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# UNIT 2 CELL AND BLOOD

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## Structure

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## 2.1 INTRODUCTION

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In this unit, we will study about the basic unit of life – the cell and the elixir of life – the blood. The mysteries of a cell, its structure and working – organization, functions and divisions are the major aspects covered in this unit.

In this unit, we will also deal with the composition of blood, i.e. what makes it so unique, the different blood cells – their functions. Then the issues related to various blood groupings and incompatibility among blood groups will be dealt with.

### Objectives

After studying this unit, you will be able to:

- discuss and understand cell cycle and cell division,
- explain the structure of the cell,

- describe the cell functions,
- explain the composition of blood and its role in our body,
- discuss about various blood groups,
- enlist the disorders of coagulation and haemostasis, and
- visualize the physiology of blood transfusion and blood flow dynamics.

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## 2.2 CELL: THE BASIC UNIT OF LIFE

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You must be aware of the fact that the cell is the basic unit of life. What do you understand by the term 'cell'? What are the components of the cell, its structural features and functions that make it such an essential component of all the living beings? Well, here in this section, we shall study about all these aspects related to cell.

What would be the answer to the question what is a cell? Well, a cell is the *smallest self-functioning unit found in all the living organisms*. Cells may exist as independent units of life (as in monads) or may form colonies or tissues as in the higher plants and animals. Each cell is enclosed by an outer membrane or wall called as the *cell membrane*. A cell has receptors on its surface which have unique functions and identifying properties. Also, it contains genetic material (DNA) and other parts to carry out its life functions. Within the cell are the nucleus and the cytoplasm. The nucleus contains the genetic material-DNA. The cytoplasm contains organelles that carry out the cell's functions. We shall read about these components of the cell in a little while from now.

An aggregation of cells having a common origin and performing a similar but one or more specific functions in the body constitute a *tissue* (e.g. muscle). Several types of tissues may join collectively to form an *organ* that carries out one or more specific functions (e.g. kidney, liver, leaf and roots). In majority of animals, several organs are interrelated to perform a specific function within a multicellular organism and thus constitute an *organ-system*. We will learn about these organ systems i.e. gastrointestinal system, renal system in the subsequent units. You would realize that several types of organ-systems in the body of an organism show unique example of *division of labor*.

It is important to note that the cells are not only the building blocks of the body, but are the functional unit of life too. Every cell arises from preexisting cells. The cells have the same genetic material. It is, therefore, capable of giving rise to a new individual. This potential of the cell to give rise to unlike cells and so to develop a new organism or a part is termed as *totipotency*.

Interestingly, all the activities of an organism are present in miniature form in each and every cell. Therefore, the cell can be called as a *basic unit of life* and *the structural unit of an organism*. 'All organisms are composed of cells'. 'All cells come from pre-existing cells'. These two statements constitute the *cell theory*. We will learn about how the cell was discovered and what the cell theory is, next.

### 2.2.1 Discovery of Cell

Let us study here about the scientists who played a pioneer role in discovering the basic component of any living organism – the cell.

*Robert Hooke* (1665) is credited with the discovery of cell. *Hooke* observed a honeycomb-like pattern in a very thin slice of cork as shown in the Figure 2.1. As you can see, this honeycomb-like structure consists of a thick wall, enclosing box-like compartments for which he coined the term *cellulae* for the first time and this term is synonymous to what we call as *cells*. He regarded *cellulae* as passages for conducting fluids.

Antony Van Leeuwenhoek (1683), on the other hand, was the first to observe free cells, like bacteria, protozoa, red blood cells and sperm. You may already be aware that these are single organisms.

Let us now try and understand what the cell theory is.

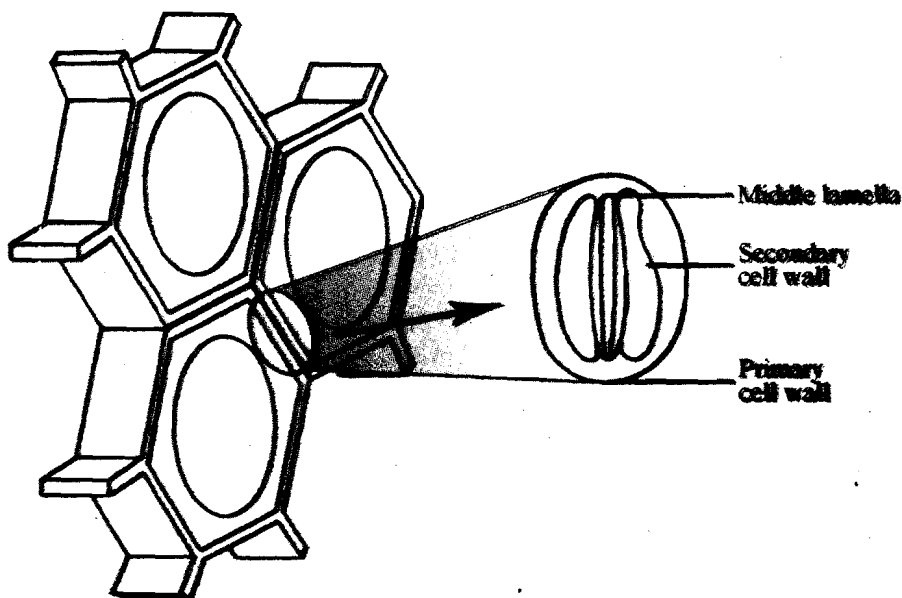


Figure 2.1 : Microscopic structure of a cell

## 2.2.2 Cell Theory

The cell theory, as we understand it today, is composed of following two tenets:

- 1) *All living organisms are composed of cells and their products:* The bodies of animals and plants are composed of the cells and products of cells. All plant tissues are made up of cells. These cells are having a thin outer layer, which we now know as *plasma membrane*.
- 2) *All cells arise from pre-existing cells:* Cells divide and new cells are formed from preexisting cells (*Omnis cellulae-e cellulae*). *Louis Pasteur* (1862), based on his experiment, successfully established that life originates from pre-existing life.

It is this basic understanding of the cell theory that leads to one of the fundamental requirements for life. The smallest living organisms are made of a single cell, whether they are *prokaryotes* (e.g. bacteria) or single-celled *eukaryotes* (e.g. protista). What do we mean by prokaryotes and eukaryotes? We will get to know about prokaryotes and eukaryotes in section 2.3.

When we examine how multicellular organisms function, such as ourselves, we come back to how the muscle cells contract, nerve cells communicate, white blood cells detect and eliminate the infections. When we look at the structures of the bodies of organisms, we start at the building blocks, the cells. The shape of a bone starts with the shape of bone cells. The shape of our brain starts with how the brain's nerve cells connect with each other. Hence, we can say that the '*cell theory*' is the most basic condition for determining if something is functional.

With our understanding of the cell theory, let us now study about the unicellular and multicellular organisms.

### 2.2.3 Unicellular and Multicellular Organisms

You may be aware that some organisms are made up of only one cell, while others have more than one cell. Well, the single-celled organisms are called as *unicellular organisms*, for example, bacteria and amoeba. These organisms are capable to breathe, divide and nourish. While, the organisms with more than one cell are termed as *multicellular organisms*, for example, humans, birds, reptiles and fish.

You might wonder what functions a single-celled organism is capable of performing. Surprisingly, a unicellular organism is able to perform a large number of functions such as respiration, absorption of nutrients, exchange of gases with the environment and metabolism. The volume of cell determines the amount of chemical activity of cells per unit of time, whereas, the surface area determines the amount of absorption and the amount of release of waste products by the cells. To maintain the surface area-to-volume ratio in a balanced state, some cells have acquired additional structures in the form of projections such as *microvilli*. These increase the absorptive surface area, for example, the cells in the intestine have microvilli that help to increase the absorptive surface for absorption of essential nutrients for the body. We will read about this later in Unit 6, under gastrointestinal system.

Multicellular organisms are specialized quite similar to a team that does a lot of work efficiently as compared to a single person who may only be able to perform only some of the functions. Most cells are tiny and their volume ranges between 1 to  $1000\mu\text{m}^3$ . Some of the benefits and constraints of multicellular organisms are as follows:

- 1) There is a unique co-ordination among the cells of multicellular organisms, like pumping of blood by the heart muscle and the transmission of information (nerve impulse) through the nerve cells. This co-ordination and specialization gives the organism a special edge in survival in the world and also helps us to understand the body's complex system and its wonders.
- 2) Living cells can multiply and replace the lost cell without losing its own identity. This is a clear-cut benefit over unicellular organisms. Unicellular organisms divide and the initial organism material is separated into two progeny cells.
- 3) Differentiation bestows tremendous benefits on the multicellular organisms. These are: a) increased survival b) increased specialization, and c) a proper balance between the cell surface and cell volume for receiving an external stimuli, exchange of materials, transport, secretion etc. This is essential in interacting with its external environment and in communicating with the world.

Cells in an organism, you would realize, can be grouped under three major categories on the basis of the levels of differentiation:

- i) *Undifferentiated cells*: These cells are capable of undergoing division and development, for example, the stem cells (animals) and meristematic cells (plants). These are the highly immature cells that can be molded like wet clay into cells that are called as differentiated cells.
- ii) *Differentiated cells*: These are the post-mitotic cells, which have undergone specialization and/or exhibit the division of labor. Therefore, these cells acquire distinct character and perform a definite function. For example, RBCs carry out the transportation of oxygen and carbon dioxide, the muscle cells perform kinetic functions or movement and the mesophyll cells carry out photosynthesis. These cells are the cells that help to perform the functions of our body.

- iii) *Dedifferentiated cells*: Some differentiated cells are capable of reverting back to the undifferentiated meristematic state as and when required. These cells are important for wound healing, regeneration and secondary growth. The process by which they lose their specialization is referred to as 'dedifferentiation'.

The cells that start or give rise to the new cells are called *undifferentiated cells*. Those that maintain body functions are the *differentiated cells* and those that have lost their specialized functions are called as the *dedifferentiated cells*.

Before we further move on to important cell constituents, let us take a break here and recapitulate what we have learnt so far.

**Check Your Progress Exercise 1**

1) Briefly explain the following terms:

a) Cell

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 .....

b) Totipotency

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 .....

c) Cell theory

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2) List some benefits and constraints of multicellular organisms over unicellular organisms.

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3) List three major categories of cells on the basis of the levels of differentiation.

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## 2.3 STRUCTURE OF THE CELL

You have learnt about the diversity of the living world comprising of various organisms like microscopic bacteria to huge multicellular plants and animals. Let us now come to know the structure and functions carried out by various parts of the cell.

In general, the cells can be divided into two types:

- a) *Eukaryotic cells*: These are the large multicellular cells that have a nucleus bounded by a double-layered membrane, for example, all plant and animal cells. They show a high degree of differentiation.
- b) *Prokaryotic cells*: These are very small cells that multiply very rapidly, for example, bacteria and blue green algae. These are unicellular and are believed to be evolutionary primitive.

Let us get to know them better.

### 2.3.1 Eukaryotic Cell and Organization

*Eukaryotes* (true nucleus) are organisms consisting of one or more eukaryotic cells, such cells contain membrane-bound nuclei, as well as organelles. Animals, plants, fungi, and various other groups collectively referred to as protista are all eukaryotes, varying from single-celled organisms to truly multicellular forms, in which different cells are specialized for different tasks and in general do not survive when isolated. Figures 2.2(a) and 2.2(b) illustrate the animal and plant cell respectively.

Now you must have a basic idea of what is a eukaryotic cell. You can see from Figures 2.2(a) and 2.2(b) that these cells have a highly complex organization consisting of the cytoplasmic matrix and several organelles such as mitochondria, endoplasmic reticulum, golgi apparatus, ribosomes, nucleus etc.

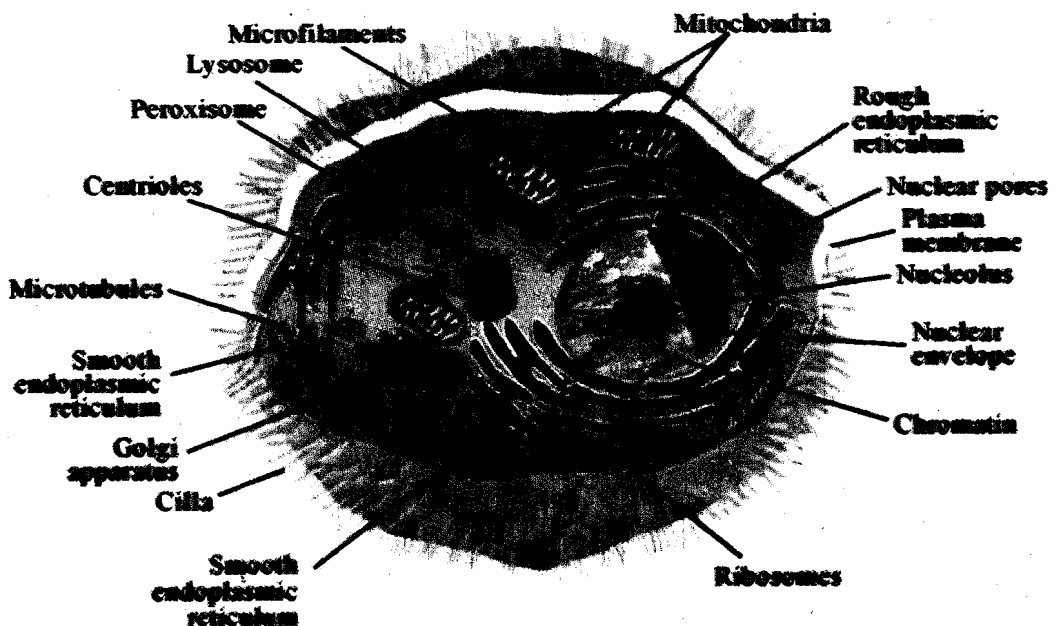


Figure 2.2(a): Animal cell

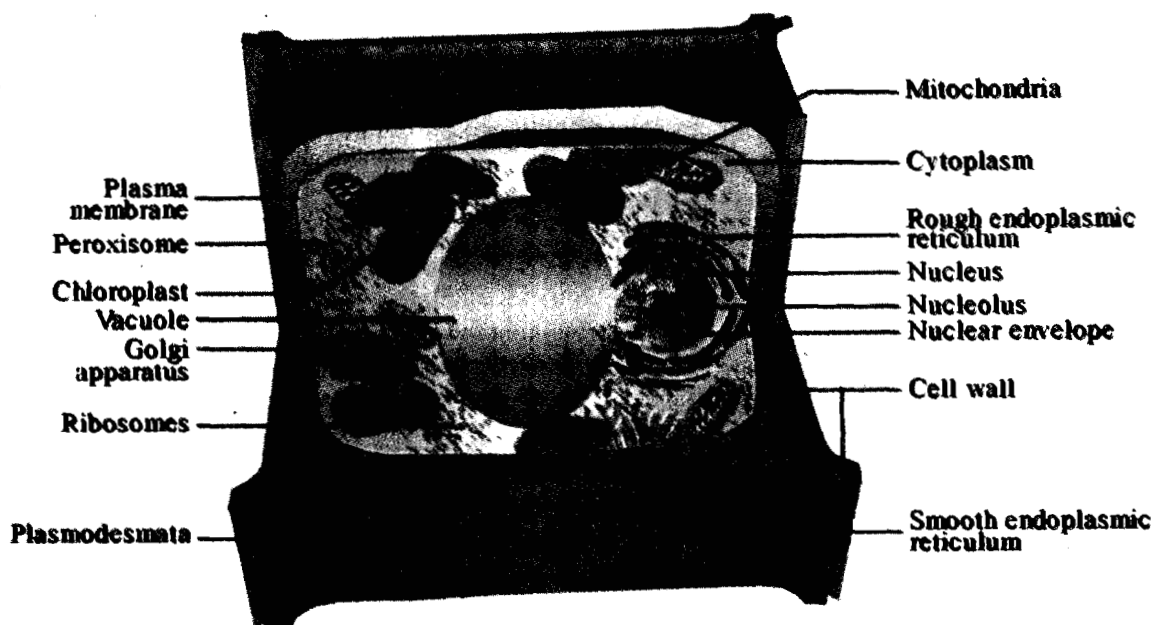


Figure 2.2(b): Plant cell

Let us now study the basic parts of the eukaryotic cell:

- **Cell wall:** The plant cells have a definite cell wall, which the animal cells lack as can be seen in Figure 2.2(b). The plant cells have a fixed shape because of a cell wall. It is sufficiently strong, thick and rigid.
- **Plasma Membrane:** Cells are guarded from the outside world by a membrane, called as the plasma membrane shown in Figure 2.2(a), (b). This membrane controls the flow of molecules to and fro the cell. This membrane is responsible for the communication of a cell with the outside world.

