(a) Components of a DNA Molecule

Most of the time DNA molecules exist as loose coils within the nucleus of a cell, resembling spaghetti inside a balloon, and this form of DNA is visible only through a high-powered electron microscope. At other times the DNA molecules are fat, shorter, thick strands that can be seen through a compound microscope. DNA molecule consists of thousands of nucleotides joined in two long chains (see Figure 8.8). A single DNA nucleotide consists of a ***deoxyribose sugar***, a **phosphate group**, and a nitrogen base that are bonded together with covalent bonds. The nitrogen base in a DNA nucleotide can be one of four compounds; cytosine, guanine, thymine or adenine.

The nucleotides in a DNA molecule are arranged in a ladder-like structure. The ladder twists around itself in a shape known as a ***double helix***. The sides of the ladder consist of alternating sugars and phosphate groups that are bonded together.

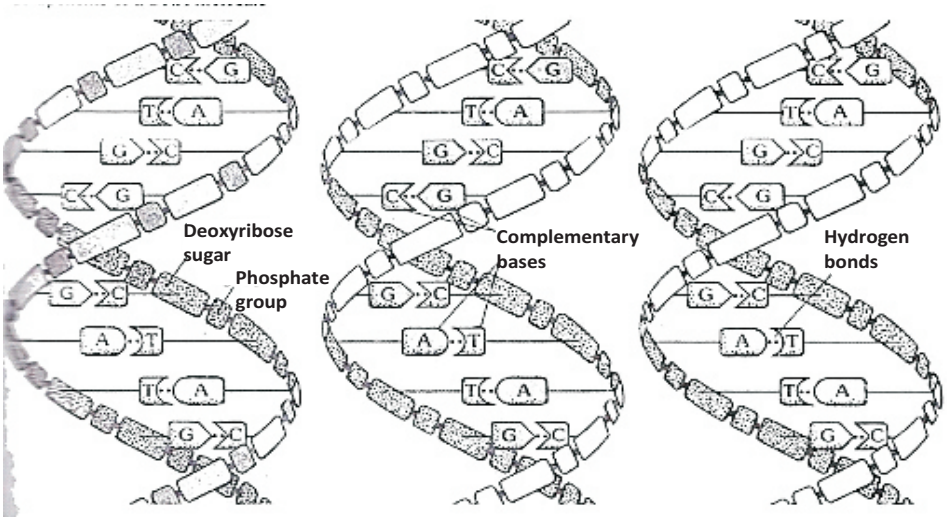
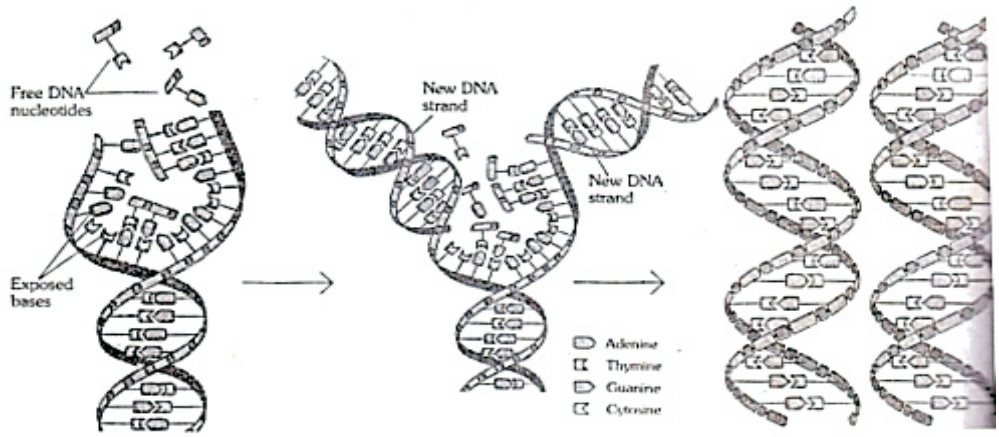


Figure 8.8: Component of a DNA molecule.
Source: (Slesnick *et al,*1985).

The rungs of the ladder consist of pairs of nitrogen bases that always pair in the same way. Adenine and thymine pair together, and cytosine and guanine pair together. The two bases that pair with each other are ***complementary bases.*** Thus, adenine and thymine are complementary bases, and cytosine and guanine are complementary bases.

Weak chemical forces, called hydrogen bonds, and ***Van der Waals forces*** join the complementary bases to each other. These bonds are only about one hundredth as strong as the covalent bonds that hold together the sugars and phosphate groups. So, even though these bonds hold parts of the DNA molecule together, they can break easily. When the bonds break, the DNA molecule separates into two ***complementary strands***.

a) DNA Replication When a cell reproduces to form daughter cells, each new cell receives exact copies of the DNA molecules found in the original cell. The copies carry the same instructions as is in the original DNA molecules to make exact copies of themselves in a process called ***DNA replication***. In the Figure 8.9, a single DNA molecule (two stands) replicates to form two molecules (four strands).



Original DNA molecule beginning to replicate | Two new DNA strands forming | Two DNA molecules

Figure 8.9: DNA replication.
Source: (Adapted from Ekanem et al,2013).

DNA replication begins when part of the DNA molecule unwinds. The bond holding the base pair in that part of the molecule breaks and the two complementary strands separate, exposing two rows of ***nitrogen bases***. The nitrogen bases of free ***nucleotides*** present in the nucleus begin to match up and form hydrogen bonds with exposed bases on each strand of the DNA molecule. Adenines and thymines pair together, and cytosines and guanines pair together.

The free nucleotides are bonded together covalently and begin to form two new DNA strands. Notice that each strand of the original DNA molecule acts as a pattern, or template, for the synthesis of a new DNA strand.

The process of replication continues all the way through the original DNA molecule. Each original strand makes a copy that is complementary to itself. The final products are two new DNA molecules that are identical to the original DNA molecule and contain the same information.

(a) DNA and Cell Functions

Cells carry out many functions. For example, they make proteins that form different structures inside the cells, and break down food to release energy. Certain enzymes control the chemical reactions in a cell. DNA controls cell functions by instructing cells to manufacture enzymes and other proteins. Some proteins are only a few dozen amino acids long; others are thousands of amino acids in length. Since there are twenty different kinds of amino acids, the sequences of amino acids in proteins can vary. DNA contains the instructions for linking the amino acids to make all the different kinds of proteins.

For years, scientists were baffled by the way DNA determined the amino acid sequence of proteins. The answer became clear when scientists discovered the structure of a DNA molecule. The revolution started earlier in elucidating the structure of DNA terminated 1953 with the Watson and Crick's discovery of the chemical and molecular structure of DNA. The structure consists of a twisted ***double helix***, held together by ***hydrogen bonds*** and ***Van de Waals forces*** between pairs of specific bases. Thus, provided solutions to age-long questions about the mechanisms of heredity, ***mutation*** and ***evolution***. They realized that the bases on the DNA strand actually code for the amino acids in a protein. Notice in the diagram (see Figure 8.10) below that a segment of three bases, known as a ***triplet*****,** codes for a single amino acid. So, if a particular protein consists of ten amino acids, thirty bases are necessary to code for those amino acids.

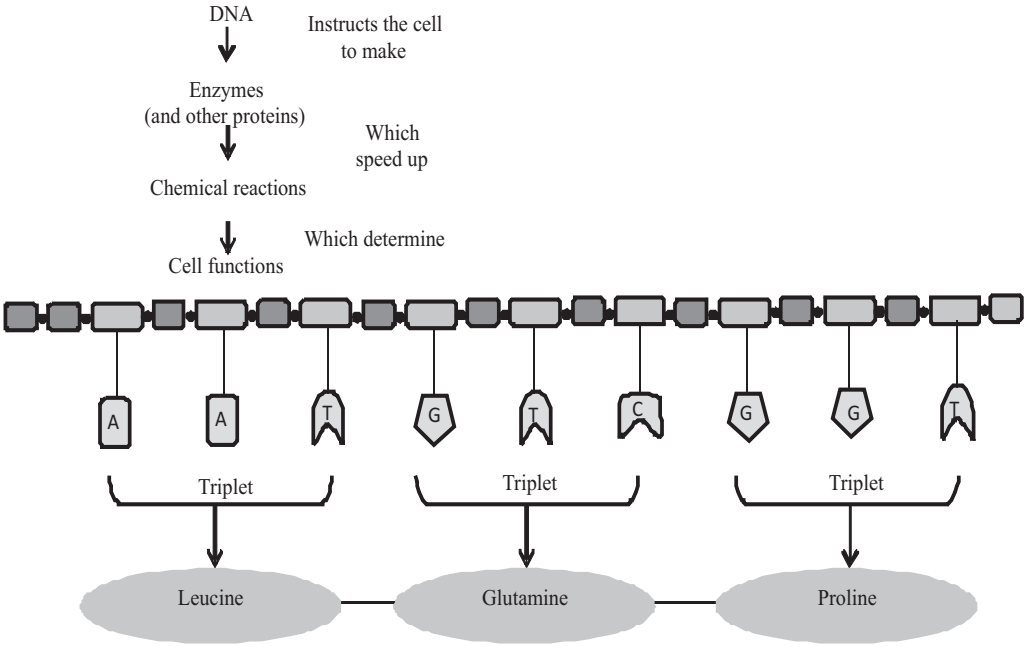


Figure 8.10: DNA base triplets code for amino acids.
Source: (Slesnick et al, 1985).

(a) The DNA Code (Triplet codon)

Once scientist learned that a segment of three bases in ***DNA codes*** for a single amino acid, they set out to learn exactly how the code works. Since DNA consists of four kinds of bases, the bases can combine to form triplet in 64 different ways. The chart below shows these 64 possible combinations of base triplets in DNA. Scientists conducted experiments to determine the kind of amino acid that is coded for by each of the 64 triplets. Notice that more than one kind of triplet can code for a particular kind of amino acid. For example, six kinds of triplets code for the amino acid arginine. Also, some triplets do not code for any kind of amino acid. These triplets indicate where the code for an amino acid sequence ends. Note, all organisms use the same ***codons*** to specify the particular ***amino acid*** they synthesized. The 64 possible ***codons*** (4^3) codes for 20 amino acid out of these, 61 are called sense ***codons*** that code for amino acids and 3 are called nonsense codon the serve as the stop signal to terminate protein synthesis for each sense codon, there is tRNA with complementary antisense codon. The tRNA carries the amino acid specified by the codon (see Figure 8.11). There are no tRNA molecules with ***anticodons*** to the 3 nonsense codons (stop codons) UAA, UAG and UGA, and thus, no amino acid. The start codon is AUG and codes for ***amino acid*** methionine, the start codon establish the reading frame of the mRNA, all other codons (Three nucleotide) can be read once the start has been identified.

Second Letter of Triplet

FIRST LETTER OF TRIPLET	A	G	T	C	THIRD LETTER OF TRIPLET
A	AAA, AAG – Phe; AAT, AAC – Leu	AGA, AGG, AGT, AGC – Ser	ATA, ATG – Tyr; ATT – STOP; ATC – STOP	ACA, ACG – Cys; ACT – STOP; ACC – Trp	A G T C
G	GAA, GAG, GAT, GAC – Leu	GGA, GGG, GGT, GGC – Pro	GTA, GTG – His; GTT, GTC – Gln	GCA, GCG, GCT, GCC – Arg	A G T C
T	TAA, TAG, TAT – Ile; TAC – Met	TGA, TGG, TGT, TGC – Thr	TTA, TTG – Asn; TTT, TTC – Lys	TCA, TCG – Ser; TCT, TCC – Arg	A G T C
C	CAA, CAG, CAT, CAC – Val	CGA, CGG, CGT, CGC – Ala	CTA, CTG – Asp; CTT, CTC – Glu	CCA, CCG, CCT, CCC – Gly	A G T C

Figure 8.11: The DNA code.
Source: (Slesnick et al,1985).

(a) Amino Acid Abbreviations

Ala-alanine	Gin-glutamin	Leu-leucine	Ser-serome
Arg-arginine	Glu-glutamic acid	Lys-lysine	Thr-threonine
Asp-asparagine	Gly-glycine	Mel-methionine	Try-tryptophan
Asp-aspartic acid	His-histidine	Phe-phenylalanine	Tyr-tyrosine
Cys-cysteine	Iie-isoleucine	Pro-proline	Val-valine

Scientists learned that the sequence of specific base triplets in a DNA strand determines the sequence of specific amino acids in a protein. ***DNA molecules*** consist of thousands of base triplets on each of their strands. Consequently, DNA can code for all the proteins a cell needs to function properly.

8.8 RNA (RIBONUCLEIC ACID)

DNA in the nucleus codes for the sequence of amino acids in proteins. But proteins are made or synthesized on the ribosomes outside the nucleus. How does the information stored in the DNA move from the nucleus to the ribosomes? Once the information reaches the ribosomes, how does the cell use the information to make proteins? All these steps require a second kind of nucleic acid – RNA. This nucleic acid exists in different forms in the cell, and each form has a different function in protein synthesis. Apart from DNA, RNA is the other important nucleic acid present inside the cell.

(a) Function of various type of RNA

mRNA (messenger RNA)

mRNA (messenger RNA) is transcribed in the nucleus to carry the information for protein to be synthesized from DNA to site of ***protein synthesis*** in the cytoplasm.
mRNA is transcribed as a strand of complementary bases of one of the DNA strands and carries the information for the synthesis of a particular protein or ***polypeptide***.

(b) tRNA (transfer RNA)

tRNA (transfer RNA), also called soluble RNA has a clover leaf structure (see Figure 8.12) with loops. One loop recognizes the ribosome; the top loop has an 'anticodon' to recognize the codon (triplet nucleotide sequence coding for amino acids) on mRNA. tRNA 'transfer' the amino acids at their respective positions during synthesis of protein.

There are many tRNAs which differ in their ***anticodon***. Each tRNA is specific for an amino acid and can carry that ***amino acid*** to the ribosome during protein synthesis.

The 3' end of every tRNA ends in the bases CCA (Cytosine-Cytosine-Adenine) and the 5' end of the tRNA end in G. (Guanine) Amino acid is carried at 5' end. tRNA contains unusual bases like ***inosine***, ***dihyrouridine*** etc.

) rRNA (ribosomal RNA)

rRNA is a component of ribosomes which are ribonucleoprotein particles containing RNA and proteins. rRNA is synthesized from the information in ribosomal genes present at "nucleolar organizer" region in a chromosome. rRNA has a role in protein synthesis.

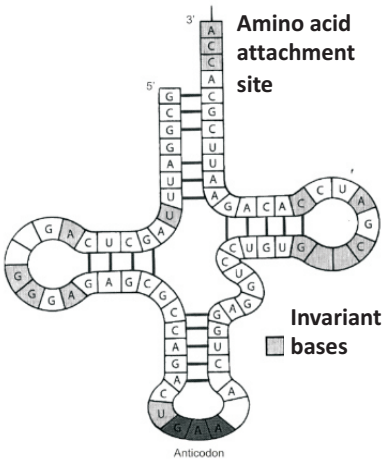


Figure 8.12: tRNA in Protein Synthesis.
Source: Raven, Evert and Eichhorn (1999).

Note: *Figure 8.12 shows the Structure of tRNA protein synthesis. Each tRNA molecule consists of about 80 nucleotides linked together in a single chain. The chain always terminates in a CCA sequence at its 3' end. An amino acid links to its specific tRNA molecule at this end. Some nucleotides are the same in all tRNAs; these are shown in gray. The other nucleotides vary according to the particular tRNA. The unlabeled boxes represent unusual modified nucleotides characteristics of tRNA molecules.*

Some of the nucleotides are hydrogen -bonded to one another, as indicatesd by the dashed lines. In some regions, the unpaired nucleotides form loops. The loop on the right in this diagram is thought to play a role in binding the tRNA molecule to the surface of the ribosome. Three of the unpaired nucleotides in the loop at the bottom of the diagram (brown) form the anticodon. They serve "plug in" the tRNA molecule to an mRNA codon.

8.9 ERRORS IN STORED INFORMATION

Every day the cells make trillions of proteins without errors. But sometimes cells make proteins that have errors in their amino acid sequence. Changes in the DNA that code for those proteins can cause the errors. This section describes some of the ways a DNA molecule can change and how those changes can affect the cell.

(a) Mutations

The Figure 8.13 shows three kinds of changes – or ***mutations*** – in DNA molecules that can lead to errors in the amino acid sequence of protein. The first DNA molecule in each diagram has a normal sequence of bases. The second DNA molecule is nearly the same as the first but has a change in its base sequence. The ***mutations*** in the second ***DNA molecules*** are described below.

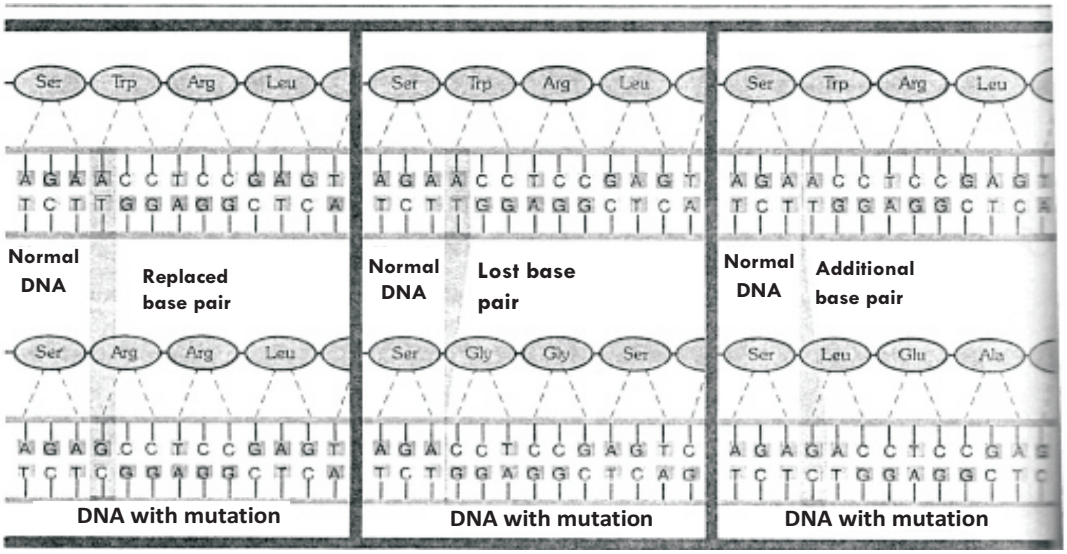


Figure 8.13: Mutation in DNA.
Source: (Slesnick et al, 1985).

One of the complementary base pairs is replaced by a different base pair. An adenine-thymine pair is replaced by a guanine-cytosine pair. Notice that this ***mutation*** changes the amino acid sequence coded for by that portion of the DNA molecule. Instead of coding for tryptophan the DNA now codes for arginine.
A base pair is lost. Notice that an adenine-thymine pair is missing in the second DNA molecule. This kind of mutation changes a number of base triplets beyond the site of the mutation. As a result, the sequence of the amino acids that follow the mutation changes.
An addition of a base pair also can change the base sequence. Notice that an additional guanine-cytosine pair is inserted in the DNA. As in the loss of a base pair, an addition rearranges the base triplets that follow and leads to a change in the amino acid sequence and thus, the type of protein synthesized.

(b) Causes of Mutations

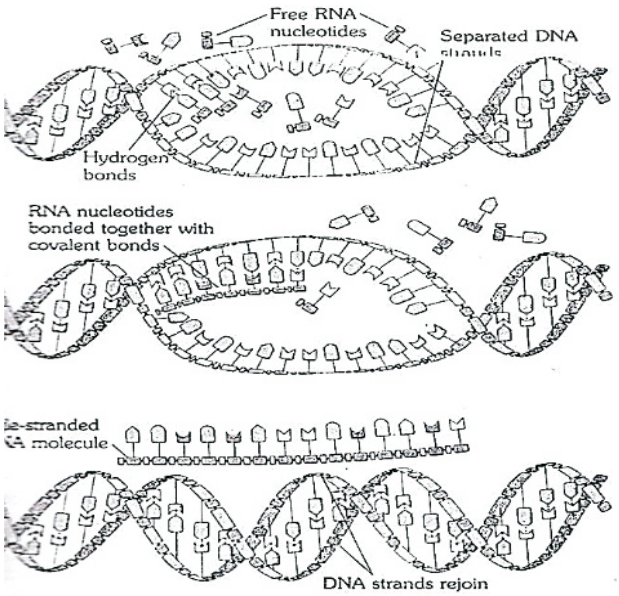
Scientists think that radiation which constantly enters earth's atmosphere naturally do cause some mutations. This natural radiation includes ***gamma rays***, ***cosmic rays***, and ***ultraviolet rays*.** In addition, certain chemicals, X-rays, and some viruses can cause mutations. Anything that causes mutations is called a mutagen. ***Geneticists*** have estimated that the chance for a particular human gene to mutate in one generation is between 1 in 10,000 and 1 in 1,000,000. Since humans have about 40,000 genes, it is likely that every person carries at least one mutation.
Mutations are one source of the great variety of traits we see among individuals, such as hair colour, eye colour, and facial features. Some mutations are helpful because they result in traits that allow an individual to adapt to the environment. However, in general, mutations are harmful. In fact, most harmful mutations do cause the death of organisms. Many harmful mutations are recessive and can remain unexpressed for many generations. ***Mutations*** are like random changes in musical composition. The chances of improving the music in this way are very small.

Similarities between DNA and RNA

Nucleic acids form the building blocks of all living organisms. They are group of complex compounds of linear chains of ***monomeric nucleotides*** where each of these nucleotides is made up of a phosphate backbone, sugar, and nitrogenous base. They are involved in the maintenance, replication, and expression of ***hereditary information***. Two of the famous ones are DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). The DNA is awe-worthy, holding the key to heredity. RNA is just as impressive, as it pretty much runs the show, with DNA as the main star. Together these molecules ensure that the DNA is replicated, the code is translated, expressed and that things go where they should go. DNA and RNA are very similar to each other while they also manage to be different in just the right way.

8.11 SYNTHESIS OF MESSENGER RNA (TRANSCRIPTION)

Messenger RNAs (mRNAs) carry the information coded in DNA because they are synthesized from DNA molecules (Figure 8.14). Every hour a cell synthesized hundreds or thousands of mRNA molecules from different parts of its DNA molecules. The diagram below shows how the cell synthesizes a single mRNA. Special enzymes control each step of the processes.



Messenger RNA synthesis begins when part of a DNA molecule unwinds, and the two DNA strands separate. Free RNA nucleotides present in the nucleus match up and form hydrogen bonds with complementary bases along one of the DNA strands.

The RNA nucleotides that line up along the DNA strand are bonded together covalently, forming a strand of mRNA.

The hydrogen bonds between the mRNA and the DNA strand break, and the mRNA molecule is synthesized from part of a DNA molecule is known as ***transcription***.

Figure 8.14: Synthesis of Messenger RNA.
Source: (Adapted from Ekanem et al, 2013)

(a) Messenger RNA Codons

Notice that the base sequence in the newly synthesized mRNA molecule is the exact complement of the base sequence in the DNA strand. So, the code that was on the DNA is now carried by the mRNA, but in a complementary form. As in DNA, every segment of three bases on the ***mRNA codes*** for a certain amino acid. The chart below compares the DNA and the mRNA codes for a couple amino acids (see Table 8.2). Notice how the mRNA base triplets are complementary to the DNA base triplets. Each of these mRNA base triplets is called a ***codon***.

Table 8.2: Comparing the DNA and the mRNA codes for a couple amino acids, (tyrosine and histidine)

(c) Mutations and Disease

A single DNA molecule can code for thousands of proteins. The portion of a DNA molecule that codes for a particular protein is known as a ***gene***. For many years scientists have studied genes in human cells. Now, they know the kinds of protein some of those genes code for and the functions for those proteins in the cells. Scientists also have learned that mutations in some genes can cause changes in proteins which result in certain diseases.

One example of a human disease caused by a mutation in a gene is the condition known as sickle cell ***anemia***. People afflicted with this disorder have red blood cells that change to a crescent or sickle shape. You can see the difference between a sickle-shaped and a normal red blood cell by studying the photographs of a normal red blood cell. Their sickle shape causes them to clump together in small blood vessels. This clumping can block the blood vessels and cut off the blood supply to a particular part of the body.

Scientists have learned that people with sickle cell ***anemia*** produce ***abnormal haemoglobin*** molecules that cause the red blood cells to become sickle shaped. The ***abnormal haemoglobin*** differs from ***normal haemoglobin*** by only one amino acid. A mutation in a gene that codes for ***haemoglobin*** causes this difference.

8.10 DIFFERENCES AND SIMILARITIES BETWEEN DNA AND RNA

DNA and RNA perform different functions in humans. DNA is responsible for storing and transferring genetic information, while RNA directly codes for amino acids and acts as a messenger between DNA and ribosomes to make proteins.

DNA and RNA base pairing is slightly different since DNA uses the bases adenine, thymine, cytosine, and guanine; RNA uses adenine, uracil, cytosine and guanine. Uracil differs from thymine in that it lacks a ***methyl group*** on its ring. The differences are listed in Table 8.1.

(i). Double stranded molecule.	(i). Single stranded molecule.
(ii). Contains deoxyribose sugar	(ii). Contains ribose sugar. Thymine
(iii). Pyrimidine base complementary to .Adenine is Thymine.	(iii). Pyridine base complementary to adenine is uracil.
(iv)DNA has only one function, which is to bear hereditary information.	(iv)Many species of RNA such as mRNA, tRNA, rRNA with different functions RNA
(v). DNA can duplicate on its own.	(v). RNA is synthesized on a DNA template.

Source: NIOS (2017)

(i) mRNA molecule is transcribed from a molecule of DNA in the nucleus.

(ii) An mRNA molecule leaves the nucleus through pores in the nuclear membrane. The mRNA then moves through the cytoplasm to the ribosomes and attaches itself to a ribosome.

(iii) Another kind of RNA – transfer RNA(tRNA) – is present in the cytoplasm. The structure of a tRNA molecule is different from an mRNA molecule. And shows that tRNA folds into a clover like structure. One end of the tRNA molecule attaches to an amino acid in the cytoplasm. The opposite end of the molecule contains a triplet of exposed bases known as an ***anticodon*.** The kind of anticodon on the tRNA molecule determines the kind of amino acid that attaches to the tRNA.

(iv) In a sequential manner, the anticodons on the tRNAs match up and form hydrogen bonds with complementary codons on the mRNA. Since amino acids are attached to the tRNAs, the amino acids line up in a sequence along the mRNA. Notice in the diagram that the sequence of codons on the mRNA directs the sequence of bases in DNA originally specified the sequence of codons on the mRNA.

(v) The amino acids are bonded together and begin to form a protein.

(vi) The tRNAs that are attached to the bonded amino acids break away from both the amino acids and mRNA. The ribosome moves down the mRNA to the next codons. Other tRNAs match up with those codons. The ribosome continues to move down the mRNA molecule. tRNAs match up with all the codons on the mRNA until a codon that does not code for an amino acid, called a stop codon, is reached. Finally, a complete protein is formed. The entire process by which a cell reads codons on an mRNA molecule to synthesize a protein is called ***translation*.** Special proteins control each step of the ***translation*** process.

(vii) A cell synthesizes all proteins in the manner described above. Many proteins are synthesized simultaneously on different ribosomes in the cell. A different mRNA carries the code for each kind of protein.

(viii) The amino acid which has been activated binds to the Adenine residue at the 3^{1} end. The bonding is called an ***aminoacylbond***, while the complex is called aminoacyl – tRNA. The anticodon side contains three bases which form hydrogen bonds with complementary base triplet on the mRNA. The tRNA on the ribosomes. The enzyme recognition site binds the specific synthase those catalyses the formation of an ***aminoacylbond*** to the correct amino acid.

8.12 PROTEINS, POLYPEPTIDES, AND AMINO ACIDS

8.12.1 Meaning of Proteins

Proteins are naturally occurring, extremely complex molecules that consists of ***amino acid*** residues joined by pepetide bonds. They are ***nitrogenous compounds*** formed by the condensation of large numbers of ***amino acids***. They contain carbon, hydrogen, oxygen, nitrogen and sometimes sulphur. ***Proteins*** are very important because: they are the materials from which new tissues are made. If organisms areto grow and if they are to repair damaged tissues, they need ***proteins***. The cells of living organisms contain from several hundred to many thousands of different kinds of

If an animal is not consuming sufficient protein, the body begins to break down protein rich tissue, such as muscles, leading to muscle wasting and eventually death if the deficiency is severe.Analysis of proteins helps evolutionary botanist sort out relationships and heredity among plants and is a popular, current area of research.***Proteinmolecules*** are usually very large and consist of one or more ***polypeptide*** chains and sometimes also have simple sugars or other smaller molecules attached.

