CHAPTER

1

Introduction To Biology

Science is the study in which observations are made,experiments are done and logical conclusions are drawn in order to understand the principles of nature.

In ancient times, the scientific information was not classified into different branches, as it exists today. All the scientific information was included under one head i.e. 'science'. With the passage of time scientific information increased many folds and this enormous scientific knowledge was then classified into different branches like, biology, physics, chemistry, mathematics etc.

Scientific knowledge is the common heritage of mankind.
Dr. Abdus Salam

1.1 Introduction To Biology

Biology is the scientific study of life. The word "biology" has been derived from two Greek words; '**bios**' meaning 'life' and '**logos**' meaning 'thought or reasoning'. In the course of biology, we will study how man has thought about living things. To understand and appreciate nature, it is essential to study the structures, functions and related aspects of living organisms. The study of living organisms also provides information and remedies to human problems regarding health, food, environment etc.

Animation 1.1: Microscope
Source & Credit: savillbiology

1.1.1 Divisions and Branches of Biology

There are three major divisions of biology which study the different aspects of the lives of the major groups of organisms.

ZOOLOGY
This division of biology deals with the study of animals.

BOTANY
This division of biology deals with the study of plants.

MICROBIOLOGY
This division of biology deals with the study of microorganisms such as bacteria etc.
In order to study all the aspects of life, these divisions are further divided into different branches as defined below.

Morphology
This branch deals with the study of form and structures of living organisms.

Molecular biology (biochemistry) deals with the study of the molecules of life; e.g. water, proteins, carbohydrates, lipids, and nucleic acids.

Anatomy
The study of internal structures is called anatomy.

Histology
The microscopic study of tissues is called histology.

Cell biology
The study of the structures and functions of cells and cell organelles is called cell biology. This branch also deals with the study of cell division.

Physiology
This branch deals with the study of the functions of different parts of living organisms.

Genetics
The study of genes and their roles in inheritance is called genetics. Inheritance means the transmission of characters from one generation to the other.

Embryology
It is the study of the development of an embryo to new individual.

Taxonomy
It is the study of the naming and classification of organisms into groups and subgroups.

Palaeontology
It is the study of fossils, which are the remains of extinct organisms.

Environmental biology
It deals with the study of the interactions between the organisms and their environment.

Socio-biology
This branch deals with the study of social behaviour of the animals that make societies.

Parasites are the organisms that take food and shelter from living hosts and, in return, harm them.

Parasitology:
This branch deals with the study of parasites.

Biotechnology:
It deals with the practical application of living organisms to make substances for the welfare of mankind.

Immunology
It is the study of the immune system of animals, which defends the body against invading microbes.

Entomology
It is the study of insects.

Pharmacology

It is the study of drugs and their effects on the systems of human body.

Human population growth, infectious diseases, addictive drugs and pollution are the major biological issues today.

1.1.2 Relationship of biology to other sciences

The interrelationship among different branches of science cannot be denied. Biology includes information on various aspects of living things but these information relate to the other branches of science as well. Each branch of science has relationship with all other branches. For example, when studying the process of movement in animals, the biologists have to refer to the laws of motion in physics. This forms the basis of **interdisciplinary sciences** (Figure 1.1).

Biophysics:

It deals with the study of the principles of physics, which are applicable to biological phenomena. For example there is a similarity between the working principles of lever in physics and limbs of animals in biology.

Biochemistry:

It deals with the study of the chemistry of different compounds and processes occurring in living organisms. For example the study of basic metabolism of photosynthesis and respiration involves the knowledge of chemistry.

Discussion / Debate

Identify and evaluate the impact of scientific ideas and/or advancements in technology on society.

Biomathematics / Biometry:

It deals with the study of biological processes using mathematical techniques and tools. For example to analyze the data gathered after experimental work, biologists have to apply the rules of mathematics.

Biogeography:

It deals with study of the occurrence and distribution of different species of living organisms in different geographical regions of the world. It applies the knowledge of the characteristics of particular geographical regions to determine the characteristics of living organisms found there.

Bioeconomics:

It deals with the study of organisms from economical point of view. For example the cost value and profit value of the yield of wheat can be calculated through bioeconomics and benefits or losses can be determined.

Discussion / Debate
Identify and evaluate the impact of scientific ideas and/or advancements in technology on society

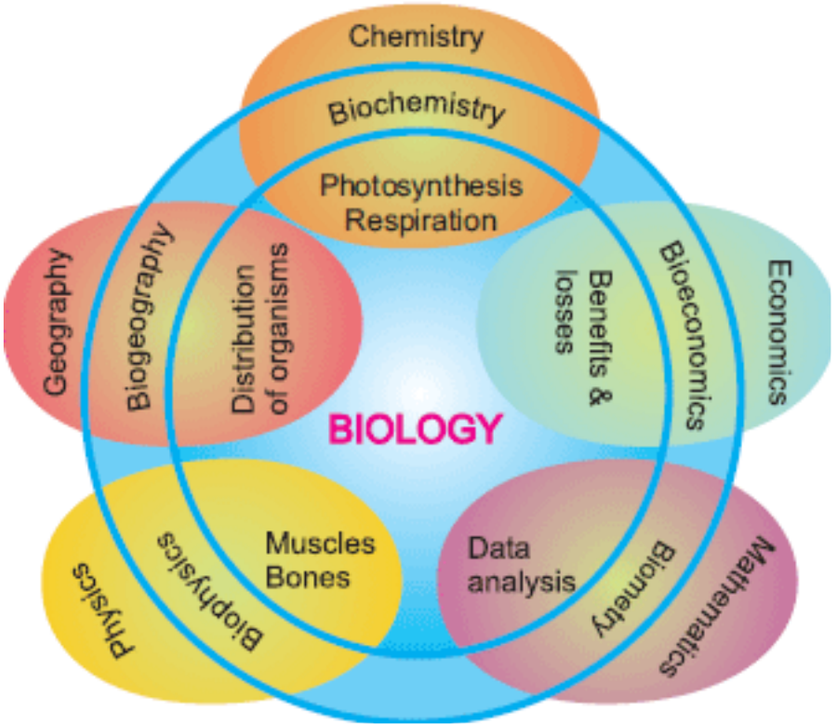


Figure 1.1: Relationship of biology with other sciences

1.1.3 Careers In Biology

It is essential that students of today, who will occupy positions of leadership tomorrow, have the background of the modern and forward-looking branches of science. An accurate and modern knowledge of biology, will promote a comprehension of both science and scientific research projects. It will benefit the learners in diverse list of careers. The following are the careers that a student of biology can plan to adopt.

Medicine / Surgery:

The profession of medicine deals with the diagnosis and treatment of diseases in human. In surgery the parts of the body may be repaired, replaced or removed, for example the removal of stones through renal surgery, transplantation of kidney, liver etc. Both these professions are studied in the same basic course (MBBS) and then students go for specializations.

Fisheries:

Fisheries is the professional study of fish production. There are departments in Pakistan where professionals of fisheries are employed. They serve for enhancing the quality and quantity of fish production. In Pakistan, this profession can be adopted after the bachelor or masters level study of zoology and fisheries.

Agriculture:

This profession deals with the food crops and animals which are the source of food. An agriculturist works for the betterment of crops like wheat, rice, corn etc and animals like buffalo cow etc from which we get food. In Pakistan there are many universities which offer professional courses on agriculture after the higher secondary education in biology.

Animal husbandry:

It is the branch of agriculture concerned with the care and breeding of domestic animals (livestock) e.g. cattle, sheep etc. Professional courses in animal husbandry can be adopted after the higher secondary education in biology.

Horticulture:

It deals with the art of gardening. A horticulturist works for the betterment of existing varieties and for the production of new varieties of ornamental plants and fruit plants. Biology students can adopt this profession after their higher secondary education.

Farming:

It deals with the development and maintenance of different types of farm. For example in some farms animal breeding technologies are used for the production of animals which are better protein and milk source. In poultry farms chicken and eggs are produced. Similarly in fruit farms, different fruit yielding plants are grown. A student who has gone through the professional course of agriculture, animal husbandry or fisheries etc. can adopt this profession.

Forestry:

In forestry, professionals look after natural forests and advises to the government for planting and growing artificial forests. Many universities offer professional courses in forestry after the higher secondary education in biology or after bachelor level study of zoology and botany.

Biotechnology:

It is the latest profession in the field of biology. Biotechnologists study and work for the production of useful products through microorganisms. Universities offer courses in biotechnology after the higher secondary education in biology and after the bachelor level studies of botany or zoology.

1.1.4 Quran and biology

At many places in Holy Quran, Allah hints about the origin and characteristics of living organisms. In the same verses human beings have been instructed to expose the unknown aspects of life, after getting the hints. Here are few examples of such guidelines.

وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ ۖ

"We made every living thing from water."
(Sura: Ambia, Verse: 30)

We know that water makes the 60-70% of the composition of protoplasm of all living things. The above Verse hints at the common origin of all living things in water. As Allah has ordered human beings to think at the hints given by Him, we should study living things so that the mysteries of their origin can be revealed.

خَلَقَ الْإِنسَانَ مِن صَلْصَالٍ كَالْفَخَّارِ ۝

"He made man from clay like the potter."
(Sura: Rehman, Verse: 14)

In another verse, God says:

ثُمَّ خَلَقْنَا النُّطْفَةَ عَلَقَةً فَخَلَقْنَا الْعَلَقَةَ مُضْغَةً
فَخَلَقْنَا الْمُضْغَةَ عِظَامًا فَكَسَوْنَا الْعِظَامَ لَحْمًا ۝

"Then fashioned We the drop a clot, then fashioned We the clot a little lump, then fashioned We the little lump bones, then clotted the bones with flesh"
(Sura: Al-Mominoon, Verse: 14)

When we think at the hints given in both these Verses, we find the events that occurred in the creation of human beings. Allah also hints at the method of the development of animals including human beings.


وَاللّٰهُ خَلَقَ كُلَّ دَآبَّةٍ مِّنْ مَّآءٍ ۚ فَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى بَطْنِهٖ ۚ وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى رِجْلَيْنِ ۚ
وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰٓى اَرْبَعٍ ۚ يَخْلُقُ اللّٰهُ مَا يَشَآءُ ۚ اِنَّ اللّٰهَ عَلٰى كُلِّ شَيْءٍ قَدِيْرٌ ۝

"Allah hath created every animal from water. Then some of them creep up over their bellies, others walk on two legs, and others on four. Allah creates what He pleases."
(Sura: Al-Nur, Verse: 45)

This Verse describes the common origin and modification of organisms and also supports the modern concepts of classification.
Thus, Quran hints not only at the origin and development of life but also at many characteristics of living organisms.

