Lecture Series on Biochemistry (Part 1)

What is a Cell?

- Cell is the basic structural and functional unit of all living organisms. A cell, within a selective and retentive semipermeable membrane, contains a complete set of different kinds of sub-units necessary to permit its own growth and reproduction from simple nutrients.
- A.G. Loewy and P. Seikevitz (1963) have defined a cell as "*a unit of biological activity delimited by a semipermeable membrane and capable of self-reproduction in a medium free of other living systems*".
- John Paul (1970) has defined the cell as "*the simplest integrated organization in living systems, capable of independent survival*".

Cells of cellular organisms

- The body of all living organisms except viruses has cellular organisation and may contain one or many cells.
- The organisms with only 1 cell are called unicellular organisms (e.g. bacteria, protozoa etc.)
- The organisms having numerous cells in their body are called multicellular organisms (most plants and animals).

- Any cellular organism may contain one type of cell from among the following types:
  - Prokaryotic cell
  - Eukaryotic cell

(The terms prokaryotic and eukaryotic were suggested by Hans Ris in the 1960s)

Prokaryotic cells

- The prokaryotic cells are small, simple and most primitive. They are probably the first to come into existence.

  (E.g. the stromalites (giant colonies of extinct cyanobacteria or blue green algae) of Western Australia are known to be at least 3.5 billion years old.)
- Most primitive from morphological point of view.
- It is essentially a one-envelope system organised in depth.
- Consists of central nuclear components (viz. DNA molecules, RNA molecules and nuclear proteins) surrounded by cytoplasmic substance with the whole enveloped by a plasma membrane.
- Neither the nuclear apparatus nor the respiratory enzymes are separately enclosed by membranes, although the inner surface of plasma membrane serve for enzyme attachment.
- Cytoplasm of prokaryotic cell lacks in well-defined cytoplasmic organelles.

Eukaryotic cells

- The first eukaryotic cells may have arisen 1.4 billion years ago (Vidal, 1983)
- The eukaryotic cells are essentially two-envelope system and are very much larger than prokaryoyic ones.
- Secondary membranes envelope the nucleus and other internal organelles.
- Though they have different size and shape, all the cells are typically composed of plasma membrane, cytoplasm and its organelles
- Nuclear contents such as DNA, RNA, nucleoproteins and nucleolus remain separated from the cytoplasm within a thinly perforated nuclear membrane.

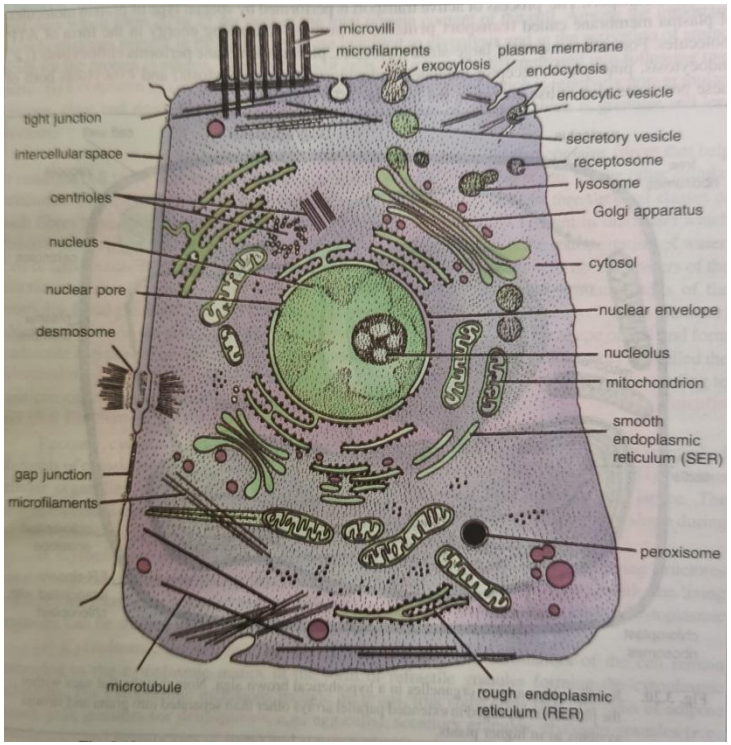


Fig: Ultrastructure of a typical animal cell as seen under electron microscope.

