CHAPTER I

1. Introduction to Cell Biology

1.1 Definition of Cell

Cell Biology is the study of structure and function of individual cell or cells. It is the fundamental unit of life, the basic building block from which all other organisms are constructed.

1.2 Importance of Cytology

a) Cell utility in diagnostics

Cytopathology is used to make preliminary diagnosis and follow laboratory technique.

i) It is of importance to physicians involved in the long-term and continuous care of patients because examination can be done serially with minimal trauma and pain to patient.
iii) Compared to tissues acquisition of cells is less painful and expensive.
vi) When used together with X-ray cells can be used to diagnose lung cancer at early stages to patients with chronic cough and or a history of occupational exposure to noxious agents and cigarette smoking. In such cases cytodifferentiation of inflammatory infections, premalignant and malignant conditions can be made.
v) When questionable symptoms or signs become apparent during evaluation of the patient`s conditions and cause of the disease is unclear cytology can be used to discriminate the value.
vi) To provide timely and meaningful clinical information in ambulatory setting.
vii) Technique for preparing the cellular material is quite simple and inexpensive participants in the diagnostic and evaluative process.
vii) Use of cells allow the clinicians the opportunity to investigate suspicious, possibly malignant conditions early in the course of suspected disease process. Thus cytology act as a preventive tool e.g. useful in gynealogical cytology.

b) Cell utility in Industries

i) Fermentation to make products like; Yorghurt
ii) Expression systems to produce cloned proteins. Include prokaryotic and Eukaryotic cells. Example of using bacteria in producing gene products are cloned insulin, used in treatment of diabetes bacteria and bovine growth hormone, used to increase milk yield of cows.
iii) Multiplication of viruses during vaccine production. Examples include production polio, Hepatitis B, rabies etc vaccines
iv) Bacteria vaccines

Making of non- vaccines products e.g. anti-blood clotting agent used in surgery, antibiotic e.g. Penicillin, used to kill bacteria, hormones e.g. bovine growth hormone, used to increase milk yield of cows, enzymes e.g. DNase- enzyme used to treat CF, AAT(α-1-antitrypsin)- clotting factor, cellulose and enzyme used in paper production is produced in bacteria

c) Cell utility in Agriculture

i) Cellular culture to generate plants e.g . protoplast culture, anther culture
ii) Nitrogen fixation by nitrogen fixing bacteria
iii) Decomposition of organic residuals
iv) Gene cloning e.g. using agrobacteium to clone genes and transform plants
v) Cybridization to produce new plants. This production of hybrids by fusing somatic cells.
vi) Production of edible vaccines e.g.
vii) Production of biodegrable plastics in plants.
viii) Production of transgenic animals
ix) Artificial insemination of animals
x) Intracytoplasmic sperm injection

d) Research and Product development

Cell and organ cultures are used to maintain living animal cells and groups of cells outside the body (in vitro) for the following reasons;

i) With separate, living cell cultures, it is possible to see and study the behavior of animal and plant cells in greater detail than when they are in the in vivo.
ii) Cell culture frees the cells from some of the controls that normally regulate their activities.
iii) By use of cell culture technology it is possible to study a wide variety of species, such as humans, monkeys, mice, dogs, cats, frogs, insects, fish and many others and from a number of organs – heart, lungs, liver, kidney, blood, skin etc
iv) In disease like cancer research it is common practice to grow cells from normal and cancerous tissues to compare their properties. Cell cultures has become one of the best means of testing potential anti-cancer drugs; utilizing cell cultures is more cost effective and faster than Experiments using animals and, with this method, isolated human cancerous tissue can be tested.
v) The rapid advances in our knowledge and control of human and animal viral diseases are largely from the use of cell culture methods.
vi) Vaccines for diseases such as poliomyelitis and measles are made entirely from viruses grown in cell culture.
vii) Additionally, many of the new human and animal viral diseases have been discovered through isolating the viral agents in the cell culture systems.
viii) The cell have been widely used for studies on the patterns of growth, differentiation and development to various foetal organs and the influences of various factors like hormones, vitamins, etc. on these parameters.
ix) To produce tissues for implantation in patients; this is often called tissue engineering. Human skin has been successfully produced in vitro and used for transplantation in many cases of serious burns, ulcers etc. Tissue engineering will enable to reconstitute body parts in vitro for use as grafts or transplants e.g. cartilage tissue developed in vitro (artificial cartilage) will be available for human implantation in cases of injuries, arthritis etc. It is hoped that studies will permit the culturing and constitution of bones, liver, pancreas etc.
x) Cultured cells and tissue provide good models for studies on drug delivery and action.
xi) Other applications of cell and organ cultures include studying inheritance, embryological development, mechanisms of drug action on cells, cellular immunity, and cellular disease