1.2 Muslim Scientists

Muslim scientists have made great contributions to the study of science and we are aware of their success in different fields of science. Here we would summarize the work of Jabir Bin Hayan, Abdul Malik Asmai and Bu Ali Sina in the development of the present day knowledge of plants and animals.

Jabir Bin Hayan (721 - 815 AD):

He was born in Iran and practised medicine in Iraq. He introduced experimental investigation in chemistry and also wrote a number of books on plants and animals. His famous books are "Al-Nabatat" and "Al-Haywan".

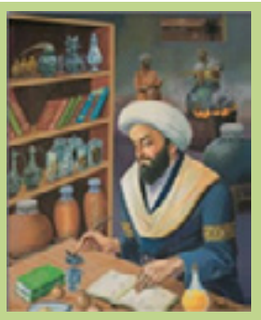
Abdul Malik Asmai (740 - 828 AD):

He is considered the first Muslim scientist who studied animals in detail. His famous writings include "Al-Abil (camel)", "Al-Khail (horse)", "Al-Wahoosh (animal)", and "Kalq al-Ansan".

Bu Ali Sina (980 - 1037 AD):

He is honoured as the founder of medicine and called as Avicenna in the West. He was a physician, philosopher, astronomer and poet. One of his books “Al-Qanun-fi al-Tib” is known as the canon of medicine in West.

Bu Ali Sina



Jabir Bin Hyan

1.3 The Levels Of Organization

In order to understand the various phenomena of life, biologists study biological organization at different levels, which are as follows.

1. Subatomic and Atomic level

All types of matter are made up of elements and each element contains a single kind of atoms (‘a’: not, ‘tom’: cut). The atoms are actually made up of many subatomic particles.

The most stable subatomic particles are electrons, protons and neutrons. Out of the 92 kinds of elements that occur in nature, 16 are called bioelements. These take part in making the body mass of a living organism (Figure 1.2). Out of these bioelements; Only six (O, C, H, N, Ca, & P) make 99% of the total mass. Other ten (K, S, Cl, Na, Mg, Fe, Cu, Mn, Zn, & I) collectively make 01% of the total mass.

Recalling

Protons and neutrons are located inside nucleus of atom while electrons orbit in energy levels (electrons shells) around the nucleus. The number of electrons in the outermost shell determines the manner in which atoms react with each other.

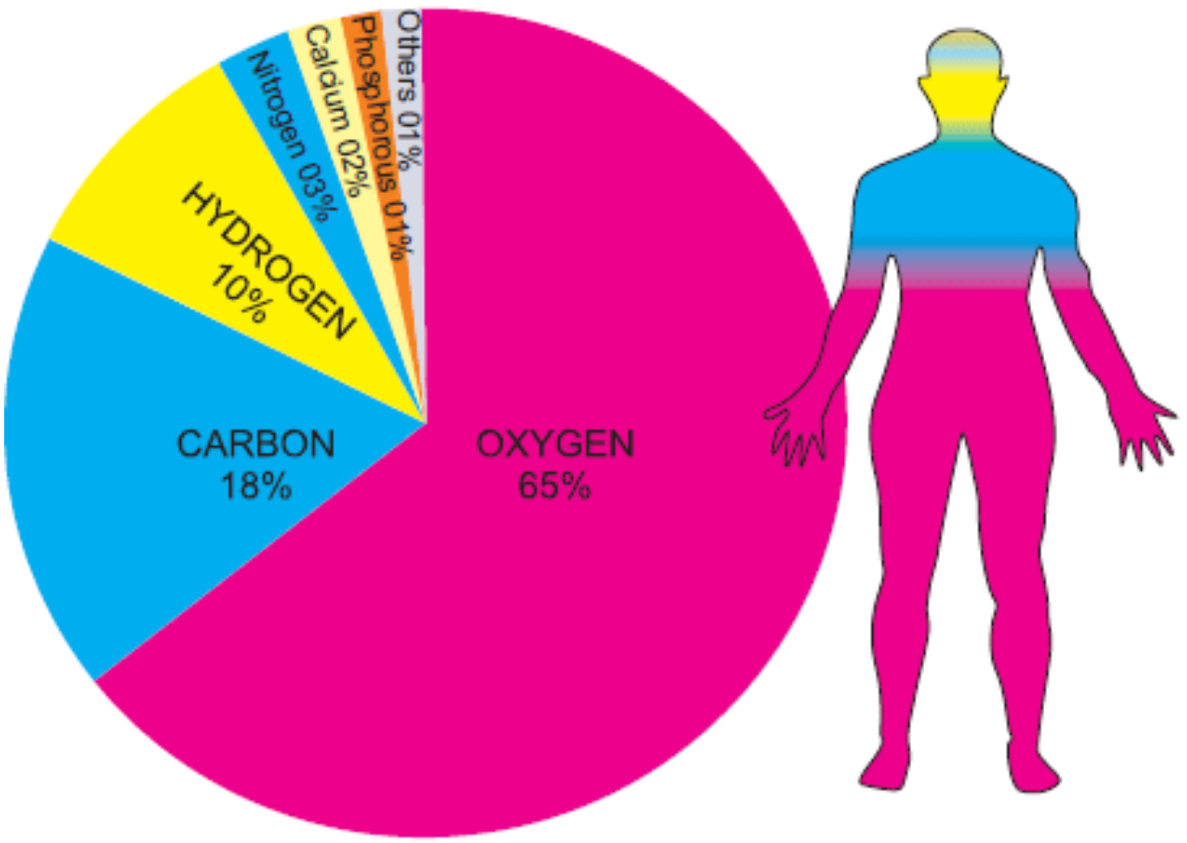


Figure 1.2: Percentage composition (by mass) of bioelements in the protoplasm of living organisms

Recalling

A molecule is the smallest part of a compound that retains the properties of that compound.

2. Molecular level

In organisms, bioelements usually do not occur in isolated forms rather they combine through ionic or covalent bonding. The stable particle formed by such bonding is called as molecule or biomolecule.

An organism is formed by enormous number of biomolecules of hundreds of different types. These molecules are the building material and are themselves constructed in great variety and complexity due to specific bonding arrangements. Biomolecules are classified as micromolecules and macromolecules. **Micromolecules** are with low molecular weight e.g. glucose, water etc. and **macromolecules** are with high molecular weights e.g. starch, proteins, lipids etc.

3. Organelle and Cell level

Biomolecules assemble in a particular way and form organelles. The organelles are actually sub-cellular structures and when they assemble together, units of life i.e. cells are formed.

Each type of organelle is specialized to perform a specific function. For example; mitochondria are specialized for cellular respiration and ribosomes are specialized for protein synthesis. In this way, functions of the cell are accomplished by these specialized structures. It is an example of the division of labour within the cell.

In the case of prokaryotes and most protists, the entire organism consists of a single cell. In the case of most fungi, all animals and all plants, the organism consists of up to trillions of cells.

4. Tissue level

In multicellular organisms, similar cells (performing similar functions) are organized into groups, called tissues. We can define a tissue as a group of similar cells specialized for the performance of a common function. Each cell in a tissue carries on its own life processes (like cellular respiration, protein synthesis), but it also carries on some special processes related to the function of the tissue. There are different types of plant tissues e.g. epidermal tissue, ground tissue, etc. Animal tissues are also of different types e.g. nervous tissue, muscular tissues etc.

5. Organ and Organ system level

In higher multicellular organisms more than one type of tissue having related functions are organized together and make a unit, called organ. Different tissues of an organ perform their specific functions and these functions collectively become the function/s of that organ. For example stomach is an organ specialized for the digestion of proteins and for storing food. Two major types of tissue are present in its structure. Epithelial (glandular) tissue secretes gastric juice for the digestion of proteins.

Muscular tissue performs contractions of stomach walls for grinding of food and moving food to posterior end. So two tissues perform their specific functions, which collectively become the function of stomach.

The next level of organization in multicellular organisms is the organ system level. Different organs performing related functions are organized together in the form of an organ system. In an organ system, each organ carries out its specific function and the functions of all organs appear as the function of the organ system. For example, digestive system is an organ system that carries out the

process of digestion. Major organs in its framework are oral cavity, stomach, small intestine, large intestine, liver, and pancreas. All these organs help in the process of digestion.

The organ system level is less complex in plants (e.g. root system) as compared to animals. This is due to a greater range of functions and activities in animals than in plants.

6. Individual level

Different organs and organ systems are organized together to form an individual or organism. In organism, the functions, processes and activities of various organs and organ systems are coordinated. For example, when a man is engaged in continuous and hard exercise, not only his muscles are working but also there is an increase in the rate of respiration and heart beat. This accelerated rate of respiration and heart beat supplies more oxygen and food to the muscles which they need for continuous work.

7. Population level

Biologists extend their studies to the population level where they study interactions among member of the same species living in the same habitat. A population is defined as a group of organisms of the same species located at the same place, in the same time. For example, human population in Pakistan in 2010 comprises of 173.5 million individuals (according to the Ministry of Population Welfare, Government of Pakistan).

A species is defined as a group of organisms capable of interbreeding and producing fertile offspring.

Habitat means the area of the environment in which organism lives.

8. Community Level

A community is an assemblage of different populations, interacting with one another within the same environment. A forest may be considered as a community. It includes different plant, microorganisms, fungi and animal species. Communities are collections of organisms, in which one population may increase and others may decrease. Some communities are complex e.g. a forest community, a pond community etc. Other communities may be simple e.g. a fallen log with various populations under it. In a simple community number and size of populations is limited. So any change in biotic or abiotic factors may have drastic and long lasting effects.

9. Biosphere level

The part of the Earth inhabited by organisms' communities is known as biosphere. It constitutes all ecosystems (areas where living organisms interact with the nonliving components of the environment) and is also called the zone of life on Earth.

1.3.1 Cellular organizations

All the organisms have been divided into five major groups i.e. prokaryotes, protists, fungi, plants and animals. All organisms are made of cells. There are two basic types of cells. The organisms in first group are made of prokaryotic cells while all other groups have eukaryotic cells.

Cells organize in three ways to make the bodies of organisms. Cells make unicellular, colonials and multicellular organizations and the organisms formed through these organizations are unicellular organisms, colonial organisms and multicellular organisms.