The cell membrane is a dynamic structure undergoing a variety of changes. What makes the nature quasi-fluid? S. Jonathan Singer and Garth Nicholson (1972) proposed a *Fluid mosaic model*, as shown in the Figure 2.3.

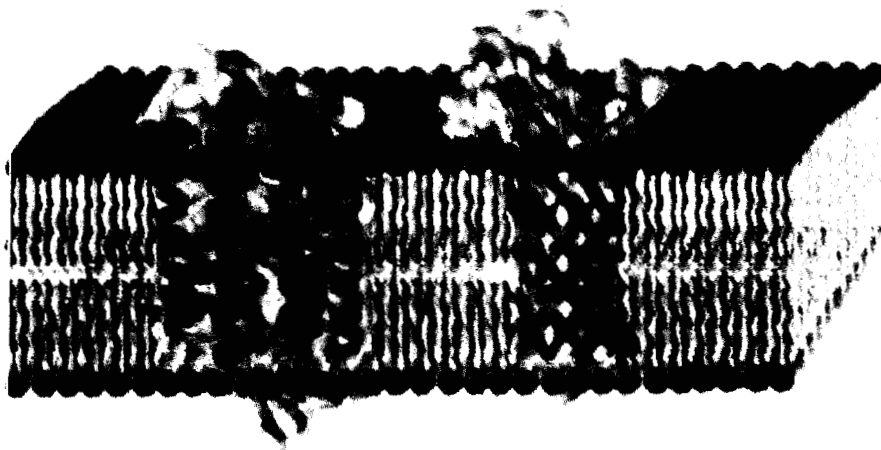


Figure 2.3: Fluid mosaic model

As you can observe from the Figure 2.3, the membrane is composed of a lipid bilayer and is studded with the structural proteins. It is a two-dimensional fluid or liquid crystal, in which the hydrophobic integral components such as lipids and

membrane proteins are constrained within the plane of the membrane, but are free to diffuse laterally. In the Figure 2.3, you can see two integral membrane proteins are embedded in the membrane.

The membrane performs an incredible variety of roles. The proteins found freely on the surface act as the transporters and serve to carry molecules across the cell membrane. The cell membrane maintains the cell environment. It also has the enzymes essential for critical metabolic processes like respiration, photosynthesis of lipids and cell wall constituents. These membranes are selectively permeable and so they help in the transport of certain molecules.

- **Cytoskeleton:** The ability of cells to change shape and carry well-directed movements depends on the skeleton of the cell, *the cytoskeleton*. The cytoskeleton is a network of fibers running throughout the matrix of living cells that provides a framework for organelles, anchors the cell membrane, facilitates cellular movement and provides a suitable surface for chemical reactions to take place. These are of three types:
  - 1) **Microfilaments:** These are a network of filaments within the cytoplasm as shown in Figure 2.4 which helps to play a major role in cell motion, allowing the cell to adapt to new shapes and maintaining the structural integrity of a cell. The microfilaments allow pigment granules to slide along them like a roller on a straw, they help plasma to stream and amoeba to move by pseudopodia or false feet. The microfilaments are solid tubes made up of actin-like protein.
  - 2) **Microtubules:** A network of proteinaceous cylindrical hollow tubes that are distributed throughout the cytoplasm of eukaryotic cells. It is made up of tubulin molecules, as shown in the Figure 2.4. The microtubules perform the following functions. These:
    - i) help in maintaining cell shape by providing support and anchoring the cell membrane,
    - ii) along with microfilaments, are involved in cell movement, and
    - iii) participate in intracellular transport, for example, movement of organelles and chromosomes at the time of cell multiplication.

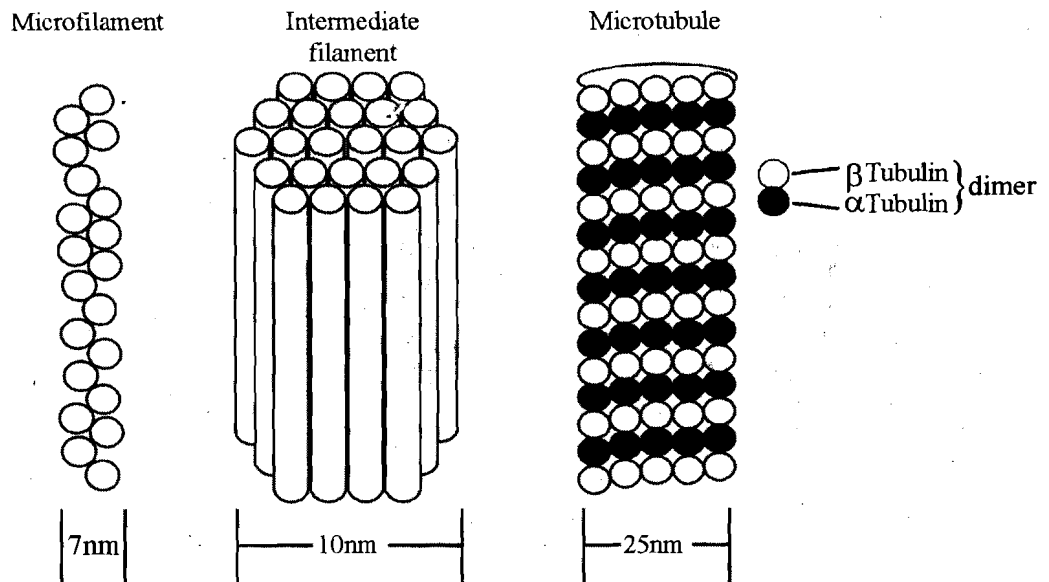


Figure 2.4: Structure of microfilaments and microtubules

- 3) **Intermediate filaments:** These are filaments of protein fibers in the cytoplasmic matrix. They bind cells together at cell-cell junctions and form a basket around the nucleus interweaving it in most of the animal cells. These provide the structure for the cell components. They are tough and durable.
- **Endoplasmic Reticulum:** The endoplasmic reticulum (ER) is a fine reticulum or network in the plasma of the cell. The endoplasmic surface is studded on its outer surface with ribosomes as you can see in the Figure 2.5, and is termed as *Rough Endoplasmic Reticulum (RER)*. These are present in abundance in the cells that are involved in active protein secretion, synthesis, modification and transport of cellular materials.

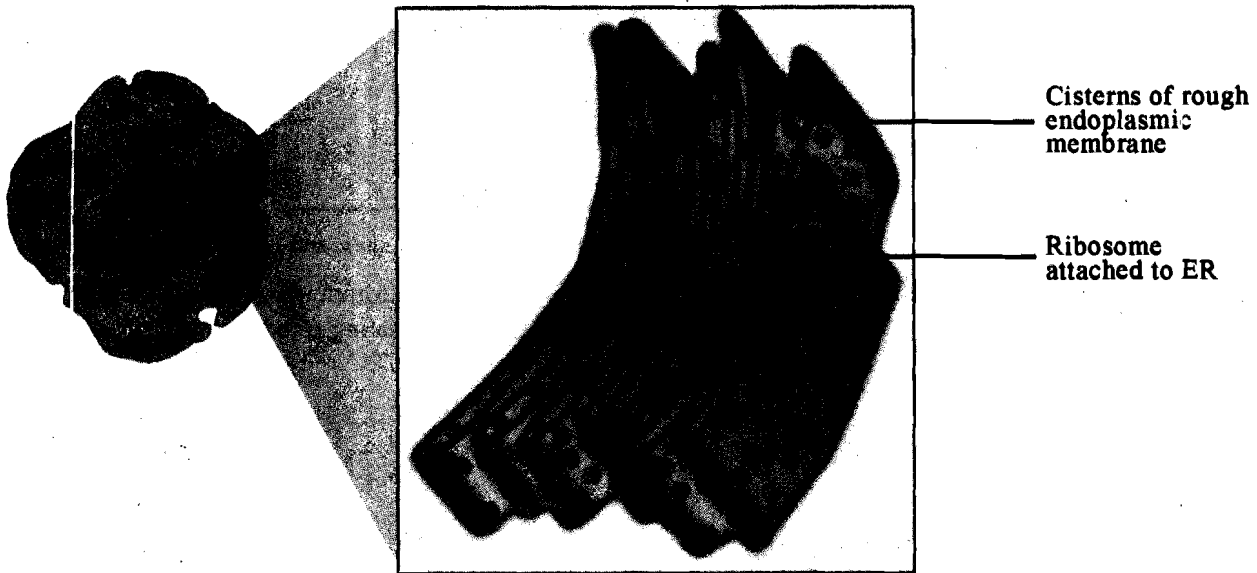


Figure 2.5 : Structure of endoplasmic reticulum

The cells which produce large quantities of lipid, have ER that is without the ribosomes. Such ER is known as *Smooth ER (SER)*.

What are the functions of the ER? This remarkable network of membranous sheet of tubules performs a myriad of functions such as:

- 1) The RER synthesizes serum proteins, globulin, albumin, fibrinogen and membrane proteins of the lysosome and cell membrane.
  - 2) The SER synthesizes lipids.
  - 3) The ER detoxifies the impure food and drugs that we eat.
  - 4) The movement of muscles we flex is brought about by the calcium ions released.
- **Golgi apparatus:** As you can see in Figure 2.6, golgi apparatus consists of stacks of flat-membranous sacs. The golgi apparatus serves to package the material for export to the other parts of the cell and prepare for secretions. The packaging industry of the cell moves material from the ER to the golgi apparatus. The proteins synthesized in the ER are modified by adding specific groups or folded and then bundled to their appropriate location in vesicles that bud from the golgi apparatus.
  - **Lysosome:** Look at Figure 2.2(a) for the structure of lysosome. They are formed from the leftovers of the vesicles budded of the golgi apparatus. They are involved in intracellular digestion and are the scavengers of the cell. These release enzymes that digest the cell particles. If they are released in tissue, they may kill other cells and the cell in which they were stored. Thus, these are labeled as *autophagic vacuoles* or cell suicide causing particles.

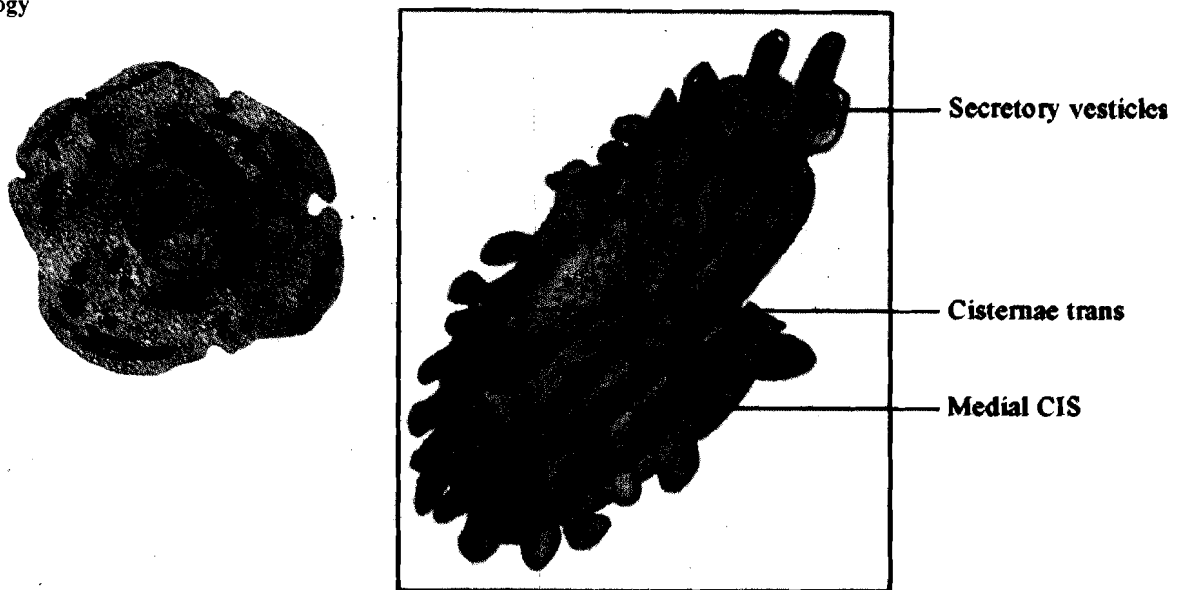


Figure 2.6: Structure of golgi apparatus

Cells take in material (*Endocytosis*) or give out or excrete (*Exocytosis*). Endocytosis is divided into cell drinking (*Pinocytosis*) and cell-eating (*Phagocytosis*). You can see the various steps of these processes in the Figure 2.7.

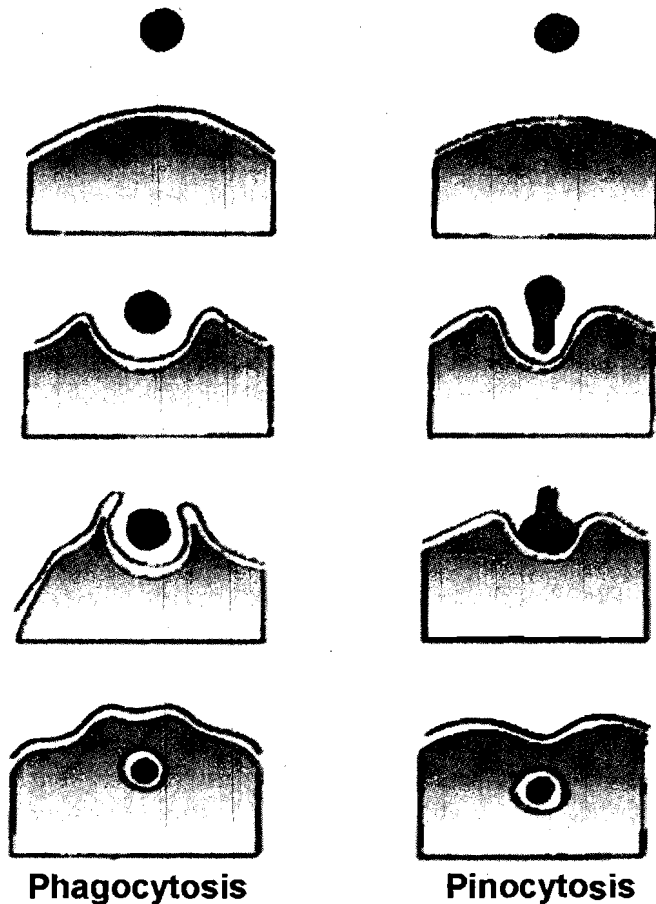


Figure 2.7: Endocytosis in cells

The cell membrane invaginates or encloses the fluid droplet or solid particle. The cell membrane then completely engulfs the particle and a part of its membrane pinches off to encircle the particle within the cell. This ingested vacuole is termed as *pinosome* or *phagosome*. This is referred to as *endocytosis*.

*Exocytosis* involves expulsion of materials out of the cell. The unwanted materials are leftovers of digested particles found in vesicles called 'residual body'. The lysosomes are also important cellular organelles for nutrition.

- **Cytoplasmic Vacuoles:** Figure 2.2(b) illustrates the structure of vacuoles. These are the voids in the cytoplasm which store small molecules such as water, ions, sucrose and amino acids. They appear as blobs and perform a variety of functions such as concentrating mineral salts in plant cells or excrete materials and digest food nutrients. Some primitive prokaryotes float in water because of air present in the vacuoles called as 'air vacuoles'.
- **Ribosomes:** Ribosomes are small, but complex structures, roughly 20 to 30 nm in diameter, consisting of two unequally sized subunits, referred to as *large* and *small subunits* which fit closely together as seen in Figure 2.8. These are the small cellular components composed of specialized ribosomal RNA and protein. We have just read that they are found studded like jewels on RERs. They are responsible for synthesizing proteins that form the membrane of secretory organelles and lysosome membranes.