processes. Tissues are cut into very small fragments, called explants, which are put into vessels and bathed with nutrient medium.

xii) In plants most cells are easily regenerate to produce new plants e.g. root cells easily grow to other cell a phenomenon known as plasticity. Such plasticity can be easily be used to study of cell reprogramming.

xiii) It is easy to induce various to various organisms through mutation of cell and regenerating to full organism. This a method used to produce new crop varities.

xiv) In agriculture new plants can be produced through cell fusion a process known as cybridization.

1.3 **Characteristics of a Cell**.

i) Cells have the potential for an independent existence.

ii) Cells have ability to use energy to support essential life processes. This process include ;
-the movement of components from one part of the cell to an other
-selective transfer of molecule into and out of the cell.
- the ability to transform molecules from one chemical configuration to an other in order to replace parts as they wear out or to support growth and reproduction.

iii) Cells must have a set of genes to act as a blue prints for the synthesis of other components.

iv) Cell must have a physical boundary, called the cell membrane, that acts as a delimiter between it and the rest of the world.

1.4 History of Cell Biology (Landmarks in Study of Cell Biology)

- 1235 Roger Baccon, an Englishman invented eyeglasses.
- I590 Jans and Zacharias Jassen had combined two convex lenses within a tube to construct a forerunner of a microscope.
- The discovery of the magnifying lenses triggered a scientific and intellectual revolution. This
- discovery opened the microscope world to human eye.
- Robert Hooke- 1635-1703, was the first scientist to construct his own microscope.
- He used it to examine thin slices of cork cut with a razor blade.
- Under the microscope these slices of cork appeared to be made up of "little" boxes which Hooke termed cells, but from the present knowledge these were dead cell walls.
- 1675- Leeuwenhoek improved microscopic lenses, and with them he discovered a variety of single-celled life forms, including (in 1683) bacteria and protozoa.
- 1824-Dutrochet correctly concludes that all living tissues, animal and plant, are composed smaller units the cells.
- 1828- Wohler synthesized urea, discrediting the view that organic compounds can only be made by living things, and paving the for the systematic investigation of cellular reaction.
- 1830-Meyen suggests that each plant cell is an independent isolated unit capable of receiving nourishment and building its own internal structures.
- 1831-Brown reports the existence of nuclei.
- 1838-9 -Schleiden and Schwann, argument first brought about the issue of **Cell Theory**, stating that; a) all tissues are composed of cells; b) development of tissues are the result of cellular activity.
- 1840-Leibig proposes that alcoholic fermentation is a purely chemical reaction, independent of living cells and catalyzed by substances (enzymes) that naturally present in juices.
- 1858- Virchow correctly asserts that cells arise only from other cells and that, as a functional units of live, they are also the primary sites of disease.
- 1862-Pasteur disposes off the spontaneous generation theory of microbial appearance.