In **unicellular organisms**, only one cell makes the life of an organism. All the life activities are carried out by the only cell. Amoeba, Paramecium, and Euglena are common examples (Figure 1.4).

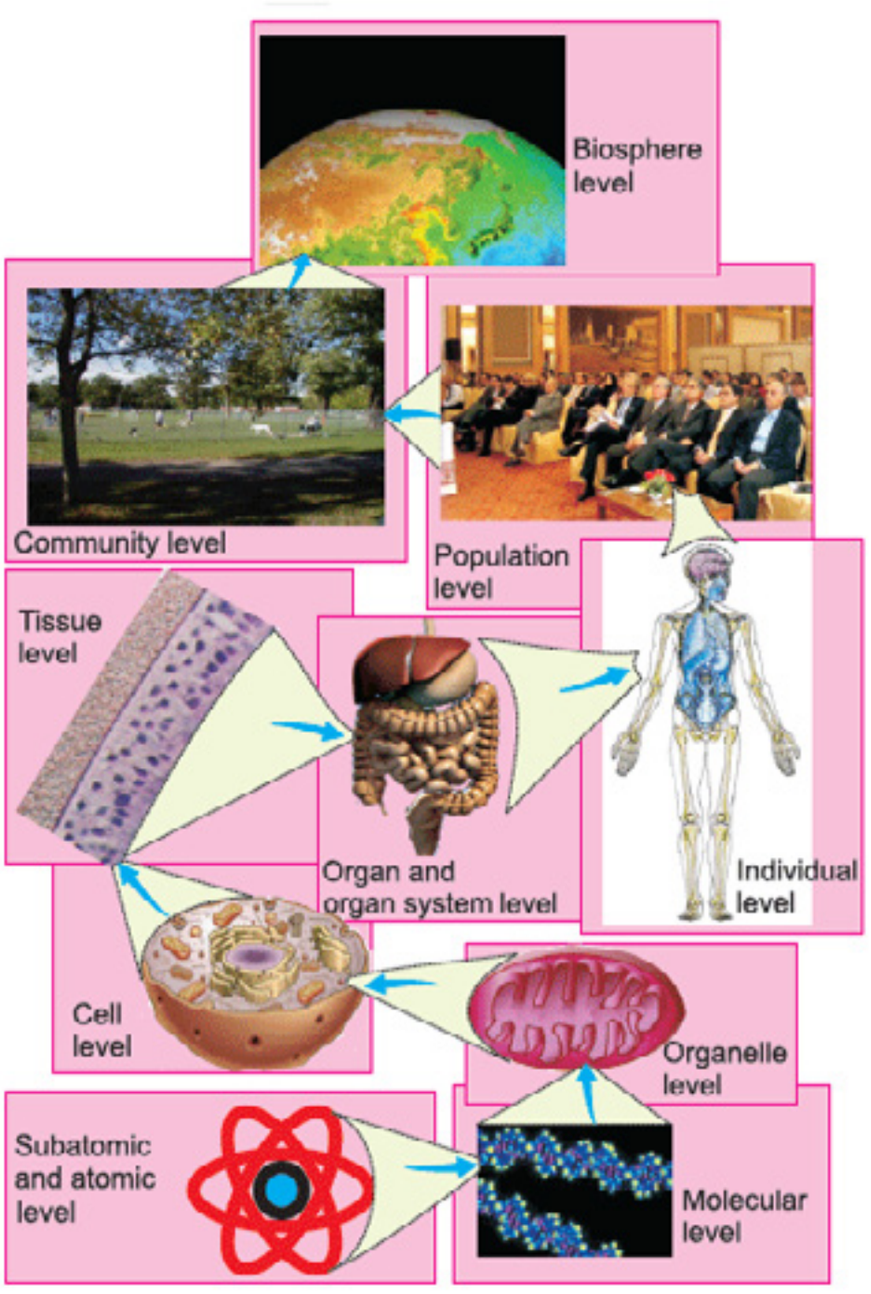


Figure 1.3: Levels of organization

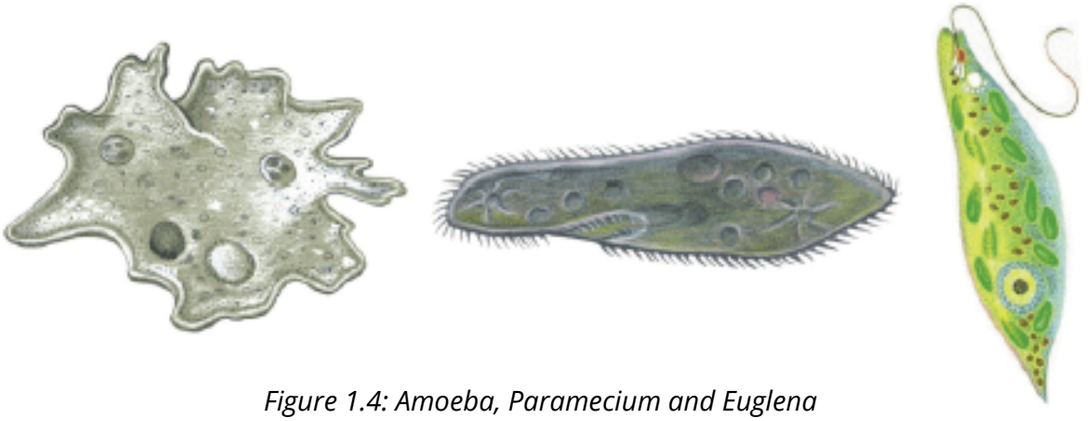


Figure 1.4: Amoeba, Paramecium and Euglena

In colonial type of cellular organization, many unicellular organisms live together but do not have any division of labour among them. Each unicellular organism in a colony lives its own life and does not depend on other cells for its vital requirements. Volvox is a green alga found in water that shows colonial organization. Hundreds of Volvox cells make a colony (Figure 1.5).

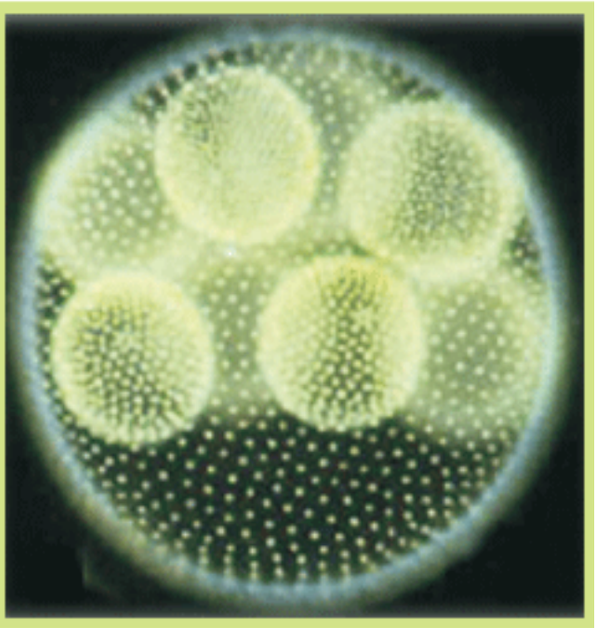


Figure 1.5: Volvox colony

In multicellular organization, cells are organized in the form of tissues, organs and organ systems. Frog and mustard are the familiar examples of multicellular organization.

Mustard plant

Mustard plant (scientific name: *Brassica campestris*) is sown in winter and it produces seeds at the end of winter. The plant body is used as vegetable and its seeds are used for extracting oil. The organs of the body can be divided into two groups on the basis of their functions. Root, stem, branches and leaves are the vegetative organs, which do not take part in the sexual reproduction of the plant. Flowers are the reproductive parts of the plant because they take part in sexual reproduction and produce fruits and seeds. (Figure 1.6)

Frog

Frog (scientific name: *Rana tigrina*) shows the multicellular organization. The body is made of organ systems and each organ system consists of related organs. All the organs are made of specific tissues (epithelial, glandular, muscular, nervous etc). Some organs and organ systems of frog have been described in the practical activity given next.

Figure 1.7: Frog

Analyzing and Interpreting:

Describe the main organs of the mustard by observing a specimen.

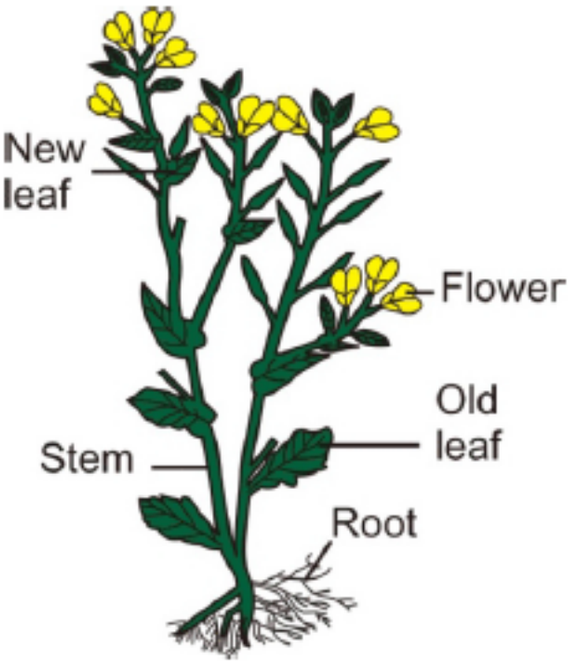


Figure 1.6: Mustard

Analyzing and Interpreting

Identify different tissues in the photomicrographs of different organs.

Practical Work:

Identification of organs and organ systems in a dissected frog

The multicellular organization can be studied in a dissected frog. Different organs and organ systems can be identified and compared with the diagrams or figures given in books or charts.

Problem:

Identify the organs that make up the internal systems of the frog.

Purpose:

In laboratory, the teacher will dissect a frog in order to expose its external and internal structures.

Background information:

Frog belongs to the class amphibia of the animal kingdom. It possesses multicellular organization consisting of tissues, organs and organ systems.