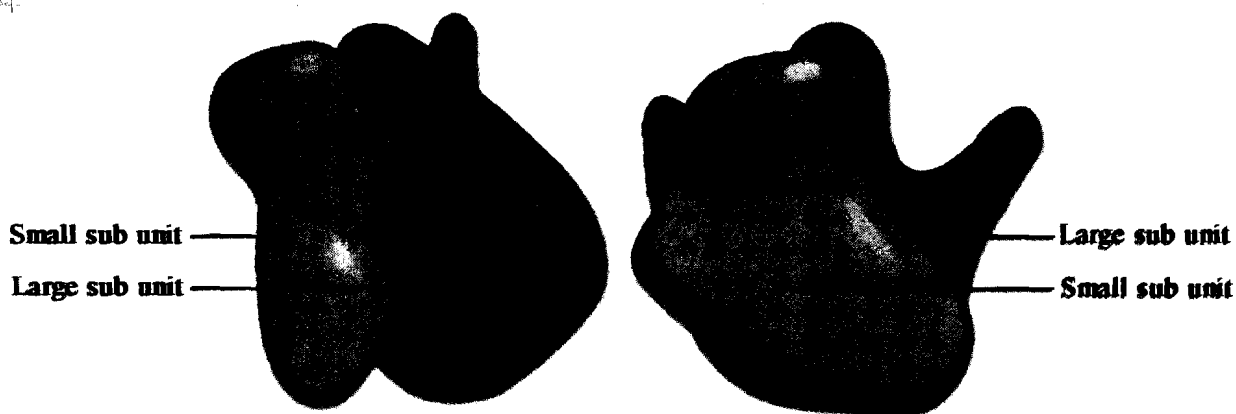


Figure 2.8: Structure of a ribosome

- **Mitochondria:** These are called as the 'powerhouse of the cell', that contain their own DNA. They are associated with the generation of ATP, the energy currency of the cell. The longitudinal section of mitochondria in the Figure 2.9 (a) shows a double membrane, the outer membrane and the inner membrane bind the mitochondria. The inner membrane has many infoldings called as *crisetae* as seen in the Figure 2.9 (b).

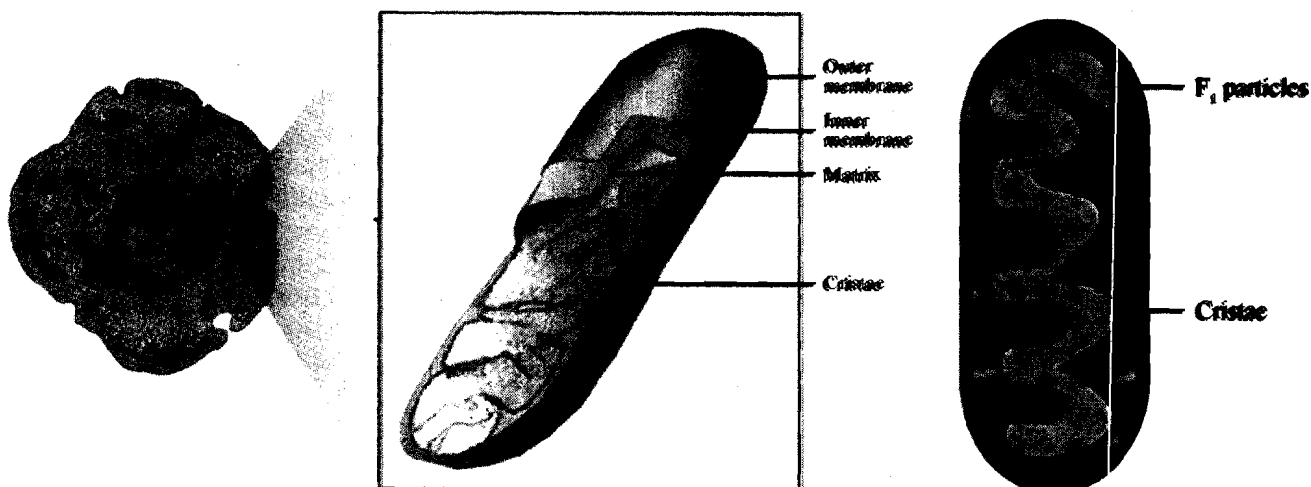


Figure 2.9: Structure of the mitochondria  
(a) Longitudinal section; (b) Sectional view

The enzymes and electron carriers for the formation of the molecule ATP are located on cristae. The cristae enclose the matrix that contain enzymes for TCA (Tricarboxylic Acid) cycle that converts all food into  $\text{CO}_2$ , water and energy. You may recall reading about the TCA cycle in the Nutritional Biochemistry Course. Energy generated as electrons is transported down a waterfall-like gradient during breathing or cellular respiration. These organelles are the independent units, they produce their own proteins, multiply to pass on the information via DNA and provide energy to the entire cell.

- **Plastids:** Plastids are the self-replicating cytoplasmic organelles of plant and algal cells. See Figure 2.10, which illustrates the microscopic structure of a chloroplast. These contain pigments or starch or oil or protein. These are divided by their colors into three classes, namely, chloroplastids, chromoplastids and leucoplastids.

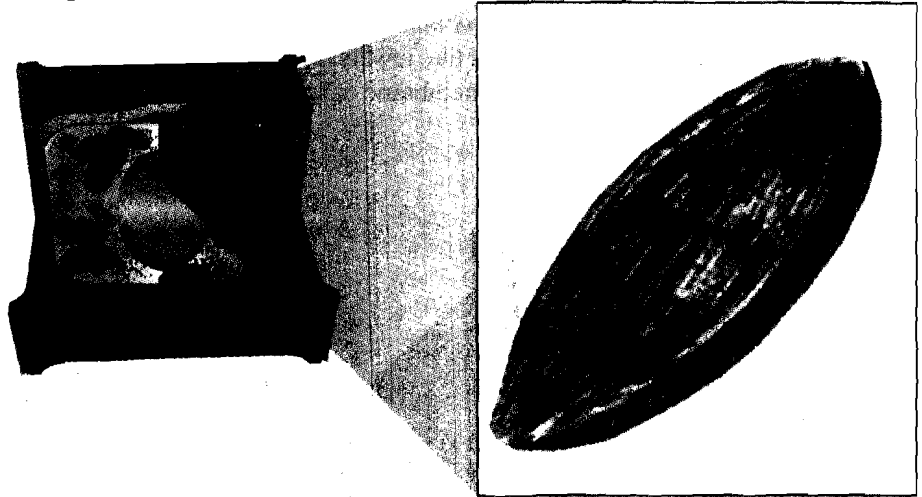


Figure 2.10: Structure of a chloroplast

Plastids are the organelles of plant cells that contain chlorophyll. Chlorophyll is the green colored pigment that traps light energy in leaves to make food. It is the “sunlight trap.”

Yellow fruits and vegetables like mangoes, carrots, corn, papaya and pineapples are the rich sources of vitamin A. They have pigments called carotenoids in plastids called as *chromophobes*. These organelles are independent units like mitochondria, they produce their own proteins, multiply to pass on the information via DNA and trap energy for food production.

- **Nucleus:** Nucleus is the core of the cell. It is a part of the cell that contains DNA and RNA and is responsible for growth and reproduction. It is a large organelle that controls all activities of the cell. The nucleus is the storehouse of hereditary information. Two membranes, the nuclear envelope, enclose it. This appears to modulate the exchange of nuclear fluid and cytoplasm. The envelope disappears during cell division and reappears in the daughter cell. The site for synthesis of ribosomes is the *nucleolus*. They control protein synthesis.

The molecule for heredity is the DNA. This is coiled like springs in threads called *chromosomes*, as seen in the Figure 2.11. Chromosomes have a short arm and a long arm and a central portion referred to as *centromere*.

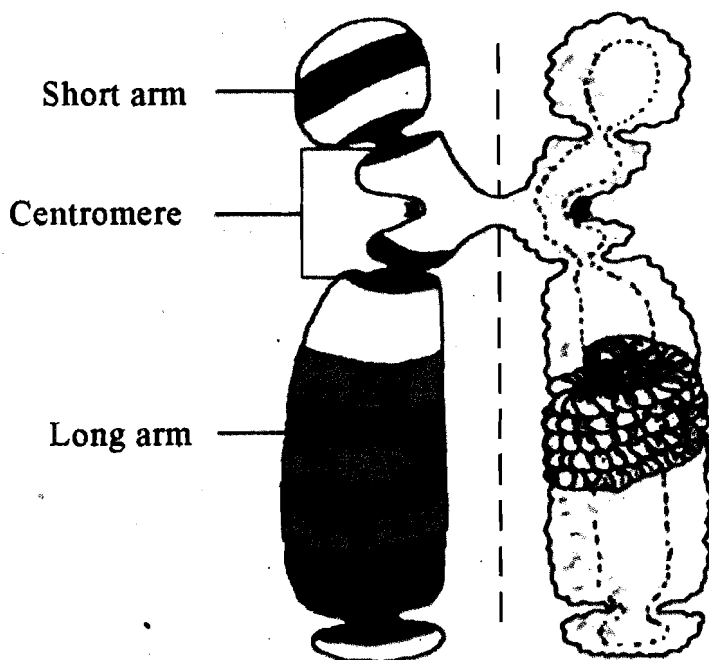


Figure 2.11: Structure of chromosomes

**Centrioles:** These are the two small cylindrical cell organelles that are found near the nucleus. They are self-replicating, short, fibrous, rod-shaped organelles of animal cells. They are responsible for forming the cilia, flagella and astral spindle during cell division. Centrioles are composed of short microtubules arranged as a cylinder, as can be seen in Figure 2.12. They have a cartwheel – like organization having a whorl of nine protein molecules on the rim of the wheel connected by spokes to a center, (9 + 0) having 3 tubules, A, B and C, as shown in Figure 2.12. Centrioles come in pairs, each organized at right angle to the other.

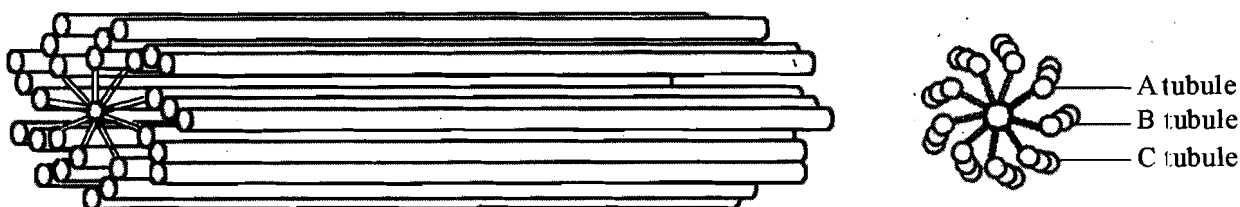


Figure 2.12: Centriole in transverse section

**Cilia and Flagella:** Look at Figure 2.2(a) and identify the cilia in the structure. Yes, cilia and flagella are projections from the cell. They are made up of microtubules, like the centrioles. They are motile and designed either to move the cell itself or to move substances over or around the cell. Cilia and flagella have the same basic structure but flagella are longer in proportion to the cell bearing them and present in much smaller numbers, as you can see from the Figures 2.13 and 2.14. Cilia and flagella beat at a rate of about 10-40 strokes or waves per second and propel microorganisms rapidly. The beating of cilia and flagella is termed as *whip-like*. See Figure 2.15 which illustrates the cilia movement. It has a power stroke in which the locomotion occurs in a direction opposite to the stroke and a passive recovery stroke in which the hair-like organelles come back and get ready for the power stroke. This is similar to the power stroke and recovery stroke of a flying bird.

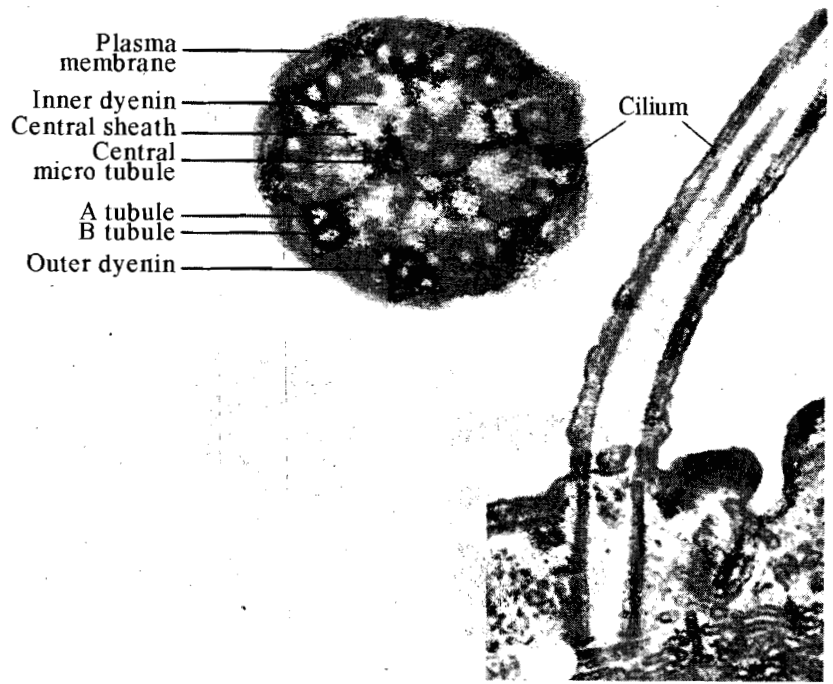


Figure 2.13: Cilia section

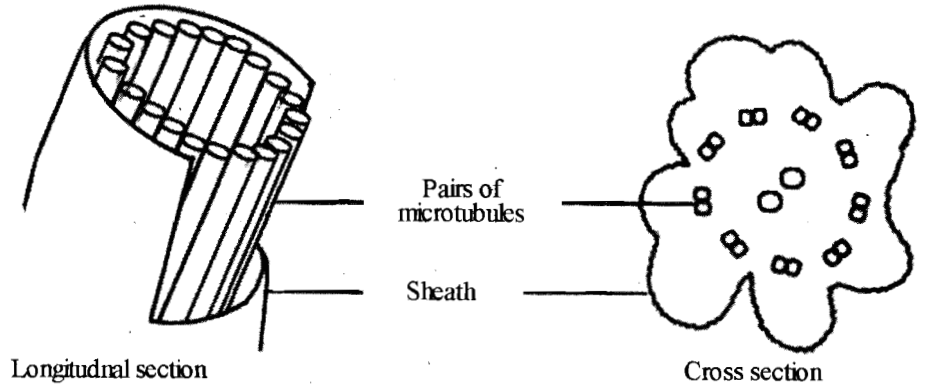


Figure 2.14: Structure of flagellum

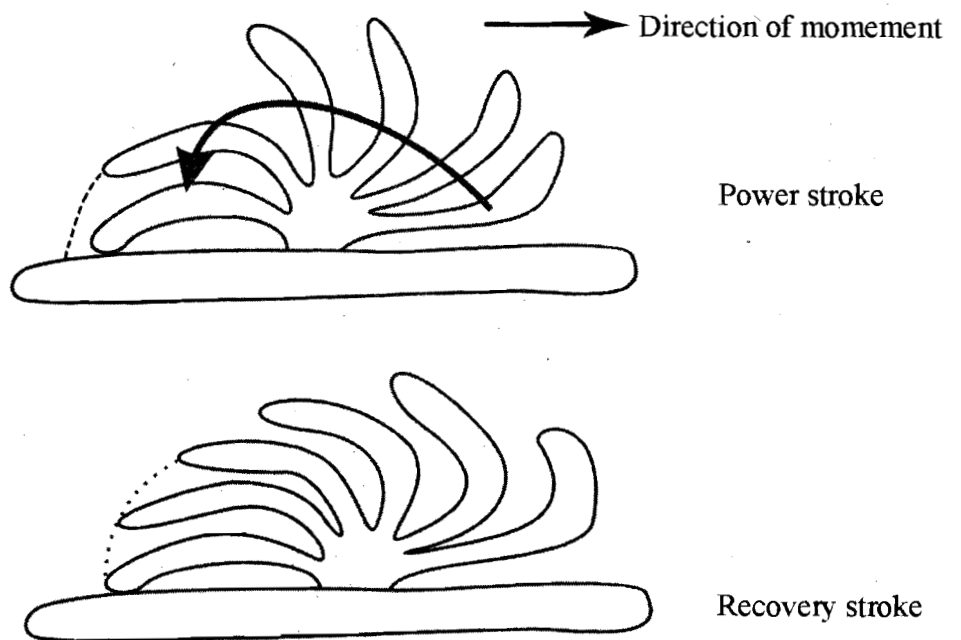
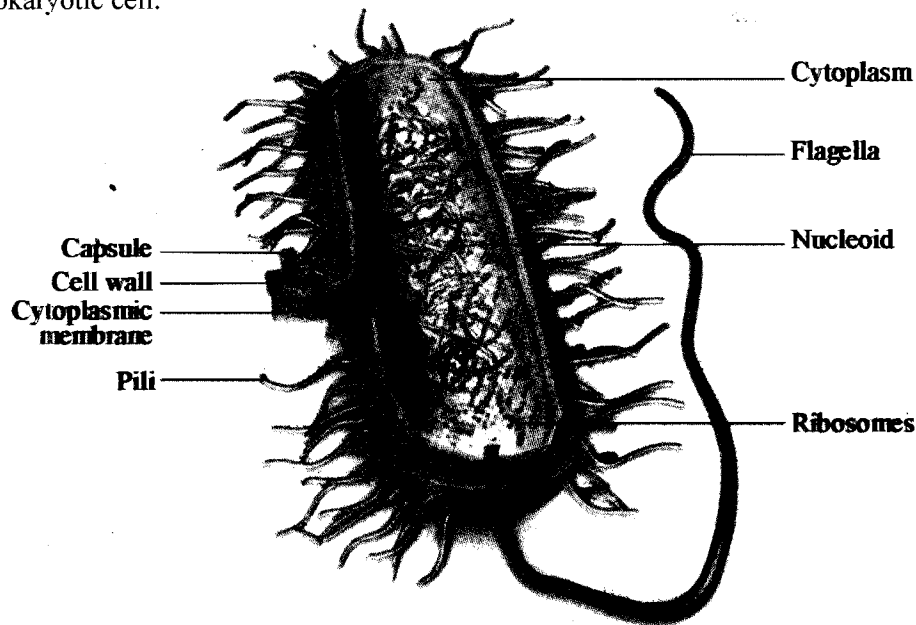


Figure 2.15: Cilia movement

The discussion above focused on the components of the eukaryotic cells. Next, let us see how the prokaryotic cell differs from the eukaryotic cell.