- 1871- Pasteur proves that natural alcoholic fermentation always involves yeast.
- 1897- Buchner found that alcoholic fermentation requires only the extract of yeast, not the cell themselves.
- 1898 Golgi described the golgi apparatus.
- Svedberg developed the first analytical ultracentrifuge.
- Behrens used differential centrifugation to separate nuclei from cytoplasm.
- Siemens produced the first commercial transmission electron microscope.
- Coons used fluorescent labeled antibodies to detect cellular antigens.
- 1907- Harrison found a satisfactory way of growing animal cells in the laboratory, so that future study of cellular functions can be carried out under controlled conditions.
- 1952 Gey and co-workers established a continuous human cell line.
- 1953 Crick, Wilkins and Watson proposed structure of DNA double-helix.
- 1955 Eagle systematically defined the nutritional needs of animal cells in culture.
- 1957 Meselson, Stahl and Vinograd developed density gradient centrifugation in cesium chloride solutions for separating nucleic acids.
- Ham introduced a defined serum-free medium. Cambridge Instruments produced the first commercial scanning electron microscope.
- 1976 Sato and colleagues publish papers showing that different cell lines require different mixtures of hormones and growth factors in serum-free media.
- 1981 Transgenic mice and fruit flies are produced. Mouse embryonic stem cell line established.
- 1987 First knockout mouse created.
- 1998 Mice are cloned from somatic cells.
- 2000 Human genome DNA sequence draft.
- 2005 : project of Genome to life proposed – this explores ways of getting the genomes and making them work.

1.5 Cell Theory or The Cell Doctrine (in modern way).

1 all known living things are made up of cells.
2 the cell is structural & functional unit of all living things.
3 all cells come from pre-existing cells by division (Spontaneous Generation does not occur).
4 cells contains hereditary information which is passed from cell to cell during cell division.
5 all cells are basically the same in chemical composition.
6 all energy flow (metabolism & biochemistry) of life occurs within cells.

1.6 General cell chemical composition

Water 75-90%
Protein
Lipids
CHO
RNA (nucleoic acid) } 10-25%
Inorganic
DNA (nucleoic acid)
Other organic

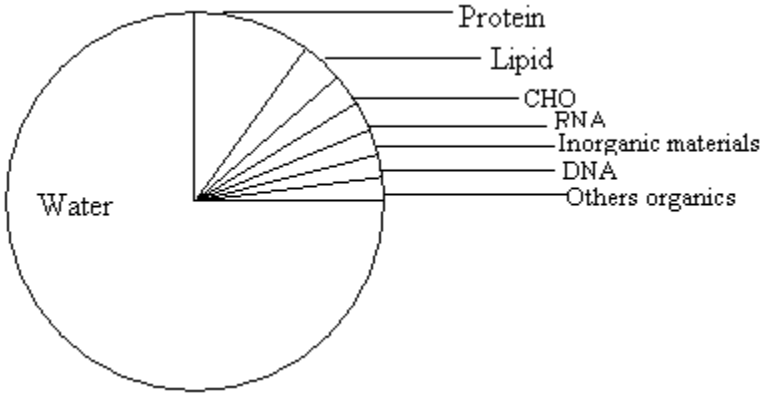

Fig. 1.1 Chemical constituents of cell

1.7 Prokaryotic cells

These are mainly unicellular organisms.

Microbial group	Structural organization
Virus	No cell
Archaebacteria	Prokaryotic cell
Eubateria	Prokaryotic cell
Fungi	Eukaryotic cell
Algae	Eukaryotic cell
Protozoa	Eukaryotic cell

Table:1.1 Microbial cell structures.

Microorganisms with prokaryotic cells

Cells in this category include archaebacteria and eubacteria.

Archaebacteria

Are classified in the kingdom Archaea.

Categories of Archaebacteria

i) Thermophilic -leave in high temperatures (90 C°)
ii) Thermoacidophiles -grow in hot and acidic conditions.
iii) Methanogens -produce methane from carbondioxide and leave in place only where molecular oxygen is absent.
iv) Halophilics -salt loving -live in highly saline environment.
v) Acidophilic- acid loving -live in pH similar to concentrated sulphuric acid.