- On the outside of the frog's head are two external nostrils; two tympani, or eardrums; and two eyes, each of which has three lids. The third lid, called the nictitating membrane, is transparent.
- The digestive system consists of the organs of the digestive tract and the digestive glands.
- The respiratory system consists of the nostrils and the larynx, which opens into two lungs.
- The circulatory system consists of the heart, blood vessels, and blood.
- The urinary system consists of the kidneys, ureters, bladder, and cloaca.
- The organs of the male reproductive system are testes, sperm ducts, and cloaca. The female system consists of ovaries, oviducts, uteri, and cloaca.
- The central nervous system of frog consists of the brain, which is enclosed in the skull, and the spinal cord, which is enclosed in the backbone. Nerves branch out from brain and spinal cord.
- The frog's skeletal and muscular systems consist of its framework of bones, to which all the skeletal muscles of the body are attached.

Material Required: Preserved frog, dissecting tray, paper towels and dissecting kit

Procedure:

The teacher will place an unconscious frog on a dissection tray on its back and pin down the legs. From the ventral side, he / she will lift the skin and use scissors to cut along the center of the body from the cloaca to the lip. He / she will turn back the skin, cut toward the side at each leg, and pin the skin flat. Then he / she will lift and cut through the muscles and breast bone to open up the body cavity.

1. Use the diagram below (Figure 1.8) to locate and identify the organs of the digestive system: esophagus, stomach, small intestine, large intestine, cloaca, liver, gallbladder, and pancreas.
2. Again refer to the diagram below to identify the parts of the circulatory and respiratory systems that are in the chest cavity. Find the left atrium, right atrium , and ventricle of the heart. Find the two lungs.
3. Use a probe and scissors to lift and remove the intestines and liver. Identify the parts of the urinary and reproductive systems. Find the ureters; the urinary bladder; the testes and sperm ducts in the male; and the ovaries, oviducts, and uteri in the female.
4. Remove the kidneys and look for threadlike spinal nerves that extend from the spinal cord.
5. Dispose of your materials according to the directions from your teacher.
6. Clean up your work area and wash your hands before leaving the lab.

Observation: After identifying the important organs and organ systems, draw your observation in the form of diagrams.

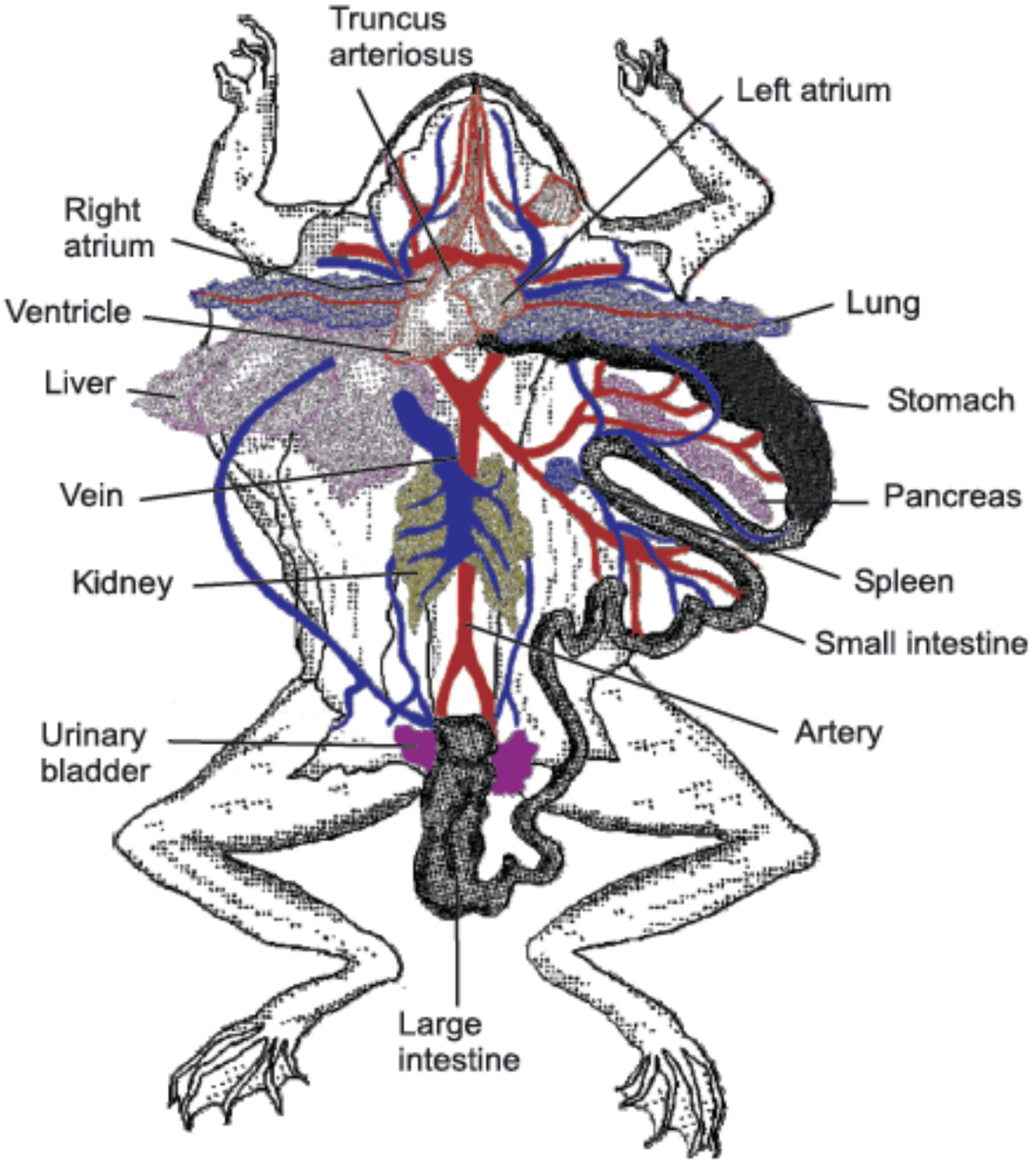


Figure 1.8: Anatomy of dissected frog

Evaluation:

1. What may be the purpose of nictitating membrane in frog?
2. On which side of body did you see the kidneys? Dorsal or ventral?
3. Which part is the common passage in the digestive, excretory and reproductive systems?
4. What was the sex of the dissected frog? How would you differentiate male and female frogs while looking at their anatomy?

UNDERSTANDING THE CONCEPTS

1. Arrange these structures in order of lower level of organization to upper level and write the level against each structure. Neuron, nervous system, electron, man, mass of neurons, carbon, mitochondria, brain, protein
2. How would you define biology and relate it with its major divisions?
3. Draw a table showing the branches of biology and the studies these deal with.
4. Give points to advocate that Biology is linked with physics, chemistry, mathematics, geography and economics.
5. How would you distinguish the biomolecules from other molecules? What is the criterion for classifying a biomolecule as micromolecule or macromolecule?
6. Describe the levels of organization of life.
7. Is there any division of labour among the cells of a colony? If you find division of labour among the cells and tissue what level of cellular organization is it?

SHORT QUESTIONS

1. Define biotechnology.
2. What do you mean by horticulture and how is it related to agriculture?

THE TERMS TO KNOW

Agriculture
Anatomy
Animal husbandry
Biochemistry
Bioeconomics
Bioelement
Biogeography
Biology
Biomathematics
Biomolecule
Biophysics
Biotechnology
Botany
Cell
Cell biology
Colony
Community
Embryology
Entomology
Environmental biology
Farming
Fisheries
Forestry
Fossil
Genetics
Histology
Horticulture
Immunology
Inheritance
Macromolecule
Microbiology
Micromolecule
Microorganism
Morphology
Organ
Organ system
Organelle
Palaeontology
Parasite
Parasitology
Pharmacology
Physiology
Population
Prokaryote
Protist
Science
Socio-biology
Surgery
Taxonomy
Tissue
Volvox
Zoology

INITIATING AND PLANNING

1. Draw a linkage chart connecting different organs with the relative organ systems.

ANALYZING AND INTERPRETING

1. Identify different tissues in the photomicrographs of different organs.

ACTIVITIES

1. Identify major organs and organ systems in a dissected frog (Dissection by teacher / demonstrator).

SCIENCE, TECHNOLOGY AND SOCIETY

1. Identify and evaluate the impact of scientific ideas and/or advancements in technology on society.
2. List organs of human body that some notorious diseases of today damage and specify the ones, which can be transplanted.

ON-LINE LEARNING:

1. www.biology-online.org/dictionary/Branches_of_biology
2. en.allexperts.com/q/Biology-664/
3. www.usoe.k12.ut.us/curr/Science/sciber00/7th/cells/sciber/levelorg.htm
4. www.ofsd.k12.wi.us/science/frogdiss.htm

CHAPTER

2 Solving A Biological Problem

Animation 2.1: Solving A Biological Problem
Source & Credit: Wikispace

Science is the systemized knowledge derived from observations and experiments.These experiments are carried out to determine the principles about how nature operates. Scientists like chemists, biologists and physicists use the same scientific method to make and test new theories.

In this chapter, we will study the steps of biological method. We will study malaria as an example to understand the steps in detail.

2.1 Biological Method

Questions about living things have provided problems that man has investigated to aid his own survival and to satisfy his desire to know. The scientific method in which biological problems are solved, is termed as biological method. It comprises the steps a biologist adopts in order to solve a biological problem.

Biological method has played an important part in scientific research for almost 500 years. From Galileo's experiment (in the 1590s) to current research, the biological method has contributed to the advancements in medicine, ecology, technology etc. Biological method also ensures the quality of data for public use

Man has always been a biologist. He had to be a biologist in order to live. Early in history, he was a hunter of animals and a gatherer of fruits, seeds, roots etc. The more he knew about animals and their habitat, the more successful hunter he was. The more he knew about plants, the better he distinguished between edible and non-edible plants.

2.1.1 Biological problem, hypothesis, deductions and experiments

In biology (like other sciences), new things are being discovered and long-held theories are being modified or replaced with better ones as more data/knowledge is accumulated. This happens when biologists recognize some biological problem and go for its solution. In solving a biological problem, biologist takes following steps;

- Recognition of biological problem
- Observations
- Hypothesis formulation
- Deductions

- Experimentation
- Summarization of results (create tables, graphics etc)
- Reporting the results

The details of these steps are as under:

1. Recognition of the Biological Problem

Biologists go for adopting biological method when they encounter some biological problem. A biological problem is a question related to living organisms that is either asked by some one or comes in biologist's mind by himself.

2. Observations

As the first step in solving a biological problem, biologist recalls his/her previous observations or makes new ones. Observations are made with five senses of vision, hearing, smell, taste and touch. Observations may be both qualitative and quantitative. Quantitative observations are considered more accurate than qualitative ones because the former are invariable and measurable and can be recorded in terms of numbers. Examples of qualitative and quantitative observations are given below.