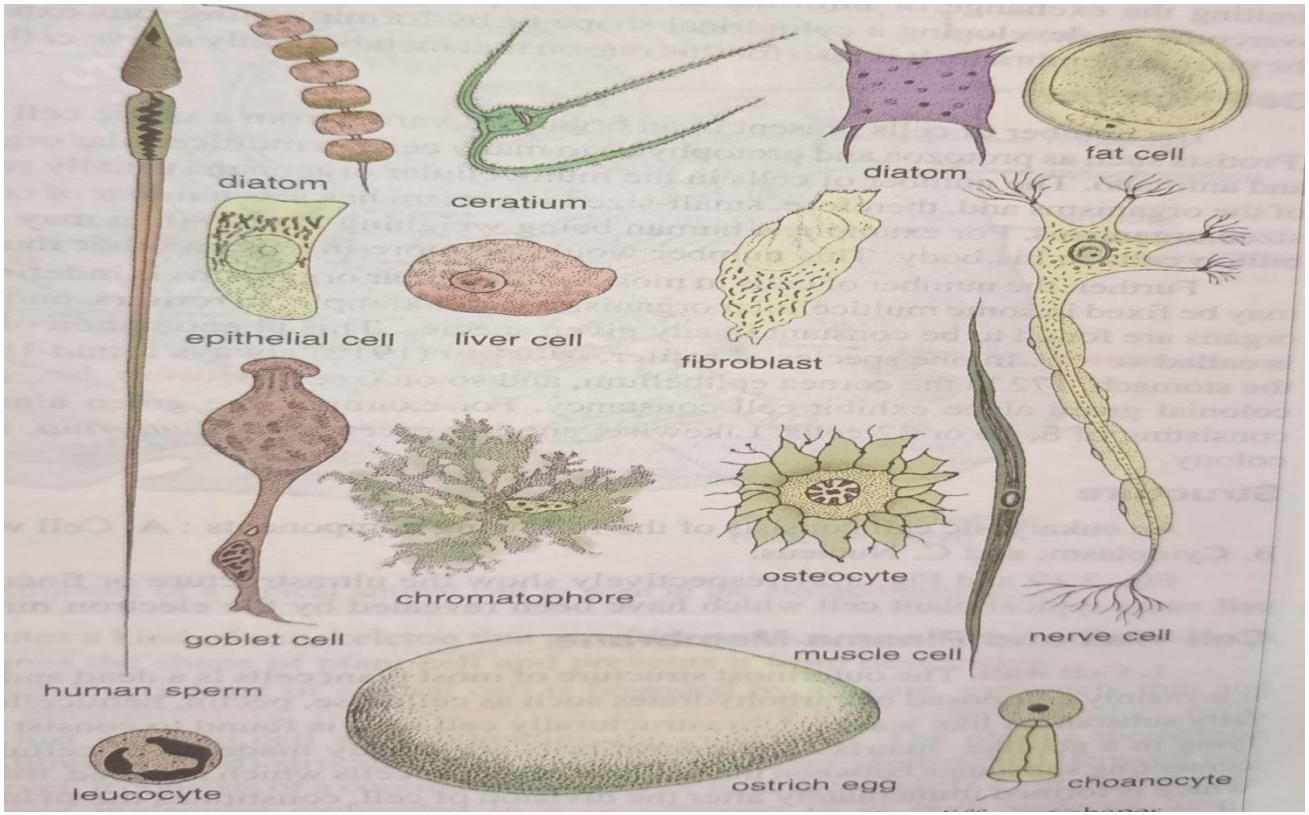
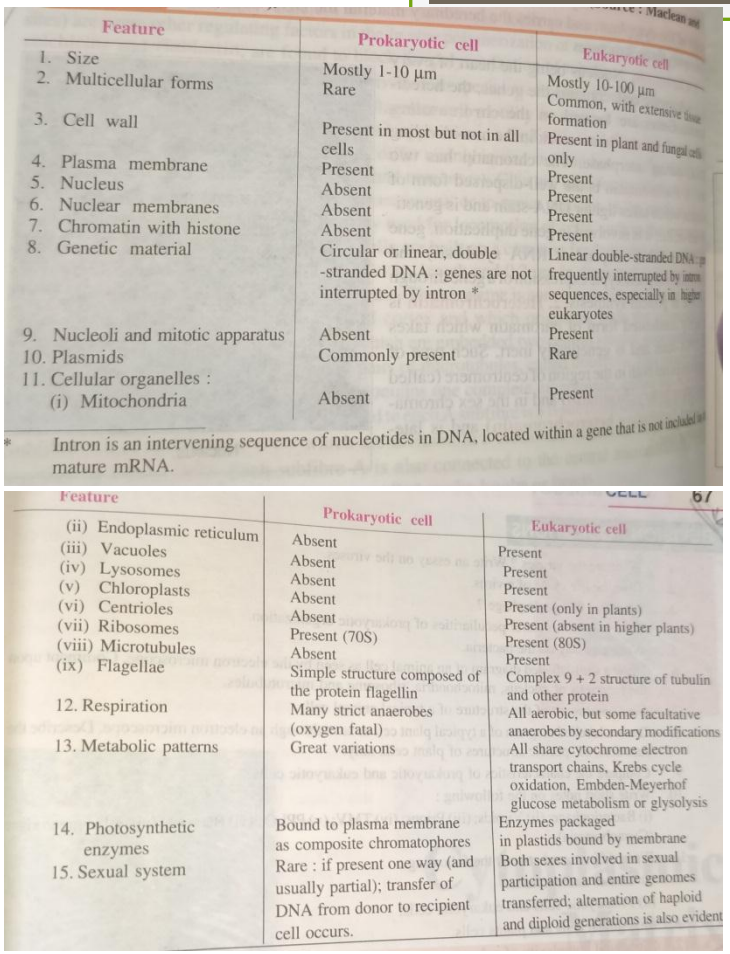