### 2.3.2 Prokaryotic Cell and Organization

Prokaryotic cells, you would realize, are the primitive cells lacking a nuclear membrane. These are very small cells that multiply very rapidly, for example, bacteria and blue green algae. Look at the Figure 2.16, which represents the structure of the prokaryotic cell.



**Prokaryotic Cell Structure**

Figure 2.16: A Bacterial cell

Can you make out any differences between the eukaryotic and prokaryotic cell? Yes, in a prokaryotic cell:

- DNA is not coiled into springs but is arranged in a circular forms,
- Chromosomes and microtubules are absent, and
- membrane-bound organelles are absent, for example, mitochondria.

You would realize that prokaryotic cell may be divided into two types on presence or absence of outer membrane – *gram positive* and *gram negative*. In gram-positive cell (bacteria), the stain is trapped by the layer of peptidoglycan, which forms the outer layer of the cell. In gram-negative bacteria, the outer membrane, present on the cell, prevents the stain from reaching the peptidoglycan layer in the periplasm.

**Check Your Progress Exercise 2**

1) Briefly explain the following terms:

a) Fluid mosaic model

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b) Cytoskeleton and its types

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c) Endocytosis

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d) Cristae

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 .....

e) Chromophobes

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 .....

2) Differentiate between eukaryotic cells and prokaryotic cells.

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 .....

3) List the basic parts of a cell.

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 .....  
 .....

4) Give functions of the following:

S.No.	Component	Functions
a)	Endoplasmic reticulum	..... .....
b)	Mitochondria	..... .....
c)	Lysosomes	..... .....
d)	Nucleolus	..... .....
e)	Golgi apparatus	..... .....
f)	Ribosomes	..... .....

Having understood the structure of the cell, let us learn about the cell cycle.

## 2.4 CELL CYCLE

What do we mean by cell cycle? Let us first understand this concept. When a cell is to divide, the genetic material gets duplicated so that all the daughter cells get equal material. *The orderly sequence of events by which the cell duplicates its contents and divides into two is termed a cell cycle.* A typical cell cycle and its phases are shown in Figure 2.17. All cells divide except the nerve cells of mammals after birth. The division takes place either by mitosis or meiosis.

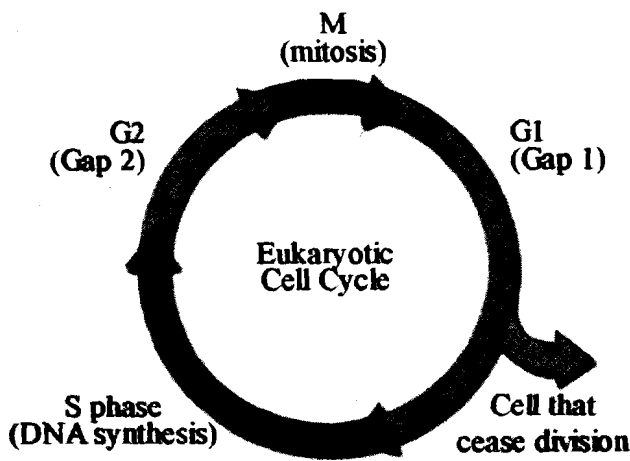


Figure 2.17: Phases of cell cycle

As you can see in Figure 2.17, the different phases are represented as G1, S, G2, M. What do these phases indicate? Let's find out. The cell cycle consists of four phases, which include:

G1 = growth and preparation of the chromosomes for replication

S = synthesis of DNA (and *centrosomes*)

G2 = preparation for

M = mitosis, when nuclear (chromosomes separate) and cytoplasmic (cytokinesis) division occur

Mitosis is further divided into four phases about which we shall read next. But, first what is mitosis?

### 2.4.1 Mitosis

Mitosis is *the process of nuclear division in cells that produces genetically identical daughter cells, which are identical to the parent cell*. In this process of cell division, the chromosomes are duplicated and distributed equally to the daughter cells. It is also called as *equational division*. Figure 2.18 illustrates the various stages of mitosis in a typical plant cell. *Interphase* is often included in discussions of mitosis, but interphase is technically not part of mitosis, but rather encompasses stages G1, S and G2 of the cell cycle we discussed above. The phases of mitosis include:

- **Prophase:** The chromatin, diffuse in interphase, condenses into chromosomes. Each chromosome has duplicated and now consists of two sister chromatids. Have a look at the Figure 2.18. At the end of prophase, the nuclear envelope breaks down into vesicles.
- **Prometaphase:** The nuclear membrane dissolves, marking the beginning of prometaphase. Proteins attach to the centromeres creating the kinetochores. Microtubules attach at the kinetochores and the chromosomes begin moving.
- **Metaphase:** The chromosomes align at the equatorial plate as illustrated in the Figure 2.18 and are held in place by microtubules attached to the mitotic spindle and to part of the centromere.
- **Anaphase:** The centromeres divide. Sister chromatids separate and move towards the corresponding poles as you can see in the Figure 2.18.
- **Telophase:** Chromatids arrive at opposite poles of cell, and new membranes form around the daughter nuclei. The chromosomes disperse and are no longer visible under the light microscope. The spindle fibers disperse and cytokinesis or the partitioning of the cell may also begin during this stage.

*Cytokinesis* results when a fiber ring composed of a protein called *actin* around the center of the cell contracts pinching the cell into two daughter cells, each with one nucleus. In plant cells, the rigid wall requires that a cell plate be synthesized between the two daughter cells.

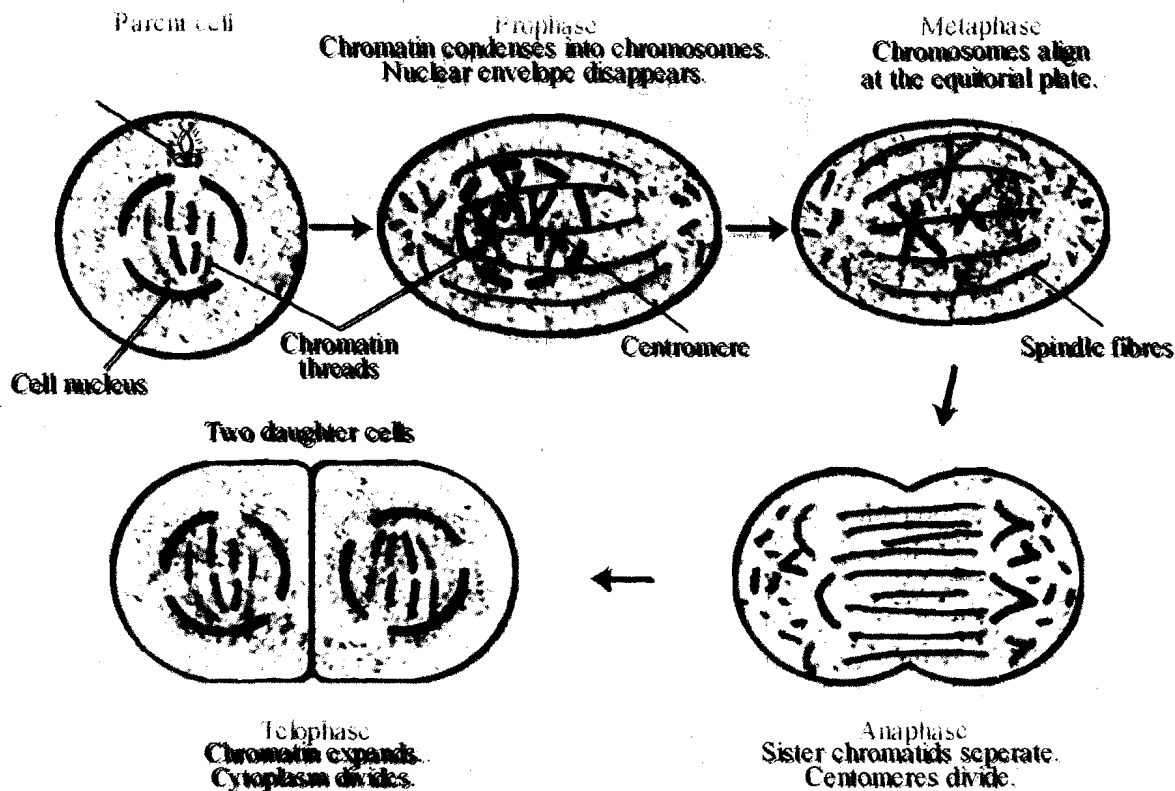


Figure 2.18: Mitosis – cell division process

Mitosis takes place in somatic cells or cells of the body. For example, cells of the skin are scraped off when you scratch it only to be replaced by underlying mitotically dividing cells. The cells divide only once and the chromosome number remains constant at the end of mitosis.

*What is the significance of mitosis?*

Mitosis is significant for the following purposes:

- i) Equal distribution of chromosomes. This ensures same genetic constituents of all cells of the body.
- ii) Mitosis restores the surface/volume ratio of the cell.
- iii) Cells of the body are renewed and replaced through the process of mitosis. For example, the cells of the skin die and are replaced by underlying cells.

Next, let us learn about meiosis, the other cell division process.

## 2.4.2 Meiosis

*A reproductive process that involves two successive divisions of a cell, results in four daughter cells, is called as meiosis.* Unlike what occurs in mitosis, the daughter cells produced in meiosis are not identical to each other. Meiosis is the process by which sperm and egg cells are made. The division of germ cells to form gametes in sexually reproducing organisms occurs by a process of cell division termed as *meiosis*. In meiosis, the chromosomal number is reduced from double to half. See how this division takes place in the Figure 2.19. The different stages of meiosis are also highlighted in the figure. The genetic constituent of the daughter cell differs from the parent cell due to

crossing over. Each chromosome of the daughter cells usually contains a mixture of mother and father genes.

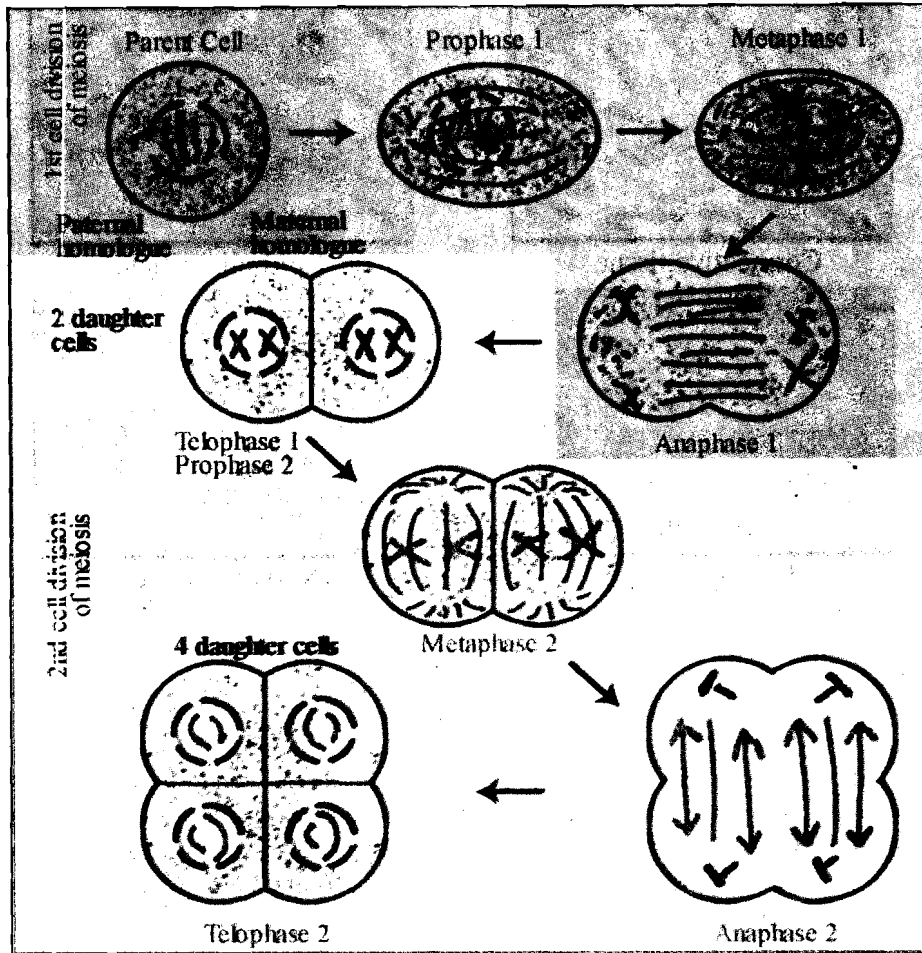


Figure 2.19: Stages of meiosis

*What is the significance of meiosis?*

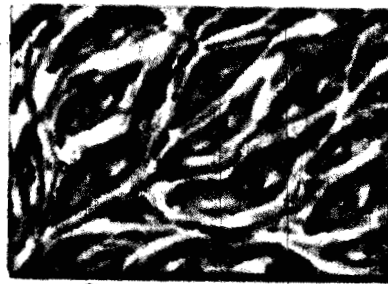
Meiosis is important for the following purposes:

- The meiosis maintains a definite and constant number of chromosome on organisms.
- By crossing over, the meiosis provides an opportunity of exchange of genes and thus, causes variation within species. This serves as the basis of evolution.

Having understood the structure, organization and function of the cells, we will move on to the study of tissues.

## 2.5 TISSUE AND THEIR FUNCTIONS

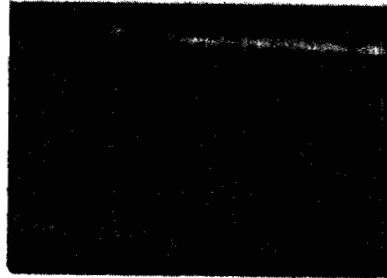
A tissue is a mass of similar cells usually continuous, held together in a supporting matrix, performing a common function usually forming a part of an organ. Animal tissues are usually classified as: Epithelial tissue, Connective tissue, Muscle tissue and Nervous tissue. Figure 2.20 illustrates these tissues. A detailed discussion on each of them follows.



Connective tissue



Epithelial tissue



Muscle tissue



Nervous tissue

Figure 2.20: The animal tissues

### 2.5.1 Epithelial Tissue

Epithelial cells are generally closed packed cells, as can be seen in Figure 2.20, like a bricks in a pavement and form solid protective layers on the outside. You may remember having studied these cells under the microscope after taking scraping from the buccal (mouth) mucosa. The epithelial cells line external surfaces like skin, cavities like stomach, tubules like urethra and produce secretions and proliferate. Epithelial cells in glands exude secretions, for example, the earthworm may secrete a cuticle or a crab may secrete a shell.