Qualitative observations	Quantitative observations
• The freezing point of water is colder than the boiling point. • A liter of water is heavier than a liter of ethanol.	• The freezing point of water 0 °C and the boiling point is 100 °C. • A liter of water weighs 1000 grams and a liter of ethanol weighs 789 grams.

Observations also include reading and studying what others have done in the past because scientific knowledge is ever-growing.

Biologists can't usually check every situation where a hypothesis might apply. Let's consider a hypothesis:
"All plant cells have a nucleus". Biologist cannot examine every living plant and every plant that has ever lived to see if this hypothesis is false. Instead, biologists generate deduction using reasoning. From the above hypothesis, a biologist can make the following deduction: "If examine cells from a blade of grass, then each one will have a nucleus".

3. Formulation of Hypotheses

Observations do not become scientific observations until they are organized and related to a question.Biologist organizes his/her and others' observations into data form and constructs a statement that may prove to be the answer of the biological problem under study. This tentative explanation of observations is called a hypothesis. It may be defined as a proposition that might be true. A hypothesis should have the following characteristics:

- It should be a general statement.
- It should be a tentative idea.
- It should agree with available observations.
- It should be kept as simple as possible.
- It should be testable and potentially falsifiable. In other words, there should be a way to show the hypothesis is false; a way to disprove the hypothesis.

A great deal of careful and creative thinking is necessary for the formulation of a hypothesis. Biologists use reasoning to formulate a hypothesis.

4. Deductions

In the next step, biologist draws deductions from hypotheses. Deductions are the logical consequences of hypotheses. For this purpose, a hypothesis is taken as true and expected results (deductions) are drawn from it.

Generally in biological method, if a particular hypothesis is true then one should expect (deduction) a certain result. This involves the use of "if-then" logic.

5. Experimentation

The most basic step of biological method is experimentation. Biologist performs experiments to see if hypotheses are true or not. The deductions, which are drawn from hypotheses, are subjected to rigorous testing. Through experimentations, biologist learns which hypothesis is correct.

The incorrect hypotheses are rejected and the one which proves correct is accepted. An accepted hypothesis makes further predictions that provide an important way to further test its validity.

6. Summarization of results

Biologist gathers actual, quantitative data from experiments. Data for each of the groups are then averaged and compared statistically. To draw conclusions, biologist also uses statistical analysis.

What is "Control" in experiments?

In science when doing the experiment, it must be a controlled experiment. The scientist must contrast an "experimental group" with a "control group". The two groups are treated exactly alike except for the one variable being tested. For example, in an experiment to test the necessity of carbon dioxide for photosynthesis, one can contrast the control group (a plant with freely available carbon dioxide) with an experimental group (a plant with no carbon dioxide available). The necessity of carbon dioxide will be proved when photosynthesis occurs in the control group and does not occur in the experimental group.

7. Reporting the results

Biologists publish their findings in scientific journals and books, in talks at national and international meetings and in seminars at colleges and universities. Publishing of results is an essential part of scientific method. It allows other people to verify the results or apply the knowledge to solve other problems.

Study Of Malaria - An Example Of Biological Method

We know malaria is a common disease in many countries including Pakistan. We will go through the history of this disease to know how biology solved the biological problem concerning the cause and transmission of malaria. In ancient times (more than 2000 years ago), physicians were familiar with malaria. They described it as a disease of chills and fevers with recurring attacks. They also observed that the disease was more common among people living in low, marshy areas. It was thought that the stagnant water of marshes poisoned the air and as a result of breathing in this "bad air", people got malaria. This belief led to the name of this disease. The Italian words **"mala"** means bad and **"aria"** means air. For further clarification of the observation, some volunteers drank stagnant water from the marshes. They did not develop malaria.

In the 17th century when the New World (America) was discovered, many plants from America were sent back to Europe to be used as medicines. The bark of a tree known as **quina-quina** was very suitable for curing fevers. It was so beneficial that soon it was impossible to carry enough bark to Europe. Some dishonest merchants began to substitute the bark of another tree, **cinchona** which closely resembled quina-quina. This dishonesty proved much valuable for mankind. Cinchona bark was found to be excellent for treating malaria. We now know the reason: cinchona bark contains **quinine** that is effective in treating the disease

At that time, physicians treated malaria with cinchona without understanding the cause of malaria. Two hundred years later, it was found that some diseases are caused by tiny living organisms. After this discovery, it also became a belief that malaria, too, might be caused by some microorganism. In 1878, a French army physician **Laveran** began to search for the "cause" of malaria. He took a small amount of blood from a malarial patient and examined it under microscope. He noticed some tiny living creatures. His discovery was not believed by other scientists. Two years later, another physician saw the same creatures in the blood of another malarial patient. Three years after the second discovery, the same creatures were observed for third time. The organism was given a name ***Plasmodium***.

In the last part of nineteenth century, many different causes of malaria were being suggested. By that time, there were four major **observations** about malaria.

- Malaria and marshy areas have some relation.
- Quinine is an effective drug for treating malaria.
- Drinking the water of marshes does not cause malaria.
- Plasmodium is seen in the blood of malarial patients.

We know that a scientist uses whatever information and observation he has and makes one or more hypotheses. The **hypothesis** made in this case was;

"Plasmodium is the cause of malaria."

Scientist does not know whether his hypothesis is true or not, but he accepts it may be true and makes **deductions**. One of the deductions from the above hypothesis was;

"If Plasmodium is the cause of malaria, then all person ill with malaria should have Plasmodium in their blood."

The next step was to test the deduction through **experiments** which were designed as;

"Blood of 100 malarial patients was examined under microscope. For the purpose of having a control group, the blood of 100 healthy persons was also examined under microscope."

The results of experiments showed that almost all malarial patients had Plasmodium in their blood while 07 out of 100 healthy persons also had Plasmodium in their blood (now we know that Plasmodium in the blood of healthy people was in incubation period i.e. the period between the entry of parasite in host and the appearance of symptoms). The results were quite convincing and proved that the hypothesis "Plasmodium is the cause of malaria" was true.

Malaria has killed more people than any other disease. The account of malaria is an example of a biological problem and of how such problems are solved.

Next biological problem was to learn about "How *Plasmodium* gets into the blood of man". Biologists were having following observations;

- Malaria is associated with marshes.
- Drinking water of marshes does not cause malaria.
-

From these observations, it can be concluded that Plasmodium was not in the marsh water. But it must be carried by something that comes to marsh water. In 1883, a physician **A. F. A**. King, listed 20 observations. Some important observations of King were:

- People who slept outdoors were more likely to get malaria than those who slept indoors;
- People who slept under fine nets were less likely to get malaria than those who did not use such nets; and
- Individuals who slept near a smoky fire usually did not get malaria.
-

On the basis of these observations King suggested a hypothesis:

"Mosquitoes transmit Plasmodium and so are involved in the spread of malaria."

Following deductions were made considering the hypothesis as true i.e. If mosquitoes are involved in the spread of malaria then;

"Plasmodium should be present in mosquitoes."

"A mosquito can get Plasmodium by biting a malarial patient."

In fact quinine was the only effective remedy for malaria from the 17th to the 20th century.

In order to test the above deductions, **Ronald Ross:** a British army physician working in India in 1880's; performed important experiments. He allowed a female **Anopheles** mosquito to bite a malarial patient. He killed the mosquito some days later and found Plasmodium multiplying in mosquito's stomach.

The next logical experiment was to allow an infected mosquito (having Plasmodium) to bite a healthy person. If hypothesis was true, the healthy person would have got malaria. But scientists avoid using human beings for experiments when results can be so serious. Ross used sparrows and redesigned his experiments. He allowed a female **Culex** mosquito to bite on the sparrows suffering from malaria. Some of the mosquitoes were killed and studied at various times. Ross found that Plasmodium multiplied in the wall of mosquito's stomach and then moved into mosquito's salivary glands. He kept some mosquitoes alive and allowed them to bite healthy sparrows. Ross found that the saliva of the infected mosquito contained Plasmodia (plural of Plasmodium) and these entered the sparrow's blood. When he examined the blood of these previously healthy sparrows, he found many *Plasmodia* in it.

In the end, the hypothesis was tested by direct experimentation on human beings. In 1898, Italian biologists allowed an *Anopheles* mosquito to bite a malarial patient. The mosquito was kept for a few days and then it was allowed to bite a healthy man. This person later became ill with malaria. In this way, it was confirmed that mosquitoes transmit Plasmodium and spread malaria. (Figure 2.1)

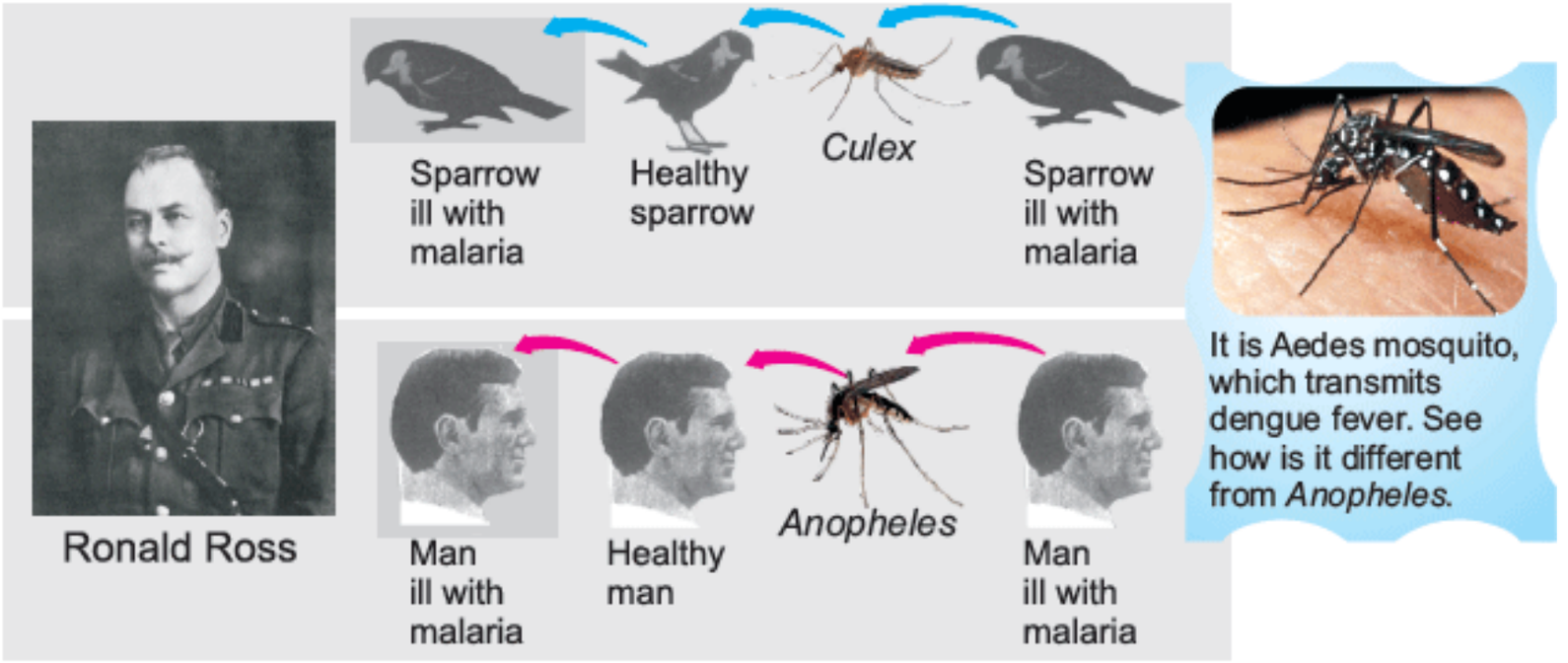


Figure 2.1 : Malaria in sparrow and man is transmitted by *Culex* and *Anopheles* mosquitoes respectively