8.12.2 Polypeptides

Polypeptidesare chains of ***amino acid***. There are 20 different kinds of amino acids, and from 50 to 50,000 or more of them are present in various combinations in each ***protein molecule***. Each amino acid has two special functional groups of atom plus a remainder called the ***R group***. One functional group is called the amino group ($-NH_2$); the other, which is acid, is called the carboxyl group (-COOH). Amino acids are linked to other amino acids by ***peptide bonds***, which are covalent bonds formed between the carboxyl carbon of one amino acid and the nitrogen of the ***amino group***of another, with a molecule of water being removed in the process. The makeup of the ***R group*** is distinctive for each of the 20 amino acids. Some ***R groups*** (which can consist of just a single hydrogen atom or, in others, a complex ring structure) are polar while some are

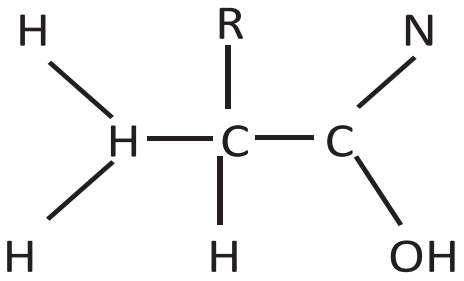


Figure 8.15: General formula for Amino Acid

Plants can synthesize amino acids they need from raw materials in their cells, but animals have to supplement from plant sources some amino acid they need, since they can manufacture only a few amino acids themselves.

8.12.3 Structure of Protein

Protiens are ***polymers***, specifically polypeptides, formed from sequences of amino acids, the monomer of the polymer. Each polypeptide usually coils, bends, and folds in a specific fashion within a protein, which characteristically has three levels of structure and sometimes four. The complete structure of a protein can be described at four different levels of complexity namely primary, secondary, tertiary and quaternary structure.

(a) A sequence of amino acid fastened together by peptide bonds forms the primary structure of a protein.

(b) As hydrogen bonds form between oxygen and nitrogen atoms of different amino acids, the polypeptide chain coils like a spiral staircase, and the secondary structure develops. Some secondary structures include polypeptide chains that double back and form hydrogen bonds between the two lengths in what is referred to as beta sheet, or pleated sheet.

(c) Tertiary structure develops as the polypeptide further coils and folds. The tertiary structure is maintained by bonds between R groups.

(d) If a protein happens to have more than one kind of polypeptide, a fourth, or quaternary structure, may form (Figure 8. 16).

The following are six steps during protein synthesis:

(I) DNA strands separate.
(ii) mRNA leaves the nucleus and travels to ribosome.
(iii) Code on mRNA determines what amino acids can attach.
(iv) tRNA contains bases that recongnize mRNA.
(v) Amino acids line up in proper sequence on ribosome.
(vi) Peptide bonds form creating a peptide chain.

8.12.5 Storage Proteins

Some plant food-storage organs, such as potato tubers and onion bulb, store small amounts of proteins in addition to large amounts of ***carbohydrates***. Seeds, in particular, however, usually contain proportionately larger amounts of proteins in addition to complement of ***carbohydrates*** and are very important sources of nutrition for humans and animals. One example of an important protein source in human and animal diets is wheat glutten (to which, incidentally, some humans and animal become allergic). The glutten consists of a complex of more than a dozen different proteins.

A seed's proteins get used during germination and its subsequent development into seeding. Some legume seeds may contain more than 40% protein, but legume are deficient in certain amino acids (e.g, methionine), and a human diet based on beans needs to be balanced with other storage proteins (e.g, those found in unpolished rice) to furnish a complete complement of essential amino acid. Some seed proteins, such as those of jequirity beans (*Abrus precatorius*- used in India to induce abortions and as a contraceptive), are highly poisonous.

8.13 CLASSIFICATION OF PROTEINS

There are two types of proteins:

(a) Simple protein
(b) Conjugated protein

8.13.1 Simple proteins

Proteins contain only the ordinary amino acids without organic and inorganic structure. Based on solubility, this major group may be classified into:

(i) **Albumin:** Are soluble in water, dilute salts acids and alkalies and can be coagulated by heat, they vary in sentivity. Examples eggs albumin, serum albumin from blood and enzymes.
(ii) **Globulins:** Are insoluble in water and dissolves in salt solution of moderate concentration. It coagulates on heating. Examples of globulin are seed protein myosin from muscles and antibodies of blood.
(iii) **Glutelins:** Dissolves in dilute acid and alkaline but insoluble in water. Seed protein e.g glutelin found in wheat, oryzenin in rice are some examples.
(iv) **Prolamines:** Dissolves in 70% – 80% percent ethanol but insoluble in water. Prolamines have few polar groups and are high in proline and amide groups some examples include gliadin (wheat) horedein (barley) and Zein (corn).
(v) **Scleroproteins** an albumniods: are insoluble in most solvent. Structural and fibrous proteins such as keratin, collagen or elastin.
(vi) **Histones:** are soluble in dilute ammonia. Globin, haemoglobin and protein components of most nucleoproteins are examples.
(vii) **Protaminesa:** are not coagulated by heat but are soluble in most aqueous systems. Protamines are known only when they are combined with nucleoprotein of sperm of fish.

8.13.2 Conjugated proteins

Conjugated proteins compose of a simple protein and another compound (a prothetic group) associated with it.
On hydrolysis, they yield amino acid and the component prosthetic group. Examples include:

(i) . Nucleoprotein (Proteins and nucleic acid). These are proteins conjugated with nucleic acid. Nucleoproteins occur in DNA, RNA and Viruses.

(ii). Glycoproteins (proteins + Carbohydrates). These proteins are conjugated with carbohydrates usually mcro molecular polysaccharides containing acetyglucosamine, other sugars or sugar acids and sulphate or phosphate esters. One less known example is Gonotropic hormone

(iii). Lipoproteins (protein + Lipid). They are conjugates of proteins and lipids. The lipid portion cannot be extracted with ether. Lipoproteins are widely distributed especially in animals tissues lke egg, brain and blood, cell membrane, nuclear membrane and vascular membrame.

(iv). Chromoproteins (protein + coloured pigments). These are coloured and possessed structure absorbing visible light which may be due to metals like Cu or metals with organic groups in Fe and Mg porphyrin. Examples are respiratory pigment and large number of enzymes.

8.14 CHAPTER SUMMARY

- Nucleic acids contain genetic information and play a key role in proteinbiosynthesis. They are formed by the polymerization of units called nucleotides, which consist of a nitrogenous base, pentose sugar, and phosphoric acid.
- The base can be either a Pyrimidine (Thymine (T), Cytosine (C), or Uracil (U) or a Purine (Adenine (A) and Guanine (G).
- The aldopentose is d-ribose in ribonucleic acid (RNA) or d-2- deoxyribose in deoxyribonucleic acid (DNA).
- Nucleotides form chains by binding through ester links established by phosphate between the OH group in $C5^{1}$ of the pentose of one nucleotide and the OH of $C3^{1}$ of the pentose of another nucleotide.
- DNA, together with proteins, forms the chromatin of the cell nucleus and is also present in mitochondria.
- In eukaryotes, chromatin is formed by the association of DNA with basic proteins.
- In contrast, bacteria, plasmids, mitochondria, and chloroplasts have circular DNA.
- RNA is another polynucleotide that differs from DNA because it has a single chain instead of two; it contains ribose instead of deoxyribose and uracil instead of thymine.
- Different types of RNA exist in cells, including messenger RNA (mRNA), which transmits genetic information from the cell nucleus to the cytoplasm; transfer RNA (tRND), which carries amino acids to the site of protein synthesis; and ribosomal RNA (rRnA), which has a large (60s) and a minor particle (40s) and is involved in amino acid assembling during protein synthesis.
- Other types of RNA include small nuclear, small cytosolic RNA, micro-RNA, small silencing RNA, and long non-coding RNA.
- Viruses are agents of disease in animals and plants, formed by nucleic acids surrounded by a protein coat.
- Proteins are usually large molecules composed of sub-units called amino acids.

- Each amino acid has an amino group (-NH_2) and a carboxyl group (-COOH); these groups bond are called peptide chains; the bonds are called peptide bonds.
- The protein cover is the viral genetic material, DNA or RNA, commonly single- stranded.
- Genetic traits in cells are transformed from parent to offspring from generation to generation without alteration, except when acted upon by mutation or other forces.

8.15 STUDENTS' PRACTICALACTIVITIES

ACTIVITY 1: Isolate DNA from a Plant Tissue

AIM: To observe DNA from a Plant Tissue

Materials

Onion	Plastic syringe (10 cm^3)
Washing-up liquid (not the concentrated type)	2 beakers (250 cm^3)
Blender	Timer
Distilled water	Boling tube
Sharp knife	Test tube rack
Table salt (3g)	Graduated cylinder (100 cm^3)
Chopping board	Retort stand
Protease enzyme e.g. trypsin (1%)	Glass rod/wooden skewer/wire loop
Coffee filter paper	Electronic balance
Ethanol at freezer temperature	Large funnel
Droppers	Weigh boat
Water bath (60^0C)	Glass stirrer
Spatula	Plastic syringe
Ice-water bath	Disposable gloves
	Thermometer

PROCEDURE

(i) Familiarize yourself with all procedures before starting.
(ii) Add 3g of table salt to 10cm^3 of washing-up liquid in the beaker and make up to 100cm^3 with distilled water.
(iii) Chop the onion into small pieces.
(iv) Add the chopped onion to the beaker with the salty washing-up liquid solution and stir.
(v) Put the beaker in the water bath at 60^0C for exactly 15 minutes.
(vi) Cool the mixture by standing the beaker in the ice-water bath for 5 minutes, stirring frequently.
(vii) Pour the mixture into the blender and blend it for no more than 3 seconds.
(viii) Carefully filter the mixture into the second beaker.
(ix) Transfer about 10cm^3 of this filtrate into the boiling tube.
(x) Add 2-3 drops of protease to the filtrate and mix gently.
(xi) Trickle about 10cm^3 of the ethanol, straight from the freezer, down the side of the boiling tube, to form a layer on top of the filtrate. Leave the tube for a few minutes without disturbing it.
(xii) Observe any changes that take place at the interface of the alcohol and the filtrate.
(xiii) Using the glass rod, gently draw the DNA out from the alcohol.
(xiv) Record the result.

ACTIVITY 2: Demonstrating the Transfer of Information within a cell

AIM: To demonstrate the base sequence in DNA and messenger RNA that can code for a certain sequence of amino acids.

MATERIALS

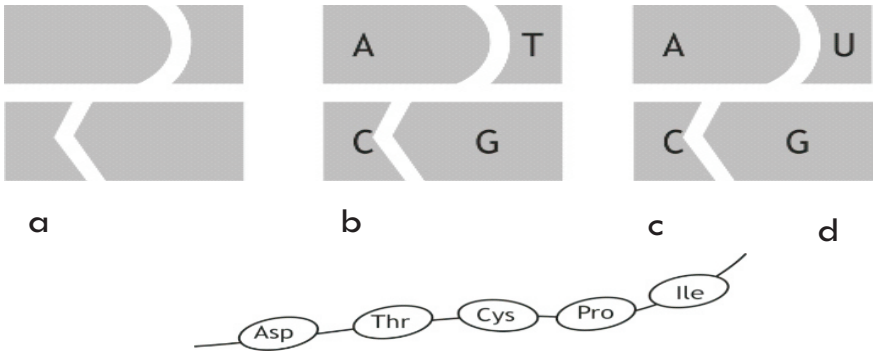
(i) Metric ruler
(ii) One sheet of red paper
(iii) One sheet of blue paper
(iv) One sheet of drawing paper
(v) Scissors
(vi) Tape

PROCEDURE

(i) Cut the red paper into 30 strips about 2cm wide and 4 cm long. Then cut the strips into the shapes shown in picture a, so that each strip forms two pieces that fit together;
(ii) The pieces of paper that you have cut will represent the nitrogen bases in DNA. Label the pieces of paper as shown in b. G will stand for guanine, C for cytosine, A for adenine, and T for thymine. Be sure that guanine matches with cytosine, and adenine matches with thymine
(iii) Repeat step (i) using blue paper. The blue pieces of paper will represent the nitrogen bases in messenger RNA. Label the pieces as shown in c. Notice that one of the bases is labeled with a U for uracil instead of a T for thymine.
(iv) Picture d shows the sequence of amino acids that make up a small portion of a protein molecule. Use the chart on page 92 to determine the sequence of bases on a single strand of a DNA molecule that could code for the sequence of amino acids shown. Show the DNA code using the red coloured DNA bases that you cut out. Tape the DNA bases to a sheet of drawing paper.
(v) Determine the messenger RNA that would be synthesized from the DNA strand you constructed. Using the blue-coloured RNA bases, order the bases of the mRNA molecule, and tape them next to the DNA bases.

ANALYSIS

(a) Explain how more than one kind of sequence of DNA bases could code for the amino acid sequence in picture d.
(b) If a mutation changed the first base of your DNA sequence from a cytosine to an adenine, how would the amino acid sequence be changed?
(c) How many bases long would a strand of DNA have to be coded for 120 amino acids?



Base sequence in DNA and Messenger RNA

8.16 TUTOR MARKED ASSESSMENT QUESTIONS

HAVING READ THROUGH **CHAPTER EIGHT**, ANSWER THE FOLLOWING QUESTIONS IN THE SPACES PROVIDED.

1 (a) Define the Term Nucleic Acid.

.....

.....

.....

.....

(b) Write Briefly on RNA and DNA as the **Two** Types of Nuclear Acids:

RNA

.....

.....

.....

.....

DNA

.....

.....

.....

.....

(c) Draw the Structure of DNA Molecule and Indicate the Phosphate Group, Deoxyribose Sugar and a Nitrogenous Base.

Drawing $4\times\frac{1}{2}$ **=2 Marks**
Lebeling $6\times\frac{1}{2}$ **=3 Marks**

CHAPTER NINE

CELL CYCLE AND CELL DIVISION

Dr. Aniefon A. Ibuot & Ubokobong J. Okoko

9.1 INTRODUCTION

All cells are produced by divisions of pre-existing cells. The continuity of life depends on cell division. A cell born after a division proceeds to grow by ***macromolecular synthesis*** until it reaches a species-determined division size and divides. This cycle acts as a unit of biological time and defines the life history of a cell. ***Cell division*** is essential to life. It enables a multicellular organism to grow to adult size. It also replaces worn-out or damaged cells, keeping the total cell number in a mature individual relatively constant. Some cells divide once a day, others less often, but highly ***specialized cells***, such as our nerve and muscle cells, not at all. Cell division is the basis of reproduction in every organism including single-celled organisms such as *Amoeba proteus*. Eukaryotic cells divide and undergo a ***cell cycle***, which is an orderly sequence of events that extends from the time a cell divides to form two daughter cells, to the time those daughter cells divide again. Cell division in eukaryotes consists of two overlapping stages, mitosis and ***cytokinesis***. In mitosis, the nuclear membrane breaks down. The ***chromosomes***, which have previously been duplicated, are divided equally, to form two new nuclei. In ***cytokinesis***, the cytoplasm of the parent cell divides into two parts, each containing one of the nuclei.

9.2 LEARNING OBJECTIVES

After reading this chapter, you should be able to:

(i) Explain cell cycle division.
(ii) Draw the structures of chromosome and chromatid.
(iii) Discuss the two types of cell division: mitosis and meiosis.
(iv) Define mitosis and explain the stages of mitotic division.
(v) Define meiosis and stages of meiotic division.
(vi) State the differences between mitosis and meiosis.
(vii) Highlight the similarities between mitosis and meiosis
(viii) Enumerate the significance of mitosis and meiosis.
(ix) Explain the importance of mitosis and meiosis to living organisms.
(x) State the meaning of somatic and sex cell.
(xi) Explain alternation of generation during meiosis.

9.3 MEANING OF CELL CYCLE AND CELL DIVISION

(a) **Cell cycle:** can be defined as the entire sequence of events happening from the end of one nuclear division to the beginning of the next.
The ***cell cycle*** involves the following three processes:

(i) **Chromosome cycle**: Here, DNA synthesis alternates with mitosis (or **karyokinesis** or nuclear division). During DNA synthesis, each double – helical DNA molecule is replicated into two identical daughter DNA molecules and during mitosis the duplicated copies of the ***genome*** are separated.

(ii) **Cytoplasm Cycle**: Here, cell growth alternates with ***cytokinesis*** (or cytoplasmic division). During cell growth many other components of the cell (RNA, protein and membranes) become double in quantity and during ***cytokinesis***, cell as a whole divides into two. Usually, the ***karyokinesis*** is followed by the ***cytokinesis*** but sometimes the ***cytokinesis*** does not follow the ***karyokinesis*** and results into the multinucleate cell.

(iii)**Centrosome Cycle**: Both the above cycles require that the ***centrosome*** be inherited reliably and duplicated accordingly in order to form the two poles of the mitotic spindle; thus, centrosome cycle forms the third component of ***cell cycle***.

(b) **Cell division** is a process whereby a single cell divides many times to form a multicelled organism. Unicellular bacteria and protozoa divide and increase in number in this manner. Damaged or injured tissues are replaced by new cells via ***cell division***. Therefore, cell division is one of the most essential activities in all living organisms.

9.4 THE CELL CYCLE

Dividing cells pass through a regular series of events, known as the ***cell cycle***. Completion of the cycle requires varying periods, depending on both the type of cell and external factors, such as temperature and for available nutrients. Whether it lasts an hour or a day, however, the relative amount of time spent at each phase is about the same.

The S (synthesis) phase of the ***cell cycle*** is the period during which the genetic material (DNA) is duplicated. G (gap) phases precede and follow the S phase. The G_1 period occurs after mitosis and precedes the S phase; the G_2 period follows the S phase and occurs before mitosis. The G and S phases together are referred to as ***interphase*** (see Figure 9.1).

The G_1 phase, between mitosis and chromosome synthesis, is principally a period of growth of the cytoplasmic material, including all the various organelles. Also, during this G_1 period, according to current ***hypothesis***, substances are synthesized that either inhibit or stimulate the S phase and the rest of the cycle, thus determining whether or not cell division will occur. During the G_2 phase, structures involved directly with mitosis, such as the spindle fibers are synthesized.

Some cells pass through successive ***cell cycles*** repeatedly. This group includes the one-celled organisms and certain cells in growth centers. Some specialized cells lose

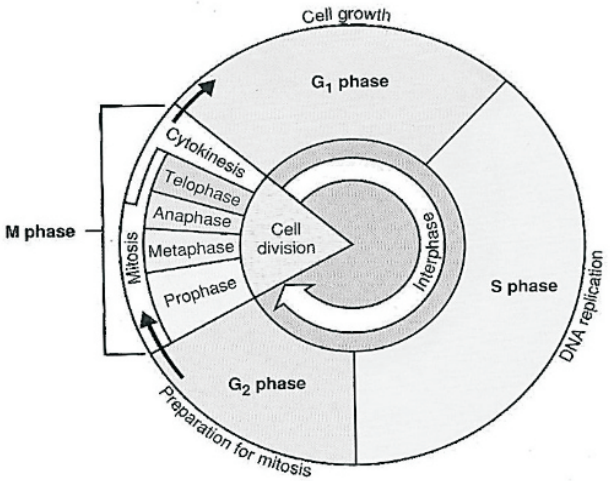


Figure 9.1: The Cell Cycle.
Source: Campbell (1993).

Note: *During the cell cycle, the cell grows, replicates its DNA, and divides into two daughter cells. DNA synthesis takes place during the S phase. Cell division takes place during the M phase. G_1 and G_2 are gap phases.*

Dividing cells go through four principal phases, including the phases of mitosis and S phase, during which the chromosomes are duplicated. Separating mitosis and the S phase are two G phases. The first of these (G_1) is a period of general growth and replication of cytoplasmic organelles. During the second (G_2), structures directly associated with mitosis, such as the spindle fibers, are synthesized. After the G_2 phase comes mitosis, which is, in turn, divided into four phases. Mitosis actually occupies only 5 to 10 percent of the cell

9.5 STRUCTURES OF CHROMOSOME SHOWING CHROMATIDS

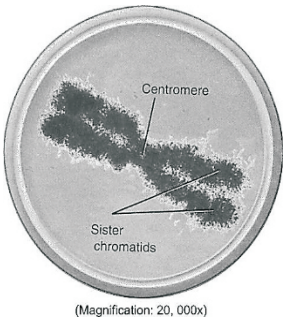


Figure 9.2: Structure of a Chromosome.
Source: Miller and Levine (2006).

Note: *This is a human chromosome shown as it appears through an electron microscope. Each chromosome has two sister chromatids attached at the centromere.*

Note*:* ***Chromosomes*** *are tread-like structures present in the nucleus, which carries genetic information from one generation to another. They play a vital role in cell division, hereditary, variation,* ***mutation****, repair and regeneration. Chromosomes are made up of a DNA -protein complex called chromatin that is organized into subunits called nucleosomes. They way in which eukaryotes compact and arrange their chromatin not only allow a large amount of DNA to fit in a small space, but it also helps regulate* ***gene expression****. As shown in Figure 9.2,* ***chromatid*** *is one of the two identical parts of the chromosome after S phase. Whereas, centromere is the point where the two chromatids touch.*

Condensed ***chromosomes*** observed in the cell of eukaryotes during cell division, range from ¼ micron in fungi to 30 microns in Trillium plants. Electron microscope studies of ***chromosomes*** shows that the ***chromosome*** is made of fibres that may range in thickness from 100 – 500A, depending on the treatment to which they have been subjected. Mitotic ***chromosome*** is usually a rod-like body with one constriction at the ***centromere*** called the primary constriction. Two arms can be seen which may include pinching off of a small chromosomal section called satellite (see Figure 9.2). The secondary constrictions are often associated with regions of attachment of ***bucleolar organizers*** or nucleolus. Along the length of the chromosomes are knob-like regions known as chromomeres, which occupy specific regions, giving the chromosomes distinct morphological appearance. Each chromosomes type is found in pairs in the cells of diploid organisms. In the ***sex cells*** or gametes, the ***chromosomes*** are represented in single copies. The gametes are therefore said to be haploid (n). If we were to longitudinally dissect the chromosome, we would have two structures are called a ***chromatid***. Two chromatids of a chromosome could be referred to as sister chromatids. Unless there has been a ***mutation***, ***sister chromatids*** contain the same sequence and number of genes, and so are genetically identical. Thus, one may visualize them as "mirror images" of each other.

9.6 TYPES OF CELL DIVISION

There are two types of cell division- mitosis and meiosis.

(i) Mitosis: Cell division for growth and replacement wherein the two daughter cells are identical and similar to mother cell in all respects.

(ii) Meiosis: It occurs in the gonads for sexual reproduction to produce gametes. The resultant cells, egg (in female) and sperms (in male), possess half the chromosome number of the parent cell.

9.7 MEANING AND STAGES OF MITOSIS DIVISION

(a) Meaning: ***Mitosis*** is the process of nuclear division in which the nucleus divides into two daughter nuclei with each nucleus having the same chromosomes as the parent nucleus. The resulting daughter cells have the same number and type of chromosomes as the parent cell. In 1882, the behavior of chromosomes during normal body cell division was described by W. Flemming. He called the events he observed in the nucleus mitosis after the Greek word for thread.

Mitosis occurs in smooth and continuous fashion but for convenience, science describes ***mitosis*** as it takes place in a series of phases. The events of ***mitosis*** are divided into four phases: prophase, metaphase, anaphase and lastly ***Telophase***. Depending on the type of cell, the four ***stages of mitosis*** may last from a few minutes to several days.

(a) Stages of mitosis:

When cell undergoes mitosis, it divides into two smaller cells, identical to each other and the parent cell. They contain the same complete chemical code as the parent cell within their chromosomes and a more or less equal number of cell organelles. For each daughter cell to have a complete DNA code, ***DNA replication*** (copying) has to occur in the parent cell. The following are stages or phases of mitosis;

(i) Interphase

Interphase is the stage where the cell replicates its genetic material (i.e., double its DNA), and grows in size (Figure 9.3).

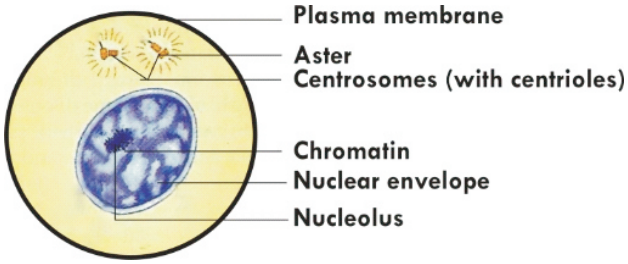


Figure 9.3: G_2 Interphase.
Source: Campbell (1993).

(ii) **Prophase**

Prophase is characterized by a shortening and thickening of the chromosomes so that individual chromosomes become distinct (see Figure 9.4).

During ***prophase***, changes occur in both the nucleus and the cytoplasm. In the nucleus, the nucleoli disappear. The ***chromatin fibers*** become more tightly coiled and folded into discrete chromosomes observable with a light microscope. Each duplicated chromosome appears as two identical sister chromatids joined at the ***centromere***. In the cytoplasm, the mitotic spindle forms; it is made of ***microtubules*** and associated proteins arranged between the two ***centrosomes***. During ***prophase***, the centrosomes move away from each other, apparently propelled along the surface of the nucleus by the lengthening bundles of ***microtubules*** between them.

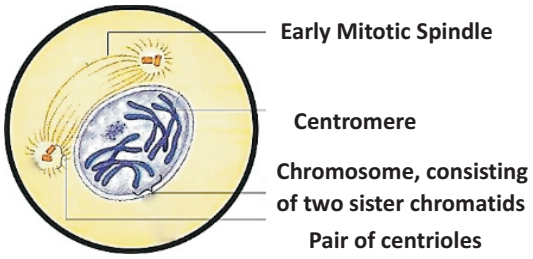


Figure 9.4: Prophase.
Source: Campbell (1993).

(iii) **Prometaphase**

In ***Prometaphase***, the chromosome begins to align themselves in the mid-portion of the cell perpendicular to the axis/poles established by the spindle fibres. The nuclear evelope is broken down completely by now (see Figure 9.5).

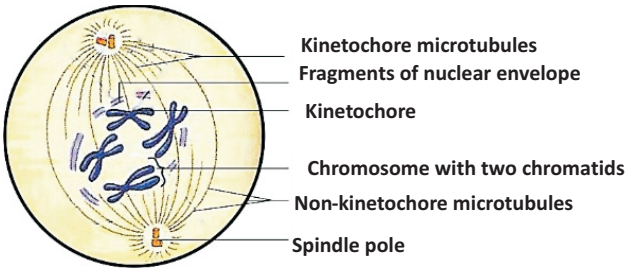


Figure 9.5: Prometaphase.
Source: Campbell (1993).

(iv) Metaphase

Here, the chromosomes are completely aligned at the mid-portion of the cell (called ***metaphase*** plate). The chromosomes are attached to the spindle fibres at their centromere, by the help of a ***Centromeric structure*** called ***kinetochore***.

The ***centromere*** is the actual part of the chromosomes that is aligned at the ***metaphase*** plate; the chromatid arms are freely suspended in any direction (Figure 9.6).

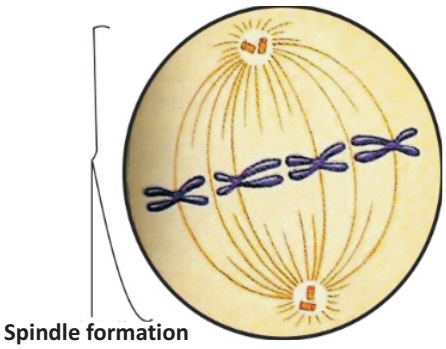


Figure 9.6: Metaphase.
Source: Campbell (1993).

(v) Anaphase

Anaphase begins when the paired centromeres of each chromosome divide, liberating the sister chromatids from each other. Each chromatid is now considered a full-fledged chromosome. The spindle apparatus then begins moving the once-joined sisters toward opposite poles of the cell. Because the kinetochore microtubules are attached to the centromere, the chromosomes move ***centromere*** first (their pace is about 1 um/sec). The kinetochore microtubules shorten as the chromosomes approach the cell poles. At the same time, the poles of the cell also move farther apart. By the end of ***anaphase***, the two poles of the cell have equivalent-and complete-collections of chromosomes (see Figure 9.7).

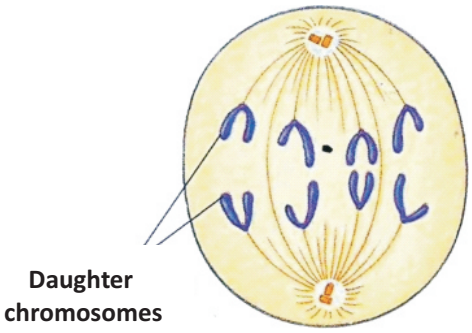


Figure 9.7: Anaphase.
Source: Campbell (1993).