Fig: Various types of eukaryotic cells showing different shapes



Feature	Prokaryotic cell	Eukaryotic cell
1. Size	Mostly 1-10 µm	Mostly 10-100 µm
2. Multicellular forms	Rare	Common, with extensive tissue formation
3. Cell wall	Present in most but not in all cells	Present in plant and fungal cells only
4. Plasma membrane	Present	Present
5. Nucleus	Absent	Present
6. Nuclear membranes	Absent	Present
7. Chromatin with histone	Absent	Present
8. Genetic material	Circular or linear, double -stranded DNA : genes are not interrupted by intron *	Linear double-stranded DNA : genes frequently interrupted by intron sequences, especially in higher eukaryotes
9. Nucleoli and mitotic apparatus	Absent	Present
10. Plasmids	Commonly present	Rare
11. Cellular organelles : (i) Mitochondria	Absent	Present
(ii) Endoplasmic reticulum	Absent	Present
(iii) Vacuoles	Absent	Present
(iv) Lysosomes	Absent	Present
(v) Chloroplasts	Absent	Present (only in plants)
(vi) Centrioles	Absent	Present (absent in higher plants)
(vii) Ribosomes	Present (70S)	Present (80S)
(viii) Microtubules	Absent	Present
(ix) Flagellae	Simple structure composed of the protein flagellin	Complex 9 + 2 structure of tubulin and other protein
12. Respiration	Many strict anaerobes (oxygen fatal)	All aerobic, but some facultative anaerobes by secondary modifications
13. Metabolic patterns	Great variations	All share cytochrome electron transport chains, Krebs cycle oxidation, Embden-Meyerhof glucose metabolism or glysolysis
14. Photosynthetic enzymes	Bound to plasma membrane as composite chromatophores	Enzymes packaged in plastids bound by membrane
15. Sexual system	Rare : if present one way (and usually partial); transfer of DNA from donor to recipient cell occurs.	Both sexes involved in sexual participation and entire genomes transferred; alternation of haploid and diploid generations is also evident

* Intron is an intervening sequence of nucleotides in DNA, located within a gene that is not included in mature mRNA.

Fig: Differences between prokarytic and eukaryotic cell

Cytoplasmic Matrix

- Cells are composed of chemicals many of which are identical to those found in non-living matter, whilst other are unique to living organisms.
- The study of chemical compounds found in living systems and reactions in which they take part are is known as biochemistry.
- Studies of the structure and behaviour of individual molecules constitute molecular biology.
- If the '*secret of life*' is to be found anywhere, it is in these molecules (Roberts, 1986)

Chemical composition of the Cell

- Within the cells of any organism, the living substance or the protoplasm, is itself comprised of a multitude of non-living constituents: proteins, nucleic acids, fats (lipids), carbohydrates, vitamins, minerals, waste metabolites, crystalline aggregates etc. all of which are molecules and their contstituent atoms.
- The protoplasm is alive because of the highly complex organisation of these non-living substances and the way they interact with one another.