### 2.5.2 Connective Tissue

Connective tissues connect and bind different tissues and organs. They also provide a structural framework and mechanical support. They contain a lot of extra cellular material and very few cells, as shown in Figure 2.20. There are eight type of connective tissues: areolar, adipose, white fibrous tissue, tendon, ligament, cartilage, bone and blood. Let us get to know more about these connective tissues.

- *Areolar tissue*

This is a loose tissue beneath the scalp. They are made up of elastin and collagen fibers that provide support. They interweave a network of scar tissue during healing.

- *Adipose tissue*

This is the tissue that stores fat. It is very prominent in obese people, in animals living in Polar Regions. It prevents heat loss by forming a heat-insulating layer beneath the skin and also forms shock absorbers around the eyeballs and kidneys.

- *White fibrous tissue*

The tissue is made up of fibers that have great tensile strength. The many bones of the skull are made immovable by this tissue to render the skin as one protective unit.

- *Tendon*

Tendon joins muscle to bone. They are made of collagen fibers.

- *Ligament*

Ligament joins bones at the joints. They are made up of elastin fibers.

- *Cartilage*

Cartilages are the flexible semi-rigid structures that are present in the pinna (part of the ear). Connect ribs to the sternum and between intervertebral discs.

- *Bone*

Bones have a cavity called marrow cavity. They are red and yellow marrows. Red marrow forms erythrocytes and leucocytes. *Red marrows* are found in ribs, vertebrae, skull bones and ends of the long bones. *Yellow marrow* is composed of fatty tissue. It stores fat and produces blood corpuscles only in emergency situations. It is found in the central parts of long bones, for example, femur.

### 2.5.3 Muscle Tissue

Muscle is a very specialized tissue that has both the ability to contract and to conduct electrical impulses. Muscle contractile proteins are *actin* and *myosin*, as shown in Figure 2.21.

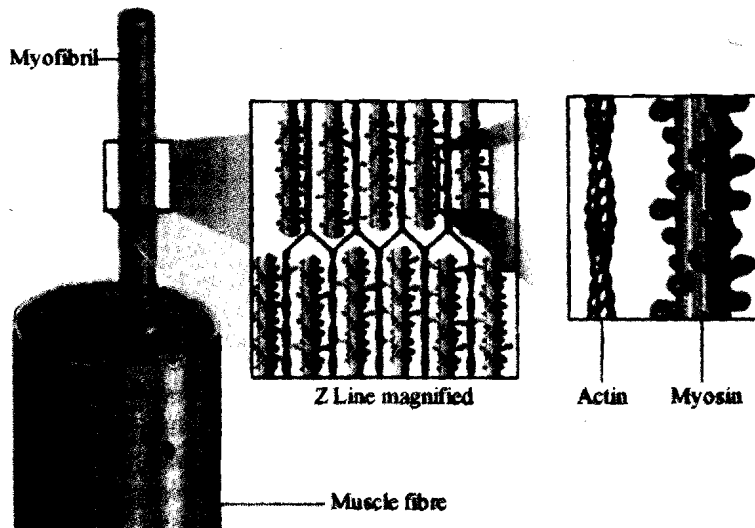


Figure 2.21: The muscle proteins and myofibrils

Muscles are classified both functionally as either *voluntary or involuntary* and structurally as either *striated or smooth*. The muscle fibers are striated, banded, unbranched and cylindrical and are termed as *myofibrils* as shown in Figure 2.21. During contraction, both the thick and thin filaments retain their original length, contraction results in an increase in overlap between the filaments. Plasma membrane called *sarcolemma* surrounds muscle cytoplasm or sarcoplasm. Basically, you would realize there are three types of muscles, as shown in Figure 2.22. A brief review on these muscle tissues follows:

- *Cardiac muscle – striated involuntary muscle*: The muscle proteins of cardiac muscle are identical to those of skeletal muscle. They are actin, tropomyosin and troponin. Under electron microscope, the cardiac muscle shows a striking resemblance to skeletal muscle, as you can observe in the Figure 2.22. We will learn more about the cardiac muscle in the next unit.
- *Skeletal muscle – striated voluntary muscle*: Skeletal muscle is attached to the bones. One can contract them on desire and are thus termed as *voluntary muscle*.
- *Smooth muscle – smooth involuntary muscle*: Smooth muscle is known for its property of plasticity. The urinary bladder is a typical example. The urine fills without distending the pressure of the bladder till a point where the bladder contracts as one unit and expels the urine. Smooth muscle is not under voluntary control and is divided into type's – single unit or multi unit. Single unit act as a single unit and multiunits are present in the blood vessels.

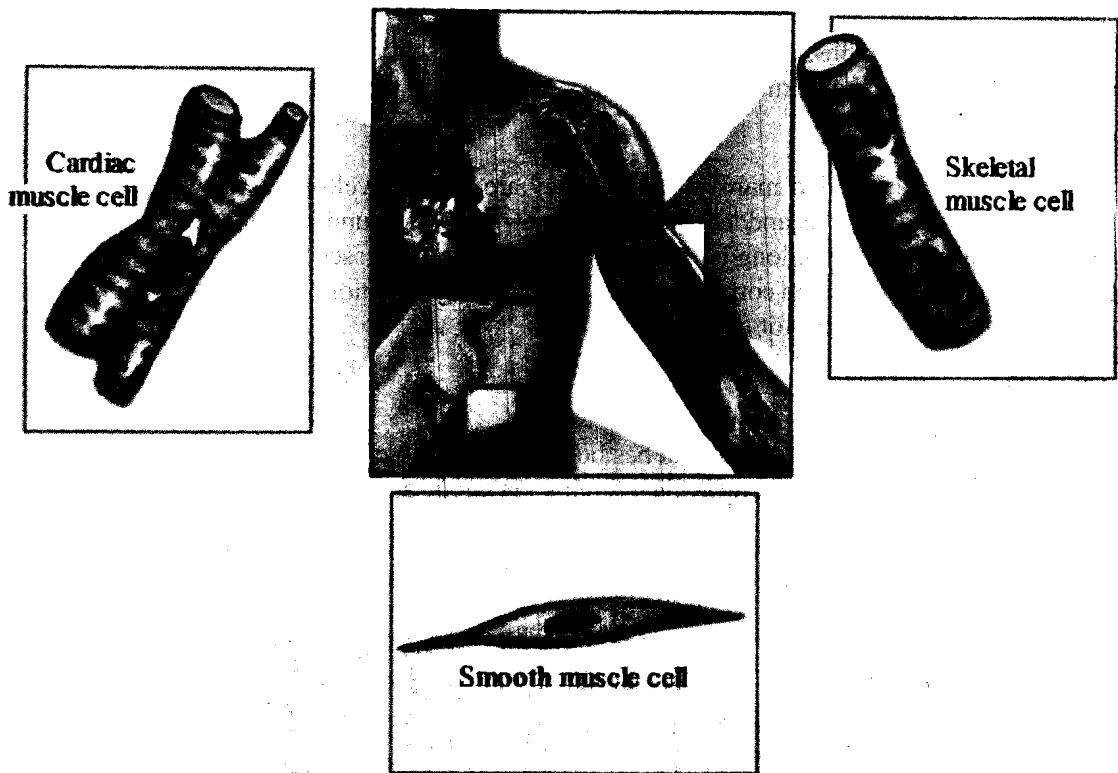


Figure 2.22: The three types of muscle tissue

### 2.5.4 Nervous Tissue

Nervous tissue comprises of two types of cells: *nerve cells* or *neurons* and *glial cells*. Neurons have numerous long processes and transmit nerve impulses. The glial cells have short processes and protect neurons. The largest neuronal process is termed as *axon* that transmits electrical signal away from the cell body. The remaining processes are small and radiate like branches of a tree and are called *dendrites* or *dendrons*. We will learn about these structures in greater details later in Unit 9. Nerve impulses or electrical signals cannot be transmitted at the same strength from head to toe. As a result, nature has designed a mannerism in which the impulses jump across clefts or synapses between the axon of a neuron and the cell body of another nerve cell. Nerve impulses jump from one node to the other by means of saltatory conduction (jumping of a frog). A node is that bare part of the axon or nerve fibre that is not insulated by a lipid myelin sheath. Deficiency of Vitamin B<sub>12</sub> in the diet results in demyelinating diseases: This is quite common in strict vegetarians who don't even take milk and milk products.

With nervous tissue, we end our discussion on tissues, their types and functions. Next, we shall focus on blood, the elixir of life. But before that, let us review what we have learnt so far.

**Check Your Progress Exercise 3**

1) What do you understand by the term 'cell cycle'? Discuss its four phases.  
 .....  
 .....

2) What do you understand by the terms 'mitosis' and 'meiosis'? Explain giving significance of each.  
 .....  
 .....

3) What is a tissue? How are tissues classified? Give two examples of each.

.....

.....

.....

## 2.6 BLOOD

“The ancients believed that blood was the seat of the emotions.” Blood, a body fluid, has been rightly termed as an elixir of life. We all have blood flowing inside our bodies. Blood, as you already know, has several important roles to play. It carries oxygen and nutrients to the tissues and carries waste products away. Blood helps maintain body temperature and normal pH levels in body tissues. The protective functions of blood include *clot formation* and the *prevention of infection*.

Let us start our study on blood by first getting to know the historical development of the concept of blood.

### 2.6.1 History and Milestones

In this section, we will discuss about the historical development of the concept of blood and blood cells. This discussion is an overview of sequence of events that took place during different times in the past. Let us go through it.

- The ancients must have observed that if an animal or a man lost a considerable quantity of blood, it generally did not survive. This must have led them to associate blood with life. *Ebers Papyrus* said that in ancient Egypt, it was believed that food in the stomach was turned into blood by heart.
- According to the ancient European doctrine of four humors, blood was one of the humors which makes the body. The other three humors were phlegm, black bile and blue bile. The blood is considered as one of the four humors.
- The Ayurvedic concept of three humors is very similar. The three humors are *kapha* (phlegm), *pitta* (bile) and *vayu* (air). Health is thought to be a state of balance of these humors. In this system, air comes closest to blood.
- In the recent history of growth of our knowledge about blood, the advent of microscopy in the seventeenth century was an important milestone. *Antony Van Leeuwenhoek* is considered a pioneer in microscopy. He examined blood under the microscope and could describe red blood cells and even measured their size.
- In the eighteenth century, extensive studies on blood and related structures such as lymphatics and thymus were undertaken by *William Hewson*. He described the leukocytes and demonstrated that coagulation was due to the changes in the plasma rather than the blood cells, and hence *Hewson* is called the ‘father of hematology’.
- In the nineteenth century, *Paul Ehrlich* used dyes for staining cells, which helped him to distinguish different types of blood cells and red cell changes in diseases and also identified the different types of white blood cells.
- In the twentieth century, *George Whipple’s* studies on the relationship between diet and haemoglobin, *George Minot’s* discovery of the liver treatment for pernicious anaemia and *William Castle’s* discovery of intrinsic and extrinsic factors were some of the milestones in hematology.

Having learnt about the historical development, let us next get to know about the constituents of blood.

## 2.7 BLOOD COMPOSITION

Blood, as you learnt earlier, is a fluid connective tissue. It is composed of 2 parts. The intercellular fluid is called *plasma* in which the *blood cells* or corpuscles float as shown in Figure 2.23 herewith. Thus, blood consists of a fluid (blood plasma) containing cells (erythrocytes and leucocytes) and platelets. Plasma forms about 55% of the blood volume, whereas, the cells occupy the remaining 45%. The composition of blood is as follows:

Water	—	91.0 %
Protein	—	08.0 % (Albumin, Globulin, Prothrombin, Fibrinogen)
Salts	—	0.9 % (NaCl, NaHCO <sub>3</sub> , salts of calcium, phosphorus, magnesium, iron etc.)

The balance (0.1%) is made up of traces of a number of organic materials: glucose, fats, urea, uric acid, creatinine, cholesterol, amino acids, gases, internal secretions, enzymes and antigens.

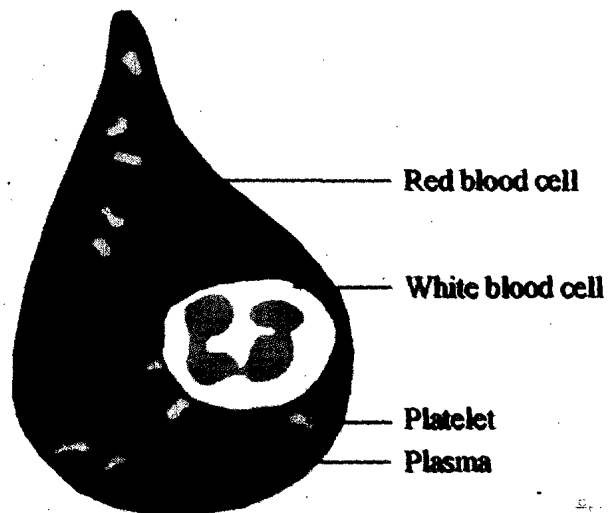


Figure 2.23: Composition of blood

Let us get to know more about the plasma and the cells next.

### 2.7.1 The Plasma

Plasma, as you already know, is the fluid in which the cellular elements of blood are suspended. *Plasma* is a faint yellow colour and has a slightly alkaline pH. Plasma is 90% water and 10% solutes. In order to separate plasma from the blood cells, a substance which prevents the clotting of blood is added to the blood, after which the blood is left, for the cells to settle down. However, a speedy separation is achieved if blood containing the anticoagulant is centrifuged. The normal plasma volume of an adult is 3 liters. The composition of plasma resembles that of other extracellular fluids of the body except for the presence of a significant concentration of proteins.

Plasma contains different types of proteins, which perform a wide range of functions. Let us get to know about these proteins.

#### *Plasma proteins*

Normal plasma has proteins in a concentration of 6 to 8 g/100 ml of plasma. The proteins present in the plasma act as enzymes, hormones and hormone-binding proteins. Some of these proteins perform specific functions in blood, like maintaining colloid osmotic pressure of blood, viscosity of blood and helps in the exchange of fluid across the capillary.

There are basically three types of plasma proteins, namely:

- Albumin (4-5 g/100 ml)
- Globulin (2-3 g/100 ml)
- Fibrinogen (0.3 g/100 ml)

*Plasma albumin* maintains plasma volume by holding water at the capillary level. *Fibrinogen* helps form a meshwork of solid fibrin that clots blood, preventing haemorrhage (excessive loss of blood). *Plasma globulin* is the body's defense against invading pathogens. They constitute the immunoglobulins. Plasma proteins are synthesized in the liver. Immunoglobulins are formed in the plasma cells and B lymphocytes.

So we have seen that plasma is a pale yellow mixture of water, proteins and salts. One of the functions of plasma is to act as a carrier for blood cells, nutrients, enzymes and hormones. Let us learn about the functions of plasma proteins in greater details.

#### *Functions of plasma proteins*

The functions of plasma proteins are many and are listed as:

- 1) *Osmotic Pressure*: Plasma proteins exert an osmotic pressure of 25 mm Hg, which helps in maintaining plasma volume. The osmotic pressure exerted by plasma proteins plays an essential part in the fluid balance. Having a small molecular size, albumin exerts the maximum colloid osmotic pressure.
- 2) *Viscosity*: Plasma proteins account for about half of the viscosity of blood, the other half being due to the blood cells. The contribution of each type of plasma protein to viscosity depends more on the molecular shape rather than the molecular size. That is why, a given concentration of fibrinogen, which has a long fibrillar molecule, contributes much more to viscosity than the same concentration of albumin, which has an elliptical molecule.
- 3) *Protein Reserve*: Plasma proteins provide a reserve, which can be drawn upon for vital functions in the situations of starvation and protein depletion/malnutrition.
- 4) *Antibodies*: Plasma proteins belonging to the class of  $\gamma$ -globulins act as antibodies, which protect us from infections and several other harmful substances.
- 5) *Clotting*: Several plasma proteins are involved in the cascade of chemical reactions, associated with the coagulation of blood.
- 6) *Transport*: Hormones and several other small molecules travelling in the plasma would themselves get filtered in the renal glomeruli and get excreted in the urine. This wastage is prevented during the journey of these substances from their origin to their destination by their getting bound to the plasma proteins.

