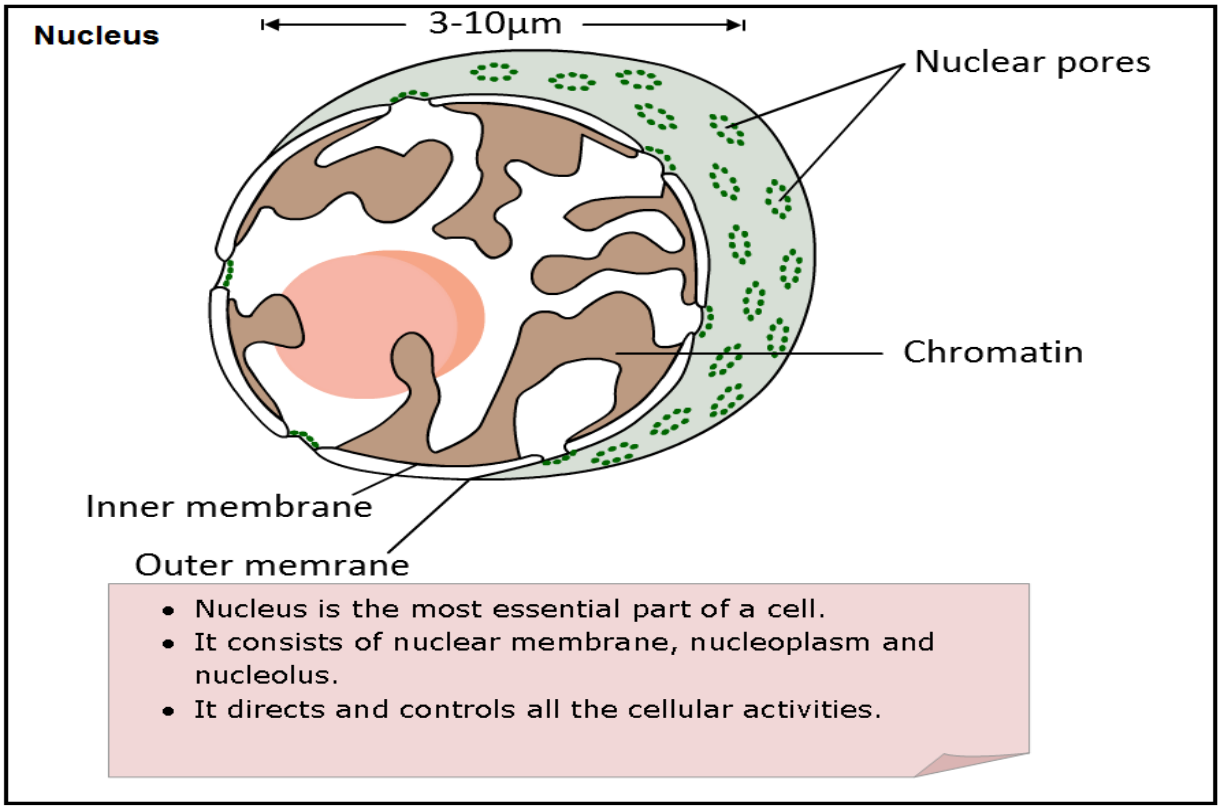
(B)


Golgi Body
Lumen
• Golgi discovered this complex by silver staining method in the cytoplasm.
• These are also known as 'dictyosomes'.
• Golgi complex is the sites for the formation of primary Lysosomes.

(C)