Eubacteria

Eubacteria are classified in the kingdom bacteria

Characteristics

i) Are diverse in morphologies and physiologies e.g. some are spherical (coccids),
ii) cylindrical (rods), Spiral (spirilla) and pleomorphic (irregularly shaped).
iii) Some can photosynthesize e.g. cynobacteria (blue green algae) .
iv) Other eubacteria obtain their energy by metabolism of inorganic compounds such as ammonia and element sulphur.
v) There are others that can degrade organic compounds e.g. hydrocarbons found on petroleum.

Importance of prokaryotic cell

i) Are disease pathogens
ii) Genetic engineering: very good in gene cloning e.g. Escherichia coli

iii) Agriculture: used in nitrogen fixation e.g. Rhizopium species,

1.8 Eukaryotic cell

Cell growth and multiplication

Types of cell

Somatic cell (body cells).

Characteristics are;

a) Are diploid
b) Reproduce by mitosis

b Germ cells (gametes)

Characteristics are;

a) Are haploid
b) Reproduce by meiosis

Cell multiply using the following mechanism;

a) Cell division -mitosis and meiosis
b) Budding e.g. in unicellular organisms such as fungi, yeast hydra etc

Bud develop side of the cell and new individual is finally formed.

Pinching e.g. in flat worm. Constriction form on sections of the body and later pinches of.

1.9 Cell size and shape

a) Cellular Size

As a guide in determine cells sizes it is important to know the following conversions

1 meter = 100 cm = 1,000 mm = 1,000,000 µm = 1,000,000,000 nm
1 centimenter (cm) = 1/100 meter = 10 mm
1 millimeter (mm) = 1/1000 meter = 1/10 cm
1 micrometer (µm) = 1/1,000,000 meter = 1/10,000 cm
1 nanometer (nm) = 1/1,000,000,000 meter = 1/10,000,000 cm

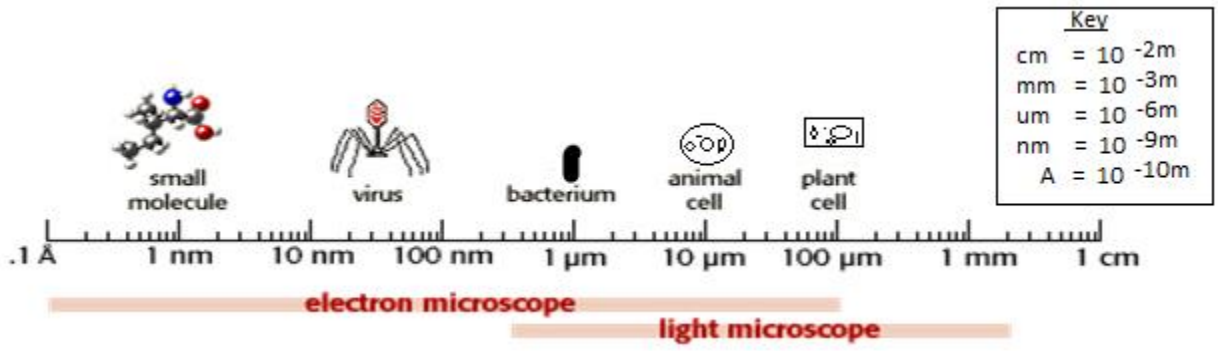

Fig. 1.2. Relative sizes of cells and their compound

a) Smallest cell is mycoplasma which is a about 1000Å in diameter.
b) Bacteria cell size varies between 5000 Å in diameter for cocci bacteria and 20µm length for

filamentous bacteria.

c) Unicellular organism – many are motile and have cilia and flagella.
Size – range from 0.5 mm(500 µm) to 120µm in length.
Blue green algae – single celled is about 10µm
Diatoms – most important primary producers of sea has the measure up to 100µm or more in length.
Amoeba – largest unicellular organism is about 1mm (1000µm) in length.

d) Higher organism (plants and animals) – most cell size range between 20 and 30 µm
Largest cell produced by animal is yolk of an Ostrich which is about 50cm in diameter
Human ovum is about 100 µm. Human sperm – Head is about 5 µm long and tail is a 30-50 µm long.