Next, let us study about the cells found in the blood.

### **2.7.2 Blood Cells**

The cells found in blood are called *corpuscles*. These are also of three types as illustrated in Figure 2.24 and highlighted herewith:

- 1) Red Blood Cells (RBC) or Erythrocytes
- 2) White Blood Cells (WBC) or Leukocytes
- 3) Platelets or Thrombocytes

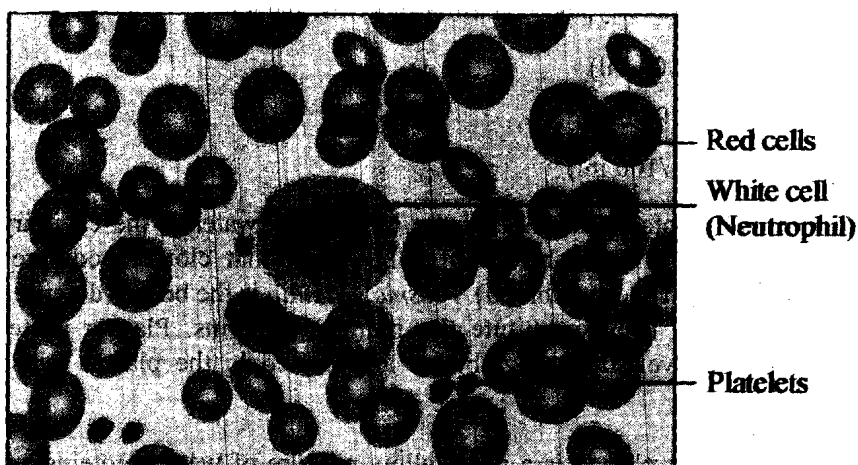


Figure 2.24: The blood cells

Let us get to know about them in more details.

#### A) Red Blood Cells (RBCs)

RBCs are also called 'erythrocytes' (*erythros*, red; *kytos*, cell). They are biconcave in shape as can be seen in Figure 2.24, which has at least three major advantages, as highlighted herewith:

- RBCs can swell quite bit before bursting in a hypotonic solution (a solution which contains less dissolved salts than cellular content).
- The biconcave shape (is best suited for) can squeeze through narrow spaces, by even bending along the middle, if necessary.
- The biconcave shape implies a large surface to volume ratio, which increases the efficiency of oxygen transfer across the RBC membrane.

Let us now further study about the dimensions of RBCs and the number of RBCs present in our body.

The mean diameter of RBC is 7.5 microns, maximum thickness at the edges is about 2.5 microns and minimum thickness in the center is about 0.8 microns.

The number of red cells in the blood is about 5 million per cubic mm of blood in normal healthy adults. It is about 0.5 million per cubic mm higher in men than women and higher in those living at high altitude than those living at sea level. RBCs occupy about 45% of the blood volume. This figure is referred to as '*packed cell volume*' (PCV) or *haematocrit*. The concentration of haemoglobin in blood is about 15 g/100 ml of blood. *The average volume of an RBC is called 'Mean Corpuscular Volume' (MCV). Mean Corpuscular Haemoglobin Concentration (MCHC)* is the amount of haemoglobin per unit volume of red cell mass, expressed as a percentage.

Now, after having a basic understanding about how RBCs look like, let us move on to study its role in our body.

#### *Function of Erythrocytes*

The basic function of red cells is to transport oxygen, which is made possible by the high affinity, which the haemoglobin (Hb) has for oxygen. RBCs contain haemoglobin, a protein that binds oxygen. You would be surprised to learn that one gram of Hb carries 1.34 cc of O<sub>2</sub>. Further, have you ever wondered how much haemoglobin a RBC can carry/store? Well, the red blood cells (RBCs) have the ability to concentrate Hb in the cell fluid to upto about 34 g/dl of cells. This being the metabolic limit, the concentration never rises above. When the haematocrit (% age of blood cells) is 40-45%, the quantity of Hb is normal. Whole blood contains an average of 16 g/dl of Hb in men and 14 g/dl of

Hb in women, each gram of pure Hb is capable of combining with 1.34 millimeters of O<sub>2</sub>.

Besides oxygen transport, haemoglobin also plays a role in carbon-dioxide transport and maintenance of pH of blood.

Next let us find out what is the life span of this cell.

### *Erythrocytes – the dynamic blood cells*

Blood cells, including erythrocytes, are a dynamic population. Old cells are destroyed and replaced by the new ones. The turnover is quite rapid, hence precursors of blood cells are among the most actively dividing cells of the body. What is the life span of erythrocytes? The life span of red cells in healthy individuals is about 120 days.

Let us now move on to the next cell that is WBC.

### B) *White Blood cells (WBCs)*

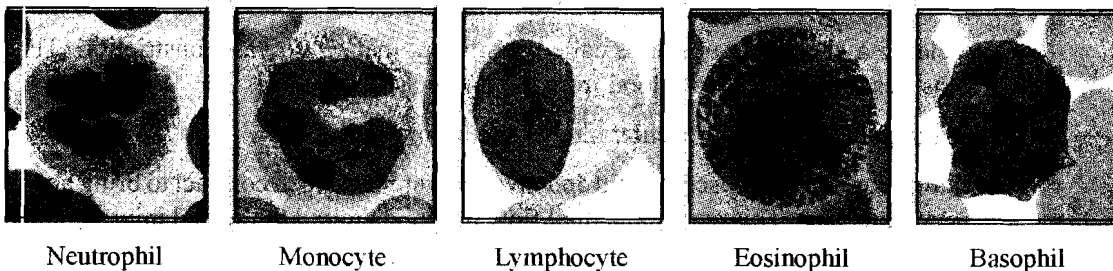
WBCs are also called leukocytes, as they are colourless. They are the army of the human body. Whenever a germ or infection enters our body, the WBCs snap to attention and destroy the culprit. Their primary function is to produce antibodies (humoral immunity) or kill the invading bacteria directly (cytotoxic immunity). We will learn more about this later in the next unit on the Immune System.

WBCs are divided into two types on basis of presence and absence of granules in the cytoplasm – *granulocytes* and *agranulocytes*. Under the light microscope as shown in Figure 2.25, they are classified into *basophils*, *eosinophils*, *neutrophil* (remember BEN is granulocytes) and *monocytes* and *lymphocytes* (are agranulocytes) on the basis of:

- 1) Size
- 2) Granules
- 3) Nucleus, and
- 4) Nucleus/ Cytoplasmic ratio

Each type of leukocyte is present in the blood in different proportions:

Neutrophil	:	50 – 70 %
Eosinophil	:	2 – 4 %
Basophil	:	0.5 – 1 %
Lymphocyte	:	20 – 40 %
Monocyte	:	3 – 8 %



**Figure 2.25: Different types of WBCs**

The *monocyte* is the largest WBC measuring 2 to 3 times of the RBC. Monocytes leave the cells and become macrophages. Macrophages are large, phagocytic cells that engulf foreign material (antigens) that enter the body and dead and dying cells of the body. The nucleus of a monocyte is kidney-shaped (as can be seen in Figure 2.25),

surrounded by an equal amount of cytoplasm and that of the lymphocyte occupies a major part of the cell.

*Lymphocytes* are extraordinarily diverse in their functions. The most abundant lymphocytes are:

- B lymphocytes (often simply called *B cells*) and
- T lymphocytes (likewise called *T cells*).

*Basophils* have purple coarse granules. Basophils make up only a small portion of the number of white blood cells but are an important part of the body's immune response. They release histamine and other chemicals that act on the blood vessels when the immune response is triggered.

*Neutrophils* are the most abundant of WBCs. The neutrophil has pink fine powdery granules. The nucleus of a neutrophil is multi-lobed (>2) as you can see in Figure 2.25. This is its distinguishing feature. Neutrophils squeeze through the capillary walls and into infected tissue where they kill the invaders (e.g., bacteria) and then engulf the remnants by phagocytosis.

The *eosinophil* is brick red coarse granules. Have a look at Figure 2.25. You would notice that it has a bi-lobed spectacle shaped nucleus. The number of eosinophils in the blood is normally quite low (2–4%). However, their numbers increase sharply in certain diseases, especially infestation by parasitic worms and allergies.

You might be wondering why does the body need so many types of WBC's? Basically, the neutrophils are the first line of defense that fights against the bacteria. The eosinophils have larger granules and fight larger parasites and are also active during skin infections and allergic condition such as asthma. The agranulocytes, such as monocytes and lymphocytes are active against bacteria present in the body for a long time such as tuberculosis and leprosy.

Next, we shall look at the platelets.

### C) *Platelets*

Blood platelets, the third blood cells are the smallest (look at Figure 2.24) formed by the pinching of a very large bone marrow cell called *megakaryocyte*. Platelets literally mean a small plate. The platelets form a plug to stop bleeding when an injury disrupts the lining of the blood vessel. Their diameter is about 2-3  $\mu\text{m}$ , hence they are much smaller than erythrocytes. Their density in the blood is 2,00,000-3,00,000 / $\text{mm}^3$ .

*What are the functions of platelets?*

The main function of platelets, or thrombocytes, is to stop the loss of blood from wounds, i.e. haemostasis. Let us learn about this function. The platelets:

- i) release a chemical substance called serotonin, that cause vasoconstriction. This ensures reduced flow of blood from the injured site,
- ii) aggregate to plug the vascular plug at site of injury, and
- iii) have like skeletal muscles, actin and myosin proteins, which contract to bring about clot retraction. This ensures normal flow of blood around the sealed injured blood vessel.

The plug formed by the platelet arrests bleeding. The time taken for the blood to cease flowing from an injured site is termed as *bleeding time*. The platelet plug that is formed is friable and cannot be relied to check bleeding for very long. The blood forms a fibrin meshwork of threads that forms a better plug. This may take a few minutes before such a first aid mechanism acts in the body. The time taken for a clot to form is termed as *clotting time*. Before a patient is taken to the operation theatre, the doctor assesses the

bleeding and clotting time to prevent excessive loss of blood during time of operation. The patient whose bleeding time is less than 4 minutes and clotting time is less than 12 minutes may be taken up for surgery after the other investigations are normal.

So far, we have learnt about the constituents and functions of blood – the fluid connective tissue. Do you know how the blood formation takes place? In which part of the body the blood is formed? We will find the answers to all these queries in the next section, which deals with erythropoiesis.

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## 2.8 ERYTHROPOIESIS

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*Erythropoiesis*, derived from the word 'erythros' meaning *red* and 'poiesis' meaning *making*, is a part of a broader process, hemopoiesis, i.e., formation of blood cells in general. Let us get to know about it.

The precursor of all blood cells is a primitive stem cell, also called as a *Totipotent Hematopoietic Stem Cell* (THSC). THSC is a cell capable of rapid proliferation accompanied by differentiation. Differentiation of the THSC is associated with subtle biochemical changes, which eventually result in a cell committed to forming a specific variety of blood cell. The process of proliferation and differentiation continues till the mature blood cells, incapable of proliferation, are formed.

The general process of proliferation and progressive differentiation leads to an important question. If the process of differentiation affects every daughter cell, why do we not finally reach a stage wherein all the cells are highly differentiated but are incapable of dividing? The answer to this question is that immature cell has a nucleus and as it matures, the nucleus disappears, and hence the cell is incapable of dividing but capable of differentiating.

You would realize that the site of erythropoiesis varies somewhat with age. Let us go through the different stages and find out what these age-related differences are.

- During intrauterine life, in the early embryo, erythropoiesis occurs in the mesoderm (the middle of the three germ layers of an embryo) of yolk sac. In a few weeks, the process shifts to the mesoderm of the body. During these stages, erythropoiesis is intravascular. It takes place by some endothelial cells undergoing transformation into blood cells and detaching themselves from the vessel wall to enter the circulation.
- After the third intrauterine month, erythropoiesis takes place in the liver and spleen, in the mesenchymal tissue (embryonic connective tissue) between the blood vessels and tissue cells.
- After the fourth intrauterine month, the fetal bone marrow also starts manufacturing blood cells.
- By the time of birth, bone marrow takes over erythropoiesis completely.

Thus, all *extrauterine* (occurring outside the uterus) erythropoiesis is medullary, i.e., in the bone marrow. Red cells, white cells and platelets are made in the marrow of bones.

But liver and spleen retain the potential for erythropoiesis throughout the life. Hence, in those situations where the demand for red cells exceeds the capacity of the bone marrow to manufacture them, extramedullary erythropoiesis is often seen. In a new born, all bones have a red bone marrow, i.e. the marrow which manufactures blood cells. But as the child grows, the bones also grow and so does the marrow. But the need for manufacturing blood cells does not grow proportionately. Hence, progressively larger parts of the bone marrow changes to yellow bone marrow, i.e., marrow which does not manufacture blood cells. The red marrow in the shafts of long bones is the first to be replaced by yellow marrow, followed by that at the ends of long bones.

Finally, in the adult, the red marrow exists only in the sternum, ribs, vertebrae, pelvis and skull. Therefore, if a sample of bone marrow is required for diagnostic purposes, it is usually obtained from either the sternum or the iliac crest (the hip bone in which a large quantity of bone marrow is concentrated). However, when the need for manufacturing blood cells is heavy, first the area occupied by the red marrow expands and then extramedullary haemopoiesis may also begin.

Let us now study about the regulation of the process of erythropoiesis in the following section.

### 2.8.1 Regulation of Erythropoiesis

Since the red cell mass of an individual is essentially stable in spite of constant formation and destruction of erythrocytes, the process must be finely regulated. The factors regulating erythropoiesis are as follows:

- 1) *Erythropoietin*: Erythropoietin is a glycoprotein, which is released predominantly from the kidneys in response to the tissue hypoxia. When the haemoglobin concentration of blood falls, oxygen tension in the tissues also falls at least slightly, the kidneys also share this fall in tissue oxygen tension and respond to it by secreting the hormone, erythropoietin into the blood stream. Hence low tension of O<sub>2</sub> in blood in the renal artery leads to the release of erythropoietin. Erythropoietin is also released by the isolated kidney if it is perfused with a hypoxic fluid. However, erythropoiesis continues fairly normally even after removal of both the kidneys.
- 2) *Androgens*: Since men have a higher red cell count than women, and the difference between sexes appears at puberty, androgens are likely to at least stimulate, if not regulate erythropoiesis.
- 3) *Oestrogen*: Oestrogen has an inhibitory effect on erythropoiesis.
- 4) *Thyroxine, Cortisol and Growth Hormone*: The deficiency of these hormones is generally associated with anaemia. These hormones stimulate erythropoiesis possibly by increasing the oxygen consumption of tissues and thereby promoting tissue hypoxia. Tissue hypoxia, in turn, stimulates erythropoietin production.
- 5) *Neural control*: Some controversial experimental evidence indicates that some hypothalamic cells may sense hypoxia and respond to it by stimulating erythropoiesis through a neurohumoral mechanism.
- 6) *Products of hemolysis*: It is controversial whether products released by red cells stimulate or inhibit erythropoiesis or do not affect the process at all. It is believed that some products of red cells may be exerting a feedback effect on erythropoiesis.
- 7) *Dietary factors*: Some dietary factors are essential for erythropoiesis. For example, amino acids are required for the synthesis of globin, iron for synthesis of heme, and Vitamin B<sub>12</sub> and folic acid for maturation of red cell precursors. Therefore, a deficiency of any of these factors reduces erythropoietic activity. And if the erythropoietic activity is low due to a dietary deficiency, the activity can be stimulated (or rather restored back to normal) by providing the deficient nutrient. This effect of nutrients cannot however, be termed as a regulatory effect.

#### Check Your Progress Exercise 4

- 1) What is the composition of blood?

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2) What is plasma? Enumerate a few important function of plasma proteins.

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3) List the functions of the three blood cells in the body.

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4) What is erythropoiesis? List the factors regulating the process of erythropoiesis.

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 .....  
 .....

5) Match the following:

**A**

**B**

- |                           |   |
|---------------------------|---|
| i) Antony Van Leeuwenhoek | a) Relationship between diet and haemoglobin. |
| ii) William Hewson        | b) Described RBCs                             |
| iii) George Whipple       | c) Described Leukocytes                       |
| iv) Wiliam Castle         | d) Liver treatment                            |
| v) George Minot           | e) Intrinsic and extrinsic factors            |

The discussion above focused on erythropoiesis and the process of blood formation and regulation. With this discussion our understanding of blood is somewhat complete or is it. There is one more important aspect related to blood which can be of interest to us. What is it? You must have seen or heard about blood groups, such as B+ve, O+ve, AB+ve and so on. What do we mean by these blood groups? Do all of us have similar blood groups? And if no, what parameters make it distinct from a person to person? We shall find the answers to all our queries in the next section. We begin our discussion with an understanding about blood groups.