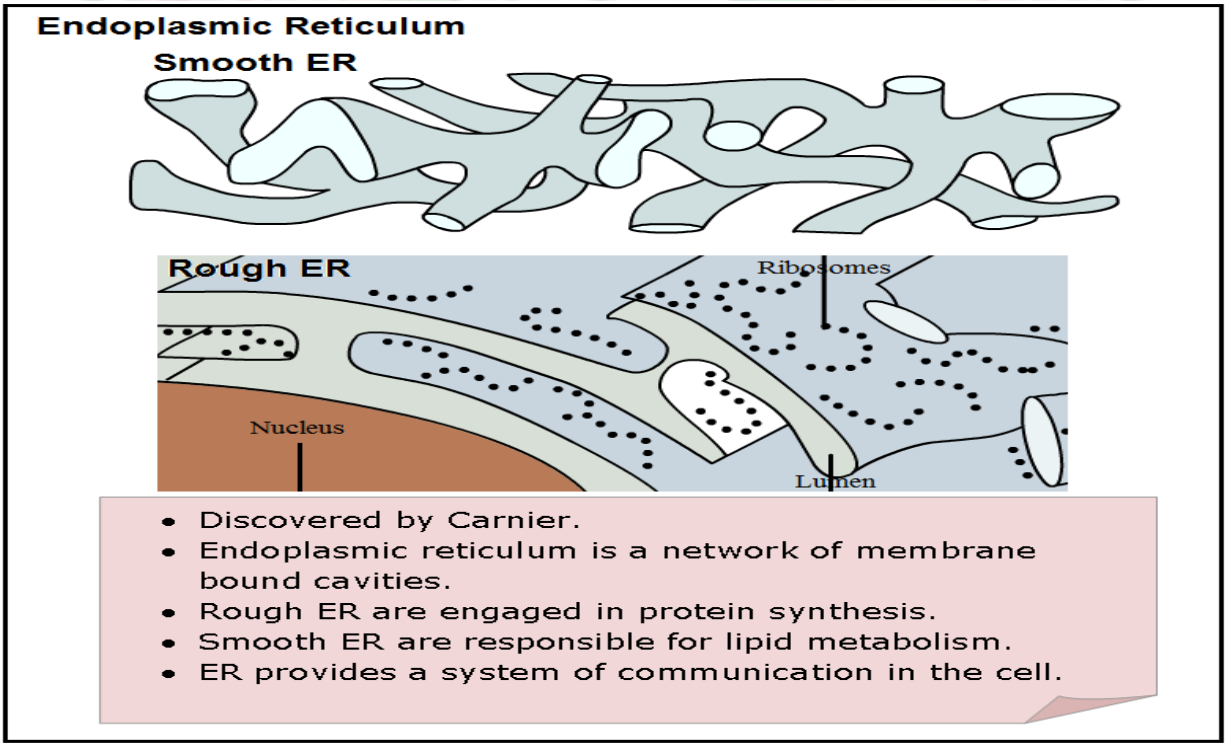

Plasma Membrane
Pump protein
EXTRACELLULAR SPACE
Liquid bilayer
CYTOPLASM
Protein
Channel protein
• Pfeffer coined the name 'plasma membrane'.
• It is a trilayered structure and is differentially permeable.
• Most favoured model is Fluid mosaic model, given by Sanger and Nicholson.

(D)



- Nucleus is the most essential part of a cell.
- It consists of nuclear membrane, nucleoplasm and nucleolus.
- It directs and controls all the cellular activities.

(E)

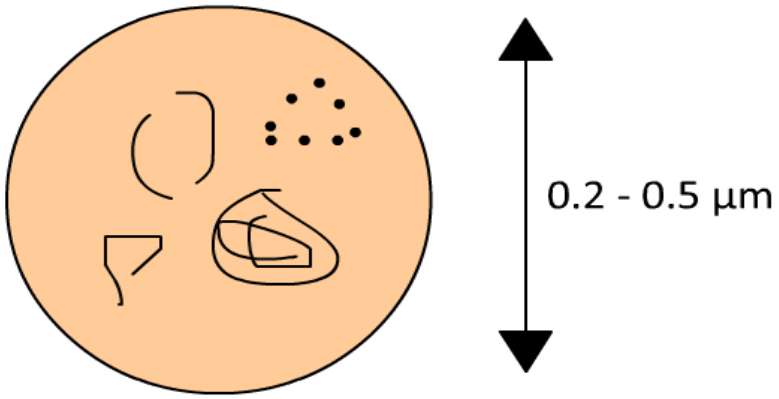


- Discovered by Carnier.
- Endoplasmic reticulum is a network of membrane bound cavities.
- Rough ER are engaged in protein synthesis.
- Smooth ER are responsible for lipid metabolism.
- ER provides a system of communication in the cell.

Prokaryotic and Eukaryotic Cells

(F)

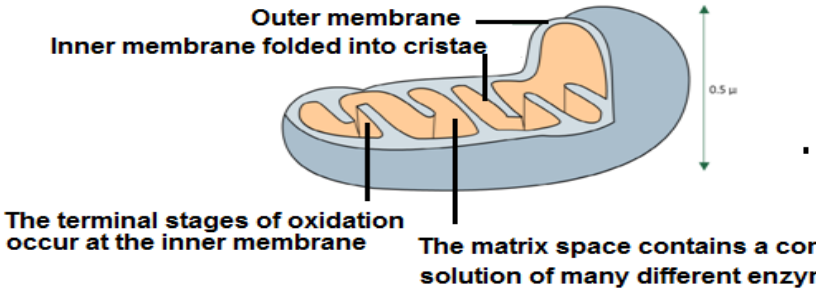
Lysosome



- First described by De Duve.
- Lysosomes are vesicles derived from golgi complex.
- They are called as 'Suicide bags' as they digest substances like protein, nucleic acis, polysaccharides etc.