0.1 nm (nanometer) diameter of a hydrogen atom
0.8 nm Amino Acid
2 nm Diameter of a DNA Alpha helix
4 nm Globular Protein
6 nm microfilaments
10 nm thickness cell membranes
11 nm Ribosome
25 nm Microtubule
50 nm Nuclear pore
100 nm Large Virus
150-250 nm small bacteria such as Mycoplasma
200 nm Centriole
200 nm (200 to 500 nm) Lysosomes
200 nm (200 to 500 nm) Peroxisomes
800 nm giant virus Mimivirus
1 µm (micrometer)
(1 - 10 µm) the general sizes for Prokaryotes
1 µm Diameter of human nerve cell process
2 µm E.coli - a bacterium
3 µm Mitochondrion
5 µm length of chloroplast
6 µm (3 - 10 micrometers) the Nucleus
9 µm Human red blood cell
10 µm Blue green algae – single celled
10 - 30 µm Most Eukaryotic animal cells
10 - 100 µm Most Eukaryotic plant cells
90 µm small Amoeba
100 µm Human Egg
up to 160 µm Megakaryocyte
up to 500 µm giant bacterium Thiomargarita
up to 800 µm large Amoeba
1 mm (1 millimeter, 1/10th cm)
1 mm Diameter of the squid giant nerve cell
120 mm Diameter of an ostrich egg (a dinosaur egg was much larger)
3 meters length of a nerve cell of giraffe's neck

Table 1.2. Sizes of selected of selected cells.

Factor affecting cell sizes

a) Lower cell size limit

This is determined by the smallest volume into which the minimum number and size of essential components may be fitted in order for cellular existence to be possible.
Biggest upper cell size limit – is determined by;

i) volume of cytoplasm a cell nucleus can handle e.g. Amoeba are multinucleate to manage the large cytoplasm
ii) cell and its environment – proper area to volume ratio must be maintained.

Cellular shapes

Microbes

- Spheres called cocci (greek = berry) can divide once in one axis to produce diplococci (*Neisseria gonnorrhoeae*, *N. meningitidis*), or more than once to produce a chain (*Streptococcus pyogenes*), divides regularly in two planes at right angles to produce a regular cuboidal packet of cells (xxx) or in two planes at different angles to produce a cluster of cells (*Staphyloccus aureus*)
- Cylinders called rods or bacilli (Latin *bacillus* = walking stick)
- Spiral or spirilli (Greek *spirillum* = little coil*)*

Animal cells

Cells come in different shapes. They can be shaped like snowflakes, balls, cubes, saucers, rectangles, boxes, coils, or blobs of jelly. Animals cells are usually spherical or flat-sided. The amoeba, a one-celled organism that lives in water, has no regular shape. It is a jelly-like cell that changes shape to move around. Some muscle cells are long, thin, and pointed on both sides. Some nerve cells, with their long branches, look like trees.