## 2.9 BLOOD GROUPS

We start our discussion by answering the question – do all of us have the same blood group? No, each individual has a different blood group. The differences in human blood are due to the presence or absence of certain protein molecules called *antigens* and *antibodies*. The antigens are located on the surface of the red blood cells and the antibodies are in the blood plasma. Individuals have different types and combinations of these molecules. The blood group you belong to depends on what you have inherited from your parents.

Blood group, therefore, is based on the type of antigens present on the surface of RBCs. There are more than 30 antigens, but for the purpose of blood transfusion, very few of them are practically significant. For all practical purposes, the starting point in determining the suitability of a donor is to type the donors, as well as, recipients blood in

terms of ABO and Rh grouping. Sometimes there can be a mismatch reaction. Hence, besides an ABO and Rh grouping, cross matching of the donors' and recipients' blood is important. What is the ABO and Rh grouping? Let's get to know about these grouping systems.

### 2.9.1 ABO Blood Grouping System

As the name suggest, this is based on the presence or absence of 9 antigens A and B, on the surface of RBC. If either of these antigens is present on the surface of RBC, it can react with the corresponding antibody. Reaction between a blood group antigen and its corresponding antibody leads to clumping (agglutination) of RBCs. Hence, blood group antigens are known as 'agglutinogens' and the corresponding antibodies are known as 'agglutinins'.

*Landsteiner* found that if RBC of an individual carries a particular group antigen, RBC can circulate safely only if corresponding antibody is not present in the plasma of same individual. Hence a law was formulated by him, which states that 'if an antigen is present on the surface of RBC, the corresponding antibody would be absent in plasma'. Conversely, if an antigen is absent, the corresponding antibody is present. This law is good for ABO and not for Rh system.

According to the ABO blood typing system, therefore, there are four different kinds of blood types: A, B, AB or O (null). What do they signify? Let's find out.

If you belong to the blood group A, it means you have A antigens on the surface of your red blood cells and B antibodies in your blood plasma, as shown in Figure 2.26. If you belong to the blood group B, you have B antigens on the surface of your red blood cells and A antibodies in your blood plasma. If you belong to the blood group AB, you have both A and B antigens on the surface of your red blood cells and no A or B antibodies at all in your blood plasma. If you belong to the blood group O (null), you have neither A or B antigens on the surface of your red blood cells, but you have both A and B antibodies in your blood plasma as you can see in the Figure 2.26.

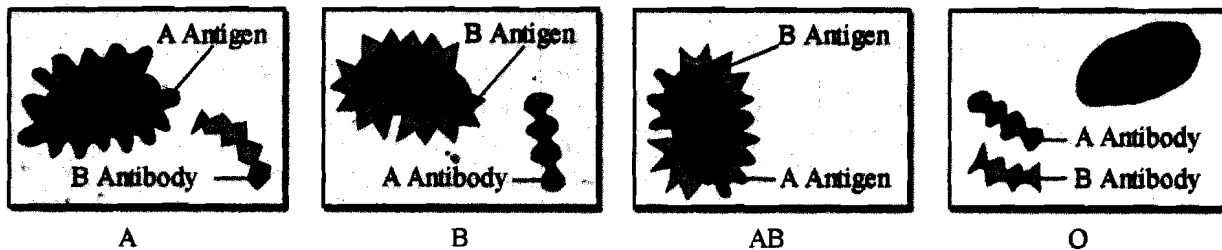


Figure 2.26: The ABO blood grouping system

The next question which might interest you is how do you find out which blood group one belongs to? The process is simple. First, the blood with three different reagents including either of the three different antibodies, A, B or Rh antibodies is mixed. Then one looks that in which mixtures agglutination has occurred? The agglutination indicates that the blood has reacted with a certain antibody and therefore is not compatible with blood containing that kind of antibody. If the blood does not agglutinate, it indicates that the blood does not have the antigens binding the special antibody in the reagent. If you know which antigens are in the person's blood, it's easy to figure out which blood group he or she belongs to.

Further, you may have come across the terms 'Universal Donor' and 'Recipients' in the context of blood transfusion. What do these terms mean? Let's find out.

Based on the above mentioned concept, O group individuals are sometimes considered as 'universal donors', since they have no antigens and the blood does not generate any antibody reaction. Group AB is called 'universal recipients' as their plasma has no antibody. They can receive blood from anybody as highlighted in Table 2.2 herewith. The donor cells irrespective of whatever antigen they contain will not cause a reaction.

**Table 2.2: The blood groups and the universal recipient and donor concept**

Blood Group	Antigens	Antibodies	Can give blood to	Can receive blood from
AB	A and B	None	AB	AB, A, B, O
A	A	B	A and AB	A, O
B	B	A	B and AB	B, O
O	None	A and B	AB, A, B, O	O

Other than the A and B antigen, some other factor is also present on the surface of the RBCs. What is this factor and the corresponding blood grouping system? Let's find out.

### 2.9.2 Rh Blood Grouping System

Some individuals also have a so called Rh antigen on the surface of their RBCs. Those who have it are called Rh (+) and those who do not have it are Rh (-). This is the basis of the Rh blood group system. In Caucasian (white) races, about 85% of human are Rh +ve, but among African blacks almost everyone is Rh -ve.

Rh stands for Rhesus monkey. RBC of Rhesus monkey when injected into rabbit develops antibodies to rhesus RBC. Later, it was discovered that rabbit serum containing anti-rhesus antibodies could agglutinate not only rhesus RBC, but also human RBC in about 85% cases, which was suggestive that these 85 % of human beings have on their RBC an antigen identical to or remarkably similar to Rhesus RBC. This antigen was named as 'Rh antigen'. Human beings having this antigen were labeled 'Rh positive'. Thus, in a Rh system, blood may be either positive or negative.

A person with Rh -ve blood does not have Rh antibodies naturally in the blood plasma (as one can have A or B antibodies, for instance). But a person with Rh -ve blood can develop Rh antibodies in the blood plasma if he or she receives blood from a person with Rh+ve blood, whose Rh antigens can trigger the production of Rh antibodies. A person with Rh+ve blood can receive blood from a person with Rh -ve blood without any problems. So it must be clear by now that Rh positive or negative individuals do not have anti Rh antibodies. But, if an Rh -ve individual is given Rh +ve blood, he develops anti Rh-ve antibodies.

Rh incompatibility can therefore occur sometime. What are the consequences? Read and find out.

#### Rh Incompatibility

Rh compatibility sometimes leads to complications which are generally not seen with other types of mismatched transfusions. If a Rh negative is given Rh positive blood, there is no immediate adverse reaction because Rh negative individuals do not normally have anti-Rh antibodies which may damage the donor red cells. The donor red cells induce immune response in the recipient, as a result of which anti-Rh antibodies are synthesized. It takes 2-4 months before a high tirtre of anti-Rh antibodies are achieved.

By this time, most of the donor cells die a natural death. The anti-Rh antibodies can do no harm. Hence, first phase of transfusion passes silently. If the second dose is given,

the memory cells ensure anti-Rh antibodies are synthesized in proper amounts. Second transfusion acts as a booster dose. High dose of anti-Rh antibodies can be achieved. Donor cells are thus damaged. Since anyone may need a second blood transfusion later in life, Rh negative individuals should never be given Rh positive blood.

One of the critical manifestations of Rh-incompatibility is '*Erythroblastosis Foetalis*'. What is it? Let us study and find out.

### *Risking Girls: Erythroblastosis Foetalis*

Besides the risk of a mismatch reaction during a second or during any subsequent blood transfusion, giving Rh-positive blood involves risk in case of young Rh-negative girls. This is because of the possibility of complication during pregnancy if the girl happens to have a Rh-positive foetus in her uterus any time later in life. The chances of any abnormalities resulting from Rh incompatibility are negligible during first pregnancy, 3% during second and 10% during third. This is due to following reasons:

- 1) Red cells of the foetus are unable to cross normal placenta. There has to be some abnormality in the placenta before foetal red cells can enter the maternal circulation.
- 2) Foetal red cells may be destroyed by maternal plasma before they can induce an antibody response. E.g., if mother is O, Rh negative and the foetus is A, Rh positive, the foetal red cells would be haemolysed by the anti-A antibodies present in the maternal plasma.
- 3) If the foetus and mother happen to be of same group, i.e., A,B or AB but mother is Rh -ve and foetus Rh +ve, during 2<sup>nd</sup> and subsequent pregnancies, mother gets sensitized with Rh antigens of fetal blood, resulting in production of anti-Rh antibodies, which will destroy foetal RBC, causing 'erythroblastosis foetalis'.

Although erythroblastosis foetalis may be treated by exchange transfusion, the prevention is routinely attempted by desensitizing the mother for production of Rh antibodies during pregnancy. The desensitized mothers don't respond to foetal Rh+ve RBCs. Thus erythroblastosis foetalis is prevented.

Apart from the Rh incompatibility as a complication leading to loss of blood, there is another condition wherein the RBCs are deficient. This is referred to as *anaemia*, a disorder related to deficiency of erythrocytes. As a student of dietetics, you must be familiar with anaemia and its consequences. Let us recharge our understanding on this topic.

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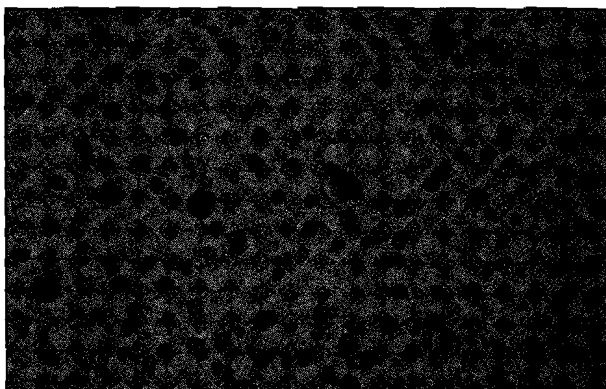
## 2.10 ANAEMIA

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Anaemia, as we already know, means '*deficiency of red blood cells, due to the rapid loss or slow production of RBCs*'. Some types of anaemia and their physiological causes are summarized below:

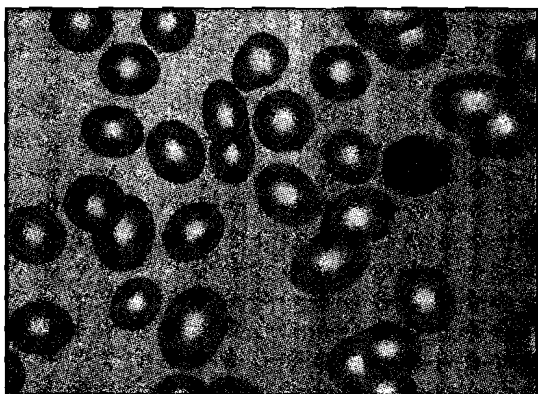
- 1) *Haemorrhagic or blood loss anaemia*: The body replaces plasma within 1-3 days after a haemorrhage, but this leaves a low concentration of red blood cells. In chronic blood loss, a person frequently cannot absorb enough iron from the intestines to form Hb as rapidly as it is lost. Red cells are then produced with too little haemoglobin inside them giving rise to microcytic hypochromic anaemia. What is microcytic hypochromic anaemia? Read on and you will find out in a little while from now.
- 2) *Aplastic anaemia*: Bone marrow aplasia means 'lack of functioning of bone marrow'. This can occur due to excessive X-ray or radiation treatment, certain industrial chemicals, sensitive drugs, nuclear exposure etc.

- 3) *Iron deficiency anaemia*: This is due to inadequate dietary intake of iron, poor intestinal absorption of iron, abnormal loss of iron from the body. For example, menstruation or haemorrhage or heavy iron requirements such as pregnancy or lactation. The RBCs in this condition are smaller than normal and have an increased zone of central pallor. This is indicative of a hypochromic (less haemoglobin in each RBC) microcytic (smaller size of each RBC) anaemia. There is also increased anisocytosis (variation in size) and poikilocytosis (variation in shape), as can be seen in Figure 2.27.



**Figure 2.27:** Smaller than normal red blood cells with central pallor seen in iron deficiency anaemia

- 4) *Megaloblastic anaemia*: The less availability of vitamin B<sub>12</sub>, folic acid, intrinsic factor of stomach mucosa etc. slows down the production of erythroblasts that occur in the bone marrow. Hence these cells grow too large with odd-shaped cells called as 'megaloblasts' as shown in Figure 2.28. The erythroblasts cannot proliferate rapidly to form enough RBCs. The cells which are formed are mostly oversized, bizarre shaped and have fragile membranes. They rupture easily, leaving the person for a need of an adequate number of cells.



**Figure 2.28:** Large, dense, oversized, red blood cells (RBCs) seen in megaloblastic anaemia

- 5) *Hemolytic anaemia*: It can occur due to various reasons and situations. The general tendency is that the fragile cells rupture when they pass through the spleen.

In hereditary *spherocytosis*, red cells are spherical and small, they cannot be compressed on passing through spleen and are easily ruptured.

In *sickle cell anaemia*, the cells contain an abnormal type of Hb which is HbS because of abnormal B-chains. This when exposed to low O<sub>2</sub>, precipitated Hb damages the cell membrane and cell becomes highly fragile, the patient suffers due to less O<sub>2</sub> availability. The abnormal haemoglobin causes red blood cells to assume a sickle shape, like the ones seen in Figure 2.29.



**Figure 2.29: Blood smear of a sickel cell anaemic patient**

In *erythroblastosis foetalis*, Rh-positive red blood cells, as you may recall reading earlier, are attacked by antibodies from a Rh-negative mother. These antibodies make the cells fragile, leading to rapid rupture causing the child to be born with serious anaemia.

The classification of anaemia presented above is based on etiology i.e. based on causes of anaemia. Anaemia, you would realize, can be further classified based on morphological classification i.e. based on the size of the RBC (Mean Corpuscular Volume or MCV) and the amount of haemoglobin in the RBC (MCH). Table 2.3 presents the morphological classification, also called the *Wintrob's Classification*.

**Table 2.3: Morphological classification of anaemia**

	<b>Normochromic</b>	<b>Hypochromic</b>
<b>Normocytic</b>	Acute Haemorrhage	Chronic Haemorrhage
<b>Macrocytic</b>	All megaloblastic anaemias e.g Vitamin B <sub>12</sub> , Folic acid deficiency	Liver Disease
<b>Microcytic</b>	Chronic infections	Iron deficiency Thalassemia

What do these terms microcytic, macrocytic etc. mean? These terminologies are explained herewith:

- hypochromic - less than normal color (decreased Hb content)
- hyperchromic - more than normal color (increased Hb content)
- macrocytic - larger than normal size
- microcytic - smaller than normal size
- normochromic - normal color (normal Hb content)

The disease conditions which present the following blood picture are summarized next:

- *macrocytic normochromic* : pernicious anaemia, folic acid deficiency and chronic liver disease
- *normochromic normocytic* : acute blood loss and hemolytic anaemias
- *microcytic normochromic* : neoplastic
- *microcytic hypochromic* : Iron deficiency anaemia (look at the picture in Figure 2.27 above which is classical microcytic hypochromic picture), thalassemia, sideroblastic anaemias

We shall not go into any further details on this topic now, as it is not within the purview of this course. We hope that the information presented above, is sufficient for you to understand the anaemia types and their causes.

With this, we come to an end on our discussion on anaemia.

**Check Your Progress Exercise 5**

1) What are the different blood group systems?

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2) What do you understand by the term 'Rh incompatibility'? List the major consequences.

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3) What is Erythroblastosis foetalis? Why does the risk of Rh incompatibility increases with more number of pregnancies?

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 .....  
 .....

4) Explain different types of anaemia.

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 .....

The last part of the unit shall focus on haemostasis. What is haemostasis? Have you ever wondered why or how the bleeding stops automatically after an injury? Read and find out.