(vi) **Telophase And Cytokinesis**

Here, the cytoplasm is partitioned into two (***cytokinesis***), isolating the chromatid collections at the poles from each other, and producing two daughter cells. The ***chromatids*** in each daughter cell uncoil into chromatin, the nuclear membrane forms and the spindle fibre disappears (Figure 9.8).

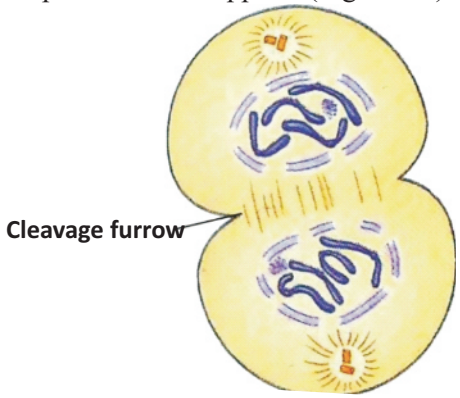


Figure 9.8: Telophase and Cytokinesis.
Source: Campbell (1993).

9.8 MEANING AND STAGES OF MEIOSIS DIVISION

(a) ***Meiosis*** is the type of cell division that takes place in reproduction/gametic cells of the body. It gives rise to gametes or spores whose number of chromatids is equal to the ***haploid number*** of the species. Unlike mitosis which maintains the cell's original ***ploidy*** level, for example, one diploid (2n) parent cell producing two diploid (2n) daughter cells, ***meiosis*** reduces the number of sets of ***chromosomes*** by half so that when gametic recombination (fertilization) occurs, the ***ploidy*** of the parents will be re-established in the zygote. In sexually reproducing organisms therefore, ***meiosis*** is important as it maintains constancy of the gamete complement in the zygote; Male gamete (n) + female gamete (n) = zygote (2n)

(b) The Stages of Meiotic Cell Division

Meiosis involves two successive nuclear divisions; meiosis I and meiosis II. In meiosis I, the ploidy level of a cell is reduced from 2n to n (reduction division) while during meiosis II, the remaining set of ***chromosomes*** divides into a mitosis –like process (equational division). At the end of meiosis, four (4) haploid cells are produced from a single diploid germ cell.

First Meiotic Division (Meiosis I)

Interphase I

Meiosis is preceded by an interphase, during which each of the chromosomes replicates. This process is similar to the ***chromosome replication*** preceding mitosis. For each chromosome, the result is two genetically identical sister chromatids attached at their centromeres. The centriole pairs (in an animal cell) also replicate to form the two pairs represented in this Figure 9.9.

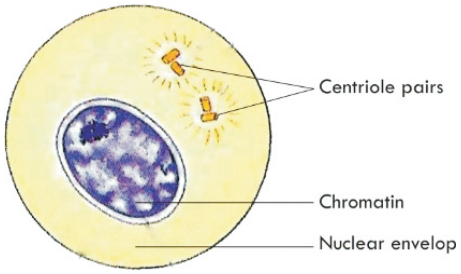


Figure 9.9: Interphase.
Source: Campbell (1993).

Prophase I

Three major events occur in this early stage of meiosis. They include: thickening of chromatin and coiling into visible chromosomes, synapsis of members of each ***homologous pairs*** of chromosomes, and crossing over (exchange of chromosomal parts) between homologs that are synapsed. The process of synapsis is said to occur when there is linking or coming together of the replicated ***homologous chromosomes***. The resulting chromosome is termed a tetrad, being composed of two chromatids from each chromosome, forming a thick (4-strand) structure (Figure 9.10). Owing to the complex nature of events that occur during prophase I, this stage has been further subdivided into five substages namely: Leptonema, zygonema, pachynema, ***diplonema*** and ***diakinesis***.

(i). **Leptonema (or Leptotene):** Here, the ***interphase*** chromatin material begins to condense and chromosomes become visible. Localized condensations resembling beads called chromosomes appear along each chromosome.

(ii). **Zygonema (or zygotene**): Here, chromosomes continue to shorten and thicken. Homologous chromosomes roughly align or pair with each other and this pairing is complete at the end of this stage. The paired homologs now take a form referred to as bivalents. At this stage, although both members of each bivalent have had their DNA replicated, it is not usually, apparent yet, and as such they may not be seen as double structured.

(iii). **Pachynema (or Pachytene):** In this phase, coiling and shortening of chromosomes continues, with further development of the ***synaptonemal complex*** between the two members of each bivalent. This leads to a closer pairing called synapsis. This pairing differs from the initial rough pairing observed in zygonema. In yeast chromosomes for example, ***homologs*** are now separated only by about 100nm, implying that complete synapsis takes place here. It is at this stage that each homolog first becomes evident as double structure thereby confirming that ***DNA replication*** in each chromosome had occurred earlier. Each bivalent at this point contains four member chromatids. The four member structure is called a tetrad, and each tetrad comprises two pairs of sister chromatids.

Diplonema (or ***Diplotene***): Each pair of sister chromatids begins to separate within each tetrad. Area where chromatids are interwined however remain in contact. These areas are called chiasmata (singular ***chiasma***) and are believed to be points where non-sister chromatids exchange genetic material, a process called ***crossing over***. Crossing over gives rise to new combinations of genetic material and is an important source of genetic variability.

(iv). **Diakinesis**: This is the final stage of prophase I. chromosomes are further pulled apart, with non-sister chromatids remaining loosely associated with the chiasmata. Terminalization (movement of chiasmata towards the end of the tetrad as separation proceeds) is completed here. Nucleolus and nuclear envelope break down and the two centromeres of each tetrad attaches to the newly formed spindle fibres.

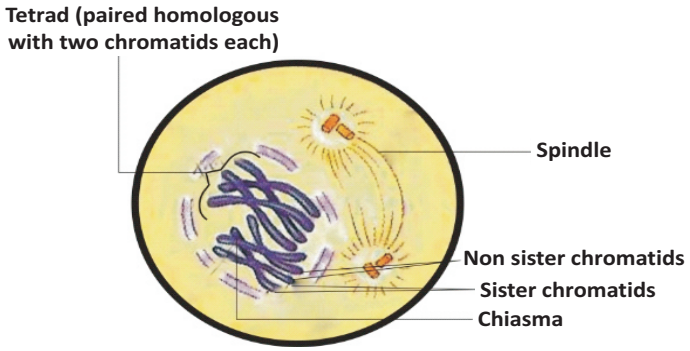


Figure 9.10: Prophase I.
Source: Campbell (1993).

Metaphase I

Chromosomes are now arranged on the ***metaphase plate***, still in homologous pairs. Spindle fibers from one pole of the cell attach to one chromosome of each pair, while spindle fibers from the opposite pole attach to the homologue (Figure 9.11).

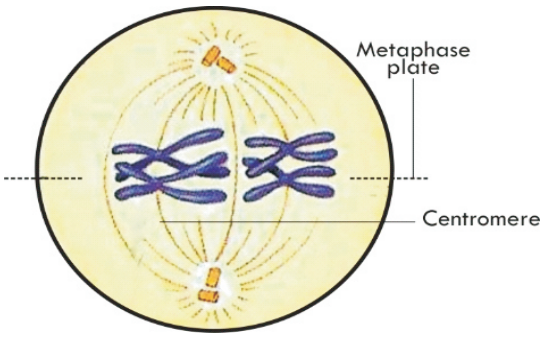


Figure 9.11: Metaphase I.
Source: Campbell (1993).

Anaphase I

As in mitosis, the spindle apparatus moves the chromosomes toward the poles. However, sister ***chromatids*** remain attached at their centromeres and move as a single unit toward the same pole. The homologous chromosome moves toward the opposite pole. This contrasts with behavior of chromosomes during mitosis. In mitosis, chromosomes align individually on the metaphase plate rather than in pairs, and the spindle separates sister chromatids of each chromosome (Figure 9.12).

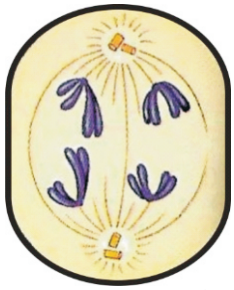


Figure 9.12: Anaphase I.
Source: Campbell (1993).

Telophase I
This stage usually reveals a nuclear envelope forming around the ***dyads***. The nucleus then enters into a short interphase period or in some other cases, the cells may proceed straight from telophase I to the second meiotic division (Figure 9.13).

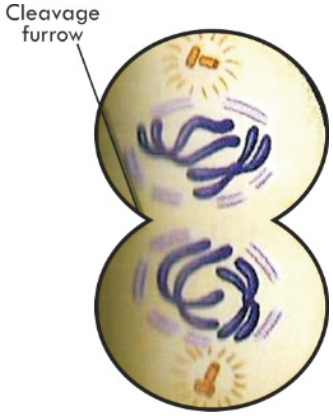


Figure 9.13: Telophase I and Cytokinesis.
Source: Campbell (1993).

Second Meiotic Division (Meiosis II)
Prophase II
The chromosomes coil and contract again; because of ***crossing over***, the chromatids are no longer identical with each other (see Figure 9.14). A spindle apparatus appears, and the chromosomes progress toward the metaphase II plate.

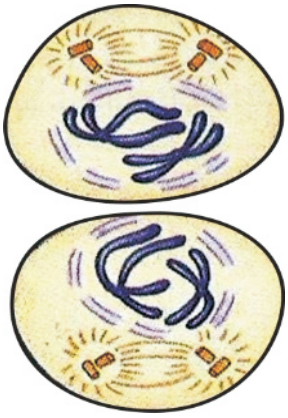


Figure 9.14: Prophase II.
Source: Campbell (1993).

Metaphase II
The chromosomes of each cell become aligned along their respective equators. The chromosomes align on the metaphase plate in mitosis-like fashion, with the ***kinetochores*** of sister chromatids of each chromosome pointing toward opposite poles (Figure 9.15).

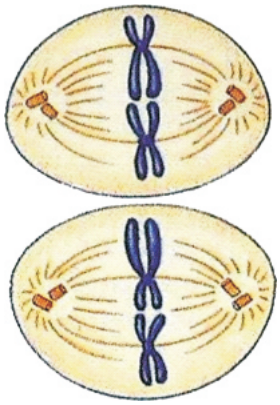


Figure 9.15: Metaphase II.
Source: Campbell (19 93).

Anaphase II

The chromatids separate completely and migrate to the poles. The centromeres of sister chromatids finally separate, and the sister ***chromatids*** of each pair, now individual chromosomes, move toward opposite poles of the cell (Figure 9.16).

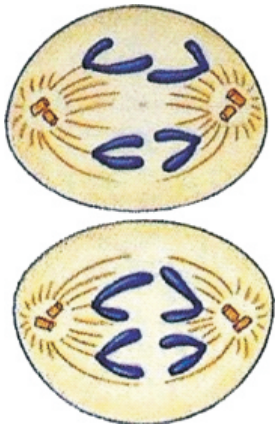


Figure 9.16: Anaphase II.
Source: Campbell (1993).

Telophase II and Cytokinesis

The four groups of ***chromatids*** (now called chromosomes again) are at the poles, new cell walls begin to form. Nuclei begin to form at opposite poles of the cell, and ***cytokinesis*** occurs. There are now four daughter cells, each with the haploid number of chromosomes (Figure 9.17).

Cytokinesis: This may occur in two successive stages, once after meiosis I and then after meiosis II, or in some instances it occurs only after meiosis II. Meiosis results in four ***haploid cells***.

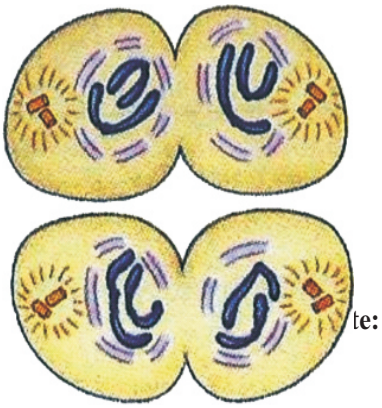


Figure 9.17: Telophase II and Cytokinesis.
Source: Campbell (1993).

9.9 DIFFERENCES BETWEEN MITOSIS AND MEIOSIS

Organisms grow and reproduce through cell division. The production of new cells occurs as a result of mitosis and meiosis. Below in Table 9.1 are some basic differences between the two processes.

Table 9.1: Differences between Mitosis and Meiosis

Mitosis	Meiosis
(i) Cell divides only once	There are two cells divisions. First meiotic division and the second meiotic division.
(ii) Takes place in somatic cells	Takes place in germ cell.
(iii) Duration of prophase is short (few hours)	Prophase comparatively longer (takes many days).
(iv) Prophase simple	Prophase complicated having five sub-stages namely leptotene, zygotene, pachytene, diplotene and diakinesis.
(v) Synapsis does not occur.	Synapsis of homologous chromosomes takes place during prophase.
(vi) No exchange of segments during prophase between two chromatids of chromosomes.	Exchange of segments during crossing over between non-sister chromatids of two homologous chromosomes.
(vii) Each chromosome consists of two chromatids united by a centromere.	Each bivalent has four chromatids and two centromeres.
(viii) Chromosomes are duplicated at the beginning of prophase.	In prophase I, chromosomes appear single although DNA replication has taken place in interphase I.

(ix) In metaphase all the centromeres line up in the same plane.	In metaphase I, the centromeres are lined up in two planes which are parallel to one another.
(x) The metaphasic plate is made up of duplicated chromosome.	The metaphasic plate is made up of paired chromosome.
(xi) Centromere division takes place during anaphase	No centromere divisions during Anaphase I, centromeres divide only during Anaphase II.
(xii) Spindle fibres disappear completely in telophase	Spindle fibres do not disappear completely during telophase I.
(xiii) Reappearance of nucleoli at telophase.	Nucleoli do not appear in telophase I.
(xiv) The chromosome number does not change at the end of mitosis.	There is reduction in the chromosome number from diploid to haploid.
(xv) The genetic constitution of daughter cells is absolutely identical to that of parent cells.	The genetic constitution of daughter cells is different as compared to the parent cells. the daughter cell chromosomes contain a mixture of maternal and paternal genes
(xvi) Mitosis is of shorter duration	Meiosis is of longer duration.
(xvii)It is the basis of growth and repair.	It is basis of maintaining chromosome number in sexual reproduction, as well as for providing variation in the progeny.

Source: *Morgan (2007)*

9.10 SIMILARITIES BETWEEN MITOSIS AND MEIOSIS

(i) Interphase is the same in mitosis and first division of meiosis, but there is however no interphase between telophase I and prophase II of meiosis.
(ii) Centrioles divide in both mitosis and meiosis at interphase. Doubling of chromosomes takes place in interphase stages in both mitosis and meiosis
(iii) Nucleolus gets dissolved in the nuclear materials at prophase in both mitosis and meiosis.
(iv) A spindle is laid down in the cytoplasm by the centrioles which divide in interphase.
(v) Both mitosis and meiosis forms new cells from pre-existing cells through cell division.

9.11 SIGNIFICANCE OF MITOSIS AND MEIOSIS

(a) Significance of Mitosis

Mitosis has the following significance for living organism;

(i) Mitosis helps the cell in maintaining proper size.
(ii) It helps in the maintenance of equilibrium in the amount of DNA and RNA in the cell.
(iii) The mitosis provides the opportunity for growth and development to organs and the body of the organisms.
(iv) The old decaying and dead cells of body are replaced by the help of mitosis.
(v) In certain organisms, the mitosis is involved in asexual reproduction.
(vi) The gonads and the sex cells depend on the mitosis for the increase in their number.
(vii)The cleavage of egg during embryogenesis and division of blastema during blastogenesis, both involve mitosis.

(b) Significance of Meiosis

(i) It helps to maintain constant number of chromosomes in a species undergoing sexual reproduction.

(ii) ***Meiosis*** occurs during gamete formation (***gametogenesis***) and reduces the number of chromosomes from diploid (2n) to haploid (n) in the gametes. These haploid gametes fuse to form diploid zygote during fertilization. The diploid zygote develops into a normal diploid individual.

(iii) Meiosis establishes new combination of characters due to (i) mixing of paternal and maternal chromosomes and (ii) crossing over during prophase I. As a result the ***progeny*** inherits the traits of both mother and the father in new gene combinations.

9.12 IMPORTANCE OF MITOSIS AND MEIOSIS TO LIVING ORGANISMS

(a) Importance of Mitosis to living Organisms

Mitosis is important during growth and development. Also specialization takes place as a result of mitosis. Repair of cells are possible through mitosis. Mitosis ensures maintenance exact copies of DNA andalso ensuresthat the sum total of inherited factors (gene) which are transmitted to the daughter cells is constant. Mitosis also ensures consistency of DNA configuration.

(b) Importance of Meiosis to living organism

(i) Meiosis is therefore the mechanism of distributing the hereditary units (genes) permitting their random independent recombination.

(ii) The study of meiosis is a pre-requisite for understanding of the chromosomal basis of genetics.

9.13 SOMATIC AND SEX CELLS

Two types of cells division are known which are mitosis and meiosis. That which involves body cells (***somatic cells***) is called mitosis and that which occurs in ***sex cells*** or gametes is meiosis. Somatic or body cells contains diploid number of chromosomes (2n); that is, each chromosome being contributed from both parents. However, in ***sex cells***, each ***sex cell*** or gamete (e.g. egg, sperm cells) contain only one chromosome (n). For example, your father has one X and one Y chromosome in all of his diploid cells, his genotype is XY and his phenotype is male. Upon the production of sperm cells, the X and Y chromosomes seperate and each sperm has either an X or a Y, but not both. How does this happen? The answer is meiosis. Hence, the cells of sex organs (sex cells) divide by meiosis. From the foregoing, ***sex cells*** divide by meiosis while body (***somatic cells***) divides by mitosis.

9.14 ALTERNATION OF GENERATIONS DURING MEIOSIS

Meiosis occurs at some point in life cycle of organisms that reproduce sexually. The chromosomes that result from the process constitute a complete set in each cell, since one member of every original pair ends up in each cell. The original chromosomal complement, consisting of two complete sets of chromosomes, is restored when gametes unite, forming a zygote.

Any cell having one set of chromosomes is said to be haploid (n), and any cell with two sets of chromosomes is said to be diploid (2n). By the time meiosis is complete; four haploid cells have been produced from one diploid cell. The gametes of any organism are haploid, while a zygote of the same organism is diploid (2n). This holds true regardless of the number of chromosomes peculiar to a given organism. We can state that an organism having n (a specified quantity) chromosomes in its haploid cells will have twice as many, or 2n, chromosomes in its diploid cells.

Sometimes, spindles may not form properly during meiosis or something else goes wrong, ultimately resulting in cells with more than one or two sets of chromosomes. Cells having three sets of chromosomes are said to be triploid (3n), and those with four sets are said to be tetraploid (4n). Since the ***homologous chromosomes*** of a ***triploidcell*** undergoing meiosis cannot pair properly.Any resulting gametes, if they survive, invariably produce a sterile individual.

In most animals, the only haploid cells (i.e. cells with n or a single set of chromosomes) are the gametes (egg and sperm) and the cells that become the gametes. In plants and other green organisms, however, this is generally not so. In a complete life cycle involving sexual reproduction, there is an alternation between a diploid (2n) ***sporophytephase*** and a haploid (n) ***gametophyte phase***. This is commonly referred to as ***Alternation of Generations***.

The diploid body itself is called a ***sporophyte***. It develops from a zygote and eventually produces sporocytes (meiocytes), each of which undergoes meiosis, producing four spores. The ***haploid bodies*** that develop from these spores are called ***gametophytes***. These eventually form sex structures, or cells, in which gametes are produced by mitosis. The ***gametophytes*** of many primitive forms constitute a large part of visible organism, but as we progress up through the plant kingdom to more complex plants, they become proportionately reduced in size until they may be only microscopic. The switch from one generation to the other takes place as spores are produced when sporocytes undergo meiosis and again when a zygote is produced through fusion of gametes, or fertilization (also called syngamy).

Although the ***sporophyte generation*** of some primitive organisms may consist of a single cell (the zygote), the basic plan of ***Alternation of Generations*** can be seen in the Protistan, Fungal, and Plant Kingdom, and it differs from one organism to the next in the forms of the various bodies and cells. In the accompanying diagram (see Figure 9.18), the following six rules pertaining to ***Alternation of Generations*** in the majority of plants and other green organisms; follow the cycle of any sexually reproducing organism.

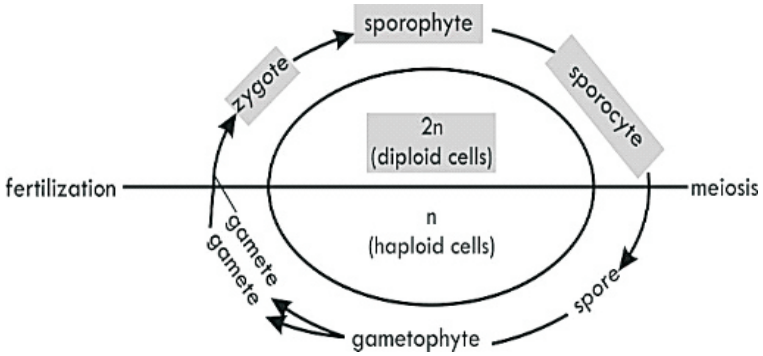


Figure 9:18: A typical life cycle of plants or related organisms that under sexual reproduction.
Source: Stern (2000).

(i) The first cell of any gametophyte generation is normally a spore (sexual spore or meiospore), and the last cell is normally a gamete.
(ii) Any cell of a ***gametophyte generation*** is usually haploid (n);
(iii) The first cell of any sporophyte generation is normally a zygote, and the last cell is normally a sporocyte (meiocyte);
(iv) Any cell of a ***sporophyte generation*** is usually diploid (2n);
(v) The change from a sporophyte to a gametophyte generation usually occurs as a result of meiosis;
(vi) The change from a gametophyte to a sporophyte generation usually occurs as a result of fertilization (fusion of gametes), which is also called ***syngamy***.
(vii) The word generation as used in Alternation of Generations simply means phase of a life cycle and should not be confused with the more widespread use of the word pertaining to time or offspring.

9.15 CHAPTER SUMMARY

- A cell cycle is a series of events that take place in a cell as it grows and divides.
- A cell spends most of its time in what is called interphase, and during this time it grows, replicates its chromosomes, and prepares for cell division.
- The cell then leaves interphase, undergoes mitosis, and completes its division.

- The resulting cells, known as daughter cells, each enter their own interphase and begin a new round of the cell cycle.
- A cell cycle is the name given to the process through which cells replicate and make two new cells. The cell cycle has different stages called G1, S, G2, and M.
- G1 is the stage where the cell is preparing to divide. To do this, it then moves into the S-phase, where the cell copies the entire DNA.
- So, S stands for DNA synthesis. After the DNA is copied and there is a complete extra set of all the genetic material, the cell moves into the G2 stage, where it organizes and condenses the genetic material, or starts to condense the genetic material, and prepares to divide.
- The next stage is M. "M stands for mitosis.
- This is where the cell actually partitions the two copies of the genetic material into the two daughter cells.
- After the m-phase is complete, cell division occurs, two cells are left, and the cell cycle can begin again.
- Cell division is the process in which one cell, called the parent cell, divides to form two new cells, referred to as "daughter cells."
- Cell division is simpler in prokaryotes than in eukaryotes because prokaryotic cells themselves are simpler.
- Prokaryotic cells have a single circular chromosome, no nucleus, and few other organelles.
- Eukaryotic cells, in contrast, have multiple chromosomes contained within a nucleus and many other organelles.
- All of these cell parts must be duplicated and then separated when the cell divides.
- Cell division is just one of several stages that a cell goes through during its lifetime. Mitosis deals with body chromosomes (autosomes of somatic cells), while meiosis acts on sex chromosomes.
- At the end of cell division, the diploid nature of an organism can be restored.

9.16 STUDENTS' PRACTICALACTIVITIES:

ACTIVITY 1: Stages of mitosis in root tip.

AIM: To observe and draw the stages of mitosis in root tip (see Figure 9.19)

MATERIALS

(i) Watch glass
(ii) Microscope
(iii) Growing root e.g. Onion, sunflower
(iv) Hydrochloric acid (1.0 mol dm^{-3})
(v) Ethanoic Orcein
(vi) Hot plate
(vii) Slides and cover slips
(viii) Filter paper
(ix) Mounted needle
(x) Razor blade

N/B: (Onion bulb should be suspended over a beaker of water for ten days before the experiment starts). This enables the roots to grow

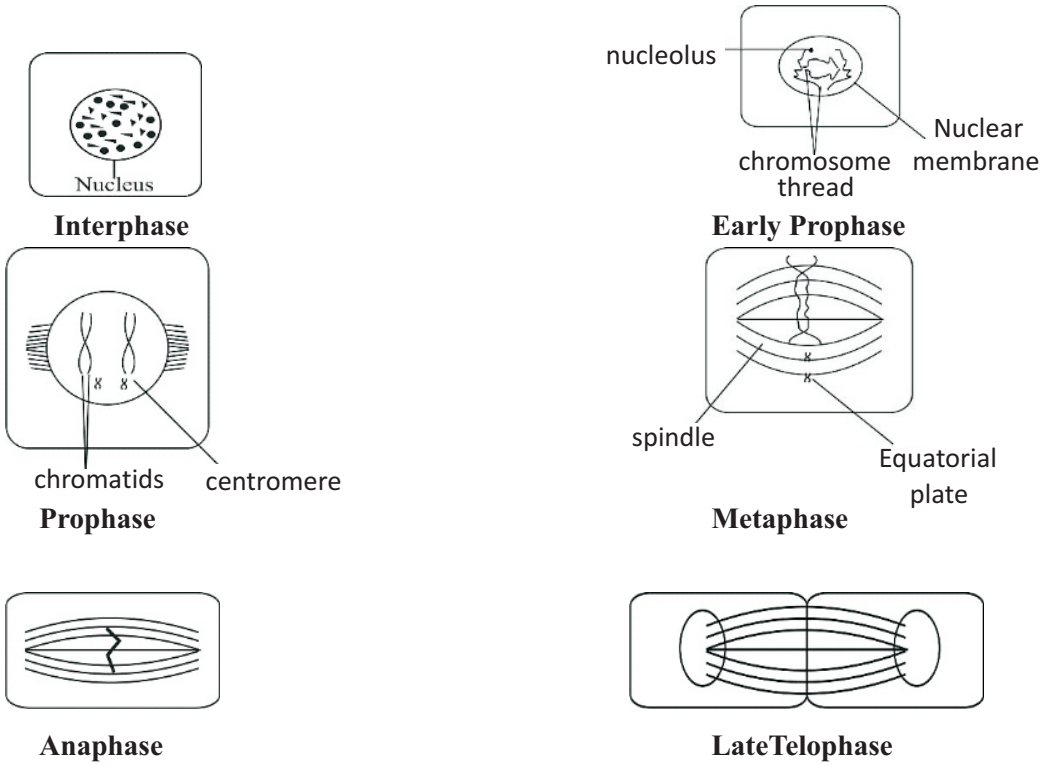
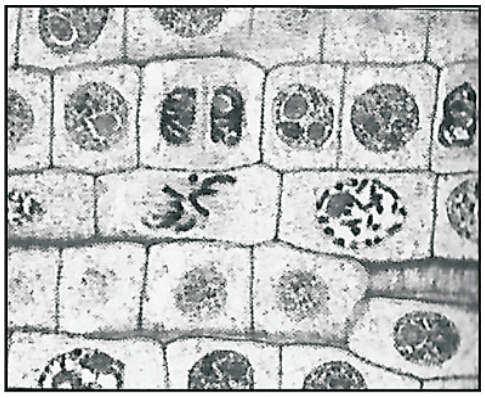


Figure 9.19: Observation of stages of mitosis in root tip.
Source: [Adapted from SRC Biology (2006): Philip Harris/itec].

PROCEDURE

(i) Cut off the apical 5mm from the tip of a growing lateral root of e.g. onion bulb.
(ii) Place the root tip in a watch glass containing ethanoic orcein stain and 1.0 mol dm^{-3} hydrochloric acid in the proportions of ten parts of stain to one part of acid.
(iii) Warm, but do not boil, for five minutes on a hot plate or on a watch glass gently heated over a Bunsen Flame. The acid helps to macerate (or breakdown) the tissue (why is this desirable?)
(iv) Place the stained root tip on a clean microscope slide. Cut it in half transversely and discard the half furthest from the apex.
(v) Add two or three drops of ethanoic orcein to the root tip on the slide.
(vi) Without interfering too much with the arrangement of the cells, break the root tip up with a needle so as to spread it out as thinly as possible.
(vii) Put on a coverslip, cover it with filter paper and squash gently. If necessary, irrigate with more stain.
(viii) Warm the slide on a hot plate for about ten seconds to intensify the staining. (The slide should be very warm, but not too hot to touch).
(ix) Examine the slides for stages in mitosis under high power.
(x) Supplement the information obtained from your own slide by observing (*Allium sepa*) Compare the slides with mitosis in the models.
(xi) Make annotated sketches of the four major stages of mitosis in your practical book showing the arrangement of chromosomes (see Figure 9.20).