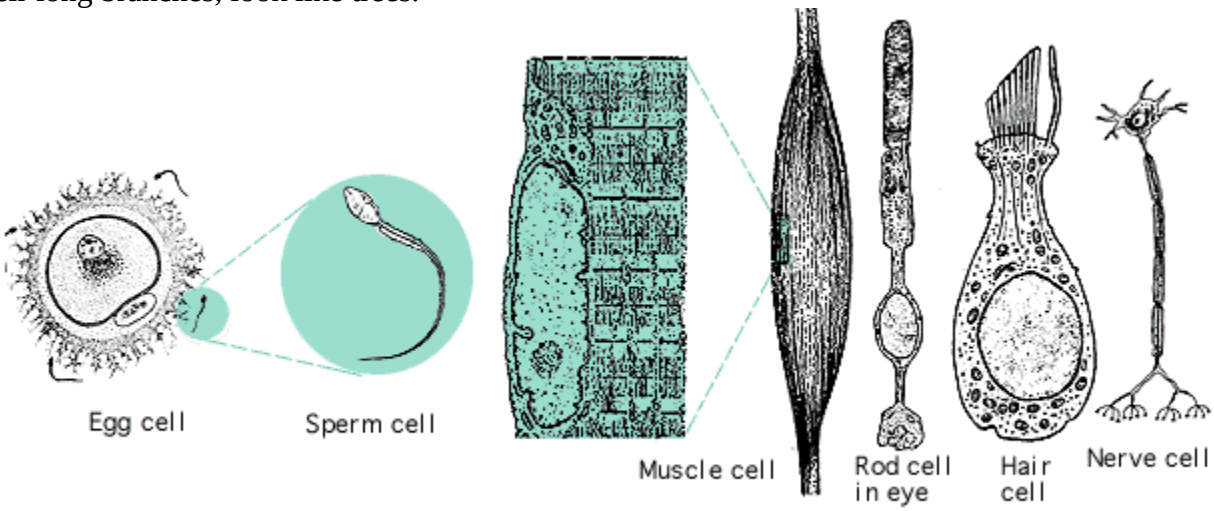

Fig. 1.3. Shapes of selected plant cells

Plants cells

Plant cell have a defined shape which helps support individual parts of plants. In young parts of plant and fruits, cell shapes are generally round, while in older sections, the cells are somewhat boxlike with up to 14 sides as they become packed together.

Cells in Association

Many of the higher organisms are multi-cellular and have the following advantages;

i) Cells can specialize in their functions.
ii) In case one or more cell faces trauma others can survive avoiding death of organism.