(G)

Mitochondria



- Richard Altmann, called them "bioblasts.
- Double membrane-bound organelle; called as "Power house of the cell".
- It consists of its own circular DNA, thus called as autonomous self regulating organelle.

(H)

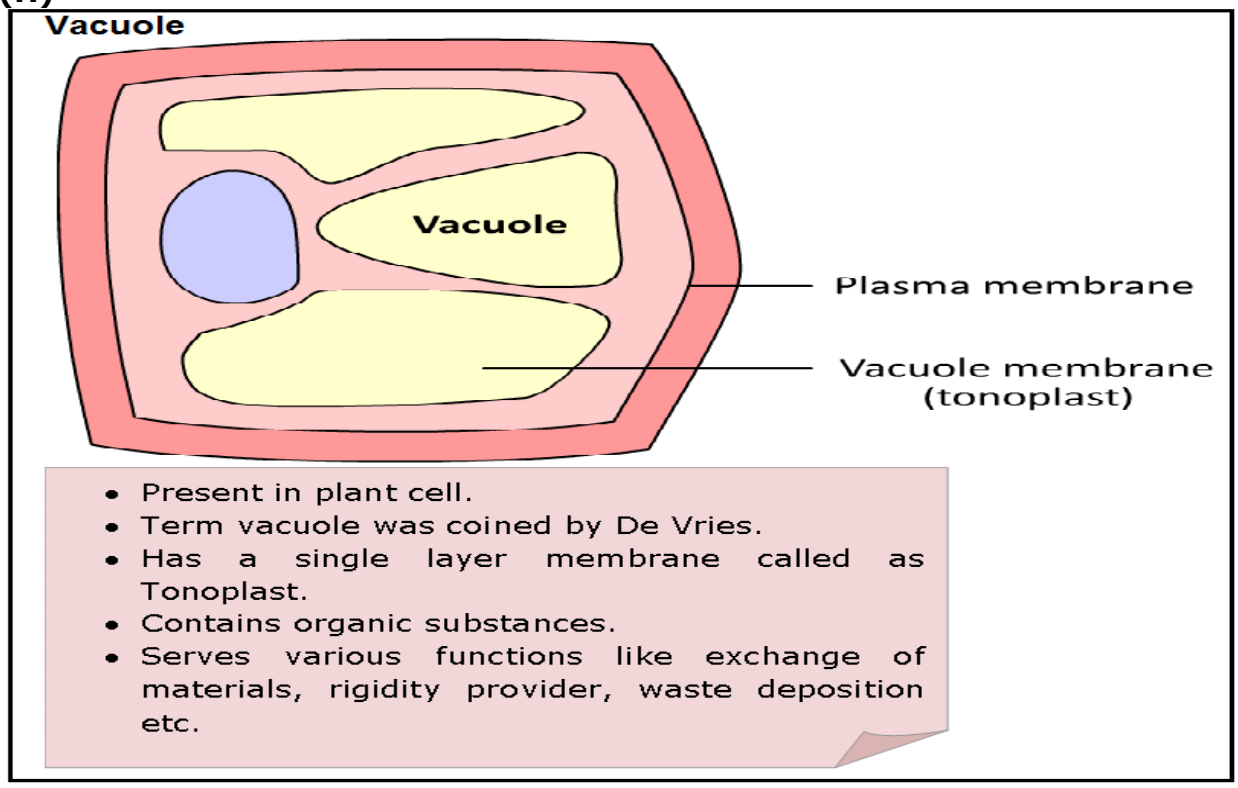


Figure 7: (A-H) Diagram showing various cell organelles.

Source: Author

Endosymbiotic theory

Theory was put forward by Lynn Margulis of Boston University. According to proposed theory, predator host (anaerobic) engulfed primitive aerobic bacteria which developed mutual relationship or association with the host. Later, these predators became the first eukaryotic cell. Predator with both aerobic as well as photosynthetic cyanobacteria (Blue Green Algae-BGA) was evolved in eukaryotic plant cell. These engulfed aerobic bacteria and cyanobacteria established themselves as mitochondria and chloroplast respectively (Figure 8).