OBSERVATION



Onion Root Tip
(Magnificatioin: 700x)

Figure 9.20: Observing the Root Apex Tip Cell/Tip of Onion (Allium cepa) Cell under the Microscope.
Source: Miller and Levine (2006).

DISCUSSION

(a) In what situations, apart from those studied here, would you expect to find mitosis taking place in animals and plants?
(b) Mitosis preserves the diploid state. Which particular events in mitosis ensure that this is so?
(c) Sometimes, search as one may, no dividing cells are visible in a root squash. Suggest possible reasons for this.

ACTIVITY 2: Stages of meiosis in an anther.
AIM: To observe the stages of meiosis in an anther
MATERIALS

(i) Forceps
(ii) Mounted needle
(iii) White tile
(iv) Microscope
(v) Glass rod
(vi) Slides and cover slips
(vii) Hand lenses or binocular microscope
(viii) Filter paper
(ix) Onion bulb
(x) Hydrochloric acid 1.0 mol dm^{-3}
(xi) Orcein

PROCEDURE

(i) Take anOnion bulb and remove the enveloping leaves so as to expose the inflorescence. The flower buds at the base of the inflorescence are the most advanced, those at the apex are the youngest. Make slides up of both areas.

(ii) Put on a cover slip, cover it with filter paper and squash gently. If necessary, irrigate with more stain.

(iii) Warm the slide on a hot plate for about ten seconds to intensify the staining. (The slide should be very warm, but not too hot to touch).

(iv) Examine the slide for stages in meiosis.

(v) Supplement the information gained from your own preparation by observing stages of meiosis in prepared sections of the anthers of e.g. lily. Compare with prepared sections of mammalian testis.

(vi) Record your observations.

DISCUSSION

a) In what situations, apart from the ones studied here, would you expect to find meiosis taking place?

b) Meiosis reduces the chromosomes number from diploid to haploid. Which particular events, in meiosis ensure that this is so?

c) What events in meiosis are similar to those that occur in mitosis?

9.17 TUTOR MARKED ASSESSMENT QUESTION

HAVING READ THROUGH **CHAPTER NINE**, ANSWER THE FOLLOWINGQUESTIONS IN THE SPACES PROVIDED.

(i) (a) Differentiate between Cell Cycle and Cell Division.

(I) Cell Cycle

$2\times\frac{1}{2}$ =1Marks

(ii) Cell Division

$2\times\frac{1}{2}$ =1Marks

(b) Name **Two** types of Cell Divisions.

$2\times\frac{1}{2}$ =1Marks

(c) Give **Two** examples each of life processes involved in each type of Cell Division.

$2\times\frac{1}{2}$ =1Marks

(d) Name **Two** types of Reproduction Usually Associated with Organisms.

$2\times\frac{1}{2}$ =1Marks

(2) (a) Explain briefly how the process of Meiotic Division contributes to variation in a population.

$4\times\frac{1}{2}$ =2 Marks

(b) Explain briefly the importance of Meiosis and Fertilization in the Reproduction of Organisms.

$4\times\frac{1}{2}$ =2 Marks

c) What is the significance of Mitosis? what events occur during each of the **Four** Mitotic Phases?

$6\times\frac{1}{2}$ =3marks

(3) (a) Define the term Cytokinesis?

$2\times\frac{1}{2}$ =1Marks

(b) Distinguish between haploid and diploid number of chromosomes.

$4\times\frac{1}{2}$ =2 Marks

c) In a Tabular Form State **Four** Differences Between Mitosis and Meiosis.

Drawing $4\times\frac{1}{2}$ =2 Marks

Labeling $6\times\frac{1}{2}$ =3 Marks

(d) What are the Events That Occur during Crossing-Over, and Why is This Process so Important?

$4\times\frac{1}{2}$ =2marks

4 (a) Define the Term Mitosis and Characterize its Main Stages?

(I) Meaning of Mitosis

$2\times\frac{1}{2}$ =1 Marks

(ii) Stages of Mitosis.

$2\times\frac{1}{2}$ =1 Marks

(b) In a Tabular Form Differentiate Between Somatic and Sex Cells.

Somatic Cells	Sex Cells

$4\times\frac{1}{2}$ =2Marks

(c)Draw a typical life cycle of plant showing alternation of generation during sexual reproduction and distinguish between gametophyte and sporophyte generation.

Drawing **$4\times\frac{1}{2}$ =2 Marks**
Lebeling **$10\times\frac{1}{2}$=5 Marks**

5 (a) What is the relationship between Haploid and Diploid Chromosome Numbers and Meiosis and Fertilization?

(I) Relationship between Haploid and Diploid Chromosomes.

$4\times\frac{1}{2}$ =2 Marks

(ii) Relationship between Meiosis and Fertilization.

$4\times\frac{1}{2}$ =2 Marks

(b) What is the principal difference between Zygotic Meiosis, Gametic Meiosis, Andsporic Meiosis?

$4\times\frac{1}{2}$ =2 Marks

(c) Term "how is a Sporophye different from a Gametophyte and what is meant by the Alternation of Generations"?

$4\times\frac{1}{2}$ =2 Marks

(i) Differences between Saprophyte and Gametophyte

Sporophtye	Gametophyte

$4\times\frac{1}{2}$ =2 Marks

(ii) What is "Alternation of Generations".

$2\times\frac{1}{2}$ =1 Marks

CHAPTER TEN

DIVERSITY IN PLANT AND ANIMAL CELLS

Dr. Ubong E. Harrison & Emem M. Eshiet

10.1 INTRODUCTION

All the cells are not identical. Cells vary in shape, size, ecological requirements, and function, but in most cases, the structural features of cells are related to the functions of such cells. In the plant kingdom, there is a great diversity that exists in size among the cells of ***mycoplasmas***, bacteria, algae, fungi, and also the very complex cell types found in higher plants. Furthermore, in the same plant, there are differences in size, shape, and internal content among ***parenchyma***, ***collenchyma***, and ***sclerenchyma*** cells, even though all of them are found in the same plant. In addition, the ***palisade cells*** of the leaf differ from the spongy cells even though they constitute the mesophyll layer. The ***guard cells***, or root hair cells, and other epidermal cells differ from one another in several ways.

In animals, a diversity of variation occurs among unicellular forms such as *amoeba*, *paramecium*, *plasmodium*, etc. For instance, the functions of cells in animals can be appreciated using human beings. For instance, muscle fiber cells differ from bone marrow cells just as sperm cells differ from those of other cells. Also, ***epithelial cells*** differ from nerve cells, which differ from blood cells.

10.2 LEARNING OBJECTIVES

After reading this chapter, you should be able to:

(i) Discuss the forms in which living cells exist.
(ii) Differentiate with examples between cells in plants and animals.
(iii) State the characteristics of monera.
(iv) Classify plant tissues.
(v) Classify animal tissues.
(vi) Describe the characteristics and structure of fungi.
(vii) State the economic importance of protists.
(viii) Explain the reproduction in fungi.
(ix) State the uses of fungi.

10.3 FORMS IN WHICH LIVING CELLS EXIST

While appreciating the fact that cells combine to form tissues and aggregate to form organs and organs aggregate to form system and make up organisms in complex (higher) organisms, cells are known to exist in some other forms or level of associated and organization. Forms in which living cells exist include ***unicellular (Single Cell)***, colonial and ***filamentous*** and multi-cellular.

(a) Unicellular (single or free-living)

Sometimes, a cell is the organism. ***Unicellular organisms*** are single-celled organisms which are capable of living freely and independently. In the Animal Kingdom, some of the protozoan such as *Amoeba*, *Paramecium*, *Euglena* and *Plasmodium* exist as ***unicellular organisms***. In plant Kingdom too, the *Chlamydomonas* exist as a unicellular organism.

(b) Colonial or Colony

These are cells which associate to form colonies. Usually, several individual cells aggregate together; secrete a ***gelatinous matrix*** into which they are then embedded to carry out life processes. In colonial cells, each cell can exist on its own but may or may not benefit from other cells in the colony. In other-words, a single cell can be the smallest possible unit and potentially grow into an entire colony. Examples are found in *Volvox*, *Pandorine*, *Eudorina* (all ***algae***) and slime moulds (a fungus) and sponges.

(c) Filamentous or filament:

Living cells may exist as a filament. Example of such living thing is a *spirogyra*. *Spirogyra* is a common ***green filamentous algae***. Many *spirogyra* filaments are held together by slimy ***mucilage***. Other examples of ***filamentous*** forms are *Chladophora, Ulothrix* and *Zygnema* etc.

(d) Multicellular Organisms

Are organisms that are made up of many cells in which individual cells associate or rather form part of a large complex structure. This is common in higher plants and animals. Each cell in a ***multi-cellular organism*** cannot exist and function alone; they depend on other cells to survive. In ***multi-cellular organisms***, cells are specialized to carry out specific tasks. For instance, in higher animals, the red blood cells are specialized to transport oxygen while the ***muscle cells*** make it possible for the animals to move. Similarly, in higher plants, the guard cells in the stomata of leaves regulate exchange of carbon (iv) oxide, oxygen and water vapour.

(e) Autotrophic and Heterotrophic Cells

All living things need energy to keep them alive and function. This energy comes either from sun or from food. Plants and some other types of organisms produce their food by being able to use the light energy from the sun. Such organisms that can produce their own food are called autotrophs. Green plants are therefore autotrophs. These organisms are composed of autotrophic cells e.g. the cells in the green leaf of a plant. In contrast, other organisms such as animal cannot use the sun's energy to produce their own food. Organisms that have to take their food from other living things in order to obtain nourishment are called Heterotrophs. ***Heterotrophs*** depend on autotrophs for survival. All animals are Heterotrophs and they obtain energy from the food they consume. Thus Heterotrophs have ***heterotrophic cells***.

10.4 DIFFERENCES AMONG CELLS IN PLANTS AND ANIMALS

Organisms have been grouped into five kingdoms. Cells from organisms in the five kingdoms are alike in some ways. Monerans, protist, fungal, plant and animal cells are all made up of the same organic chemicals, proteins, carbohydrates, lipids and nucleic acids. All cells have ***cytoplasm*** and cell membrane. Also, all cells have ***hereditary materials*** at sometimes in their existence. However, the five kingdoms differ from one other in some important ways and most of these differences arise from the kinds of the organelles the cell has. These differences among cells offer an important way to group organism within the five kingdoms.

10.4.1 Monera cells

Kingdom Monera belongs to the prokaryote family. They are the simplest organisms with no true nucleus (Figure 10.1). These are the oldest (primitive) microorganisms on earth. Their DNA is not enclosed within the nucleus. They are ***unicellular organisms*** found mostly in moist environments. They are found in hot springs, snow, deep oceans, or as parasites in other organisms. The monerans do not possess any membrane – bound organelles.

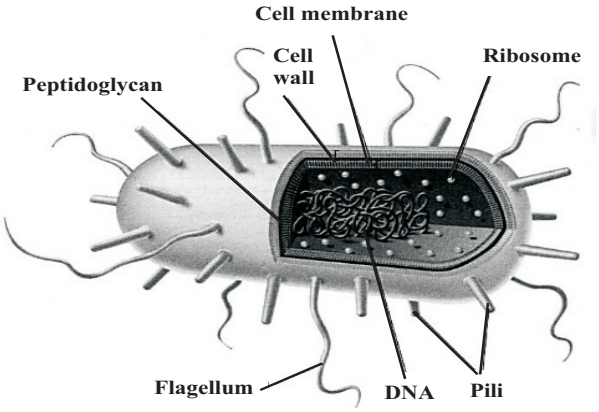


Figure10.1: Moneran cell(Bacterium).
Source: Miller and Levine (2006).

(a) Characteristics of Monera

(i). The monerans are unicellular organisms.
(ii). They contain Ribosomes
(iii). The DNA is naked and is not bound by a nuclear membrane.
(iv). They lack organelles like mitochondria, lysosomes, plastids, golgi bodies, endoplasmic reticulum and centrosome.
(v). They reproduce asexually by binary fission or budding.
(vi). Their cell wall is rigid and made up of peptidoglycan.
(vii). Flagellum serves as the locomotory organ.
(viii). They are environmental decomposers.
(ix). They show different modes of nutrition such as autotrophic, parasitic and heterotrophic.

(b) Classification of Monera

Kingdom Monera is classified into three sub-kingdoms;

(i) Archaebacteria

These are the most ancient bacteria found in the most extreme habitats such as salty area (halophiles), hot springs (thermophiles) and marshy areas (methanogens).

The structure of the cell wall is different from that of the other bacteria which helps them to survive in extreme condition and the nucleotide sequences of its tRNA and rRNA is unique.

(ii) **Eubacteria**

Eubacteria are also known as true bacteria. The cell wall is rigid and made up of peptidoglycans. It moves with the aid of flagella but a few contain short appendages on the cell surface, known as pili which help the bacteria during reproduction. Pili also help a pathogen to attach to the host. They are divided into two categories; Gram – positive and Gram- negative depending upon the nature of the cell wall and their stainability. Examples are *Pseudomonas* and *Clostridium*.

(iii) **Cyanobacteria**

These are also known as blue – green algae and are photosynthetic in nature. They contain chlorophyll, carotenoids and ***phycobilins***. Some of them even fix atmospheric nitrogen to the soil. Examples are *Nostoc*, *Anabaena* and *Spirulina*.

(c) Importance of Monerans

(i) They enrich the soil and serve as important part of the ***nitrogen cycle***.
(ii) They are also helpful in the production of some food items and antibiotics.
(iii) ***Methanogens*** play an important role in the treatment of sewage.
(iv) Many organisms rely on ***archaebacteria*** as the source of food.
(v) They take part in decomposition of organic matter.
(vi) Tools for scientific research.

10.4.2 Protist cells

The term "Protista" is derived from the Greek word "protistos", meaning "the very first". These organisms are usually unicellular and the cell of these organisms contains a nucleus which is bound by membrane. Some of them even posses structure that aids locomotion like flagella or cilia. Protists are simple eukaryotic organisms that are neither plants nor animals or fungi. Most protists live in water, damp terrestrial environment or even as parasites (see Figure 10.2). It is a collection of those eukaryotic species that do not fit properly into the main eukaryotic kingdom. They are regarded as similar to ancestors of modern animals, plants and fungi.

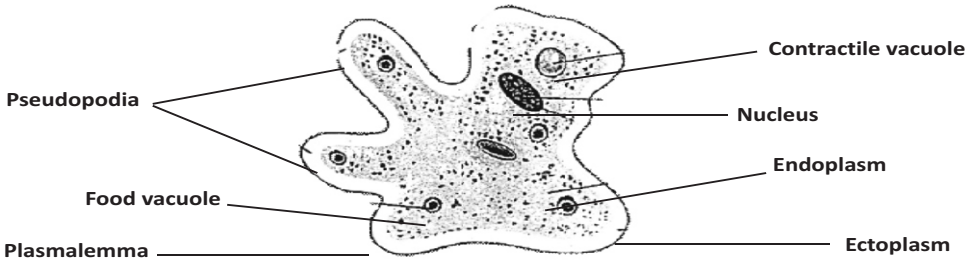


Figure 10.2: The Structure of a protist cell (Amoeba proteus).
Source: Ramalingan (2005).

(a) Characteristics of Kingdom Protista

(i) They are usually aquatic, present in the soil or in areas with moisture.
(ii) Most protist species are unicellular organisms; however, there are few multicellular protists such as Kelp.
(iii) Just like any other eukaryotes, the cells of these species have a nucleus and membrane – bound organelles.

(iv) They may be autotrophic or heterotrophic in nature

(v) ***Symbiosis*** is observed in the members of this class. For instance, kelp (seaweed) is a multicellular protist that provides otters protection from ***predators*** amidst its thick kelp. In turn, the otters eat sea urchins that tend to feed on kelp.

(vi) Parasitism is also observed in protists. Species such as *Trypanosoma* protozoa can cause sleeping sickness in humans.

(vii) ***Protists*** exhibit locomotion through cilia and flagella. A few organisms belonging to ***kingdom Protista*** have Pseudopodia that help them to move.

(viii) Protista reproduces by asexual means. The sexual method of reproduction is extremely rare and occurs only during times of stress.

(b) Classification of Protista

(i) Protozoa

The protozoans can be divided into four major groups:

- **Amoeboid protozoans**: mostly found in water bodies, either fresh or saline. They have Pseudopodia (false feet) which help to change their shape and in capturing and engulfing food e.g *Amoeba*.
- **Flagellated Protozoans**: As the name suggests, the members of this group have flagella. They can be free- living as well as parasitic e.g. *Euglena*.
- **Ciliated Protozoans**: they have cilia all over their body which help in locomotion as well as nutrition. They are always aquatic e.g. *Paramecium*.
- **Sporozoans**: These organisms are so – called because their life cycle has a spore – like stage. For example, the malarial parasite, *Plasmodium*.

(ii) **Slime moulds**

Slime moulds are saprophytic organisms (they feed on dead and decaying matter). Slime moulds are characterized by the presence of aggregates called plasmodium and are even visible to the naked eye.

(iii) **Chrysophytes**, Dinoflagellates and Euglenoids

These form another category under ***kingdom Protista***. These are generally single – celled or multicellular organisms. These are photosynthetic, found mostly in freshwater sources or marine lakes. They are characterized by a stiff cell wall. Example of chrysophytes includes diatoms and golden ***algae***. They are characterized by the presence of a hard siliceous cell wall.

Diatomaceous earth is formed due to the accumulation of cell wall deposits. They are photosynthetic organisms.

Dinoflagellates are photosynthetic and found in various different colours, according to the pigment present in them. They show ***bioluminescence*** and known to cause red tide.

Euglenoids are the links between plants and animals. They lack a cell wall but perform photosynthesis. In the absence of sunlight, they act as a heterotroph and feed on small organisms. The outer body covering is a protein – rich layer known as a pellicle as in Euglenoid species.

(c) Economic Importance of Protists

(i) Protists serve as the foundation of the food chain

(ii) Protists are symbionts – having close relationships between two species in which, one is benefited.

(iii) Some protists also produce oxygen and may be used to produce biofuel.

(iv) Protists are the primary sources of food for many animals.
(v) In some rare cases, protists are harvested by humans for food and other industrial applications.
(vi) **Phytoplankton** is one of the sole food sources for whales.
(vi) Seaweed is an alga, which is considered a plant – like protist.
(vii) **Zooplankton** is fed on by various sea creatures including shrimp and crabs.

10.4.3 Fungal cells

Fungi are eukaryotic organisms that include yeasts, moulds, Truffles, mushrooms. These organisms are classified under kingdom fungi. The organisms found in kingdom fungi contain a cell wall and are omnipresent (Figure 10.3). They are classified as heterotrophs among the living organisms.

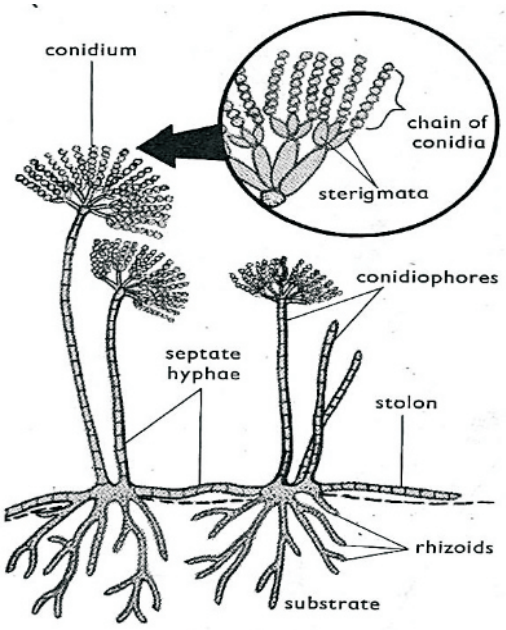


Figure 10.3: The structure of a fungal cell (Penicillium notatum).

Source: Ramalingan (2005).

(a) **Structure of Fungi**

The structure of fungi can be explained as follows:
(i) Almost all fungi have filamentous structure except the yeast cells.
(ii) They can be either single-celled or multicellular organisms.
(iii) Fungi consist of long thread – like structures known as hypae. These hyphae together
form a mesh – like structure called mycelium.
(iv) Fungi possess a cell wall which is made up of chitin and polysaccharides.
(v) The cell comprises protoplast which is differentiated into other cell parts such as cell membrane, cytoplasm, cell organelles and nuclei.
(vi) The nucleus is dense, clear, with chromatin threads, surrounded by a nuclear membrane.

Classification of fungi

The kingdom fungi are classified based on different modes. The different classification of fungi is as follows:

(a) Based on mode of nutrition, kingdom fungi can be classified into three groups

(a). Saprophyte: The fungi obtain their nutrition by feeding on dead organic substance. Examples are *Rhizopus*, *Penicillium*and *Aspergillus*

(b) Parasitic: The fungi obtain their nutrition by living on other living organisms (plants or animals) and adsorb nutrients from their host. Examples are *Taphrina and Puccinia*.

(c) Symbiotic: These fungi live by having an interdependent relationship or association with other species in which both are mutually benefited. Examples are Lichens and mycorrhiza.

(b) Based on spore formation: kingdom fungi are classified into the following based on the formation of spores:

(a). **Zygomycetes**: These are formed by the fusion of two different cells. The sexual spores are known as zygospores while the asexual spores are known as sporangiospores. The hyphae are without the septa.

(b) **Ascomycetes**: These are also called sac fungi. They can be coprophilous, decomposers, parasitic or saprophytic. The sexual spores are called ascospores. Asexual reproduction occurs by ***conidiospores*** e.g. *Saccharomyces*.

) **Basidiomycetes**: Mushrooms are the most commonly found basidiomycetes and mostly live as parasites. Sexual reproduction occurs by basidiospores. Asexual reproduction occurs by conidia, budding or fragmentation e.g *Agaricus*.

(d) **Deuteromycetes**: They are otherwise called imperfect fungi as they do not follow the regular reproduction cycle as the other fungi. They do not reproduce sexually. Asexual reproduction occurs by conidia e.g ***Trichoderma***.

(d) Reproduction in Fungi

Reproduction in fungi is both by sexual and asexual means. The sexual mode of reproduction is referred to as teleomorph and the asexual mode of reproduction is referred to as anamorph.

(a) Vegetative reproduction – By budding, fission and fragmentation

(b) Asexual reproduction: This takes place with the help of spores called conidia or Zoospores or ***Sporangiospores***.

(c) Sexual reproduction: ***Ascospores***, ***basidiospores*** and ***oospores***.

(e) **Uses of fungi**

(i) **Recycling:** they play a major role in recycling the dead and decayed matter.

(ii) **Food:** mushrooms species are edible which are cultured and are used as food by humans.

(iii) **Medicines:** There are many fungi which are used to produce antibiotics, to control diseases in humans and animals. ***Penicillin antibiotics*** are derived from a common fungi penicillium.

(iv) **Biocontrol Agents:** Fungi are involved in exploiting insects, other small worms andhelp in controlling pests. Spores of fungi are used as spray on crops.

(v) **Food spoilage:** Fungi play a major role in recycling organic material and are alsoresponsible for major spoilage and economic losses of stored food.

10.4.4 Cells in Plant Kingdom

Kingdom plantae includes all the plants. They are eukaryotic, multicellular and autotrophic organisms. The plant cell contains a rigid cell wall. Plants have chloroplast and **chlorophyll pigment**, which is required duringphotosynthesis (see Figure 10.4).

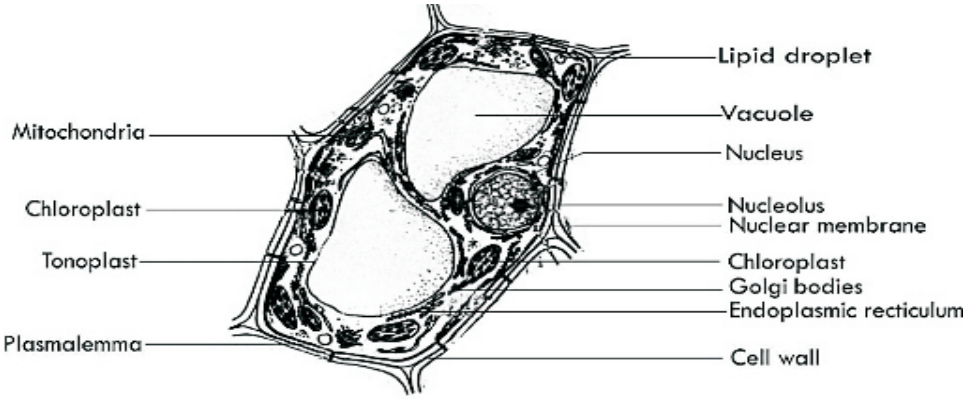


Figure 10.4: Plant cell as seen with light and electron microscopes.
Source: (Walter, 1988).

Characteristics of Kingdom Plantae

(i) They are non – motile.
(ii) They make their own food hence are called autotrophs.
(iii) They reproduce asexually by ***vegetative propagation*** or sexually.
(iv) These are multicellular eukaryotes. The plant cell contains the outer cell wall and a large central vacuoles.
(v) Plants contain ***photosynthetic pigments*** called chlorophyll present in the plastids.
(vi) They have different organelles for anchorage, reproduction, support and photosynthesis.

(b) Classification of Kingdom Plantae

A plant kingdom is further classified into subgroups. Classification is based on the following criteria:

(i) Plant body: Presence or absence of a well-differentiated plant body e.g. Root, stem and leaves.
(ii) Vascular System: Presence or absence of a vascular system for the transportation of water and other substances e.g. ***phloem*** and ***xylem***.
(iii) Seed formation: Presence or absence of flowers and seeds and if the seeds are naked or enclosed in a fruit.

The plant kingdom has been classified into five subgroups according to the above mentioned criteria:

(a) Thallophyta: Thallophytes lack a well – differentiated body structure and the plant body is thallus-like. ***Thallophyta*** includes plants with primitive and simple body structure. The plant body is thallus,it may be filamentous, colonial, branched or unbranched. Examples include green algae, red algae and brown algae. Common examples are Volvox, Fucus, *Spirogyra*, Chara, Polysiphonia and Ulothrix, etc.

(a) **Bryophyta**: Bryophytes do not have vascular tissues. The plant body has root – like, stem-like, and leaf – like structures. Bryophytes are terrestrial plants but known as "amphibians of the plant kingdom" as they require water for sexual reproduction. They are present in moist and shady places. ***Bryophyta*** includes mosses, hornworts and liverworts. Common examples are Marchantia, Funaria, Sphagnum and Antheoceros, etc.

(b) **Pteridophyta**: ***Pteridophytes*** have a well-differentiated plant body into roots, stems and leaves. They have a vascular system for conduction of water and other substances. Some of the common examples are *Selaginella*, *Equisetum*, *Pteris*, etc.

(c) **Gymnosperms**: ***Gymnosperms*** have a well – differentiated plant body and vascular tissues. They bear naked seeds i.e. seeds are not enclosed within a fruit. Some of the common examples of ***gymnosperms*** are *Cycas*, *Pinus* and *Ephedra,* etc.

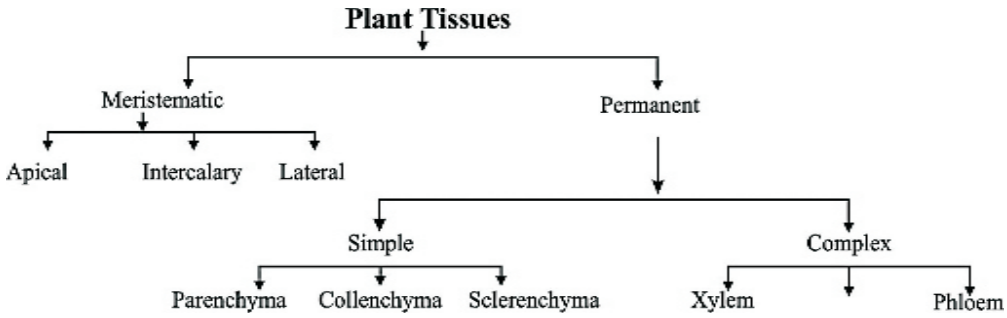
(d) **Angiosperms**: ***Angiosperms*** are seed–bearing vascular plants with a well-differentiated plant body. The seeds of ***angiosperms*** are enclosed within the fruits. ***Angiosperms*** are widely distributed and vary greatly in size, e.g. wolffia is small measuring about 0.1cm and ***Eucalyptustrees*** are around 100cm tall. ***Angiosperms*** are further divide into ***monocotyledons*** and ***dicotyledons*** according to the number of cotyledons present in the seeds. Some of the common examples are mango, rose, tomato, onion, wheat and maize, etc.