1.10 Physical Structure of the cell

Cell Electron Microscopic Structure

Animal cell

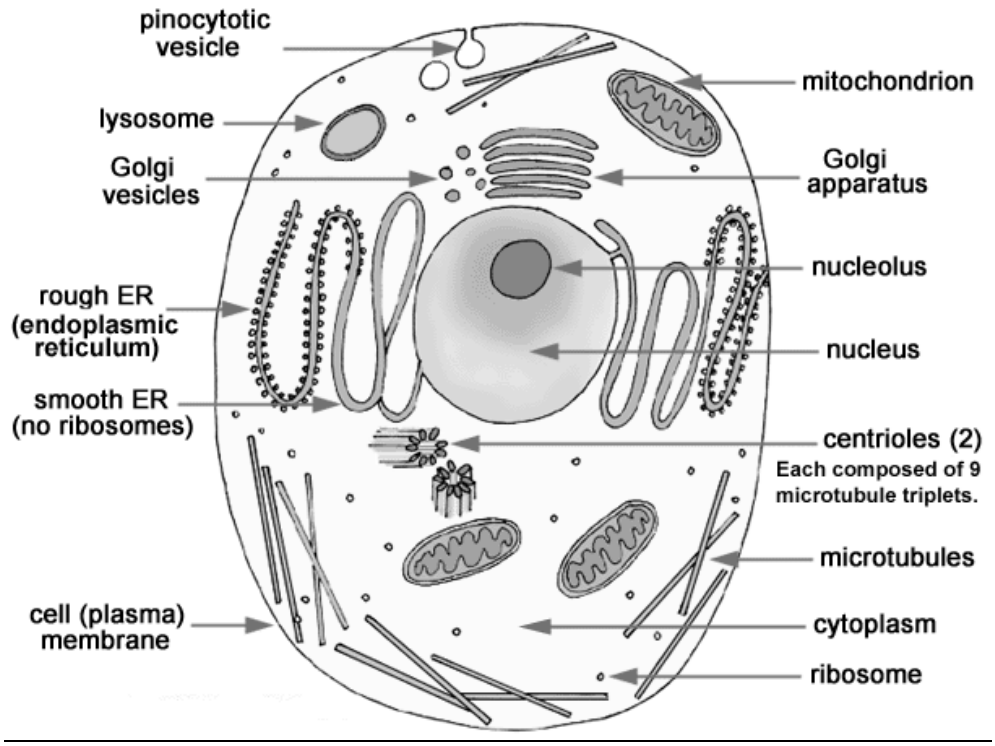

Fig.1. 3. Structure of Animal cells

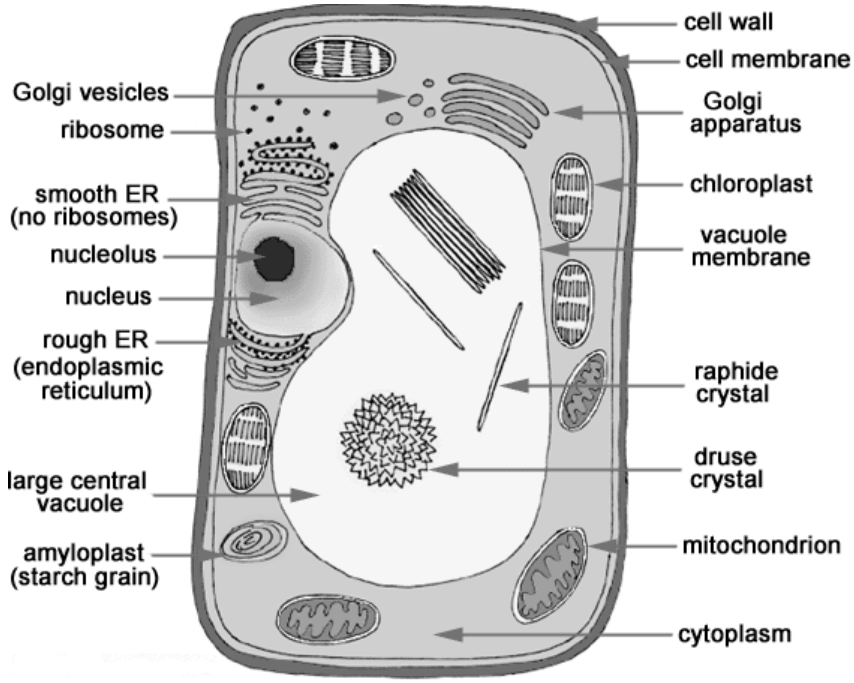

Fig.1. 3. Structure of plant cells

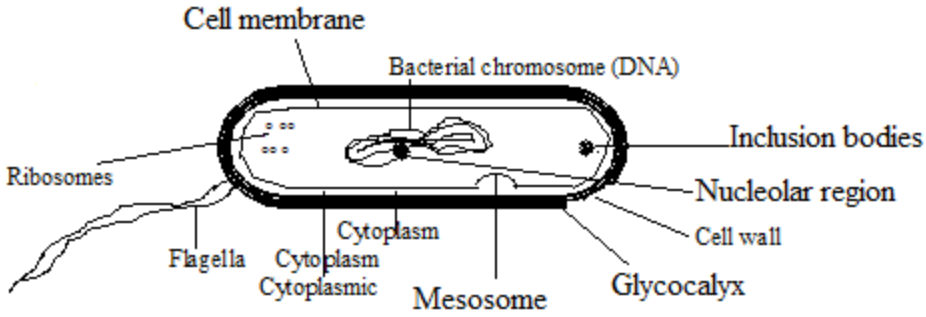

Fig. 1.4. Structure of a bacteria cells

1.11 Comparison of Prokaryotic and Eukaryotic Cells

Table:

Organelle	Prokaryotes	Eukaryotes	
		Animals	Plants
Plasma membrane	+	+	+
Cell wall	+	0	+
Ribosomes	+	+	+
Endoplasmic reticulum	0	+	+
Golgi complex	0	+	+
Lysosomes	0	+	+
Microbodies	0	+	+
Nuclear envelope	0	+	+
Nucleolus	0	+	+
Mitochondria	0	+	+
Chloroplast	0	0	+

"9+2" cilia / flagella	0	+	+
Microtubules	0	+	+
Microfilaments	0	+	+
Intermediate filaments	0	+	+

Reference

1 Cell Biology. 2nd Edition , Ambrose and Easty (1977)
2 Principles of Cell Biology. Lewis J. H.and Valerie M.K. (1988)