Prokaryotic and Eukaryotic Cells

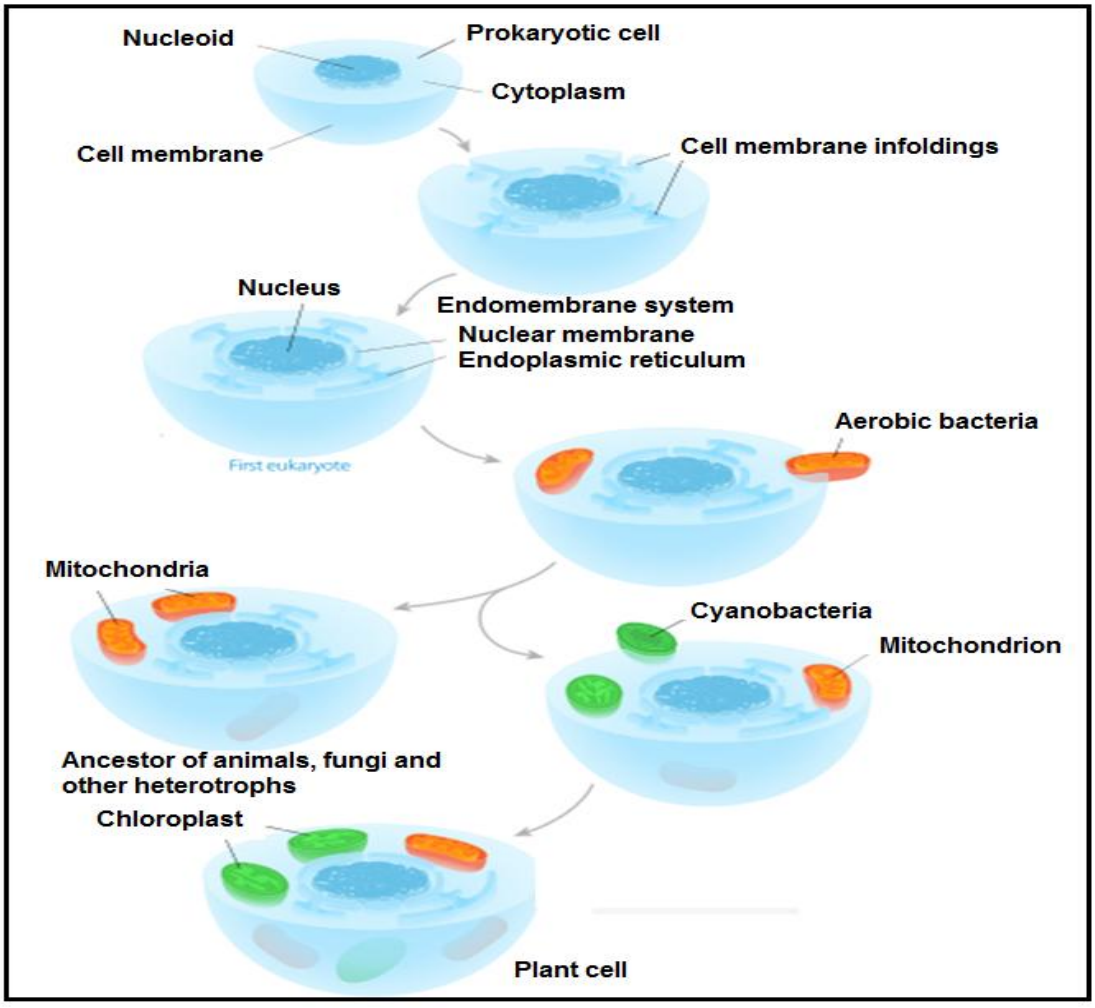


Figure 8: Diagram showing the evolution of eukaryotes through endosymbiosis

Source: https://en.wikipedia.org/wiki/Symbiogenesis#/media/File:Serial_endosymbiosis.svg

Endosymbiotic theory includes following steps:

1. Increase in surface area to volume ratio in prokaryote and development of infoldings in its cell membrane.
2. Infoldings gave rise to primitive eukaryotes through the development of endomembrane system and nuclear membrane.
3. Entry of aerobic bacteria either as a prey or parasite which avoided the digestion to become endosymbiont (living cell inside a cell).
4. This became an asset for the host as it could utilize the oxygen rich (aerobic) environment efficiently. Thus developed proterobacterium became mitochondrion.
5. Other symbiont or cyano bacteria (BGA) captured by host, which could photosynthesized, evolved as chloroplast to form plant cell.