The plant kingdom is also classified into two main groups

i. **Cryptograms**: Non-flowering and non-seed bearing plants e.g. Thallopyta, Bryophyta and ***Pteridophyta***.

ii. **Phanerograms**: Flowering and ***seed-bearing*** plants e.g. ***Gymnosperms***, ***Angiosperms***.

10.5 CLASSIFICATION OF PLANT TISSUES



Epidermal, Guard and Photosynthetic Cell in Plants

(i) . **Epidermal Cell:** This is the cell that includes several types of cells that make up the epidermis of plants. Although they serve a number of important functions, their primary role is protection from a variety of harmful factors (environmental stressors) including microbes, chemical compounds as well as ***ultraviolet light*** among others. These cells situate very close together to prevent water loss as a protective mechanism. The cell layer covers the seed, stem, root and leaves of a plant.

(ii). **Guard Cell:** Specialized cell in the epidermis of plants that controls the opening and closing of stomata by responding to changes in water pressure. They are produced in pairs with a gap between them that forms a ***stomatal pore***.

(iii). **Photosynthetic Cell:**

Photosynthetic cells contain special ***pigments*** that absorb light energy, which are characteristically found in plants and possessed various shapes and forms. They are packed with chloroplasts and they perform the task of building up complex molecules. Examples are ***palisade cells*** of leaf.

10.5.1 Cells in Animal Kingdom

The kingdom Animalia constitutes all animals. Amongst the five kingdoms, the largest kingdom is the animal kingdom. Animals are multicellular eukaryotes (see Figure 10.6). However, unlike plants, they do not posses chlorophyll or a cell wall. Therefore, members of the animal kingdom exhibit a heterotrophic mode of nutrition. Kingdom Animalia has been classified into ten different sub-phyla based on their body design or differentiation. The different phyla of the animal kingdom are as follow:

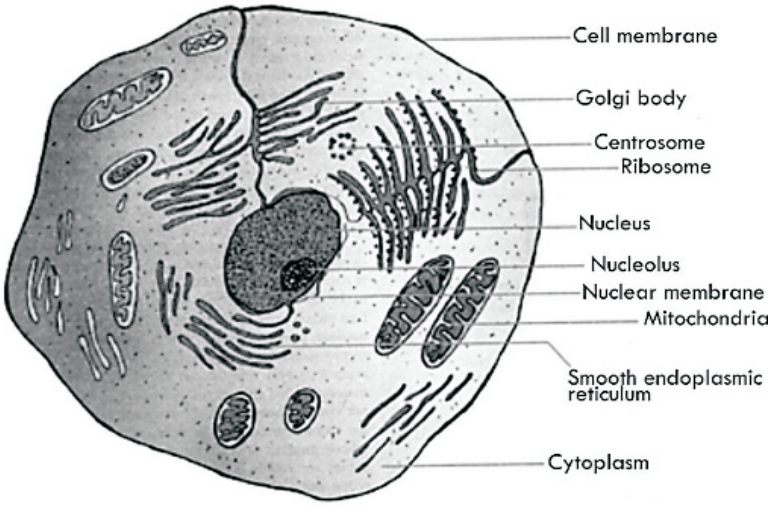


Figure 10.6: Animal cell.
Source: (Ndu et al, 2013).

(a) Phylum Porifera

Porifera means organisms with holes. They are commonly known as sponges. Features of the poriferans are:

(i) Non – motile, multicellular organisms with the hard outer skeleton.
(ii) Have a porous body.
(iii) Pores on the bodies create a canal system which helps in the circulation of substances.
(iv) Not differentiated into head and tail; do not have a well – developed organ or organ system.
(v) Examples of phylum porifera are spongilla, sycon.

(a) Phylum Coelenterata (*Cnidaria*)
The term coelenterate is derived from the Greek word "Kilos" which means hollow-bellied. Their features are:
(a) Have a hollow ***body cavity*.**
(b) The body is differentiated into two ends.
(c) The body is made of two layers of cells; Inner and outer linings.
(d) Live in colonies (corals) as well as solitary **(**Sea anemones**)**
(e) Example of phylum coelenterate includes – Hydra and Jellyfish.

(b) Phylum Platyhelminthes:
Platyhelminthes are commonly known as flatworms. Their features are:
(a) Dorsoventrally flattened body
(b) Complex and have differentiated body structure
(c) ***Tissues*** are differentiated from three layers of cells and are ***triploblastic***.
(d) Do not have a true internal cavity or coelom
(e) Have ***bilateral symmetry***
(f) Either free – living (planaria) or Parasitic (liver Flakes)
(g) Examples include Tapeworm and planaria

(c) Phylum Nematoda: The phylum Nematoda consists of nematodes or roundworms. Their features are:
(a) Nematodes have a cylindrical body
(b) Bilaterally symmetrical and triploblastic
(c) Have ***pseudocoelom***, a false body cavity
(d) Parasitic and causes diseases such as elephantiasis, ascariasis.
(e) Examples include **Ascaris, Wuchereria**

(d) Phylum Annelida: Annelids are commonly known as segmented or ringed worms. They have the following features:
(a) Have a segmented cylindrical body
(b) The body is different into head and tail.
(c) Bilaterally symmetrical and ***triploblastic*.**
(d) Have a true body cavity.
(e) Habitats are marine, freshwater and land.
(f) Examples are Earthworm and Leech.

(e) Phylum Arthropoda: Arthropod means jointed lags. Animals which have jointed appendages belong to this phylum. It is the largest phylum in the animal kingdom. They are divided into five subphyla (trilobitomorpha and the class is Trilobites (extinct); myriapoda and classes are Chilopoda, Diplopoda, Pauropoda and Symphyla; Chelicerata and classes are Arachnids, Xiphossura, Pycnogonida; Crustacea and classes are Remipedia, Cephalocarida, Branchiopoda, Maxillopoda and Malacostraca; Hexapoda and classes are Collembolan, Diplura, Protura and Insect.

Features of Arthropods are:

(i) They are bilaterally symmetrical
(ii) Have jointed appendages, exoskeleton, and a segmented body
(iii) Have well – differentiated organs and organ system
(iv) Have an open circulatory system, but do not have differentiated blood vessels.
(v) Examples are spiders, butterflies, Grasshopper and mosquitoes, etc.

(a) Phylum Mollusca: Features include:

(i) Bilaterally symmetrical and triploblastic;
(ii) Less segmented body;
(iii) Well – developed organs and organ system;
(iv) Typically, open circulatory system;
(v) Limbs are present;
(vi) Examples are snails and octopus.

(b) Phylum Echinodermata: The term Echinodermata is derived from the Greek words "echinos" meaning hedgehog and "derma" meaning skin. Thus, echinoderms are spiny – skinned animals. Features are;

(i) Radial symmetry and triploblastic;
(ii) Have true coelom;
(iii) Have hard calcium carbonate skeleton structure;
(iv) Free – living marine animals;
(v) Examples are sea-urchins**,** starfish.

(c) Phylum Hemichordata: Features are:

(i) The body is soft, fragile, and divided into proboscis ;
(ii) The epidermis is single – layered;
(iii) They have an open circulatory system;
(iv) They respire through gills since they are marine;
(v) They have separate sexes and external fertilization is seen;
(vi) Development is direct.

(d) Phylum Chordata: Features are:

(i) They are bilaterally symmetrical, triploblastic with an organ – system level of classification.
(ii) They possess a notochord and a nerve cord
(iii) The circulatory system is closed type.

The phylum chordate can be divided into following subphyla, ***urochordata*****,** ***Cephalochordata*** and Vertebrata.

10.6 CELLS IN ANIMAL TISSUE

(a) Epithelial Cells

Epithelial tissue is commonly referred to as epithelium. The epithelial tissue forms the outer covering or lining of some part of the body. It is composed of closely packed cells arranged in flat sheets. An epithelial tissue forms the surface of skin, line many cavities of the body and covers the internal organs. There are two types of ***epithelial tissues***-simple epithelium and compound epithelium.

As the name implies, simple epithelium is composed of single layer of cells. It functions as a lining of cavities of body, ducts and tubes. Compound epithelium also known as ***stratified epithelium*** is made up of two or more cell layers. It functions as a protective covering, as it does in our skin.

Simple epithelium is further classified into three types Viz:

(i) **Squamous Epithelium:** Single layered, irregular, thin and flat. It is found in the walls of blood vessels and in air sacs of lungs. Itis involved in functions like forming diffusion boundary. This cell is often less than 2.0 m thick. It is found in regions where the protective covering needs to be readily permeable to molecules of substances in solution. However, this type of epithelium often occurs where molecules need to pass through membrane during the process of absorption, for example the lining of capillaries and al

Figure 10.7: Squamous Epithelium cells.

Source: Robert (1976).

(ii) **Cuboidal Epithelium:** Component of single layered cube-like cells, they are commonly found in ducts of glands, surface of ovaries, lining of nephrons, renal tubules and parts of the eye and thyroid, along with the salivary glands. Their main functions are secretion and absorption (see Figure 10.8).

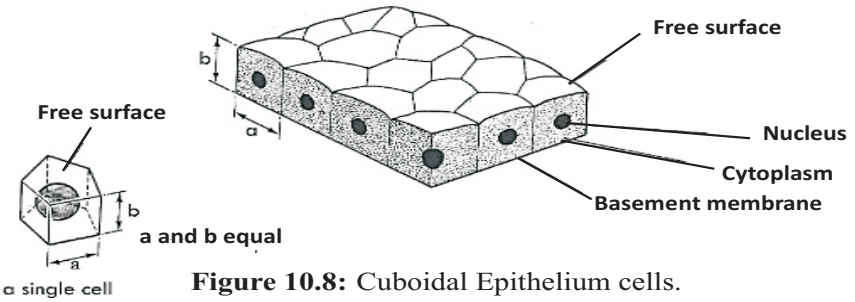


Figure 10.8: Cuboidal Epithelium cells.

Source: Robert (1976).

(iii) **Columnar Epithelium:** This type of epithelium consists of single layered of tall and slender cells which are found in the stomach lining and intestine (see Figure 10.9). It helps in secretion and absorption.The cells elongatedand column-shaped and have a height of at least four times their width. Their nucleus are usually located near the base of the cells. Examples of such cells are those lining the fallopian tubes, repiratory tract, sex organs, pharynx, etc.

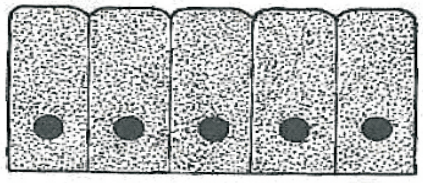


Figure 10.9: Columnar Epithelium cells.

Source: Oduebo (1984).

(iv) **Ciliated epithelium:** This is a specialized form of lining tissue. Usually columnar in shape, the free surface of each cell bears numerous cilia capable of beating rapidly and rhythmically. In the mammal ***ciliated epithelium*** lines tubes and cavities in which materials have to be moved (see Figure 10.10). For example cilia lining the respiratory tract are responsible for expelling small particles of dust and other foreign materials which are caught up in the mucus adhering to the cells. In certain animals, flatworms for example, cilia lining the underside of the body play an important part in locomotion.

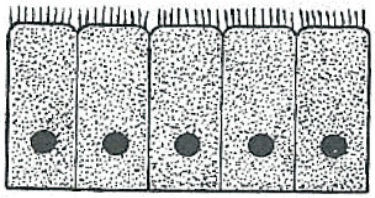


Figure 10.10: Ciliated Epithelium cells.
Source: Oduebo (1984).

(v) **Grandular epithelium:** This is the form of epithelial cells that are frequently interspersed with secretory cells. This cell secretes materials into cavity or space which it happens to be lining (Figure10.11). A good example is seen in the lining of the mammalian intestine. Amongst the ***columnar epithelialcells*** are large numbers of goblet cells which secrete mucus into the lumen of the intestine. The lubricating action of the mucus facilitates the movement of solid matter along the intestine.

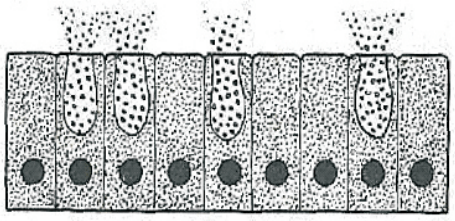


Figure 10.11: Grandular Epithelium cells.
Source: Robert (1976).

(vi) **Stratified epithelium:** This tissue is composed of more than one layer of epithelial cells, however, the tissue are made up of series of layers and is therefore, more thicker than ordinary epithelium. The main function of ***stratified epithelium*** is for protection (see Figure 10.12). The higher the number of layer the more protective it is, however, tough and impervious, epidermis of skin plays this protective function. This type of epithelium is constantly renewing itself as seen in the figure below.

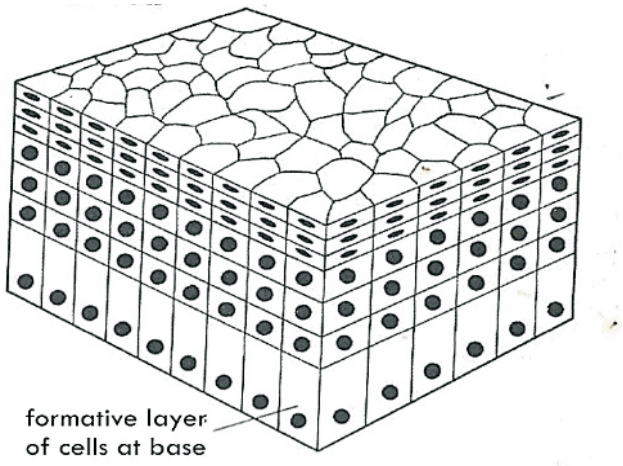


Figure 10.12: Stratified Epithelium cells.
Source: Robert (1976).

Connective Cells

These are the most abundant tissues of complex animals. They link and support other tissues/organs of the body. All connective tissues except blood secrete structural proteins called ***collagen*** or elastin. Connective tissues are classified into 3 types: Loose connective tissue, dense connective tissue and specialized connective tissue.

(i). **Loose Connective Tissue:** These tissues have cells and fibers that are loosely arranged in a semi-fluid ground substance.

Areola tissue –it is present beneath the skin, it serve as a framework support for epithelium, joining organs together and filling spaces between adjacent tissues.

Adipose tissue: This tissue is specialized to store fats.

(ii). **Dense Connective Tissues:** These are connective tissues in which the cells are densely packed. Fibers and fibro-blast are packed compactly in dense connective tissue. Tendons are dense regular tissues that attach skeletal muscle to bone and ligaments attach bone to another bone. ***Collagen*** is the dense irregular tissue present in the skin.

(iii). **Specialized Connective Tissue:** Cartilage, bones and blood are types of specialized connective tissues. Cartilage is solid, pliable tissue and is found in the tip of the nose, outer ear joints between bones of vertebral column. Bones are hard and non- pliable, rich in calcium salts and fibers. It provides structural frame to the body. Blood is fluid connective tissue. It contains plasma, red blood cells, white blood cells and platelets. The plasma is a complex mixture of solution of inorganic salts and blood proteins, glucose, fat, amino acids hormones and urea. The proteins in the blood are of three types: albumins, globulins and fibrinogen.

(c) Muscle Cells

Muscle tissues are made of long cylindrical fibers, which are arranged in parallel rays. The fibers are made up of fine fibrils known as myofibrils. Their contraction and relaxation make the body to adjust to changes in the environment. Muscles are divided into 3 types, skeletal, smooth and cardiac. ***Muscles cells*** contain filament of two kinds of protein actin and myosin, which slide past each other, as muscles contract. After muscles contract, ATP produced in the mitochondria is needed to relax the muscle and return the actin and ***myosin filaments*** to their normal positions. When a person or other animal dies and the mitochondria no longer produce ATP, the muscles cannot relax. This stiffening of the muscle is called ***rigor mortis***. Also, it is important to note that muscles can only pull or contract, not push, thus many muscles come in sets of antagonists that do opposite jobs. Example, ***bicep***and***tricepsmuscles*** found in human as shown in (see Figure 10.13 and 10.14).

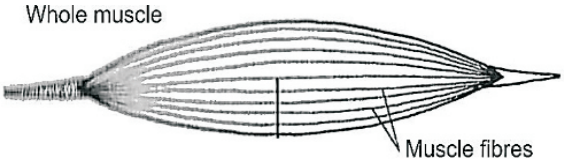


Figure 10.13: A Muscle Fibre.
Source: (Robert 1976).

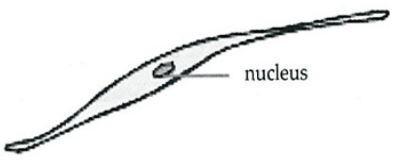


Figure 10.14: Muscle cell.
Source: (Nduet al, 2013).

(i). **Skeletal Muscles:** These kinds of muscles are closely attached to the bone example of such muscle is the biceps. ***Skeletal muscles*** are also known as striated muscle.

(ii). **Smooth Muscle:** Smooth muscles are mostly found in the walls of internal organ such as intestines. Smooth muscles fibers are not striated.

(iii). **Cardiac Muscle:** Cardiac muscle (also called heart muscle or myocardium) is one of three types of vertebrate muscle tissue, with the other two being skeletal muscle and smooth muscles. It is involuntary, striated muscle that constitutes the main tissue of the wall of the heart.

Secretory Cells

There are many different kinds of ***secretory cells*** and their structural modifications vary depending on the particular secretions they produce. The modification may be in the form of ***microvilli*** like in the absorptive cells through which secretions flow into channels. Other ***secretory cells*** have no ***microvilli***, but they have a system of very well developed membrane bound vacuoles derived from the ***Golgi vesicles***.

These vacuoles apparently migrate to the surface of the cell, fuse with the cell membrane and release their contents (such as proteins and polysaccharides) as secretions. ***Secretory cells*** have a greatly increased number of mitochondria and this indicates that a lot of energy is used up in the movement of hydrogen ions out of the cell via a specialized membrane transport mechanism called active transport.

Active transport requires the expenditure of energy in the form of ***Adenosine Triphosphate (ATP)***, a high energy compound manufactured in the mitochondria.

(e) Nerve Cells

Nervous tissues control the body's response to changing conditions. Neurons (nerve cells) are the excitable cells which form the units of ***nervous system***.While the nerve cells form the unit of neural system, the glial cells protect and support neurons. They function in receiving; processing and transferring information (see Figure 10.15).

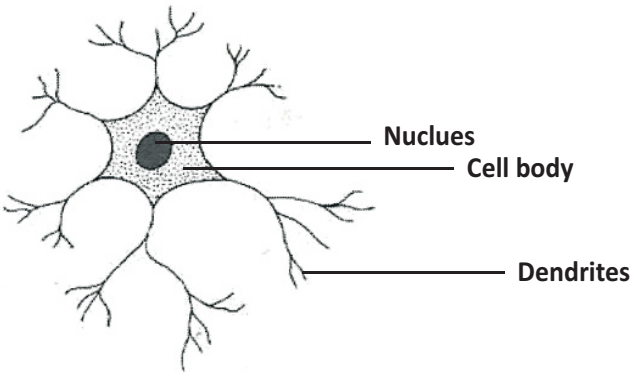


Figure 10.15: A Nerve cell.
Source: Robert (1976).

(f) Absorptive Cells

Absorptive cellsare characteristically found lining the ducts and cavities of organs such as the intestine, lungs and kidney. Their specialized function which is that of absorption and transportation of molecules is reflected by several structural modifications. The most obvious characteristic of ***absorptive cells*** is the occurrence of numerous outfoldings of the cell membrane called Microvilli.

These microvilli serve to increase greatly the amount of absorptive surface area. In addition, localized concentration of enzymes called phosphatases have been demonstrated in the membranes of microvilli. These enzymes are supposed to function in the transport of some molecules into and between the cells. Numerous elongated mitochondria may also be detected in these outfoldings, suggesting the role of energy production in the transport of material across the cell membrane into the capillaries.

(g) Reproductive Cells (Sperm and Ovum)

Reproductive cells are the eggs of female organisms and sperms of male organisms (see Figure 10.16 and 10.17). One feature they have in common is the haploid (n) (half normal) amount of ***genetic information***. The process of gamete formation (gametogenesis) results in the reduction of the genetic material from the diploid (2n) (normal complement) to haploid (n) condition by a special cell division process called ***meiosis***. Gametes are formed in the organ called ***gonad***. The male gonad is the testes while the female gonad is called the ovary.

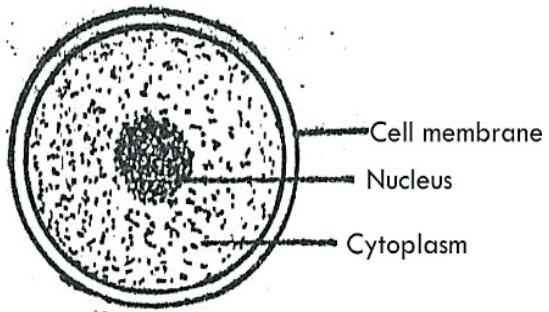


Figure 10.16: The Structure of an Ovum (Egg cell).
Source: (Nduet al , 2013).

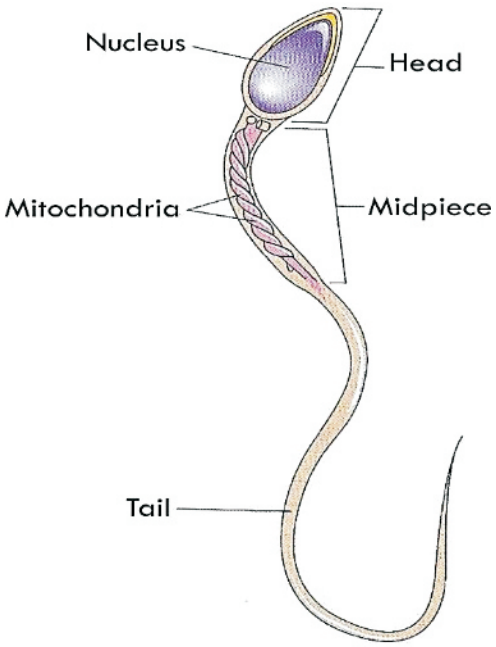


Figure 10.17: The Sperm cell is the male gamete, or sex cell.
Source: (Ndu et al, 2013).

10.7 CHAPTER SUMMARY

- Cells show a great diversity of forms and functions.
- Because of this, it was not easy to realize that all living organisms are made up of units that share a common basic structure.
- Every unit is a cell.
- The other major issue with the discovery of the cell was the very small size of the cells that they usually show.
- Cell morphology is typically drawn as rounded, but this is probably the most uncommon shape (except for a few types of cells).
- Cell morphology in animal tissues is enormously diversed.
- It can vary from rounded to star-like, from multiloped to filiform.
- Plant cells also show a wide diversity of forms, which are determined by the cell wall, with cuboidal and columnar shapes being the most common shapes.
- Many cells exist in different forms, and some cells are also of economic importance to man or other organisms.
- Living cells exist in the following forms: unicellular, colony, filament, multicellular, autotrophic, and heterotrophic.
- Plant and animal tissues have also been classified under the following: plant tissue (meristematic and **permanent tissues**) and animal tissues (epithelial cells, connective cells, muscle cells, secretory cells, nervous cells, absorptive cells, and reproductive cells).

10.8 STUDENTS' PRACTICAL ACTIVIT

ACTIVITY 1: Examining the Internal Structure of Leaves.
AIM: To Identify, draw and label the internal structure of a leaf

MATERIALS

(i) Cork or polystyrene
(ii) Young dicotyledonous leaf
(iii) Iodine solution
(iv) Razor blade
(v) Paint brush
(vi) Petri dish
(vii) Young monocotyledonous leaf
(viii) Microscope
(ix) Slides

PROCEDURE

(i) Cut a narrow strip of cork or polystyrene, this helps to cut thin sections.
(ii) Split it into two and fit a young dicotyledonous leaf in-between the 2 halves.
(iii) Cut thin sections of the cork/polystyrene and leaf.
(iv) Float them in a petri dish of water.
(v) With a paintbrush, transfer the thinnest transverse sections of the leaf into a petri dish containing iodine solution and leave them there for three minutes.
(vi) Mount a thin section of the leaf in water on a microscope slide and observe under the low power of the microscope.
(vii) Using the figure above as a guide identify the various structures of your section.
(viii) Collect prepared slides of transverse sections of dicotyledonous and monocotyledonous leaves from your teacher.
(ix) Using the figure below (Figure 10.18) as a guide, draw and label it.

OBSERVATION

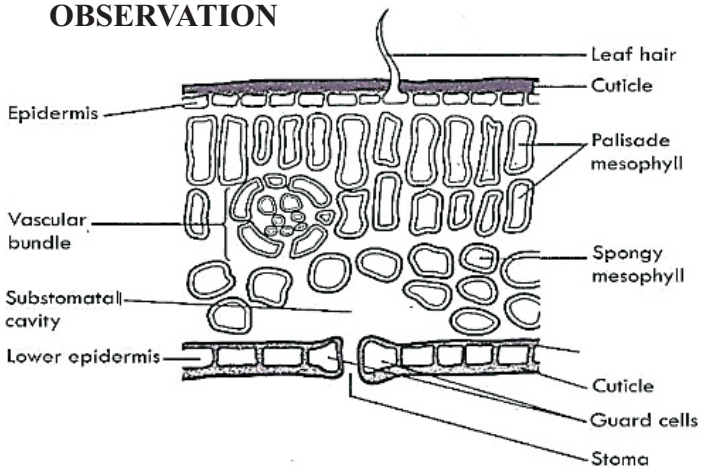


Figure 10.18: Examining the Internal Structure of Leaves.
Source: [Lack and Evans 2007].

DISCUSSION

a) In the form of a table, compare the tissue arrangements of a monocotyledonous and dicotyledonous leaf.

b) Explain how the structure of each tissue in the leaf is adapted to its specific function.

ACTIVITY 2: The Internal Structure of young Monocotyledonous Stem and Root.

AIM: To Identify, draw and label internal structure of Monocot Stem and Root (Figure 10.19 and 10.20)

MATERIALS

(i) Cover slip
(ii) Dropping pipette
(iii) Razor blade
(iv) Petri dish
(v) Plain microscope slide
(vi) Paint brush
(vii) Young monocotyledonous plant e.g. maize, cammelina sp.
(viii) Microscope
(ix) Iodine solution

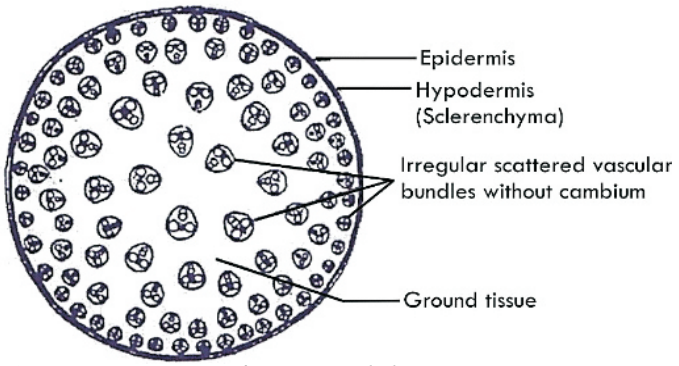


Figure 10.19: *Transverse section of a Monocotyledonous Stem.*
Source: *Fahn (1990).*

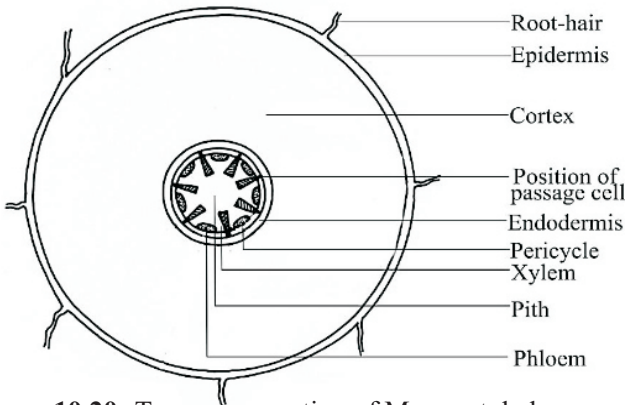


Figure 10.20: Transverse section of Monocotyledonous root.
Source: Fahn (1990).

PROCEDURE

(i) With a sharp razor blade, cut very thin transverse sections of the stem of a young plant and put them in a petri dish containing iodine solution.
(ii) Using Figure 10.19. as a guide, identify the various parts of the transverse section of the stem.
(iii) Following step 1 above, prepare a transverse section of maize root.
(iv) Using Figure 10.20 as guides identify the various parts of the transverse section of maize root.
(v) Collect a permanent slide of a monocotyledonous stem and root in transerve section from your teacher.
(vi) Examine each of them under the low power of the microscope.
(vii) Draw each one to show the distribution of the various tissues in the transverse section of the monocotyledonous stem and root.