? While testing the hypothesis that plasmodium is the cause of malaria, what would be the control group of the experiment? Blood of malarial patients or blood of healthy persons?

Blood of healthy persons

2.1.2 Theory, law and principle

When a hypothesis is given a repeated exposure to experimentation and is not falsified, it increases biologists' confidence in hypothesis. Such well-supported hypothesis may be used as the basis for formulating further hypotheses which are again proved by experimental results. The hypotheses that stand the test of time (often tested and never rejected), are called **theories**. A theory is supported by a great deal of evidence.

Productive theory keeps on suggesting new hypotheses and so testing goes on. Many biologists take it as a challenge and exert greater efforts to disprove the theory. If a theory survives such doubtful approach and continues to be supported by experimental evidence, it becomes a **law or**

principle. A scientific law is a uniform or constant fact of nature. It is an irrefutable theory. Examples of biological laws are Hardy-Weinberg law and Mendel's laws of inheritance.

When a female mosquito pierces the skin with her mouthparts, she injects a small amount of saliva into the wound before drawing blood. The saliva prevents the blood from clotting in her food canal.

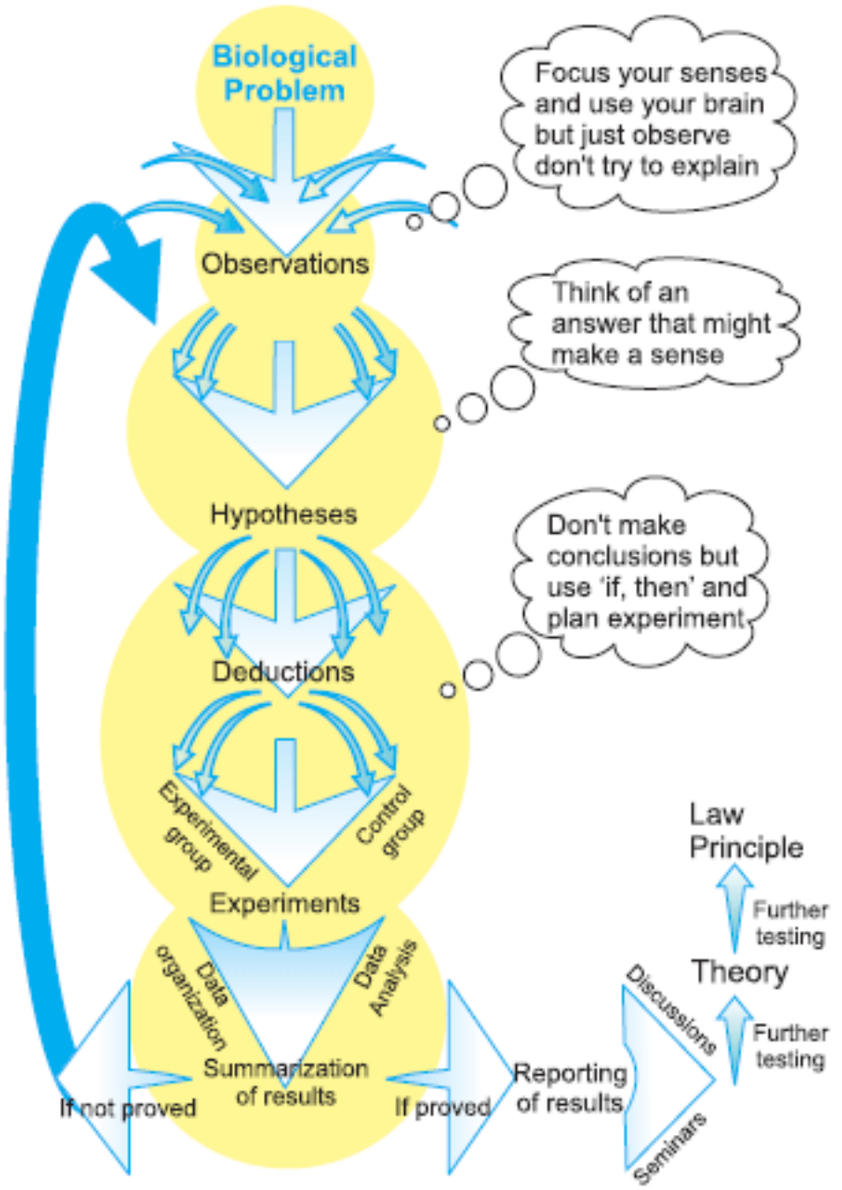


Figure 2.2: Biological method

Female mosquitoes need the blood of mammals or birds for the maturation of their eggs.

The welts that appear after the mosquito leaves is not a reaction to the wound but an allergic reaction to the saliva. In most cases, the itching sensation and swellings subside within several hours.

2.2 Data Organization And Data Analysis

Data organization and data analysis are important steps in biological method. Data can be defined as the information such as names, dates or values made from observations and experimentation.

Data organization

In order to formulate and then to test hypotheses, scientists collect and organize data. Prior to conducting an experiment, it is very important for a scientist to describe data collection methods. It ensures the quality of experiment. Data is organized in different formats like graphics, tables, flow charts, maps and diagrams.

Data analysis

Data analysis is necessary to prove or disprove a hypothesis by experimentation. It is done through the application of statistical methods i.e. ratio and proportion. When a relation between two numbers e.g. ‘a’ and ‘b’ is expressed in terms of quotient (a/b), it is called the ratio of one number to the other. Ratio may be expressed by putting a division (÷) or colon (:) mark between the two numbers. For example the ratio between 50 malarial patients and 150 normal persons is 1:3.

Proportion means to join two equal ratios by the sign of equality (=). For example; a:b = c:d is a proportion between the two ratios. This proportion may also be expressed as a:b::c:d. When three values in a proportion are known, the fourth one (X) can be calculated.

For example, a biologist can calculate how many birds will get malaria when he allows infected mosquitoes to bite 100 healthy sparrows. In the previous experiment he noted that when he allowed mosquitoes to bite 20 sparrows, 14 out of them got malaria. Now he uses the proportion rule.

1st Ratio 14:20 (14 out of 20)
2nd Ratio X:100 (How many out of 100) ⟵ Proportion 14:20 :: X:100

$$\frac{X}{100} = \frac{14}{20} \longrightarrow X \times 20 = 100 \times 14 \longrightarrow X = \frac{100}{20} \times 14 \longrightarrow X = 70$$

It means 70 out of 100 sparrows get malaria

Statistics are thus a means of summarizing data through the calculation of mean value. This step is very important as it transforms raw data into information, which can be used to summarize and report results

2.3 Mathematics: As An Integral Part Of Scientific Process

Biological method also involves the use of applied mathematics to solve biological problems. Major biological problems in which knowledge of mathematics is used include gene finding, protein structure, and protein-protein interactions etc. Bioinformatics refers to the computational and statistical techniques for the analysis of biological data.

UNDERSTANDING THE CONCEPTS

1. Describe the steps involved in biological method taking malaria as an example.
2. If a test shows that some people have Plasmodium in their blood but they do not show any symptoms of malaria, what hypothesis would you formulate to answer this problem?
3. How the principles of ratio and proportion are used in biological method.
4. Justify mathematics as an integral part of the scientific process.

SHORT QUESTIONS

1. Differentiate between theory and law.
2. Quantitative observations are better in biological method. How?

THE TERMS TO KNOW		
Bioinformatics	Deduction	Law
Biological Method	Experiment	Observation
Biological Problem	Experimental Group	Theory
Control Group	Hypothesis	

INITIATING AND PLANNING

1. Identify and pose meaningful, answerable scientific questions.
2. For a given biological problem;
3. Formulate and test a working hypothesis.
4. Write instructions for conducting investigations.
5. Organize data appropriately using techniques such as tables and graphs.
6. Analyze data to make predictions, decisions, or draw conclusions.
7. Confirm, modify, or reject a hypothesis using data analysis.
8. Use ratio and proportion in appropriate situations to solve problems.

ON-LINE LEARNING

1. en.wikipedia.org/wiki/Scientific_method
2. www.sciencebuddies.org/science-fair
3. www.visionlearning.com/library
4. www.scientificmethod.com/www.scientificmethod.com

CHAPTER

3 Biodiversity

Animation 3.1 : Ecology- Man and his environment
Source & Credit: Wikispaces

At least 10 million kinds of organisms inhabit the Earth but less than one third of these have been studied and catalogued (put in record) by biologists. Diversity among the Earth's organisms is more obvious than the fundamental unity of life. We see that all organisms share many biological characteristics. Five principal groups of organisms are prokaryotes, protists, fungi, plants, and animals. In this chapter we will focus on the differences among different groups of organisms. We will also see how are organisms classified and named and what are the concerns with the existence of biodiversity.

3.1 Biodiversity

The term "biodiversity" has been derived from 'bio' and 'diversity'. "Diversity" means variety within a species and among species. Biodiversity is a measure of the variety of organisms present in different ecosystems.