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## 2.11 HAEMOSTASIS

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Haemostasis (*Haem*: blood; *Stasis*: standing) ensures blood to coagulate into a solid gel during injury and also ensures free flow of blood in vessels under normal conditions. Haemostasis is a balance of the physiological processes, which on one hand prevent excessive bleeding after vessel injury, and on the other hand, maintain a viable circulation by keeping the blood in an uncoagulated state. Platelets are involved in almost all stages of haemostasis. What is the process of haemostasis? Primarily, haemostasis can be divided into the following four components:

- *Vessel constriction*: Vessel constriction occurs after vessel injury. This is the beginning of primary haemostasis which leads to protective vasoconstriction at the site of injury in order to arrest the bleeding. Time taken for this to occur is known as bleeding time.
- *Platelet function*: This process involves the formation of platelet plug at site of injury.
- *Coagulation* : This process include processes leading to the formation of a fibrin net which stabilizes the platelet plug in order to permanently stop bleeding.
- *Fibrinolysis*: This process involves the dissolution of blood clots. The fibrinolytic system is antagonist to the coagulation system, dissolving fibrin clots by the specific and powerful protease plasmin.

The process above must have given you a fairly good idea about the mechanism involved in the cessation of bleeding. This is a natural process which goes on in our body. But sometimes there can be a problem. There are a few disorders of haemostasis. Disorders of haemostasis can be roughly divided into platelet disorders (such as idiopathic thrombocytopenic purpura) and disorders of coagulation such as haemophilia. A brief knowledge of these disorder follows:

### *Haemophilia*

Haemophilia is a disease characterized by excessive bleeding due to deficiency of clotting factor VIII. The patient need repeated blood transfusion or may need a factor VIII concentrate.

### *Idiopathic Thrombocytopenic Purpura (ITP)*

“Thrombocytopenic” means the blood doesn’t have enough platelets. “Purpura” means a person has excessive bruising. You may also hear ITP called “immune thrombocytopenic purpura”.

We have seen that patients with haemophilia require repeated blood transfusion. What is blood transfusion? We shall look into this aspect before ending our study of blood the elixir of life.

### *Transfusion of blood*

Blood has been considered as the elixir of life. However, in ancient times, patients were bled to get rid of their foul fluid. Later, as blood was transfused after the discovery of circulation, patients died after receiving transfusion. The blood being transfused from one patient was not compatible with the recipient’s. Why is this so? Certainly you would know why, especially now that you have studied about blood groups. Considerable advances in transfusion medicine took place during the two World Wars. During the first world war, the collection and storage of blood was perfected. During the second world war, individual components of blood were separated. In early 1980’s, doctors started training in the specialty of blood transfusion and actively participating in patient care.

Blood transfusion, therefore, refers to the infusion of blood or blood components into an individual for the treatment of a medical condition (e.g., anaemia, loss of blood due to injury etc.). Transfused blood may be homologous (from a donor) or autologous (previously stored blood from the recipient).

It is important to note that blood transfusion is only to be given when there is no alternative. Though blood transfusion is safe, the main risk of transfusion is being given blood of the wrong group or a smaller risk of catching an infection. To ensure you receive the right blood, the clinical staff makes careful identification checks before any transfusion.

Finally, in what form is the blood given?

Blood is usually split up into four separate components:

- *Whole blood:* This is rarely used these days, only really in instances of severe blood loss. Instead it’s almost always separated into its individual components.
- *Red cells:* These are used in the treatment of all kinds of anaemia which can’t be medically corrected, such as when rheumatoid arthritis or cancer is involved, when red cells break down in the newborn, and for sickle cell disease. They’re also essential to replace lost red cells after such things as accidents, surgery and after childbirth, not to mention pre-op ‘top-ups’ for existing anaemic patients and for burn victims.

- *Platelets*: Bone marrow failure and post transplant and chemotherapy treatments and leukaemia. These are all instances when platelets can be of huge benefit to the recipient.
- *Plasma*: Fresh frozen plasma is used after obstetric loss of blood (which is usually childbirth), during cardiac surgery and to reverse any anti-coagulant treatment.

With this, we end our discussion on blood.

**Check Your Progress Exercise 6**

1) What is haemostasis? List its four components.

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2) Enumerate the disorders of haemostasis. How are these classified? Give an example of each.

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3) What do you understand by the term 'blood transfusion'? What is the main risk involved in it?

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4) What are the four components of blood? Which one of these is used to treat anaemia?

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**2.12 LET US SUM UP**

In this unit we have studied about the cell structure, the basic unit of life and the elixir of life, the blood. The mysteries of our cell, its working, the cell as a factory and its organization functions and division are the major aspects that have been covered in the unit.

We also learnt about the structure and functions of blood and its components. The process of haemostasis was also discussed in this unit.

## 2.13 GLOSSARY

<b>Agglutinogens</b>	:	blood groups antigens.
<b>Aplastic Anaemia</b>	:	lack of functioning of bone marrow.
<b>Centriole</b>	:	twin bodies that are found near the nucleus. They are responsible for forming the cilia, flagella and astral spindle during cell division.
<b>Cisternae</b>	:	one of the sac-like vesicles that comprise the endoplasmic reticulum.
<b>Cytoskeleton</b>	:	the ability of cells to change shape and carry well-directed movements depending on the skeleton of the cell.
<b>Fibrinolysis</b>	:	a normal ongoing process that dissolves fibrin and results in the removal of small blood clots.
<b>Glial Cells</b>	:	cells having short processes that protect neurons.
<b>Humors</b>	:	a body fluid.
<b>Hypotonic Solution</b>	:	a solution which contains less dissolved salt than cellular content.
<b>Mean Corpuscular Haemoglobin Concentration</b>	:	the amount of Hb per unit volume of red cell mass, expressed as a %.
<b>Mean Corpuscular Volume</b>	:	average volume of RBC.
<b>Microfilaments</b>	:	a network of filaments within the cytoplasm helps play a major role in cell motion and allowing the cell to adopt new shapes.
<b>Microtubules</b>	:	a network of hollow tubes that are made up of tubulin molecules.
<b>Microvilli</b>	:	some cells have acquired additional structures in the form of projections to maintain the surface area-to-volume ratio in a balanced state. These increase the absorptive surface area.
<b>Myofibrils</b>	:	the muscle fibers that are striated or banded unbranched cylindrical.
<b>Plasticity</b>	:	property of smooth muscle to maintain shape and size irrespective of force applied.
<b>Plastids</b>	:	organelles of the plant cells that contain chlorophyll.
<b>Tendon</b>	:	tendon joins muscle to bone. They are made of collagen fibers.
<b>Totipotent Hematopoietic Stem Cell</b>	:	a primitive stem cell; the precursor of all blood cells.
<b>Vasoconstriction</b>	:	the constriction or narrowing of blood vessels, so that the less blood is able to flow through at a time.

## 2.14 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

### Check Your Progress Exercise 1

- 1) a) A cell is the smallest self functioning unit found in all living organisms. Each cell is enclosed by an outer membrane or wall called as cell membrane. It contains receptors on its surface, genetic material (DNA) nucleus and the cytoplasm.
  - b) The cells have the same genetic material and each cell arises from preexisting cells. It is, therefore, capable of giving rise to a new individual. This potential of the cell to give rise to unlike cells and so to develop a new organism or a part is termed as totipotency.
  - c) Cell theory constitutes of two statements:
    - All cells arise from preexisting cells.
    - All organisms are composed of cells.
- 2) The benefits and constraints of multicellular organism over cellular organisms are:
    - Unique coordination and specialization among the cells.
    - Multiply and replace the lost cell without loosing its own identity.
    - Differentiation ability has benefits such as increased survival, specialization and a proper balance between the cell surface and cell volume.
  - 3) Undifferentiated, differentiated and dedifferentiated cells are the major categories of cells on the basis of the levels of differentiation.

### Check Your Progress Exercise 2

- 1) a) The cell membrane is a dynamic structure undergoing a variety of changes. A fluid mosaic model was proposed by Singer and Nicholson (1972), according to which the cell membrane is composed of a lipid bilayer studded with the structural proteins. It is a two-dimensional fluid in which hydrophobic integral components are constrained within the plane of the membrane, but are free to diffuse laterally.
  - b) Cytoskeleton is a network of fibers running throughout the matrix of living cells that provides a frame work for organelles, anchors the cell membrane, facilitates cellular movement and provides a suitable surface for chemical reactions. These are of 3 types: microfilaments, microtubules, and intermediate filaments.
  - c) The cell membrane invaginates or encloses the fluid droplet or solid particle. The membrane then completely engulfs the particle and a part of its membrane pinches off to encircle the particle within the cell. This is referred to as endocytosis.
  - d) The inner membrane of mitochondria having many infoldings is called as cristae.
  - e) Chromophobes are the independent units present in plastids of yellow fruits and vegetables. They produce proteins and trap energy for food production.
- 2) Eukaryotic cells are the large multicellular cells that have a nucleus bounded by a double-layered membrane. They show a high degree of differentiation e.g. all plant and animal cells while prokaryotic cells are very small cells that multiply very rapidly. These are unicellular, believed to be evolutionary primitive e.g. bacteria and blue green algae.

- 3) The basic parts of a cell are cell wall, plasma membrane, cytoskeleton (microfilaments, microtubules, intermediate filaments), endoplasmic reticulum, golgi apparatus, lysosome, cytoplasmic vacuoles, ribosomes, mitochondria, plastids, nucleus, centrioles, cilia and flagella.
- 4) a) RER synthesizes serum proteins, globulin, albumin, fibrinogen and membrane proteins of the lysosome and cell membrane
  - SER synthesizes lipid.
  - ER detoxifies impure food and drugs that we eat
  - The movement of muscles we flex is brought about by the calcium ions released.
- b) It is concerned with energy in form of ATP storage and release.
- c) These are rich in digestive enzymes and breakdown bacteria and debris from the dead cells. These engulf worn out components of the cell in which they are located forming autophagic vacuoles.
- d) It is the site at which ribosomal subunits are formed. These are then transferred to the cytoplasm where they combine to form ribosomes.
- e) It sorts the different types of proteins received from the granular endoplasmic reticulum into vesicle that will be delivered to the various parts of the cell.
- f) These are the sites for protein synthesis.

### Check Your Progress Exercise 3

- 1) The orderly sequence of events by which the cell duplicates its contents and divides into two is termed as a cell cycle. It consists of four phases which include
  - G<sub>1</sub>: growth and preparation of the chromosomes for replication.
  - S: synthesizes of DNA and centrosomes
  - G<sub>2</sub>: preparation for
  - M: mitosis, when nuclear and cytoplasmic division occurs
- 2) Mitosis: The process of nuclear division in cells that produces genetically identical daughter cells which are identical to the parent cells as well. Also called as equational division, it takes place in somatic cells or cells of the body. The cells divide only once and the chromosome number remains constant at the end of mitosis. Its significance is as follows:
  - a) equal distribution of chromosomes,
  - b) restores the surface to volume ratio of the cell, and
  - c) renews and replaces the cells of the body.

Meiosis: The division of germ cells to form gametes in sexually reproducing organisms. In this, the chromosomal number is reduced from double to half. The genetic constitution of the daughter cells differs from the parent cell due to crossing over. Each chromosome of the daughter cells usually contains a mixture of mother and father genes. It:

  - a) maintains a definite and constant number of chromosomes on organisms
  - b) provides an opportunity of exchange of genes and thus causes variation within the species.
- 3) A tissue is a mass of similar cells usually continuous, held together in a supporting matrix, performing a common function usually forming a part of an organ. Tissues are classified into:

- Epithelial tissues: skin and stomach
- Connective tissues: eyeballs and kidney
- Muscle tissues: cardiac muscle and urinary bladder
- Nervous tissues: neurons and glial cells in brain.

#### Check Your Progress Exercise 4

- 1) Blood is composed of 2 parts:
  - a) Plasma which is the intercellular fluid
  - b) Blood cells or corpuscles, such as RBCs, WBCs and platelets, which float in the plasma.

Plasma forms about 55% of the blood volume whereas the cells occupy the remaining 45%. The composition of blood is water 91.0%, Protein –08.0%, salts 0.9%. The balance (0.1%) is made up of traces of a number of organic materials: glucose, fats, urea, uric acid, creatinine, cholesterol, amino acids, gases, internal secretions, enzymes and antigens.

- 2) Plasma is a faint yellow coloured fluid in which the cellular elements of blood are suspended. It has a slightly alkaline pH. The functions of plasma proteins are osmotic pressure, viscosity, protein reserve, antibodies, clotting and transport.
- 3) The basic function of red cells is to transport oxygen, which is made possible by the high affinity, which the haemoglobin (Hb) has for oxygen. Haemoglobin also plays a role in carbon-dioxide transport and maintenance of pH of blood. Whenever a germ or infection enters our body, the WBCs destroy the culprit. Their primary function is to produce antibodies (humoral immunity) or kill the invading bacteria directly (cytotoxic immunity). The main function of platelets, or thrombocytes, is to stop the loss of blood from wounds, i.e. haemostasis.
- 4) Erythropoiesis is the process of formation of blood cells. The factors regulating erythropoiesis are Erythropoietin; androgens; estrogen; thyroxine, cortisol and growth hormone; neural control; products of hemolysis and dietary factors.
- 5)
  - i) – b)
  - ii) – c)
  - iii) – a)
  - iv) – e)
  - v) – d)

#### Check Your Progress Exercise 5

- 1) The blood grouping systems are based on the type of antigens present on the surface of RBCs. The blood group systems based on the presence/ absence of 2 antigens. A and B is the ABO system. Another system is Rh system, in which the RBCs have an antigen identical to Rhesus monkey's RBC.
- 2) Rh incompatibility is a complication which is unique to blood transfusions. If a Rh negative individual is given Rh positive blood, there is no immediate adverse reaction because Rh negative individuals do not have anti-Rh antibodies which may damage the donor red cells. Its major consequence is Erythroblastosis foetalis.
- 3) Besides the risk of a mismatch reaction during a second or during any subsequent blood transfusion, giving Rh positive blood involves risk in case of young Rh negative girls. This is because of the possibility of complication during pregnancy if the girl happens to have a Rh positive foetus in her uterus any time later in life. This is referred to as Erythroblastosis foetalis.

The risk of Rh incompatibility increases with more number of pregnancies as:

- Red cells of the foetus are unable to cross normal placenta. There has to be some abnormality in the placenta before foetal red cells can enter the maternal circulation.
- Foetal red cells may be destroyed by maternal plasma before they can induce an antibody response. E.g., if mother is O, Rh negative and the foetus is A, Rh positive, the foetal red cells would be haemolysed by the anti-A antibodies present in the maternal plasma.
- If the foetus and mother happen to be of same group, i.e., A,B or AB but mother is Rh -ve and foetus Rh +ve – during 2<sup>nd</sup> and subsequent pregnancies, mother gets sensitized with Rh antigens of foetal blood – resulting in production of Anti Rh antibodies, which will destroy foetal RBC – causing ‘erythroblastosis foetalis’.

4) The different types of anaemia are:

- Blood loss anaemia: a low concentration of RBCs. RBCs are produced with too little Hb giving rise to microcytic hypochromic Anaemia.
- Aplastic anaemia: lack of functioning of bone marrow caused due to various factors
- Megaloblastic anaemia: the slow production of erythroblasts in the bone marrow due to less availability of vitamin B<sub>12</sub>, folic acid intrinsic factor of stomach mucosa.
- Hemolytic anaemia: occurs due to rupture of fragile cells as they pass through the spleen.
- Sickle cell anaemia: presence of abnormal B-chains because of the presence of abnormal Hb type. This damages the cell membrane and makes it fragile
- Erythroblastosis foetalis: Rh positive RBCs are attacked by antibodies from Rh negative mother, making cells fragile and causing child to be born with serious anaemia.

### Check Your Progress Exercise 6

- 1) Haemostasis is a balance of the physiological processes which on one hand prevent excessive bleeding after vessel injury, and on the other hand maintain a viable circulation by keeping the blood in an uncoagulated state. Its four components are vessel constriction, platelet function, coagulation and fibrinolysis.
- 2) Disorders of haemostasis are classified into platelet disorders, for example, idiopathic thrombocytopenic purpura (ITP) and disorders of coagulation, such as haemophilia.
- 3) Blood transfusion refers to the infusion of blood or blood components into an individual for the treatment of a medical condition (e.g., anaemia, loss of blood due to injury etc.). The main risk of transfusion is being given blood of the wrong group or a smaller risk of catching an infection.
- 4) Whole blood, red cells, platelets and plasma are the four components of blood. Red cells are used to treat anaemia.