DISCUSSION: In a tabular form, compare the structure of:

a) The monocotyledonous root with the monocotyledonous stem.
b) The monocotyledonous stem with the dicotyledonous stem.
c) The monocotyledonous root with the dicotyledonous root.

ACTIVITY 3: The Internal Structures of Young Dicotyledonous Stems and Roots

AIM: To Identify, draw and label internal structure of young Dicot stem and See Figures 10.21 and 10.22).

MATERIALS

(i) Razor blade
(ii) Dropping pipette
(iii) Paint brush
(iv) Petri dish
(v) Model of conducting tissue
(vi) Plain microscope slide
(vii) Cover slip
(viii) Bean seedling (or young plant of *Talinum sp.* or *Helianthus sp.*)
(ix) Iodine solution
(x) Other stains can be used.

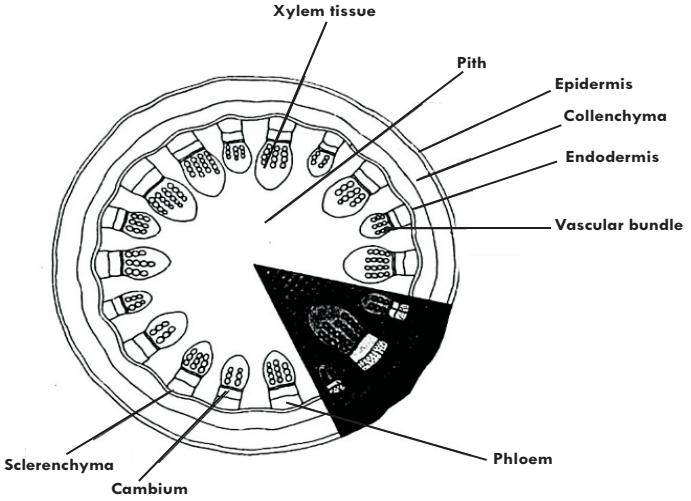


Figure 10.21: Dicotyledonous Stem.
Source: Ramalingan (2005).

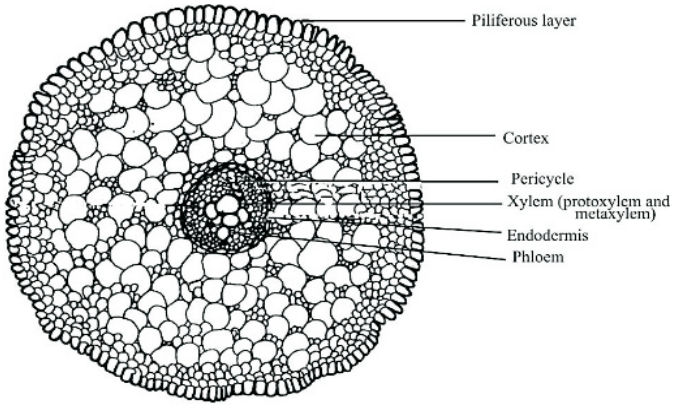


Figure 10.22: Structure of a young dicotyledonous root.
Source: Walter (1988).

PROCEDURE

(i) Obtain young bean seedling (or a young plant of *Thelianthus or Talinum).*
(ii) With a sharp razor blade, cut very thin transverse section of stem of any of the above named plants (Figure 10.21).
(iii) Float the sections in a petri dish of water.
(iv) Pour some iodine solution into a petri dish.
(v) Using a paint brush, transfer one of your thinnest sections into the iodine solution and leave it there for three minutes.
(vi) Lift the section out of the iodine and mount it in a drop of water on a microscope slide.
(vii) Cover the section with a cover slip and examine it under the low power of the microscope.
(viii) Try cutting thin longitudinal sections of the stem. Stain one thin section with iodine, mount in water and examine under low power of the microscope using steps (iii) – (vii) above.

(i) Using a razor blade carefully cut several very thin transverse sections through the root of a young bean seedling.
(x) Repeat steps (iii) – (vii) above. Compare your section with Figure 10.22.
(xi) Obtain permanent slides of a young dicotyledonous stem and a dicotyledonous root from your teacher.
(xii) Examine each one of the slides under the low power microscope and make labeled drawings of each slide to indicate the arrangement of the various tissues.

DISCUSSION

a) How do the drawings of the transverse sections of your young bean stem and root compare with Figure 10.21 and Figure 10.22.
b) What was the purpose of placing your sections in iodine solution for three minutes?
c) Tabulate as many differences as you can between the transverse sections of a young dicotyledonous stem and root.
d) Identify the numbered structures in the model of conducting tissue.

ACTIVITY 4: Observing Feeding action in Amoeba Cell
AIM: To observe Feeding action in *Amoeba* (Figure 10.23)
PROCEDURE

(i) Remove a drop of the sediment from an *Amoeba* culture and prepare a wet-mount. (Alternatively, prepare wet-mount using sediment scooped from a ditch or pond.)
(ii) Examine your slide under a microscope. To see *Amoeba* clearly, dim the light entering your microscope.
(iii) When you have spotted an *Amoeba*, locate the nucleus, contractile vacuole and food vacuoles in the endoplasm**.**

OBSERVATION

(i) Watch the ***Amoeba***move.
(ii) How many pseudopodia are produced at any one time? Make sketches at 30-second intervals to show locomotion in *Amoeba*.
(iii) Watch how the *Amoeba* engulfs its food, discharges excess water from the contractile vacuole and egests from the wastes from the food vacuole.
(iv) Add a crystal of common salt to the slide and observe how the *Amoeba* behaves.

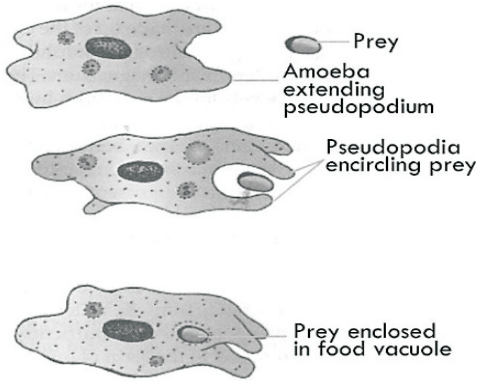


Figure 10.23: Engulfing feeding action in Amoeba.
Source: (Ndu et al , 2013).

ACTIVITY 5: Observing a Chlamydomonas *Cell*
AIM: To observe a *Chlamydomonas*(Figure 10.24)

PROCEDURE
(i) Prepare a wet-mount of *Chlamydomonas* culture.
(ii) Observe the slide under a microscope and locate the following structures: flagellum, gullet, eyespot, contractile vacuole and chloroplasts.
(iii) Make a drawing of *Chlamydomonas* showing these parts.

OBSERVATION
(i) Study the manner in which *Chlamydomonas* moves.
(ii) Make simple sketches at 30-second intervals to show *Chlamydomonas* movement.
(iii) Do you think *Chlamydomonas* has an anterior and a posterior end?

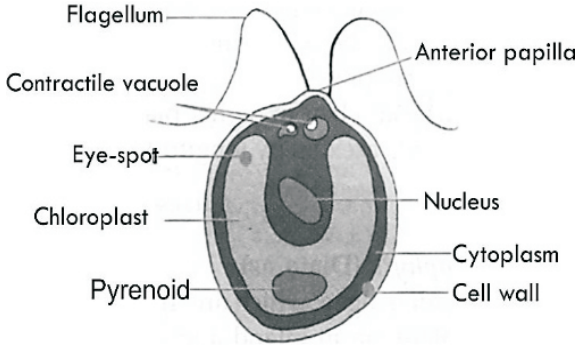


Figure 10.24: Chlamydomonas.
Source: (Ndu et al , 2013).

ACTIVITY 6: Observing Plant Cells
AIM: To observe plant cells (Figure 10.25)
PROCEDURE
(i) Carefully peel off a thin piece of skin from the inside of an onion scale leaf.
(ii) Then, place it in a watch-glass and add a drop of methylene blue to stain the skin.
(iii) Lift the skin and spread it on a clean glass slide.
(iv) Add a drop of water to it, place a cover slip over it, and examine under the low power of the microscope.
(v) Make a sketch of your specimen and label the parts that you can identify.

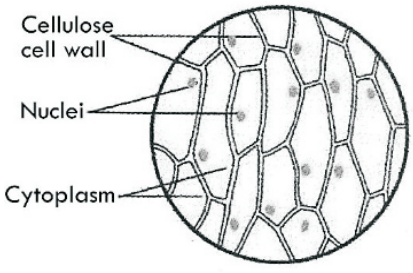


Figure 10.25: Skin from onion scale leaf.
Source: Ramalingam (2005).

ACTIVITY 7: Observing Animal Cells
AIM: To observe Animal Cells (Figure 10.26)

PROCEDURE

(i) Using the blunt end of a toothpick, scrape the cheek lining in your mouth.
(ii) Transfer the scraping to a slide and add a drop of methylene blue to it.
(iii) Place a cover slip over the specimen, and observe it under the low power of the microscope.
(iv) Do these cells look like the onion skin cells?
(v) Make a sketch of the cells from the cheek lining, and compare them with the onion skin cells.

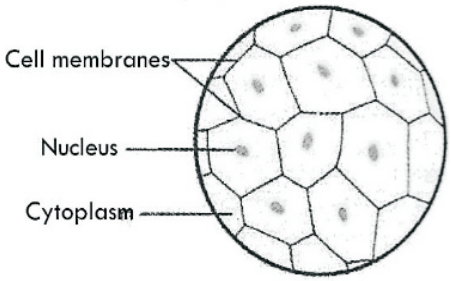


Figure 10.26: Cheek lining cells.
Source: Ramalingam (2005).

10.9 TUTOR MARKED ASSESSMENT QUESTIONS

HAVING READ THROUGH **CHAPTER TEN**, ANSWER THE FOLLOWING QUESTIONS IN THE SPACES PROVIDED.

1 (a) Write short note on the forms in which Living Cells exist.

.....

.....

.....

$2\times\frac{1}{2}$ =1 Marks

(b) List out the **Five** Kingdoms that you have studied and state their characteristics.

.....

.....

.....

.....

.....

$4\times\frac{1}{2}$ =2 Marks

2.(a) What is the function of Meristems? where are they located?.

$3\times\frac{1}{2}=1\frac{1}{2}$ Marks

(b) How are Parenchyma, Collenchyma and Sclerenchyma Distinguished from one another?

$8\times\frac{1}{2}=4$ Marks

(c) In a Tabular form Distinguish between Epidermis and Periderm.

Epidermis	Periderm.

$4\times\frac{1}{2}=2$ Marks

4. (a) What are the functions of Xylem and Phloem? what Cells are involved in their n o r m a l activities

(i) Functions of Xylem

$2\times\frac{1}{2}$ =1 Marks

(ii)Phloem

$2\times\frac{1}{2}$ =1 Marks

(ii) Normal activities involved in their Cells

$2\times\frac{1}{2}$ =1 Marks

(b) What types of substances do Secretory cells Secrete?

$2\times\frac{1}{2}$ =1 Marks

4. (a) What do you understand by Diversity of Plants and Animals Cell?

$2\times\frac{1}{2}$ =1 Marks

(b) How do the Plant and Animal Cell Differ?

$4\times\frac{1}{2}$ =2 Marks

(c) Mention one specialized Cell each of Plant and Animal stating its function in the named Organism.

$2\times\frac{1}{2}$ =1 Marks

(a) Write on the specialization in Plant and Animal Cell

$4\times\frac{1}{2}$ =2 Marks

(b) What do you understand by the term surface area to Volume Ratio.

$4\times\frac{1}{2}$ =2 Marks

(c) Classify Animal Tissues on the basis of their Cells contents.

$4\times\frac{1}{2}$ =2 Marks

Chapter Eleven

MOVEMENT OF MATERIALS ACROSS CELLS

Dr. Joseph E. Okon & Dr. Okon G. Okon

11.1 INTRODUCTION

A plasma membrane encloses every type of cell, both prokaryotic and eukaryotic cells. It physically separates the cytoplasm from the surrounding cellular environment. The plasma membrane controls the entry of nutrients and exit of waste products and generates differences in ion concentration between the interior and exterior of the cell. This chapter gives a brief review of the types of transport in cells (passive, active, and bulk transport), the meaning of ***diffusion*****,** ***osmosis*****,** and ***plasmolysis***, factors affecting the rate of diffusion, facilitated diffusion in a living cell, the differences between passive and ***active transport***, the differences between ***pinocytosis*** and ***phagocytosis***, ***turgidity***, ***flaccidity***, and ***haemolysis***, hypertonic, hypotonic, and ***isotonic solutions*** on the cell plasma. The various organelles and structures within a cell require a variety of substances in order to carry out their functions. In turn, they form products, some useful and some wasteful. Most of these substances must pass in and out of the cell. This they do by ***diffusion***, ***osmosis***, ***active transport***, phagocytosis, and pinocytosis.

11.2 LEARNING OBJECTIVES

After reading this chapter, you should be able to:

(i) Explain the three major types of transport in cell (passive, active and bulk transport).
(ii) Explain the meaning of osmosis, diffusion and plasmolysis.
(iii) Define the term osmoregulation.
(iv) List the factors affecting the rate of diffusion.
(v) Discuss facilitated diffusion in a living cell.
(vi) Differentiate between passive and active transport.
(vii) Distinguish between pinocytosis and phagocytosis.
(viii) Describe the terms: turgidity, flaccidity and haemolysis.
(ix) Examine the terms: hypertonic, hypotonic and isotonic solution on the cell plasma.
(x) State the importance of osmosis in plant life.

11.3 TYPES OF TRANSPORT IN AND OUT OF CELLS

Cellmembrane acts as a ***semi-permeable*** barrier between the cell and the ***extracellular*** environment. This ***permeability*** must be highly selective if it is to ensure that essential molecules such as glucose, amino acids and lipids can readily enter the cell, that these molecules and metabolic intermediates remain in the cell and that waste compounds leave the cell. Transport across the membrane may be passive or active.

(a) Passive transport: It is a type of diffusion in which an ion or molecule crossing a membrane moves down its ***electrochemical*** or concentration gradient. No metabolic energy is consumed in passive transport i.e. it does not use the cell's energy in bringing materials in and out of the cell.
The kinds of ***passive transport*** are osmosis, simple diffusion.

(i) Osmosis: It is the movement of water molecules from the region of higher concentration to the region of lower concentration through ***selective permeable membrane***. The to and fro movement of water molecules through the membrane occurs due to the differences in the concentration of the solute in the regions. The process by which the water molecules pass through a membrane from a region of higher water concentration (lower or weaker solution) to the region of lower water concentration (higher or stronger solution) is known as osmosis.
The process in which the water molecules enter into the cell is known as ***endosmosis***, while the reverse process which involves the exit of the water molecule from the cell is known as ***exosmosis***. Due to ***endosmosis*** or ***exosmosis*** the water molecules come in or out of the cell.

(ii) Diffusion
Diffusion is the net movement of a substance (liquid or gas) from an area of higher concentration to one of lower concentration until the entire substance is uniformly distributed. A drop of dye in water is concentrated but then begins to disperse throughout the water moving from an area of high to an area of low concentration. (See the Figure 11.1). When the substance has fully dispersed throughout the container, it has reached equilibrium. When equilibrium has been reached, there is no longer a concentration gradient. Certain molecules can freely diffuse across the cell membrane.

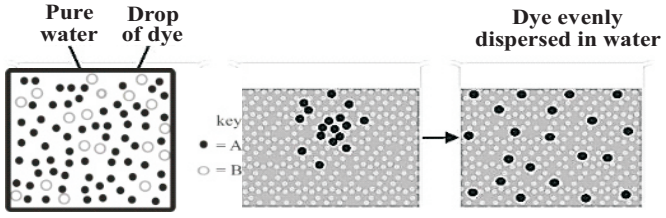


Figure 11.1: Demonstration Diffusion of Dye in Water molecules
Source: NIOS (2017).

Look at the Figure below- ***hydrophobic molecules*** and small uncharged molecules can diffuse through the membrane but large molecules or ions (atoms with a positive or negative charge) cannot move through the membrane.

(b) Active Transport

Active transport is the movement of molecules across a cell membrane from a region of lower concentration to a region of higher concentration – against the concentration gradient. ***Active transport*** requires cellular energy to achieve this movement.

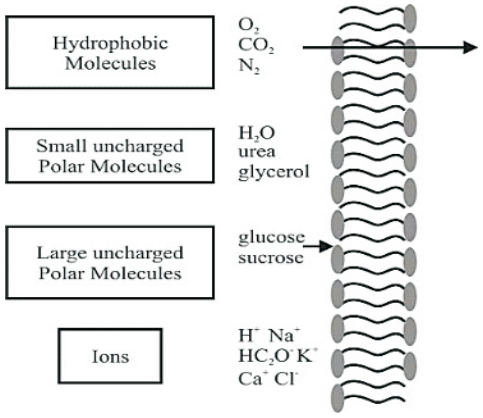


Figure 11.2: Diffusion ofOrganic substances across the membrane.

Source: NIOS (2017).

11.4 FACILITATED DIFFUSION AND ACTIVE TRANSPORT

(a) Facilitated Diffusion

Some molecules are too large to pass through the cell membrane by diffusion and need help to cross. These molecules use ***facilitated diffusion***.

Facilitated diffusion is the flow of large molecules from an area of high concentration to an area of low using proteins in the cell membrane.

Glucose is able to enter human cells from the blood stream by facilitated diffusion. A glucose molecule is too big to squeeze through the ***phospholipid*** bilayer and needs protein channels to help it pass into the cell. These protein "helpers" are extremely important because they allow much needed molecules to enter human cells. Without them, human cells would not have glucose and human cells would not be able to make energy. Examples of facilitated diffusion are ionic transport through charged pores, D-hexose ***permease*** of erythrocyte, ***Anion*** excharged ***permease*** of erythrocyte.

(b) Active Transport

Active transport is the pumping of a substance across a cellular membrane from a point of lower concentration to one of higher concentration. This movement is against a concentration gradient and it is energy requiring process. In this process, neither simple diffusion nor ***facilitated diffusion*** is capable of moving the solutes against a ***concentration gradient***. Active transport will only take place in a living system that is actively producing energy by respiration. Certain factors such as temperature and oxygen concentration which influence the rate of respiration will surely affect the rate of active transport.

Biochemical studies have provided additional evidence that active transport is linked with energy production. Usually, energy in cells comes from the breakdown of adenosine triphosphate (ATP). Any factor that inhibits the formation of ATP or prevents it from example, cyanide prevents ATP synthesis and also inhibit active transport. Certain cells that are known to indulge in active transport on a large scale have an unusually large number of mitochondria. Examples of Active Transport include:

(i) Some seaweed which take up iodine so vigorously that it is more than two million times more concentrated inside the cells than the surrounding water, is a good example of active transport.

(ii) Usually, more mineral salts are found in root hairs than in the soil solution. Minerals salts tend to enter the root hair cell membranes from the soil with a low concentration of salt into the root hair cells with a higher salt concentration. It means that ***mineral elements*** enter root hairs in a direction opposite to what is expected if diffusion alone is taking place.

The types of transport discussed so far are passive transport and do not require a cell to use its energy- the molecules flow with the concentration gradient. There are times when the cell pumps against the gradient and to do so, it must use energy. The use of energy to pump molecules against the gradient is called active transport. A cell uses in the form of ***ATP(adenosine triphosphate).*** When energy is taken from ATP, it turns into ADP (Adenosine diphosphate.

(iii) **Sodium-Potassium Pump**

The sodium-potassium pump in nerve cells is an example of active transport. Sodium and potassium atoms are pumped against the gradient using ATP. By pumping against the gradient, the cell builds an even bigger gradient (difference between concentrations across the membrane) that helps nerve impulses.

(iv) **Bulk Flow (bulk transport)**

Bulk flow is termed as overall movement of water (or some other liquids). It occurs in response to differences in the potential energy of water, also known as water potentials. Water behind the dam or at the top of a water fall is good example of water that has potential energy. As this water runs downhill, its potential energy can be converted to mechanical energy by a waterwheel or mechanical and then electrical energy by ***hydroelectric turnbine***. Another source of water potential is pressure. If we put into a rubber bulb, and squeeze the bulb, this water, like the water at the top of a water fall, has water potential and will move to an area of less water potential. Usually, water moves from an area where water potential is greater to an area where water potential is less, regardless of the reason for the difference. The concept of water potential enables ***physiologists***to predict the way in which water will move under various conditions. Water potential is measured in terms of the pressure required to stop the movement of water i.e. the hydrostatic pressure under a particular circumstances involved. The unit of its measurement is in bar (Ravern and Curtis, 1981).

11.5 ENDOCYTOSIS AND EXOCYTOSIS

(a) ***Endocytosis*** and ***exocytosis*** are active processes involving the bulk transport of materials through membranes, either into cells (***endocytosis***) or out of cells (***exocytosis***) (see Figure 11.2). ***Endocytosis*** occurs by an infolding or extension of the cell surface membrane to form a vesicle or vacuole. It is of two types.

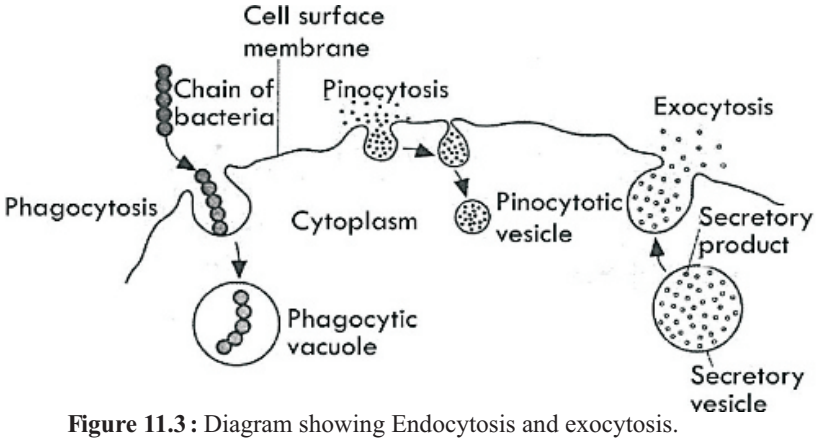


Figure 11.3 : Diagram showing Endocytosis and exocytosis.
Source: Taylor, Green and Stout (1997).

(i) **Phagocytosis** ('cell eating'): material taken up is in solid form. Cells specializing in the process are called phagocytes and are said to be phagocytic. For example, some white blood cells take up bacteria by ***phagocytosis***. The sac formed during uptake is called a phagocytic

(ii) **Pinocytosis** ('cell drinking'): material taken up is in liquid form. Vesicles formed are often extremely small, in which case the process is known as micropinocytosis and the vesicles as micropinocytotic vesicles. ***Pinocytosis*** is used by the human egg cell to take up nutrients from the surrounding follicle cells. In the thyroid gland, the hormone thyroxine is stored as thyroglobulin in hollow structures called follicles. When required, thyroglobulin is taken up by pinocytosis by the follicle cells and then converted to thyroxine for release into the blood. ***Pinocytosis*** is very common in both animal and plant cells.

(iii) ***Exocytosis***is the reverse process of endocytosis. Waste materials may be removed from cells, such as solid, undigested remains from phagocytic vacuoles, or useful materials may be secreted. ***Secretion of enzymes*** from the pancreas is achieved in this way. Plant cells use exocytosis to export the materials needed to form cell walls.

11.6 FACTORS AFFECTING RATES OF DIFFUSION

The rate of diffusion depends on the following factors:

(i) **The Concentration Gradient:** The greater the difference in concentration between two regions of a substance the greater the rate of diffusion. Organisms must therefore maintain a fresh supply of a substance to be absorbed by creating a stream over the diffusion surface. Equally, the substance, once absorbed, must be rapidly transported away.

(ii) **The Distance over which diffusion takes place:** The shorter the distance between two regions of different concentrations the greater the rate of diffusion. The rate is proportional to the reciprocal of the square of the distance (inverse square law). A structure in an organism across which diffusion regularly takes place must therefore be thin. Cell membranes for example are only 7.5nm thick and even epithelial layers such as those lining the alveoli of the lungs are as thin as 0.3nm across.

(iii) **The Area over which diffusion takes place:** The larger the surface area the greater, the rate of diffusion. Diffusion surfaces frequently have structures for increasing their surface area and hence the rate at which they exchange materials. These structures include villi and microvilli.

(iv) **The nature of any structure across which diffusion occurs:** Diffusion frequently takes place across epithelial layers or cell membranes. Variations in their structure may affect diffusion. For example, the greater the number and size of pores in cell membranes the greater the rate of diffusion.

(v) **The size and nature of the diffusing molecule:** Small molecules diffuse faster than large ones. Fat-soluble ones diffuse more rapidly through cell membranes than water-soluble ones

(a) Examples of Diffusion in Plants and Animals are:

(i) Gaseous exchanges during photosynthesis and respiration.

(ii) Loss of water vapour from the leaves into the atmosphere.

(iii) Diffusion, throughout the atmosphere, of oxygen produced during the photosynthesis activities of green plants.

(iv) Mineral salt particles diffuse from the soil solution into root hairs, and also from the cell within the plant.

(v) Exchanges of dissolved gases in respiring aquatic organisms e.g. *Spirogyra* and *Hydra*.

(vi) Carbon dioxide evolved by respiring plants and animals, diffuse throughout the atmosphere.

(vii) Dissolved gases diffuse in and out of plant cells.

(viii) Passage of dissolved gases through specialized respiratory membranes in animals e.g. lungs, gills and moist skin.

(ix) Digested food diffuses through the walls of the villi.

(b) Effect of Osmosis in Plant Cells

Plant cells are enclosed by a rigid cell wall. When the plant cell is placed in a ***hypotonic solution***, it takes up water by osmosis and starts to swell, but the cell wall prevents it from bursting. The plant cell is said to have become "***turgid***" i.e. swollen and hard. The pressure inside the cell rises until this internal pressure is equal to the pressure outside. This liquid or ***hydrostatic pressure*** called the turgor pressure prevents further net intake of water. Turgidity is very important to plants as it helps in the maintenance of rigidity and stability of plant tissue and as each cell exerts a turgor pressure on its neighbor adding up to plant tissue tension which allows the parts of the plant to "stand erect" into the sunlight. When a plant cell is placed in a ***hypertonic solution***, the water from inside the cell cytoplasm diffuses out and the plant cell is said to have become "flaccid". If the plant cell is then observed under the microscopic, it will be noticed that the cytoplasm has shrunk and pulled away from the cell wall. This phenomenon is called plasmolysis. The process is reversed as soon as the cells are transferred into a ***hypotonic solution***(deplasmolysis).

When a plant cell is placed in an ***isotonic solution***, a phenomenon called incipient plasmolysis is said to occur. "Incipient" means "about to be". Although the cell is not plasmolyzed, it is not turgid. When this happens the parts of the plant droop and are unable to hold the leaves up for the sunlight.

(c) **Effect of Osmosis in animal cells**

Animal cells do not have cell walls. In ***hypotonic solutions***, animal cells swell up and explode as they cannot become turgid because there is no cell wall to prevent the cell from bursting. When the cell is in danger of bursting, organelles called ***contractile vacuoles*** will pump water out of the cell to prevent this. In ***hypertonic solutions***, water diffuses out of the cell due to osmosis and the cell shrinks. Thus, the animal cell has always to be surrounded by an ***isotonic solution***. In the human body, the kidneys provide the necessary regulatory mechanism for the blood plasma and the concentration of water and salt removed from the blood by the kidneys is controlled by a part of the brain called hypothalamus. The process of regulating the concentration of water and mineral salts in the blood is called ***osmoregulation***. Animals which live on dry land must conserve water and also animals which live in the salty sea water, but animals which live in **freshwater** have the opposite problem; they must get rid of excess water as fast as it gets into their bodies by osmosis.

Examples of Osmosis in Plants and Animals

(I) Absorption of water by plants roots.
(ii) Re-absorption of water by the proximal and distal convoluted tubules of the nephron.
(iii) Re-absorption of tissue fluid into the venule ends of the ***blood capillaries***.
(iv) Absorption of water by the alimentary canal-stomach, small intestine and the colon.

(b) Osmoregulation

Osmoregulation is maintaining the concentration of cell cytoplasm or blood at a suitable concentration.
(i) *Amoeba*, living in freshwater, uses a ***contractile vacuole*** to expel the excess water from its cytoplasm (thus needs more respiratory, O_2 and ATP than isotonic (marine) *Amoebae*).
(ii) The kidneys maintain the blood (thus, whole body) at the correct concentration.

11.7 OSMOSIS IN PLANT CELLS

(I) Plant cells in an hypotonic (weaker) solution- cells have lower water potential
(a) The plant cells gain water by osmosis.
(b) The vacuole and cytoplasm increase in volume.
(c) The cell membrane is pushed harder against the cell wall causing it to stretch a little.
(d) The plant tissue becomes stiffer (turgid).