The diversity of plants' (flora) and animals' (fauna) in a region depends on climate, altitude, soils and the presence of other species. Biodiversity is not distributed evenly on Earth. It is richest in the tropics. Temperate regions also have many species while there are fewer species in the polar regions. Biodiversity found on Earth today is the result of 4 billion years of evolution. The origin of life is not well known to science, though limited evidence suggests that until 600 million years ago, all life consisted of bacteria and similar unicellular organisms.

Importance of biodiversity

Biodiversity provides food for humans. A significant proportion of drugs are derived, directly or indirectly, from biological sources. A wide range of industrial materials e.g. building materials, fibres, dyes, resins, gums, adhesives, rubber and oil are derived directly from plants.

Biodiversity plays important role in making and maintaining ecosystems. It plays a part in regulating the chemistry of our atmosphere and water supply. Biodiversity is directly involved in recycling nutrients and providing fertile soils.

Figure 3.1: Variety of plant life in a tropical (left) and temperate (right) region

3.2 Classification - Aims And Principles

There is a large collection of very dissimilar forms of organisms, found on Earth. Over 1.5 million types of animals and over 0.5 million types of plants are known to biologists and these are only a small percentage of the total types estimated to live on Earth. They range in complexity from small and simple bacteria to large and complex human beings. Some of them live in sea, some on land; some walk, others fly, and still others are stationary. Each has its own way of life i.e. getting food, avoiding unfavourable environmental conditions, finding a place to live, and reproducing its kind. When there are so many diverse kinds of organisms, it becomes difficult to learn about the characteristics of each.

To study such a large collection, biologists classify the organisms into groups and subgroups and for this task they require some system. Biological classification is a method by which biologists divide organisms into groups and subgroups.

Figure 3.2: Variety of animal life in polar regions

Aims of Classification

The branch of biology which deals with classification is called **taxonomy** and the branch which deals with classification and also traces the evolutionary history of organisms is known as **systematics**. The main aims of both these branches are;

- To determine similarities and differences among organisms so that they can be studied easily.
- To find the evolutionary relationships among organisms.

Basis of Classification

Classification is based on relationship amongst organisms and such relationship is got through similarities in characteristics. These similarities suggest that all organisms are related to one another at some point in their evolutionary histories.

However, some organisms are more closely related than others. For example sparrows are more closely related to pigeons than to insects. It means that the former two have common evolutionary histories. When biologists classify organisms into groups and subgroups, the similarities are seen in external and internal structures and stages of development. Modern genetics provides another type of information to taxonomists. The similarities and differences in the DNA of two studied organisms can be used for getting idea about similarities and differences in their structures and functions.

Taxonomic Hierarchy

The groups into which organisms are classified are known as taxonomic categories or taxa (singular "taxon"). The taxa form a ladder, called taxonomic hierarchy. All organisms are divided into five kingdoms. So kingdom is the largest taxon. On the basis of similarities, each kingdom is further divided into smaller taxa in the following way:

- **Phylum** (Division: for plants and fungi): A phylum is a group of related classes.
- **Class**: A class is a group of related orders.
- **Order**: An order is a group of related families.
- **Family**: A family is a group of related genera.
- **Genus**: A genus is a group of related species.
- **Species**: A species consists of similar organisms.

Members of lower taxon resemble one another more than do the members of a higher taxon. Table 3.1 illustrates the classifications of humans (*Homo sapiens*) and pea (*Pisum sativum*).

Table 3.1: Simple classification of two organisms

Taxa	Human	Pea
Kingdom	Animalia	Plantae
Phylum	Chordata	Magnoliophyta
Class	Mammalia	Magnoliopsida
Order	Primates	Fabales
Family	Hominidae	Fabaceae
Genus	*Homo*	*Pisum*
Species	*H. sapiens*	*P. sativum*

Species - The Basic Unit of Classification

Species is the basic unit of classification. "A species is a group of organisms which can interbreed freely among them and produce fertile offspring, but are reproductively isolated from all other such groups in nature." Each species possesses its own distinct structural, ecological and behavioural characteristics.

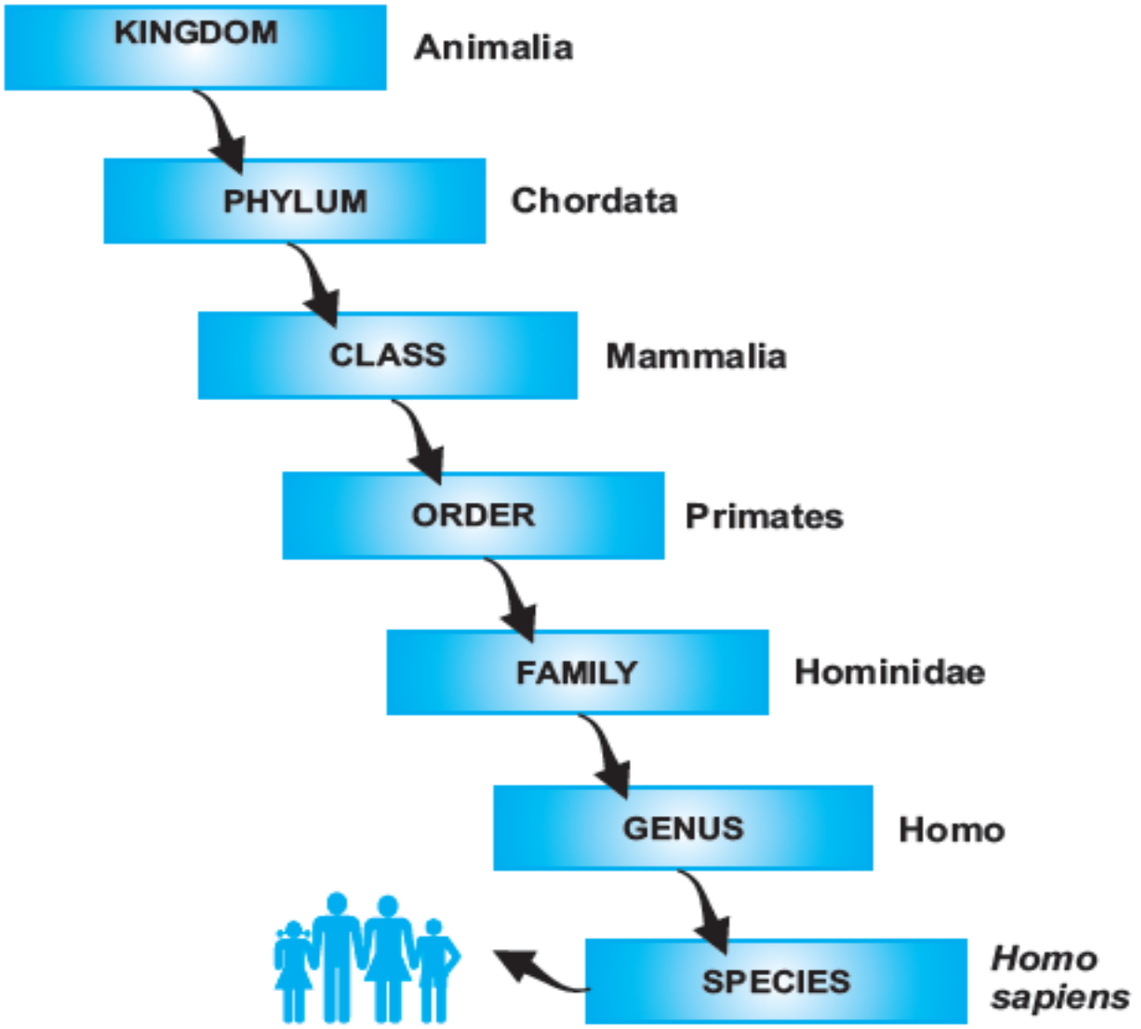


Figure 3.3: Taxonomic hierarchy

In the definition of species we must emphasize "in nature" because two organisms related to two different but closely related species can cross-breed under artificial conditions. In such unnatural crosses they produce infertile offspring. For example, a cross between a male donkey and a female horse produces an infertile offspring i.e. mule (Figure 3.4).

The criteria of interbreeding cannot be used for species recognition in organisms who reproduce asexually and do not interbreed with one another (for example many unicellular organisms).

Use internet and find the classification schemes of a fungus and a bacterium.

Figure 3.4: Infertile mule

3.3 History Of Classification Systems

The earliest known system of classification of organisms comes from the Greek philosopher **Aristotle.** He classified all living organisms known at that time as either in the group 'plantae' or in 'animalia'.
In 700s, **Abu-Usman Umer Aljahiz** described the characteristics of 350 species of animals in his book. He wrote a lot about the life of ants. In 1172, **Ibn Rushd (Averroes)** translated Aristotle's book "de Anima (On the Soul)" in Arabic. In the end of 15th century, many biologists had started work on classification methods e.g.

Carolus Linnaeus divided nature into three kingdoms: mineral, vegetable and animal. Linnaeus used five ranks in classification: class, order, genus, species, and variety. Linnaeus is best known for his introduction of the method still used to formulate the scientific name of every species.

Andrea Caesalpino (1519-1603 AD)	Divided plants into fifteen groups and called them "genera".
John Ray (1627-1705 AD)	Published important works on plants' classification.
Augustus Rivinus (1652-1723 AD)	Introduced the taxon of "order".
Tournefort (1656-1708 AD)	Introduced the taxa of "class" and "species".
Carolus Linnaeus (1707-1778 AD)	Grouped species according to similar physical characteristics.

Biologists prefer such a system that can provide maximum information about the basic differences and similarities among different organisms. According to earlier classification system, organisms were classified into two kingdoms but now taxonomists agree on five-kingdom classification system. We will see the basis of these classification systems and the drawbacks in the two-kingdom and three-kingdom classification systems.

3.3.1 Two-Kingdom Classification System

It is the oldest system and classifies all organisms into two kingdoms i.e. Plantae and Animalia. According to it, all organisms that can prepare food from simple inorganic materials and thus can store energy, are autotrophs and are included in kingdom plantae. On the other hand, the organisms that cannot synthesize their food and depend on autotrophs or others are heterotrophs and are included in kingdom animalia. According to this system, bacteria, fungi and algae were included in kingdom plantae.

Some taxonomists found this system unworkable because; many unicellular organisms like Euglena have both plant-like (presence of chlorophyll) and animal-like (heterotrophic mode of nutrition in darkness and lack of cell wall) characters. So there should be a separate kingdom for such organisms. This system also ignores the difference between organisms having prokaryotic and those having eukaryotic cells.