Chemical elements

- Chemically cytoplasmic matrix is composed of many chemical elements in the form of atoms, ions and molecules.
- Among the 92 naturally occurring elements, perhaps 46 are found in the cytosol. 24 of theses are considered essential for life (called essential elements), whilst others are present in the cytosol only because they exist in the environment with which the organism interacts.
- Of the 24 essential elements, 6 play especially important roles in living systems. These major elements are:
  - C (20%)
  - H (10%)
  - N (03%)
  - O (62%)
  - P (1.14%)
  - S (0.14%)

- Another 5 essential elements found in less abundance in living systems are
  - Ca (2.5%)
  - K(00.11%)
  - Na(0.10%)
  - Cl (0.16%)
  - Mg (0.07%)
- Some trace elements are:
  - Fe, I, Mo, Mn, Co, Zn, Se, Cu, Cr, Sn, V, Si, Ni etc

Ions

- Cytoplasmic matrix consists of various kinds of ions.
- These are important in maintaining osmotic pressure and acid-base balance in the cells.
- Retention of ions in the matrix produces an increase in osmotic pressure and, thus facilitates entry of water in the cell.
- Concentration of various ions in the intracellular fluid differs from that in the interstitial fluid.

Table: Cellular functions of certain ions (Sheetal and Bianchi, 1987)

Element	Ionic form present	Functions
1. Molybdenum	MoO_4^{2-}	Cofactor or activator of certain enzymes (*e.g.*, nitrogen fixation, nucleic acid metabolism, aldehyde oxidation).
2. Cobalt	Co^{2+}	Constituent of vitamin B_{12}.
3. Copper	Cu^{+}, Cu^{2+}	Constituent of plastocyanin and cofactor of respiratory enzymes.
4. Iodine (Heaviest trace element)	I^{-}	Constituent of thyroxin, triiodothyronine and other thyroid hormones.
5. Boron	BO_3^{3-}, $B_4O_7^{2-}$	Activates arabinose isomerase.
6. Zinc	Zn^{2+}	Cofactor of certain enzymes (*e.g.*, carbonic anhydrase, carboxypeptidase).
7. Manganese	Mn^{2+}	Cofactor of certain enzymes (*e.g.*, several kinases, isocitric decarboxylase).
8. Iron	Fe^{2+}, Fe^{3+}	Constituent of haemoglobin, myoglobin and cytochromes.
9. Magnesium	Mg^{2+}	Constituent of chlorophyll; activates ATPase enzyme.
10. Sulphur	SO_4^{2-}	Constituent of coenzyme A, biotin, thiamine, proteins.
11. Phosphorus	PO_4^{3-}, $H_2PO^{-}_4$	Constituent of lipids, proteins, nucleic acids, sugar phosphates, nucleoside phosphates.
12. Calcium	Ca^{2+}	Constituent of plant cell walls; matrix component of bone tissue; cofactor of coagulation enzymes.
13. Potassium	K^{+}	Cofactor for pyruvate kinase and K^{+}- stimulated ATPase.

Electrolytes and Non-electrolytes

- Matrix consists of both electrolytes and non-electrolytes
- **Electrolytes**: Play a vital role in maintenance of osmotic pressure and acid base equilibrium in the matrix. (For e.g. Mg^{2++} ions, phosphates)
- **Non-electrolytes**: Some minerals occur in matrix in non-ionizing state. The non-electrolytes of matrix are Na, K, Ca, Mg, Cu, I, Fe, Mn, Mo, Cl, Zn, Co, etc.
- The Fe occurs in the haemoglobin, ferretin, cytochromes and some enzymes as catalase and cytochrome oxidase.
- Ca occurs in blood, matrix and bone.
- Cu, Mn, Mo, Zn are useful as cofactors for enzymatic actions.
- I and F are essential for thyroid and enamel metabolism respectively.

Cytoplasmic Matrix (Chemical composition of the Cell)

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