(ii) Plant cells in an hypertonic (stronger) solution – cells have higher water potential
(a) The plant cells lose water by osmosis.
(b) The vacuole and cytoplasm decrease in volume.
(c) The cell membrane shrinks away from the cell wall.
(d) Shrinking stops when the cell sap is at the same concentration as the external solution.
(e) The plant tissue becomes ***flaccid***, it has shrunk slightly.
(f) The tissue may go on to become ***plasmolyzed***.

Importance of Osmosis in Plant

(i) Root hairs absorb water from the soil by the process of osmosis; at least the entry of water into root hairs is controlled by osmosis.
(ii) From the root hairs cell-to-cell osmosis takes place until the cortical cells of the roots become saturated with water. Similarly, cell to cell osmosis takes place throughout the body of the plant.

However, it has been asserted that it is the suction pressure (pressure exerted on water which makes the water to drive into the absorbing material) and not the osmotic pressure that is fundamentally responsible for the movement of water from cell to cell.

(i) The osmotic pressure generated in the root-cortex is responsible for forcing the water into the xylem vessels and possibly upwards through them at least to some height.
(ii) The living cells surrounding the ***xylem*** draw water from the xylem by ***osmosis*** and so do the ***mesophyll cells*** of the leaf at the upper end of the xylem, prior to transpiration.
(iii) Osmosis makes the cell ***turgid***. This turgid condition gives a certain amount of rigidity to the young soft parts of the plant body and is also an essential condition for growth. Enlargement of meristematic cells at the root apex and stem apex are initially due to osmosis.
(iv) Various movements, turgor movements particularly such as those exhibited by the leaflets of *Mimosapudica* (touch and die sensitive plant). Also the sleeping movement of most species of leguminosae, opening and closing of stomata, bursting of many fruits and sporangia etc. are largely due to osmotic phenomena.

11.8 PLASMOLYSIS

Plasmolysis is defined as the process of contraction or shrinking of the protoplasm of a plant cell due to the loss of water in the cell. The word plasmolysis was generally derived from a Latin and Greek word plasma – The mol and lusis meaning loosening.
Plant cells are eukaryotes, composed of specialized cellular organelles that differ in several fundamental factors from animal cell. Plant cells usually consist of a thick cell wall that functions by holding them upright and also prevents them from losing their shape. The plasma membrane, cytoplasm and all other cell organelles function together to keep the plant active. The vacuoles, a fluid-filled membrane-bound organelle, located within the cytoplasm, hold the water in the plant cell. In certain conditions, plant cells do not get a sufficient amount of water, or there is a severe loss of water from the cell. This result in the total shrinking of the plant cell and the phenomenon is called ***plasmolysis*** (Figure 11.3).

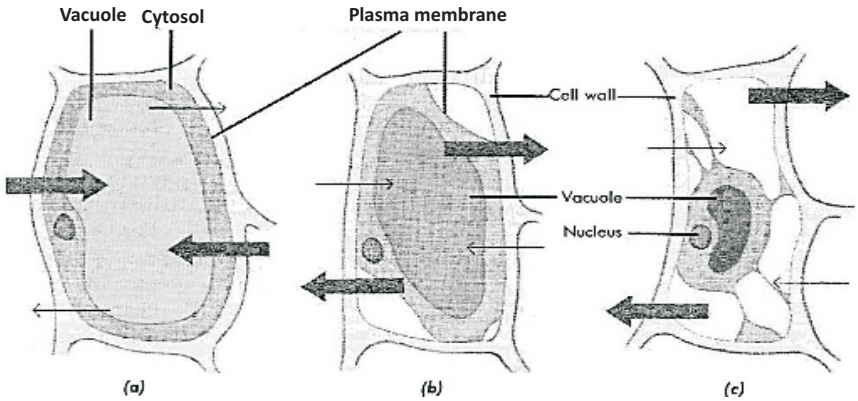


Figure 11.4 : Plasmolysis in a leaf epidermal cell.
Source: Raven, Evert and Eichhorn (1999).

Note: *(a) Under normal conditions, the plasma membrane of the protoplast is in close contact with the cell wall. (b) When the cell is placed in a relatively concentrated sugar solution, water passes out of the cell into the hypertonic medium, the protoplast contracts slightly, and the plasma membrane moves away from the wall. (c) When immersed in a more concentrated sugar solution, the cell loses even larger amounts of water and the protoplast contracts still further. As water is lost from the vacuole its contents become more concentrated. The widths of the arrows indicate the relative amounts of water entering or leaving the cell.*

(a) Demonstration of plasmolysis in the Laboratory

The process of plasmolysis can be easily explained in the laboratory by placing a living cell in a strong salt solution. When the plant cells are placed in the concentrated salt solution, due to osmosis, water from the cell sap moves out. Therefore, the water travels through the ***cell membranes*** into the neighboring medium. Finally, the ***protoplasm*** separates from the cell and assumes a spherical shape. Normally, for this experiment, Tradescantia or Rheo plant cells, Elodea plants or onion epidermal cells are used, because they have coloured sap which can be easily observed and identified under the microscope (Figure 11.4).

(b) Stages of Plasmolysis

The complete process of plasmolysis takes place in three different stages:

(i) Incipient plasmolysis: It is the initial stage of the plasmolysis, during which, water starts flowing out of the cell; initially, the cell shrinks in volume and cell wall become detectable.

(ii) Evident plasmolysis: It is the next stage of the plasmolysis, during which, the cell wall has reached its limit of contraction and cytoplasm gets detached from the cell wall attaining the spherical shape.

(iii) Final plasmolysis: It is the third and the final stage of the plasmolysis, during which the cytoplasm will be completely free from the cell wall and remains in the centre of the cell.

(c) How does water pass through the Cell Membranes?

During the process of plasmolysis within the plant cell, the cell membrane separates the interiors of the cell from the surrounding. It allows the movement of water molecules, ion and other selective particles across the membrane and stops others. Water molecules travel in and out of the cell across the cell membranes and the water flow is a necessary consequence.

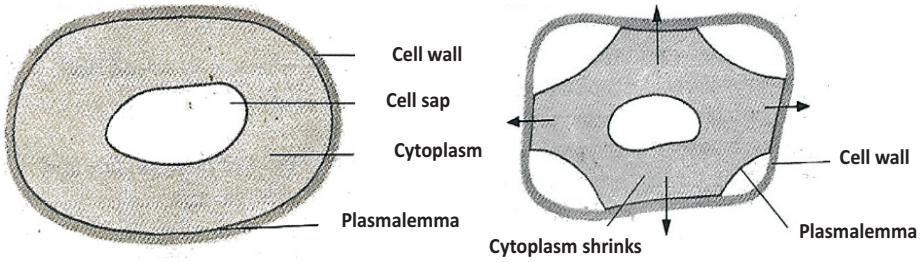


Figure 11.5: Diagram showing Plasmolysed cells.
Source: Ramalingam (2005).

Note: *As the cell contents lose water, the cytoplasm shrinks and the plasmalemma gets detached from the cell wall. When plasmolysis proceeds beyond a ce rtain limit, the plasmalemma is liable to tear, resulting in permanent damage to the cell.*

11.9 TYPES OF PLASMOLYSIS

There are two different types of plasmolysis and this classification is mainly based on the final structure of the cytoplasm.

(a) Concave Plasmolysis

During the concave plasmolysis, both the cell membrane and protoplasm shrink away and begins to detach from the cell wall, which is to the loss of water. ***Concave plasmolysis*** can be reversed by placing the cell in a ***hypotonic solution***, which helps cells to regain the water back into the cell.

(b) Convex Plasmolysis

During the ***convex plasmolysis***, both the cell membrane and protoplasm lose so much water that they completely get detached from the cell wall. Later, the cell wall collapses and results in the destruction of the cell. ***Convex plasmolysis*** cannot be reversed, and this happens when a plant wilts and dies from lack of water. This type of ***plasmolysis*** is more complicated compared to ***concave plasmolysis***. Examples of Plasmolysis

(i) Shrinking of vegetables in hypertonic conditions.

(ii) Blood cell shrinks when they are placed in the hypertonic conditions.

(iii) Spraying of weedicides kills weeds in lawns, orchards and agricultural fields. This is due to the natural phenomenon-plasmolysis.

(iv) When more amount of salt is added as the preservatives for food like jams, jellies, and pickles. The cells lose water due to higher concentration outside and become less conductive to support the growth of microorganism.

(c) Deplasmolysis

When the plasmolysed cell is placed in a ***hypotonic solution***, (the solution in which solute concentration is less than the cell sap), the water travels into the cell, due to the higher concentration of water outside the cell. Then the cell swells and becomes turgid. This is known as ***deplasmolysis***. When the living cells are placed in isotonic solution (both solutions have equal amount of solute particles), the water does not flow within or outside. Here, the water passes in and out of the cell in an equilibrium state, and therefore, the cells are said to be flaccid.

11.10 TURGIDITY, FLACCIDITY AND HAEMOLYSIS

(a) Turgidity

In biology, turgid cells refer to cells or tissues that are swollen due to water uptake. Many cell types in many different organisms can become turgid due to water uptake. Some cells will lyse, or split open if they become too turgid. Other cells are meant to be turgid and have a dense and complex woven ***extracellular matrix,*** made of special fibrous molecules. In animals, turgid cells are protected by an extracellular matrix consisting of many different molecules. Plant cells, in contrast to animal cells, are almost always turgid due to the action of a large vacuole in each of their cells. The special membrane of this plant-specific organelle, the ***tonoplast***, actively moves water into the vacuole, along with other molecules that need to be stored. This swells the vacuole, creating a pressure called turgor pressure. A cell with high turgor pressure is said to be turgid (see Figure 11.4). The ***turgor pressure*** exerted by the vacuole pushes outward on the cellulose fibers are wound tightly around each other to create a strong cell wall. When the walls of many turgid cells push against each other, a plant can gain a rigid form. While animals use turgid cells only for special functions, the many turgid cells in a plant allow it to stand straight up. Further, by lowering the pressure on specific sides of the plant, the plant can move its leaves and stems to obtain the maximum amount of sunlight. Many plants that must compete at getting sunlight are efficient in manipulating the pressures of each of their cells in order to move their leaves. It is not yet completely understood how this process works.

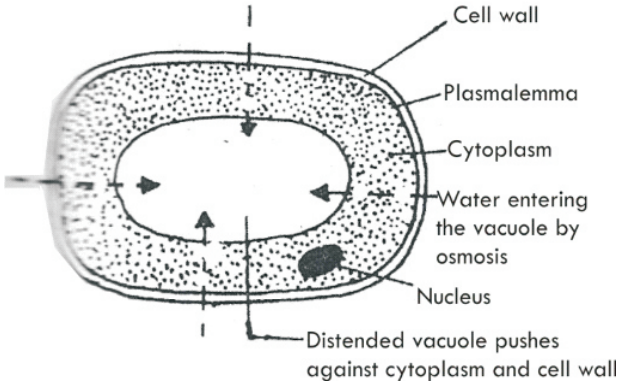


Figure 11.6 : Diagram representing a Turgid Plant Cell.
Source: Idodo-Umeh (1996).

(b) Flaccidity

In botany, a flaccid plant cell is one in which the plasma membrane is not pressed tightly against the cell wall. The plant cell will appear flaccid, and not swollen or plasmolyzed. The plant cell will lose its ***flaccidity*** when it is placed in a ***hypotonic solution*** and ***hypertonic solution.*** When turgid cell is placed in an hypertonic solution, it loses water and becomes flaccid or collapses. Flaccidity is a phenomenon whereby a turgid cell loses water to a stronger solution (hypertonic solution) when placed in such a solution and allowed for some time. ***Flaccidity*** causes the membrane to recede from the wall and is responsible for wilting in plant cells.

(c) Haemolysis

When a red blood cell is placed in weaker solution (hypotonic solution) or fresh water, it absorbs water, swells and even burst thereby separating the haemoglobin from the cell membrane. This phenomenon is known as ***haemolysis***. Thus, ***haemolysis*** can be defined as a process by which red blood cells can become lysed as a result of too much water passing into it.

There are three types of solutions that involve water and how they affect the cell. They are:

i. **Hypertonic Solution**

In a hypertonic solution, there is a higher concentration of water inside the cell than outside the cell. A hypertonic solution has more solute (salt, sugar, etc.) than the cell. Water flows from an area of high concentration to an area of low.Thus water leaves the cell. This loss of water causes the cell to shrivel.

In animal cells, the shrinking is called crenating. The cell in Figure 11.6 shown is destroyed. In plant cells, ***plasmolysis*** occurs and the cell membrane shrinks away from the cell wall. Death will result in both cells.

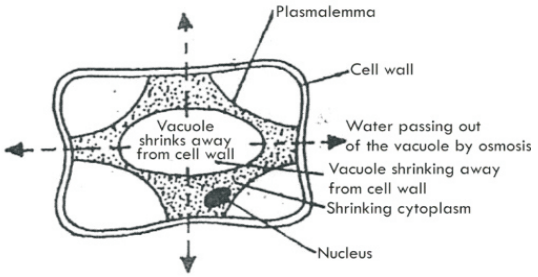


Figure 11.7: A Damaged Plant Cell due to movement of water out of the cell.
Source: Idodo-Umeh (1996).

ii. **Hypotonic Solution**

A ***hypotonic solution***, the solution contains a higher percentage of water than the cell. A hypotonic solution has less solute than the cell and this causes the solution to have more water than the cell. When a cell is placed in a hypotonic solution, water flows from an area of high concentration to an area of low concentration.Thus water rushes into the cell (see Figure 11.7). This causes the cell to expand and possibly burst. In animal cells, the cell bursts or will lyse, killing the cell. In plant, cells the cell wall does not allow the cell to expand anymore and the plant cell does not die.

\

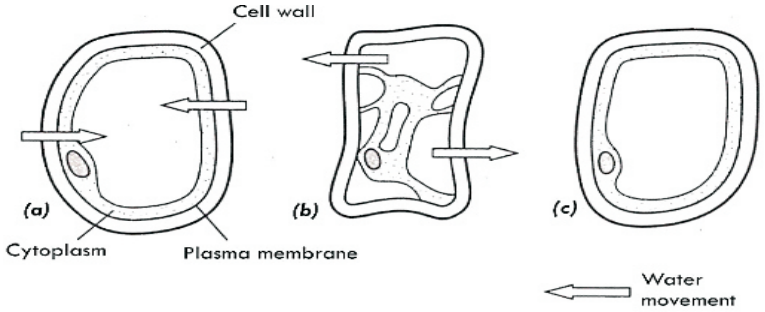


Figure 11.8: Diagram showing a cell placed in hypotonic solution as they lose water by osmosis.

Source: Lack and Evans (2007).

Note: *A cell in a hypotonic medium is fully turgid. Water move into the cell causing the protoplasm to stretch and get back to its original shape. This phenomenon is known as deplasmolysis*

iii. **Isotonic Solution**

In an isotonic solution, there is the same percentage of water on the outside of the cell as the inside of the cell. An isotonic solution has the same amount of solute as the inside of the cell. Water moves at a constant rate in and out of the cell and the cell maintains its original shape.

In animal and plant cells, the cell keeps its shape when in an ***isotonic solution***. Most cells live in an isotonic environment and they are able to maintain their shap and survive.

11.11 CHAPTER SUMMARY

- The chemical structure of the cell membrane makes it remarkably flexible, the ideal boundary for rapidly growing and diving cells.
- Yet the membrane is also a formidable barrier, allowing some dissolved substances, or solutes, to pass while blocking others.
- Lipid-soluble molecules and some small molecules can permeate the membrane, but the lipid bilayer effectively repels the many large, water-soluble molecules and electrically charged ions that the cell must import or export in order to live.
- Movement of these vital substances is carried out by certain classes of intrinsic proteins from a variety of transport systems.
- Some are open channels, which allow ions to diffuse directly into the cell; others are facilitators, which, through a little-understood chemical transformation**,** help solutes diffuse past the lipid screen; yet others are pumps, which force solutes through the membrane when they are not concentrated enough to diffuse spontaneously.

- Particles too large to be diffused or pumped are often swallowed or disgorged whole by the opening and closing of the membrane.
- Behind this movement of materials across the cell is the principle of diffusion and osmosis.
- The types of transport in the cell are passive or active transport.
- Under this passive transport, we have osmosis and diffusion.
- Active transport is the pumping of substances across a cellular membrane from a point of lower concentration to a higher concentration, and facilitated diffusion is the flow of large molecules from a higher concentration to an area of lower concentration using proteins in the cell membrane.

11.12 STUDENTS' PRACTICALACTIVITIES

ACTIVITY 1: Diffusion in Air

AIM: To demonstrate Diffusion in Air using strong scented perfume

MATERIALS

(i) One watch glass
(ii) A bottle of strong scented perfume

PROCEDURE

(i) Obtain a bottle of highly scented perfume.
(ii) Stand at the back corner of the classroom after first closing all doors, windows and turning off the fans.
(iii) Put a small quantity of the perfume in a watchglass.
(iv) Move to the opposite corner of the classroom and wait until you can detect the scent of the perfume.

DISCUSSION

(i) Explain what has happened
(ii) Why is it necessary to close all doors and windows?

ACTIVITY 2: Studying Diffusion in Liquids.

AIM: To demonstrate Diffusion in Liquids using **Potassium tetraoxomanganate (vii)** (Figure 11.8).

MATERIALS

(i) Water
(ii) Beaker (500cm^3)
(iii) Potassium tetraoxomanganate (VII)

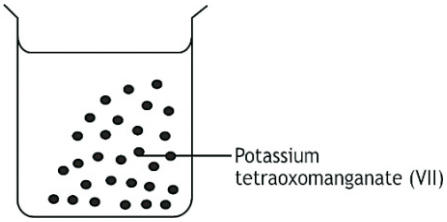


Figure 11.9: Studying Diffusion in Liquids.
Source: [Adapted from SRC Biology (2006): Philip Harris/itec].

PROCEDURE

The following procedure can be carried out as in Figure 11.7.

(i) Half fill a 500 cm^3 beaker with water.
(ii) Put a crystal of potassium tetraoxomangate (VII) into the water in the beaker, using a spatula.
(iii) Leave the beaker on a flat table for about 30 minutes.
(iv) Observe the water in the beaker every 10 minutes (Figure 11.7).
(v) Draw and label the beaker and its contents as it appears after 30 minutes.

DISCUSSION

a) What happens to the potassium tetraoxomangate (VII) crystal?
b) What is the colour of the water in the beaker?

ACTIVITY 3: Osmosis Using A Non-Living Membrane
AIM: To Demonstrate Osmosis Using A Non-Living Membrane (Figure 11.9).
MATERIALS

(i) Beaker (1000cm^3)
(ii) Graph paper
(iii) Marker
(iv) Ruler
(v) 20% sucrose solution
(vi) Strong thread
(vii) Dye e.g. eosin or ink
(viii) Clock
(ix) Visking tubing
(x) Retort stand
(xi) Long capillary tube

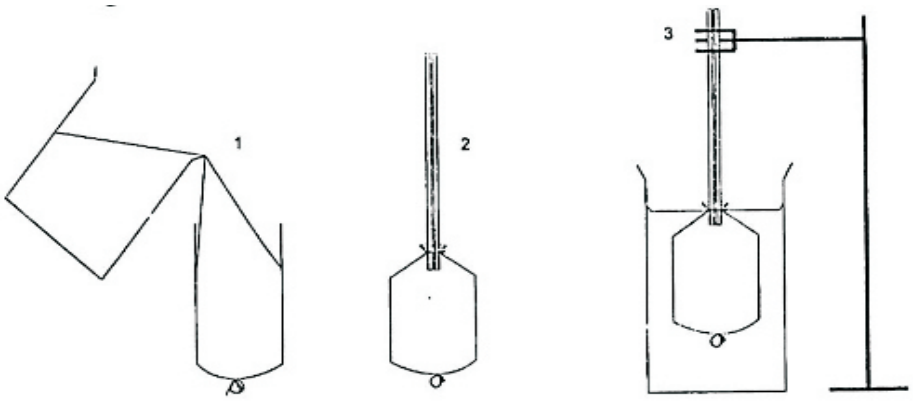


Figure 11.10: Osmosis using non-living membrane.
Source: [Adapted from SRC Biology (2006): Philip Harris/itec].

PROCEDURE

(i) Cut an 8cm length of visking tubing.
(ii) Wet it thoroughly with water.
(iii) Tie one end with a piece of strong thread, so that it forms a bag.
(iv) Fill the bag with twenty percent solution of sucrose and add dye to the solution (Figure 11.8 [1]).
(v) With a piece of thread, tie the bag to the bottom of a capillary tube (Figure 11.8 [2])
(vi) Clamp the capillary tube to a stand, and lower the bag into a beaker of water (Figure 11.8 [3])
(vii) Mark the level of the sucrose solution in the *c*apillary tube.
(viii) Set up a control in the same way using water instead of sucrose in the visking tubing.
(ix) Five minutes later, with a ruler, measure the distance which the sucrose solution has raised from the original mark. Write down the distance in millimetres.
(x) Re-measure the distance every five minutes for about half an hour. In each case write down the distance the sucrose has raised from the original mark (see Figure 11.8 [3]).
(xi) Plot your results on graph paper: put the distance the sucrose has risen on the vertical axis, and time on the horizontal axis.

DISCUSSION

a) What happens to the level of the sucrose solution in the capillary tubing and why?
b) What property of the visking tubing makes this happen?

ACTIVITY 4: Osmosis Using a Living Membrane (Raw Yam)

AIM: To study Osmosis using a Living Membrane (Raw Yam) (Figure 11.10).

MATERIALS

(i) Office pins
(ii) Saturated sugar solution
(iii) 1 yam tuber
(iv) 3 dishes (e.g petri dishes/bowls)

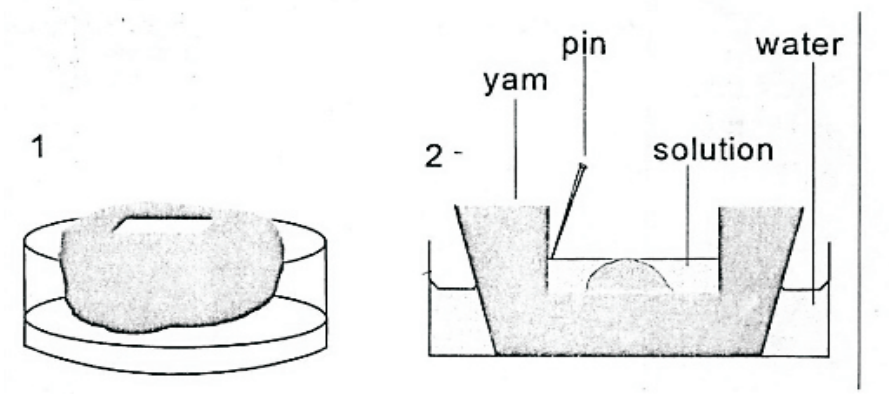


Figure 11.11 : Experiments Demonstrating Osmosis Using a Living Membrane (Raw Yam).
Source: Adapted from Esenowo (2013).

PROCEDURE

Study the diagram in Figure 11.9 to demonstrate as follows:

(i) Peel a yam tuber and cut it into three cubes of about 5cm x 5cm x 5cm.

(ii) With a knife or scalpel, make a cup shaped cavity about 2cm deep and 3cm in diameter in each cube as in Figure 11.9 [1].

(iii) Put one of the yam cubes in boiling water for about two minutes.

(iv) Half fill one of the raw yam cubes and the boiled yam cube with a saturated sugar solution. Half fill the second raw yam cube with water.

(v) Mark the level of liquid on each yam cube with pins as indicated above.

(vi) Place each yam cube in a petri dish of water and label the dishes A, B and C.

(vii) Note and record the liquid levels after two hours, as in Figure 11.10 [2].

DISCUSSION

(a) What is the reason for boiling one of the yam cubes?

(b) Explain your observations.

(c) What is the meaning of the term 'isotonic'?

ACTIVITY 5: Effect of Osmosis on a Plant Cell

AIM: To Demonstrate the Effect of Osmosis on a Plant Cell (Figure 11.11).

MATERIALS

(i) Filter paper

(ii) Slides and cover slips

(iii) Dropping pipette

(iv) Saturated sugar solution

(v) Distilled water

(vi) Microscope

(vii) *Rheo sp.* Leaves

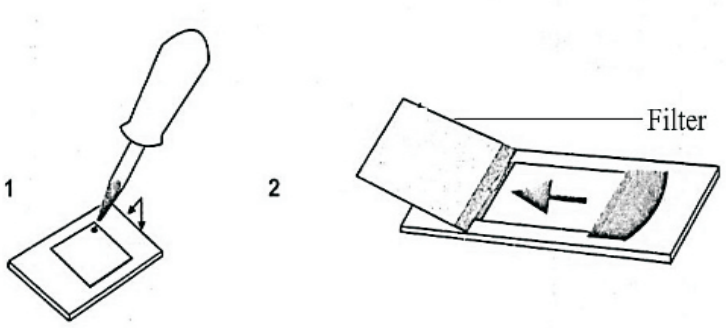


Figure 11.12 - 1 & 2: Experiment to Demonstrate the Effect of Osmosis on a Plant Cell.
Source: [Adapted from SRC Biology (2006): Philip Harris/itec].

PROCEDURE

(i) Obtain a leaf of *Rheo species.* or some other plant with a coloured epidermis.
(ii) With forceps, strip off a piece of the coloured epidermis.
(iii) Trim the piece of epidermis with scissors so that it is about one centimetre square.
(iv) Put the piece of epidermis in a drop of water on a slide, and cover it with a cover slip.
(v) Look at your slide under the low power of the microscope. Can you see the cells clearly?
(vi) With a pipette, place a drop of saturated sucrose solution against one side of the cover slip as in Figure 11.11[1]. The sucrose solution will flow under the cover slip by capillary action.
(vii) Put a piece of filter paper against the other side of the cover slip, and draw the sucrose solution across see Figure 11.11[2].
(viii) After five minutes look at the epidermal cells under the microscope.

DISCUSSION

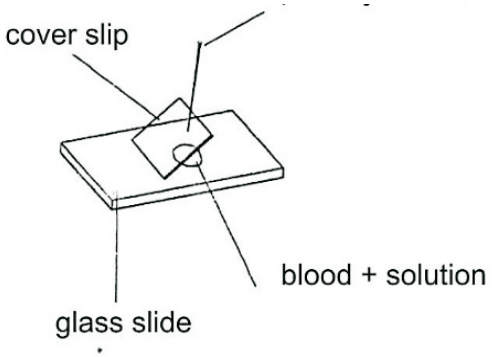
(a) How does the appearance of the epidermal cells changes?
(b) What happens to the cytoplasm inside the cells?
(c) Explain your observations.

ACTIVITY 6: Effect of Osmosis on an Animal Cell

AIM: To Demonstrate the Effect of Osmosis on an Animal Cell (see Figure 11.12).

MATERIALS

(i) Distilled water
(ii) Slides and cover slips
(iii) Dropping pipette (4)
(iv) Blood of a mammal (e.g. Rabbit)
(v) Microscope
(vi) Anti-clotting agent e.g. $10cm^3$ sodium citrate to 50cmof blood
(vii) $10cm^3$ of 0.75% sodium chloride
(viii) $10cm^3$ of 1% sodium chloride
(ix) $10cm^3$ of 3% sodium chloride



igure 11.13: Experiments to Demonstrate the Effect of Osmosis on an Animal Cell.
Source: [Adapted from SRC Biology (2006): Philip Harris/itec].

PROCEDURE

(i) Place a drop of blood on each of four slides, labelled A-D.
(ii) To A, add a drop of distilled water.
(iii) To B, C and D add a drop of 0.75 per cent, 1.0 per cent and 3.0 per cent salt solutions respectively.
(iv) Place a cover slip on each slide (see Figure 11.12).
(v) Observe the red blood cells under the high power microscope for some time.

DISCUSSION

(a) Watch what happens to the cells interprets your observations as detail as possible.
(b) Explain the term "crenation".

ACTIVITY 7: The process of diffusion
AIM: To demonstrate the process of diffusion

MATERIALS

(i) Breaker
(ii) Copper Sulphate
(iii) Water
(iv) Sugar Solutions
(v) Porous Partition

PROCEDURE

(i) Take a beaker and fill it about two third with distilled water. Now place a crystal of Copper Sulphate in this beaker and wait for some time.
(ii) In another demonstration, make two compartments in a beaker by means of a porous partition.
(iii) Now pour water or dilute sugar solution in one and concentrated sugar solution in the other component.

OBSERVATIONS

In the first demonstration, after some time, the crystal will no longer be visible but the whole of the water in the beaker will turn to blue colour. In the second demonstration, the sugar concentration and level of the solution will be the same in the two compartments

INFERENCE

Diffusion or observable movement of particles from one place to another can be seen in the difference in the concentration of a substance in the different parts of a system.