Value Addition: Lynn Margulis and Endosymbiosis
 Lynn Margulis showed that an important organizational episode in the history of life possibly drawn in the inclusion of two or more lineages through symbiosis. Margulis, in 1960s, studied the detailed structure of cells and found remarkable similarities between mitochondria and bacteria. She advocated the endosymbiotic theory for the evolution of eukaryotes. Margulis used up much of her time in 1960s polishing her argument that symbiosis was an undocumented but chief force in the evolution of cells. In 1970 she published her view in *The Origin of Eukaryotic Cells*. Source: http://evolution.berkeley.edu/evolibrary/article/history_24

Facts or evidences which support the theory:

1. Both mitochondria and chloroplast have double membranes – probably the inner membrane evolved from plasma membrane of bacteria which was engulfed while the outer membrane evolved from the plasma membrane or endoplasmic reticulum of host cell.
2. Mitochondrial size is approximately equal to bacterium with the presence of infoldings (cristae) comparable to mesosomes.
3. Mitochondrial ribosomes and DNA are also similar to ribosomes and DNA of bacteria.
4. Splitting of mitochondria and division of bacteria is similar with apparently same way of replication.

Summary

- Robert Hooke discovered Cell.
- Cell is the basic unit of life
- Schleiden and Schwann gave the Cell Theory
- Cell can be of 2 types: Prokaryotic and Eukaryotic.

Prokaryotic and Eukaryotic Cells

- Prokaryotic cells don't have a well defined nucleus, thus called as an incipient nucleus.
- Eukaryotic cells have a well defined nucleus with nuclear envelope.
- Eukaryotic cells have other organelles besides the nucleus. The only organelle in a prokaryotic cell is ribosome.
- The plasma membrane is the only disconnection between the cell's interior and the external environment in animal cell.
- There is an additional cell wall as the outer most boundary of fungi, bacteria and plants.
- Mitochondria contain its own circular DNA, thus called as an autonomous self regulating organelle.
- Endosymbiosis led to the development of eukaryotic cell from a prokaryote.
- Aerobic bacteria and cyanobacteria developed in mitochondria and chloroplast respectively of a eukaryotic cell.

Exercise/ Practice

1. Explain the Cell Theory.
2. What are the differences between prokaryotic and eukaryotic cells?
3. Give a brief account on prokaryotic cells.
4. Write a note on semi autonomous organelles.
5. What is the advantage of having organelles?
6. Why are chloroplasts found in plant cells and not in animal cells?
7. Point out the differences between animal and plant cell.
8. Beifly explain the Endosymbiotic theory.
9. Write a note in support of endosymbiotic theory.

Filling in the blanks

a. Plasma membrane is made up of ……..
b. The term plastid was coined by…….

c. Mitochondria is considered as……of the cell.
d. Ribosomes are the site of …….
e. The membrane of vacuole is known as …….
f. Term vacuole was coined by…….
g. ……are also called as suicidal bags of cell.
h. Cytokinesis in animal cell occurs by…….
i. Microfilaments are made up of…….
j. Theory of endosymbiosis was put forward by ……
k. Chloroplast was developed from…….according to endosymbiotic theory.

Glossary

Actin: The protein from which microfilaments are composed. Also forms the contractile filaments of sarcomeres in muscle cells.

Archae: Ancient group of prokaryotes; most researchers, currently place it within the kingdom Monera.

Aster: Centrosomes if present, develop radiating fibrils (astral rays) and get changed into aster.

Cell wall: Rigid extracellular matrix covering plasma membrane in prokaryotes and plant cells.

Centriole: Paired cellular organelle which functions in the organization of the mitotic spindle during cell division in eukaryotic animal cell.

Chlorophyll: The green pigment found in chloroplasts responsible for photosynthesis.

Prokaryotic and Eukaryotic Cells

Chloroplasts: Green plastids which possess photosynthetic pigments chlorophyll and carotenoids, helps in photosynthesis.

Cytoplasm: Protoplasm of a cell exclusive of the nucleus.

Cytoskeleton: Intermediate filaments, actin filaments, and microtubules which help in structuring cell shape and movement.

DNA: stands for deoxyribonucleic acid and is a double-helix encoding the genetic information of organisms.

Desmosomes: A circular region of membrane cemented to an adjacent membrane by a molecular glue made of polysaccharides found in tissues that undergo stretching.

Endoplasmic reticulum: A three dimensional, complicated and interconnected system of membrane-lined channels that runs through the cytoplasm.

Golgi apparatus: A netlike mass of material in the cytoplasm of animal cells, believed to function in cellular secretion.

Glycocalyx: Covered carbohydrate-rich outer surface of the plasma membrane of eukaryotic cells made up of glycolipids, oligosaccharide and absorbed peripheral membrane proteins.

Lysosome: Cytoplasmic organelle which degrades endocytosed extracellular materials. It is also responsible of autophagy of intracellular materials.

Mitochondria: Energy producing organelle of cell ("Power House" of cell). It is a double membrane bound organelle.

Nuclear envelope: A double membrane pore bearing outer covering or envelope of nucleus.

Nucleus: A specialized, usually spherical mass of protoplasm encased in a membrane and found in most living cells. It forms an essential element in their growth, metabolism and reproduction. It is responsible for enshrining genetic material of a cell.

Nucleolus: A conspicuous, often rounded body within the nucleus of a cell.

Prokaryotic and Eukaryotic Cells

Nucleosome: Spherical bodies formed by coils of chromatin (DNA and proteins). The nucleosome in turn coiled to form the fibers that make up the chromosomes.

Plasma membrane: A biomembrane that occurs on the outside of the cytoplasm in both prokaryotic and eukaryotic cells.

Plasmid: Self replicating circular DNA molecules found in bacterial cells; often used as vectors in recombinant DNA technology.

Plasmodesmata: Junction in plants that penetrate cell walls and Plasma membranes, allowing direct communication between the cytoplasm of adjacent cells.

Ribosomes: Minute, angular or spherical particles that are composed of protein and RNA.

RNA: Nuceic acid that contains ribose, found chiefly in cytoplasm of cells.

Rough endoplasmic reticulum (RER): It has rough membranes because a number of ribosomes are bound to the membrane surface. It is responsible for alteration of translated proteins and their post-translational modification.

Smooth endoplasmic reticulum (SER): It has smooth membranes because of the absence of ribosomes. It is related to lipid synthesis, steroid signaling and drug detoxification.

Thylakoids: Flattened internal membranes in chloroplast where the light reaction chemicals are embedded. Collection of thylakoids form the grana.

Tight junction: Junction between the plasma membrane of adjacent cells in animals that form a barrier, preventing materials from passing between the cells.

Vacuoles: Membrane-bound organelles (like a cavity) in the cytoplasm that are used for storage and digestion. It contains watery liquid or secretion.

Prokaryotic and Eukaryotic Cells

References/ Bibliography/ Further Reading

- Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P. *Molecular Biology of the Cell* (4th ed.). Garland. ISBN 0-8153-3218-1.
- *Campbell Biology—Concepts and Connections*. Pearson Education. 2009.
- Cooper GM. *The cell: a molecular approach* (2nd ed.). Washington, D.C: ASM Press. ISBN 0-87893-102-3.
- Dennis, Michael Aaron (1989). "Graphic Understanding: Instruments and interpretation in Robert Hooke's Micrographia". *Science in Context* **3** (2): 309–364.
- Jim B, Cooper M, Hunter M, Jardine L, (2003). *London's Leonardo: The Life and Work of Robert Hooke*. Oxford University Press. ISBN 0-19-852579-6.
- Keeling, PJ and Fast, NM. 2002. MICROSPORIDIA: Biology and Evolution of Highly Reduced Intracellular Parasites. *Annu. Rev. Microbiol.* 56:93”‟116.
- Lodish H, Berk A, Matsudaira P, Kaiser CA, Krieger M, Scott MP, Zipurksy SL, Darnell J. *Molecular Cell Biology* (5th ed.). WH Freeman: New York, NY. ISBN 978-0-7167-4366-8.
- Maton, Anthea (1997). *Cells Building Blocks of Life*. New Jersey: Prentice Hall.
- Peter Hamilton Raven; George Brooks Johnson (2002). *Biology*. McGraw-Hill Education. p. 68. ISBN 978-0-07-112261-0.
- Whitman, Coleman, Wiebe (1998). "Prokaryotes: The unseen majority" (PDF). *Proc. Natl. Acad. Sci. USA* 95 (12): 6578–6583.

Web Links

- https://www.en.wikipedia.org/wiki/Prokaryote
- http://www.shmoop.com/biology-cells/prokaryotic-cells.html
- http://www.biology.arizona.edu/cell_bio/tutorials/pev/page2.html
- https://www.en.wikipedia.org/wiki/Eukaryote
- http://www.animals.about.com/od/animalswildlife101/a/diffprokareukar.htm
- https://www.en.wikipedia.org/wiki/Symbiogenesis