PRECAUTIONS

i. The beaker should not fill more than two third portions.
ii. There must be difference between the concentrations of sugar solutions.

ACTIVITY 8: Process of osmosis by simple osmometer (Thistle Funnel Experiment)

AIM: To Demonstrate the Process of osmosis by simple osmometer (Thistle Funnel Experiment) (see Figure 11.13).

MATERIALS

(i) 10% sugar solution
(ii) A long stammed thistle funnel
(iii) Animal bladder or parchment paper
(iv) Thread
(v) Scissors
(vi) Stand
(vii) Beaker
(viii) Colored water
(ix) Marking pencil

PROCEDURE

(i) Cover the mouth of the thistle funnel with a semi permeable membrane (animal bladder or parchment paper) by means of a thread.
(ii) Remove the free edges of the bladder with the help of scissors as close to the thread as possible.
(iii) Then seal the free margin of the bladder by rubber solution to make the joint water-tight. About 1/3 height of long narrow neck of thistle funnel is filled with 10% sugar solution and mark the level as A.
(iv) Now dip the covered end of the thistle funnel in a beaker containing coloured water as shown in Figure 11.13.

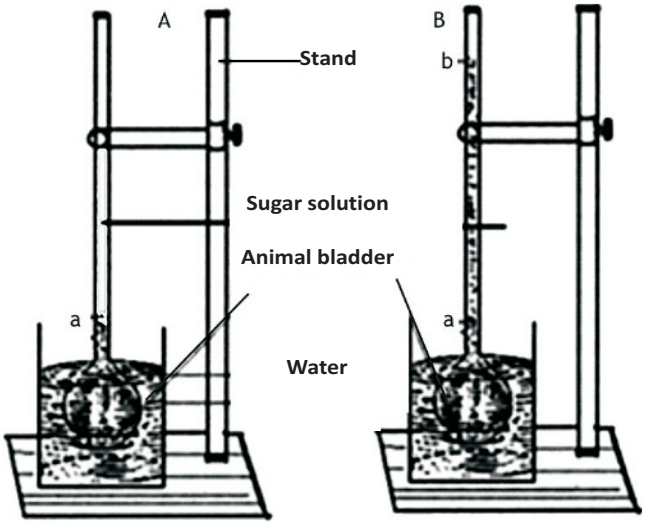


Figure 11.14: To demonstrate the process of osmosis.
Source: Gupta and Gupta (2005).

ACTIVITY 9: Osmosis using potato
AIM: To Demonstrate the phenomenon of osmosis using potato osmocope (Figure11.14).

MATERIALS

(i) A large potato tuber
(ii) Sugar solution
(iii) Knife
(iv) Petri dish
(v) Water
(vi) Capillary tube
(vii) Marking pencil

PROCEDURE

(i) Take the potato tuber and cut its one end flat.
(ii) Make a hollow cavity on another end of tuber slightly more than half of its diameter.
(iii) Also remove the skin of the tuber because it is impermeable to water.
(iv) Now place the tuber on its flat cur end in a petri-dish half full of water.
(v) Fill half of the cavity of the potato tuber with sugar solution.
(vi) Mark the initial level of the solution with the help of a pin by inserting it in the wall of the tuber.
(vii) Run the whole experiment for few hours and observe.

OBSERVATIONS

After few hours, water will begin to enter in the cavity and the level of sugar solution within the cavity will be found to increase as shown in Figure 11.14.

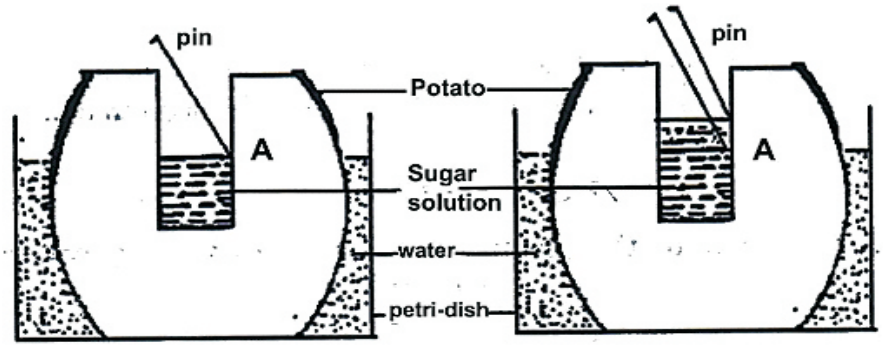


Figure 11.15: Potato osmoscope.
Source: Gupta and Gupta (2005).

INFERENCE

The rise in the level of sugar solutions in tuber cavity is obviously due to inward diffusion of water (endosmosis). The tuber wall acts as a semi permeable membrane. If the potato tuber is boiling water and protoplasm is denatured, the cytoplasm doesn't function as membrane. Thus sugar solution in the cavity does not show any change in the level.

PRECAUTIONS

1. The cavity of potato must be larger to pour sufficient amount of sugar solution.
2. The initial level of sugar solution should be marked carefully.
3. The water level in the petri-dish should be enough to dip a major portion of potato tuber.

ACTIVITY 10: The Effect of Plasmolysis and Deplasmolysis on a cell

AIM: To demonstrate the Effect of plasmolysis and deplasmolysison a cell (Figure11.15).

MATERIALS

(i) Leaf of *Tradescantia*
(ii) Sugar solution
(iii) Pipette
(iv) Petri-dishes
(v) Slides
(vi) Cover Slips
(vii) Waster etc.

PROCEDURE

(i) Peel the purple coloured lower epidermis of *Tradescantia* leaf and divide it into small stips.
(ii) Place these stripes in different concentrations of sugar solution (0.1,0.2.0.3,0.4M).
(iii) Simultaneously, also keep few peelings in fresh water as control.
(iv) Note the changes in the cells carefully with help of microscope.

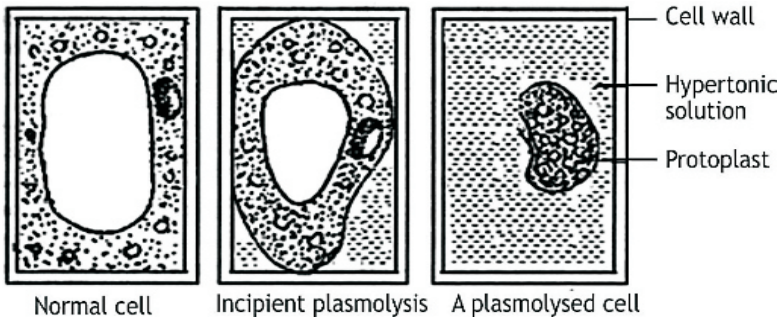


Figure 11.16: Various stages in plasmolysis.
Source: Gupta and Gupta (2005).

OBSERVATIONS

The peelings kept in lower concentration (0.1M) or in water will show no change in the condition of protoplast (the purple colour solution), which remains homogenously distributed. In contrast, the peelings kept in higher concentrations will show shrinked conditions. Count the number of cells under the microscope (see Figure 11.15).

INFERENCE

Three conditions are observed which reveal following facts.

1. The sugar solution is hypotonic, if no shrinked protoplasts are observed.
2. The sugar solution is isotonic, if 50 percent initially shrinked protoplasts are observed.
3. The sugar solution is hypertonic, if more shrinked proptoplasts are observed.

Thus, in this experiment, the phenomenon of plasmolysis has been exhibited by cells when they are kept in a hypertonic solution. The phenomenon of deplasmolysis has been exhibited by plasmolysed cells when they are kept in a water or hypotonic solutions.

PRECAUTIONS

1. Sugar solution concentration must be correctly prepared.
2. Peelings should be done from lower epidermis of leaf very carefully.
3. Mount the peeling in glycerin carefully and avoid air bubbles and folding of peelings.

11.13 TUTOR MARKED ASSESSMENT QUESTIONS

HAVING READ THROUGH **CHAPTER ELEVEN**, ANSWER THE FOLLOWING QUESTIONS IN THE SPACES PROVIDED.

1. (a) What do you understand by the statement "Transport Across Cells"?

$4\times\frac{1}{2}$ =2 Marks

(b) Write short notes on:

(i) Diffusion

$2\times\frac{1}{2}$ =1 Marks

(ii) Osmosis

$2\times\frac{1}{2}$ =1 Marks

(c) Define Plasmolysis.

$2\times\frac{1}{2}$ =1 Marks

(d) When is a solution said to be Hypertonic, Hypotonic and Isotonic?

$4\times\frac{1}{2}$ =2 Marks

2.(a) When is a Cell said to be Turgid and Flaccid?

$2\times\frac{1}{2}$ =1 Marks

(b) Write short notes on the following:
(i) Active Transport

$2\times\frac{1}{2}$ =1 Marks

(ii) Passive Transport

$2\times\frac{1}{2}$ =1 Marks

(iii) Phagocytosis

$2\times\frac{1}{2}$ =1 Marks

(iv) Pinocytosis

$2\times\frac{1}{2}$ =1 Marks

(c) In a Tabular Form distinguish Between Hypertonic, Hypotonic and Isotonic Solution

Hypertonic Solution	Hypotonic Solution	Isotonic Solution

$4\times\frac{1}{2}$ =2 Marks

(d) What Happens When Red Blood Cells are Left for Some Minutes in:

(i) Distilled Water

$2\times\frac{1}{2}$ =1 Marks

(ii) Salt of Equal Concentration as the Cytoplasmic Fluids.

$2\times\frac{1}{2}$ =1 Marks

Chapter Twelve

CELL GROWTH, DIFFERENTIATION AND SPECIALIZATION

Dr. Joseph I. Udo & Ekeng I. Okon

12.1 INTRODUCTION

Growth is an irreversible increase in the size of an organism. These involve an increase either in the number of its cells or in its ***protoplasmic material***, or both. Cell number and ***protoplasmic contents*** do not always increase together. Thus cell division can occur without any increase in protoplasm, resulting in a large number of smaller cells (e.g., cleavage). Alternatively, protoplasm can be synthesized with no cell division so that the cells become larger. Any increase in protoplasm requires the production of new cell components such as mitochondria, cell membranes, enzymes, and other proteins. Growth is an important characteristic of all living things. **Physiological** processes play essential role during ***cell growth***. Non-living materials like stones and crystals of copper sulphate in their solutions also increase in size, but this growth always takes place by the deposition of particles of these substances through external forces. This is called crystal growth. Cell differentiation is a process in which cell changes from one cell type to another. Usually, the cell change to a more specialized type. Differentiation occurs numerous times during the development of a ***multicellular organism*** as it changes from a simple zygote to a complex system of tissues and cell types. Whereas, ***cell specialization*** makes it possible to express fewer genes in individual cells of multicellular organisms, thus protecting genes from the damage of ***mutagens***. ***Cell specialization*** is the process by which generic cells change into specific cells meant to do certain tasks within the body. ***Cell specialization*** is most important in the development of embryos. In adults, stem cells are specialized to replace cells that are worn out in the bone marrow, brain, heart, and blood. ***Cell specialization*** is important because cells that make up tissues, organs, and organ systems of organisms must have different parts and or in order to specialize.

12.2 LEARNING OBJECTIVES

After reading this chapter, you should be able to:

(i) Explain the term cell growth.
(ii) Describe the processes that lead to cell growth.
(iii) List the levels of growth.
(iv) Differentiate between cell enlargement, cell differentiation and cell specialization.
(v) Explain the kinetics of cell growth.
(vi) List and explain the mechanisms of cell growth.

12.3 MEANING AND PROCESSES IN CELL GROWTH

Cell growth refers to an increase in the total mass of a cell, including both cytoplasmic, nuclear and organelle volume. ***Cell growth*** occurs when the overall rate of cellular biosynthesis (production of biomolecules or anabolism) is greater than the overall rate of ***cellular degradation*** (the destruction of biomolecules through the proteosome, lysosome autophagy or catabolism).

Cell growth must not be confused with cell division or the cell cycle, which are distinct processes that can occur alongside cell growth during the process of cell proliferation. Where a cell, known as the "mother cell", grows and divides to produce two daughter cells. Importantly, cell growth and cell division can also occur independent of one another. During early ***embryonic development*** (cleavage of the zygote to form a morula and blastoderm), cell divisions occur repeatedly without cell growth. Conversely, some cells can grow without cell division or without any progression of the cell cycle, such as growth of neurons during axonal path finding in nervous system development.

In multicellular organisms, tissue growth rarely occurs solely through cell growth without cell division, but most often occurs through ***cell proliferation***. This is because a single cell with only one copy of the genome in the cell nucleus can perform biosynthesis and thus undergo cell growth at only half the rate of two cells. Hence, two cells grow (accumulate mass) at twice the rate of a single cell, and four cells grow at 4-times the rate of a single cell. This principle leads to an exponential increase of tissue growth rate (mass accumulation) during cell proliferation, owing to the exponential increase in cell number. Cell size depends on both cell growth and cell division, with a disproportionate increase in the rate of cell growth leading to production of larger cells and a disproportionate increase in the rate of ***cell division***, which leads to the production of many smaller cells. ***Cell proliferation*** typically involves balanced cell growth and cell division rates that maintain a roughly constant cell size in the exponentially proliferating population of cells.

Some special cells can grow to very large sizes through an unusual "***endo replication***" cell cycle in which the genome is replicated during S-phase but there is no subsequent mitosis (M-phase) or cell division (cytokinesis). These large endo replicating cells have many copies of the genome, so are highly haploid (n). Oocytes can be unusually large cells in species for which embryonic development takes place away from the mother's body within an egg that is laid extremely. The large size of some eggs can be achieved either by pumping in cytosolic components from adjacent cells through cytoplasmic bridges named ring canals as Drosophila or by internalization of nutrient storage granules (yolk granules) by ***endocytosis*** frogs.

12.4 LEVELS OF GROWTH

Among living organisms, growth can be recognized at the following levels:

Cell growth in ***multicellular organisms***:

At the cellular level, the growth of all multicellular organisms is governed by two main activities. These are reproduction and growth of individual cells of the body. The growth of individual cells comprising the body is the vital and the most essential factor of growth in all multicellular organisms. The rhythmicity of cell multiplication and growth can be studied well in tissue culture or in culture of unicellular organisms.

The growth of multicellular animals and plants in relation to growth and multiplication of their individual cells falls under the following three categories:

(a) Auxetic growth (***Auxesis*** = growth resulting from increase in cell size). In this type of growth, the volume of the body increases due to the growth of body cells without any increase in the number of cells. Auxetic growth occurs in nematodes, rotifers and tunicates.

(b) Multiplicative growth: This type of growth results from the rise in the number of cells constituting the body. The increase in the number of cells is brought about by the mitotic divisions. The average size of the cells remains the same or increase insignificantly. This type of growth is called multiplicative growth and occurs in embryos during ***morphogenesis***. It is also involved in prenatal growth of higher vertebrates.

(c) Accretionary growth: Generally, post-embryonic growth of animals and plants occur due to mitotic multiplication of some special types of cells occurring in specific locations of the body. The differentiated cells of organs and tissues of the body lose the capacity of division and growth (e.g. muscles, nerve cells, osteocytes of bone, fat cells, xylem, phloem and parenchymal cells etc.). These cells tend to perform physiological functions for the survival of the animal whereas the special cells exist in an undifferentiated state as reserve cell. e.g. ***meristematic cells*** in angiosperms, stem cells such as ***erythropoietic tissue*** of red bone narrow, ***periosteum cells*** of bone, ciliary body cells of vertebrate eye seperate and epidermal cells of stratum ***germinativum***. In case of necessity, these reserve cells reinforce and replace the worn-out cells. In such an event, they differentiate into the type of cells that they reinforce and replace.

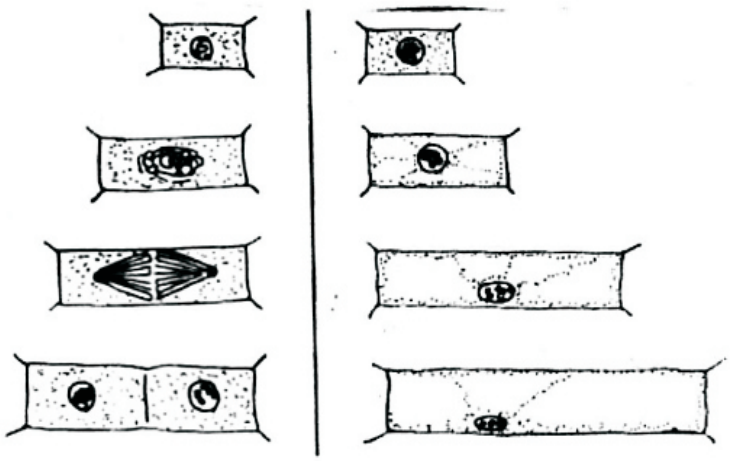
12.4.1 Stages of Cellular Growth in Multicellular Organisms

You have already learnt that growth of an organism is always associated with growth in size and number of cells. The growth of an organ or an organism occurs in three successive stages. They are:

(i) Cell division (*Hyperplasia*): The number of cells increases due to mitosis, which is a process during which a cell divides into two daughter cells having exactly the same number and types of chromosomes as parent cell. ***Mitosis*** is a normal process of growth and repair and in some simple organisms; it is a process of asexual reproduction. ***Cell division*** involves meiosis and mitosis, meiosis occurs when a cell divides to produce gametes (sex cell) containing haploid (half) the number of chromosomes found in the parent cell (see Figure 12.1a).

(ii) Cell enlargement (*Hypertrophy*): This is a process of change whereby after cell division, the resulting daughter cells increase in size due to assimilation of nutrient material and their subsequent conversion into protoplasm and in building

(i) Cell differentiation: Cells does not just grow (enlarge) and divide during ***embryonic development,*** they also undergo differentiation becoming specialized in structure and function. At thi s stage, structure of the cells changes to perform specific functions. And similar type of cells having same functions form a group, which is known as tissue.



(a) Cell Division (b) Cell Enlargement

Figure: 12.1: Comparison of cell division and cell enlargement.

Source: NIOS (2017).

In lower organisms such as bacteria and algae, the entire body grows. But in higher organisms like ferns, pine and flowering plants, growth is restricted to the cells present only in the growing regions, like shoot apex, root tip and close to the lateral sides of the stem and root. Growth at the tips leads to elongation of body parts and lateral (sideways) growth leads to increase in the thickness of stem and root.

12.5 CELL DIFFERENTIATION

Structural and functional differences occur as growth and development progress, between the various parts of the cells, tissues and organs such that "division of labour" is exhibited. Even the protoplasm of a cell is not homologous but possesses both physical and chemical diversity.

Cell differentiation is a process of change in cells during growth and development, whereby formerly undifferentiated cells become specialized for a particular function as a result of structural changes. As pointed out earlier, cells don't just grow and divide, they also undergo a process of development (differentiation), meaning they become specialized in structure and function. ***Cell differentiation*** is responsible for the development of various types of tissues in both plants and animals. For example, the primordial of leaves, flowers, and buds differentiate at the shoot apical Meristem while the ***phellen***, ***phelloderm***, fibres, ***sieve tubes,*** xylem vessels, ***companion cells*** and tracheids, etc. differentiate from the combium cells. Studies have shown that a series of genes known as hox genes controls the differentiation of cells and tissues in the embryo.

The function of hox genes is to tell the cells of the body how they should differentiate as the body grows. A mutation in one of these "master control genes" can completely change the organs that develop in specific parts of the body. Growth and differentiation usually occur together but each may take place without the other. For example, in the formation of seed endosperm, growth occurs without tissue differentiation. In many annual plants, growths usually stop after the differentiation of the reproductive organs into sepals, petals, stamens and carpels. Genetic factors, growth substances and environmental factors, especially light and nutrition play significant role in differentiation.

12.6 CELL SPECIALIZATION

All living organisms are composed of one or more cells. This statement is probably one of the most important principles of the cell theory by Theodor Schwann and Mathias Schleiden. This makes sense given that, the bodies of multi-cellular organisms are made up of cells though they are not all identical.

By virtue, of this multicellular organisms are composed of a wide variety of cells, each being specialized to perform a specific function. Of course, in order to be specialized, they need to undergo certain processes. In plants some specialized cells include ***Palisade cell, Spongy mesophyll cell,*** Guard cell**,** Xylem cell, Phloem cell and Root Hair cell.

Cell specialization (modification or differentiation) is actually a process that occur after cell division, where the newly formed cells are structurally modified so that they can perform their function efficiently and effectively. Some specialized cells in animal include Egg cell, Sperm Cell, White blood cell, Red blood cell, Ciliated Epithelial cell, ***Nerve cell*** and Muscle cell**.**

Examples of Specialised Cells

(a) Red Blood Cell (Erythrocyte)

A red blood cell is a tiny, disc-like cell (biconcave shape) which has no nucleus. In the cytoplasm of a red blood cell, there is a red pigment called haemoglobin. Each red blood cell lives for about four months, after which it breaks down. The red haemoglobin changes to a yellow pigment, which is excreted in the bile. The iron from the haemoglobin is stored in the liver. Red blood cells are made by the bone marrow of certain bones in the skeleton.

Functions of red blood cell

(i) It contains haemoglobin that can combine with oxygen to form oxyhaemoglobin.

(ii) It has no nucleus so that more haemoglobin can be accommodated (hence more oxygen can be transported). By having no nucleus enables a red blood cell to squeeze through small blood capillaries.

(iii)It has biconcave shape for increasing its surface area, thus diffusion of oxygen in and out of the red blood cell becomes easy.

(b) Root hair cell

Root hair cells are actually modified epidermal cells of the roots. A root hair cell has a long and narrow protrusion. It also has a large vacuole with lots of mitochondria in the cytoplasm. But, unlike any typical plant cells, root hair cells have no chloroplasts.

Function of root hair cell: To absorb water and mineral salts by osmosis and active transport respectively.

Adaptations to function

(i) The hair-like structure helps to increase the surface area of the root hair cell, thus helps the cell to absorb more water and mineral salts.

(ii) The hair-like structure which is long and narrow helps the cell to penetrate in between soil particles in search of water and mineral salts.

(iii) The presence of mitochondria in large number in the cytoplasm of the root hair cell helps for more absorption of mineral salts by active transport (Remember, active transport will only occur in the presence of energy provided by the mitochondria).

(iv) The large vacuole enables more water and mineral salts to be stored after being absorbed.

(a) The Xylem vessels

A xylem vessel is made up of long cells joined end to end. Once a region of the plant has ceased growing, the end walls of these cells are digested away to form a continuous fine tube. At the same time, the cell walls are thickened and impregnated with a substance called lignin which makes the cell wall very strong and impermeable. Since these lignified cell walls prevent free passage of water and nutrients, the cytoplasm dies. So a xylem is just like a water pipe which is hollow with no living materials in it.

Function of xylem vessel: To transport water and minerals from the roots to other parts of a plant as well as to provide support to the whole plant hence enable a plant to stand erect.

Adaptations to functions

(i) The cell wall of the xylem vessel being lignified adds or provides strength. This in turn provides support to the whole plant. The xylem in the leaf for example, helps the leaf to be positioned horizontally on the plant towards the sun. This helps the leaf to absorb as much light energy as possible to be used for photosynthesis.

(ii) The absence of protoplasm and cross-wall in the xylem vessel provides no obstacle for water to flow up the xylem vessel.

(iii) Being very narrow helps water to move up the xylem vessel by means of capillary action.

(b) Guard cells in between a stoma. They are specialised in such a way that the cell wall in the inner side of the guard cells is thicker than the outer side. This feature helps the guard cells to bend outward when they become turgid. This results in the opening of the stoma. If the guard cells become ***flaccid***, will bend inward resulting in the closing of the stoma.

(c) Muscle cell is generally elongated and elastic containing mitochondria in large number. The elongated and elastic feature helps muscle tissues to contract and relax. Contraction and relaxation of muscle tissues help in movement. Muscle cell bring parts of the body closer together. They contain protein fibres that can contract when energy is available, making the cells shorter.

12.7 KINETICS OF CELL GROWTH

There is a great problem in determining the kinetic enlargement between divisions, since the criteria for measuring growth (for example, dry mass, volume and linear dimensions) do not behave consistently even within the same cell. Studies on fixed cells and on living cells have revealed the following two patterns of growth namely;

(i) **Linear growth pattern:** Means that growth rate is constant throughout the cell cycle and does not increase. Here, growth rate is independent of cell mass but is related to a constant number of elements (synthetic sites), the activities of which remain unchanged throughout the growth cycle.

(ii) **An exponential growth pattern:** Means that growth rate is a function of total mass; as mass increases, growth rate increases accordingly. The curve is sigmoidal, behaving as an ***autocatalytic process*** with growth rate proportional to the amount of active protoplasm or replicating entities.

12.8 CHANGES INVOLVED IN CELL GROWTH

In most cases, the kinetics of mass increase is usually matched by parallel synthesis of RNA, protein and membrane. The synthesis of DNA, being discontinuous, is not directly related to the kinetics of ***cell growth***. It is however, involved in controlling the cell size.

(i). **RNA synthesis and cell growth**: Generally, ribosomal RNA and tRNA are synthesized continuously throughout the ***eukaryotic cell cycle***. The rate of synthesis may increase during cell cycle; in mammalian cells, rate of rRNA synthesis becomes double after S-phase. The pattern for mRNA is not known since different species of mRNA are synthesized at different periods of the cycle and at different rates. The correlation between overall cell growth patterns and rRNA synthesis suggests that the production of ribosomes might be an important site for growth regulation. Evidently, the total number of ribosomes in a bacteria cell controls the rate of synthesis of all proteins during growth i.e. the number of ribosomes per DNA genome is proportional to the rate of growth and ***protein synthesis***. In eukaryotic cells, growth rate depends on total number of cytoplasmic ribosomes per cell and these are controlled by the nucleolus, the seat of ***ribosome synthesis***.

(ii) **Nucleoli and Cell growth:** Nucleolus shows cyclic changes during the cell cycle and is somehow related to cell growth. During interphase, when cells are actively growing, nucleoli are prominent and synthesize ribosomal RNA at a high rate.

In prophase, when growth stops, nucleoli disappear, emptying their contents into the nucleoplasm. Nucleoli are absent in metaphase and anaphase but reappear early in telophase at twice their original number, as new nucleoli organize at nucleolar organizer sites in each daughter cell increases to twice the rate of the original mother cell though total ***protoplasmic mass*** has not changed. Thus, growth rate doubles after the nucleolar organizers are replicated during the S phase when twice the number of ribosomal RNA genes start to transcribe rRNA.

(iii). **Protein Synthesis and Cell Growth**: Most eukaryotic cell growth results from total protein accumulation – the net balance between total ***protein synthesis*** and protein degradation. Both processes are subject to different modes of regulation, the former largely dependent upon the availability of the ribosomes. Further, through total cell protein may seem to increase continuously through the cell, some individual proteins may be constant, others may be descreasing and still others may be increasing in a stepwise fashion. However, some set of proteins may be coordinately regulated, particularly those proteins that characterize a cell ***phenotype***.

12.9 REQUIREMENTS FOR CELL GROWTH

A characteristic of cells is their ability to grow and form a population of organisms. The requirements for successful cell growth are:

(i) **Chemical requirements:** In order to grow successfully, cells must have a supply of water as well as numerous other substances including mineral elements as iron, copper and zinc. These elements are used most often for the synthesis of enzymes. Organic growth factors such as vitamins may also be needed. Amino acids, purine and pyrimidines must also be available.

(ii) **Physical requirements:** Certain physical conditions also affect cell growth, examples of such are temperature, pH, and light, etc.

12.10 PLANT AND ANIMAL TISSUE CULTURE

Tissue culture can be defined as the process whereby small pieces of living tissues or cells are isolated from an organism and grown under aseptic conditions. They grow on defined liquid, semisolid or solid growth medium such as broth or agar. Depending on whether animal cells and tissues or plant cells and tissues are being grown, the technique is termed animal tissue culture or plant tissue culture respectively. Tissue Culture (*in vitro* - propagation) belongs to the second generation biotechnology where more specialized techniques are employed in the use of living organisms or their products for commercial purposes.

Nowadays, it is possible to grow plants of many kinds from small pieces (***micropropagation***) using tissue culture. All the plants grown from pieces or from one parent plant will be genetically alike and will grow in the same way as if they are treated identically. The small fragments begin life growing in a liquid or gel which provides all necessary substances for their development. This is an ideal way of propagating plants for glasshouse owners who want to produce many similar, healthy plants.

If ***tissue culture*** methods are used, special facilities are needed. The growing medium must be sterile. The fragments of plants are handled with sterile instruments too. Finally, the correct temperature and other conditions have to be provided. The requirements for successful tissue culture are very precise.

Plant tissue culture, or ***micropropagation***, is a method used for cloning plants. It is used widely for the rapid multiplication of commercially important plant species with superior ***genotypes***, as well as in the recovery programmes for endangered plant species.