3.3.2 Three-Kingdom Classification System

In 1866, **Ernst Hacke**l solved the first objection and proposed a third kingdom i.e. protista to accommodate euglena-like organisms. He also included bacteria in kingdom protista. In this system, fungi were still included in the kingdom plantae.

This system did not clear the difference between prokaryotes and eukaryotes. Some biologists disagreed about the position of fungi in kingdom plantae. Fungi resemble plants in many ways but are not autotrophs. They are special form of heterotrophs that get their food by absorption. They do not have cellulose in their cell walls rather possess chitin.

3.3.3 Five-Kingdom Classification System

In 1937, **E-Chatton** suggested the terms of, "Procariotique" to describe bacteria and "Eucariotique" to describe animal and plant cells. In 1967, **Robert Whittaker** introduced the five-kingdom classification system. This system is based on;

- The levels of cellular organization i.e. prokaryotic, unicellular eukaryotic and multicellular eukaryotic
- The principal modes of nutrition i.e. photosynthesis, absorption, and ingestion.

On this basis, organisms are classified into five Kingdoms: monera, protista, fungi, plantae and animalia.

In 1988, **Margulis and Schwartz** modified the five-kingdom classification of Whittaker. They considered genetics along with cellular organization and mode of nutrition in classification. They classified the organisms into the same five kingdoms as proposed by Whittaker.

3.4 The Five Kingdoms

The general characteristics of the five kingdoms are as follows (See Table 3.2 also);

1. **Kingdom monera:** It includes prokaryotic organisms i.e. they are made of prokaryotic cells. Monerans are unicellular, although some types form chains, clusters, or colonies of cells. Prokaryotic cells are radically different from eukaryotic cells. Most are heterotrophic but some perform photosynthesis because they have chlorophyll in their cytoplasm. Within this kingdom, there are two different kinds of organisms i.e. bacteria and cyanobacteria.

2. **Kingdom protista:** It includes eukaryotic unicellular and simple multicellular organisms. There are three main types of protists.
   - Algae are unicellular, colonial or simple multicellular. They resemble plant cells with cell walls and chlorophyll in chloroplasts. Simple multicellular means that they do not have multicellular sex organs and do not form embryos during their life cycles.
   - **Protozoans** resemble animals whose cells lack chlorophyll and cell walls.
   - Some protists are **fungi-like.**

3. Kingdom fungi: It includes eukaryotic multicellular heterotrophs which are absorptive in their nutritional mode e.g. mushrooms. Most fungi are decomposers. They live on organic material, secrete digestive enzymes and absorb small organic molecules formed by the digestion by enzymes.

4. Kingdom Plantae: It includes eukaryotic multicellular autotrophs. Plants are autotrophic in nutritional mode, making their own food by photosynthesis. They have multicellular sex organs and form embryos during their life cycles. Mosses, ferns and flowering plants are included in this kingdom.

5. Kingdom Animalia: It includes eukaryotic multicellular consumers. Animals live mostly by ingesting food and digesting it within specialized cavities. They lack cell wall and show movements.

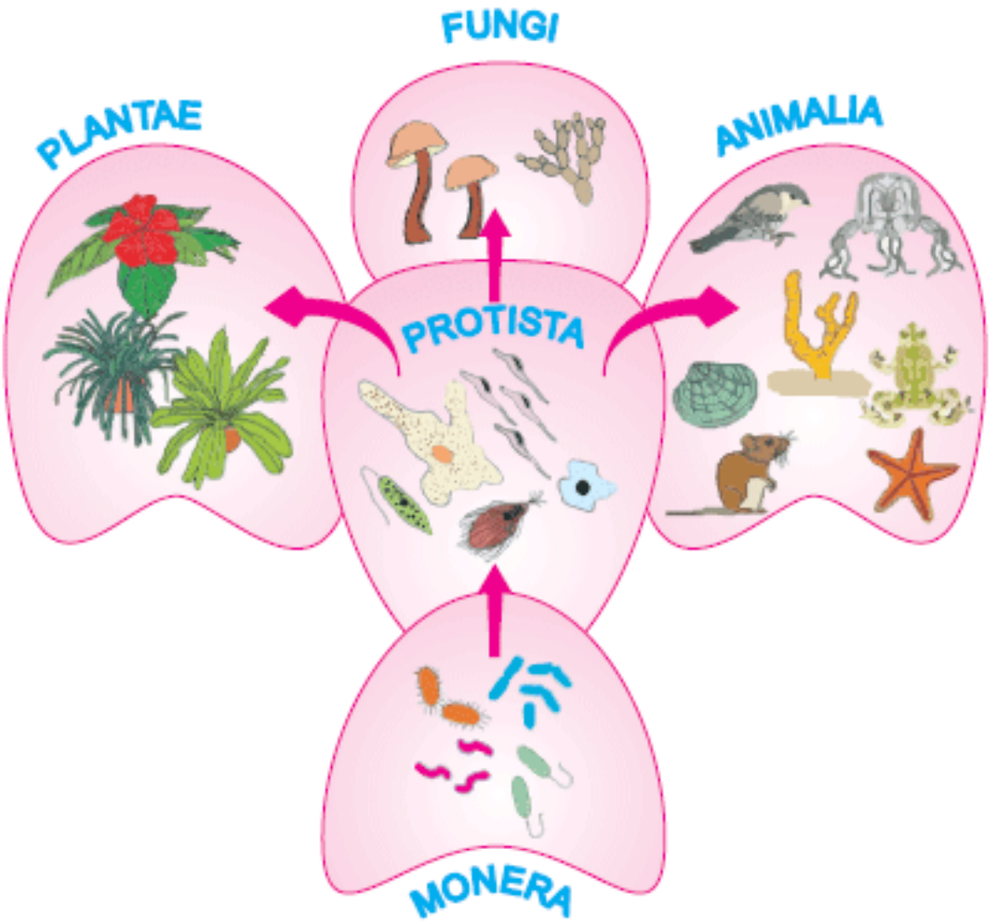


Figure 3.5: The Five kingdoms of classification

? How can you divide the five Kingdoms into two groups on the basis of types of cells?

(a) Kingdom monera including organism with prokaryotic cells and
(b) Kingdom protista, fungi,plantae and animalia include organisms with eukaryotic cells

Table 3.2: Distinguishing characteristics of the five kingdoms of life

Kingdom	Cell Type	Nuclear Envelope	Cell Wall	Mode of Nutrition	Multi-Cellularity
Monera	Prokaryotic	Absent	Non-cellulose (polysaccharide plus amino acids)	Autotroph or heterotroph	Absent
Protista	Eukaryotic	Present	Present in some forms, various types	Photosynthetic or heterotroph, or combination	Absent in most forms
Fungi	Eukaryotic	Present	Chitin	Absorptive heterotroph	Present in most forms
Plantae	Eukaryotic	Present	Cellulose and other polysaccharides	Photosynthetic	Present in all forms
Animalia	Eukaryotic	Present	Absent	Ingestive heterotroph	Present in all forms

Status of Viruses

Viruses are at the borderline of living and nonliving. Due to their crystalline nature, they are considered as non-living. They are acellular i.e. they do not have cellular organization yet show some characters of living organisms (e.g. they possess DNA). Viruses contain either RNA or DNA, normally encased in protein coat. They reproduce only in living cells, where they cause a number of diseases. They are not considered as organisms and thus are not included in the five-kingdom classification system. Prions and viroids are also acellular particles and are not included in the five-kingdom classification system.

3.5 Binomial Nomenclature

Binomial nomenclature is the method of giving scientific names to living organisms. As the word "binomial" suggests, the scientific name of a species consists of two names: the first is **genus** name and the second one is the name of **species**. Swedish biologist Carolus Linnaeus (1707-1778 AD) first introduced and adopted the system of binomial nomenclature. His system spread rapidly and became popular. Many of his names are in use today.

Some of the rules which are universally adopted while suggesting and documenting scientific names, are:

- Scientific names are usually printed in italics, such as *Homo sapiens*. When handwritten they are underlined.
- The first term (generic name) always begins with capital letter, while species name is never capitalized (even when derived from a proper name).
- The scientific name is generally written in full when it is first used. But when several species from the same genus are being listed, it may then be abbreviated by just using an initial for genus; for example Escherichia coli becomes E. coli.

Prions are composed of protein only and Viroids are composed of circular RNA only. Both these particles cause infectious diseases in certain plants.

Significance

In biological research, common names cause many problems. Different regions have different names for the same organism. For example; common name of onion in Urdu is 'Piyaz' but in different regions of Pakistan it is also known as 'ganda' or 'bassal' or 'vassal'. In other countries, it has other sets of names. In science, it is known with a single name as *Allium cepa*. In some cases, different organisms are called by the same common name. For example; the name 'black bird' is used for crow as well as for raven.

Common names have no scientific basis. For example; a fish is a vertebrate animal with fins and gills. But several common names of 'silver fish', 'cray fish', 'jelly fish', and 'star fish' do not fit the biologist's definition of a fish. To avoid all these confusions, organisms are given scientific names by using binomial nomenclature . The value of this system is due to its widespread use and the stability of its names. In binomial nomenclature, every species can be unambiguously identified with just two words. Same name can be used all over the world, in all languages, avoiding difficulties of translation.

Sometime organisms are named in honor of the research workers who described and classified them. For example; the Orchid tree (Mountain-ebony) was named as *Bauhinia variegata* after the Swiss botanists Bauhin. *Bauhinia variegata* is an ornamental tree found in southeast Asia.

Examples:

Common Name	Scientific Name
Onion	*Allium cepa*
Common sea star (starfish)	*Asterias rubens*
House crow	*Corvus splendens*

3.6 Conservation Of Biodiversity

During the last century, loss of biodiversity has been increasingly observed. In the modern era, due to human actions, species and ecosystems are threatened with destruction to an extent rarely seen in Earth history. A species that no longer lives in an ecosystem is called extinct in that ecosystem. When species of an ecosystem become extinct, the stability of ecosystem is harmed. Biologists warn that global ecosystem would collapse if biodiversity continues to be reduced at the same rate.

Many plant and animal species have gone extinct in Pakistan. Examples of endangered and extinct animal species are lion, tiger, Asiatic cheetah, Indian one-horned rhinoceros, swamp deer, Indian wild ass, hangul, blackbuck etc (Figure 3.6).

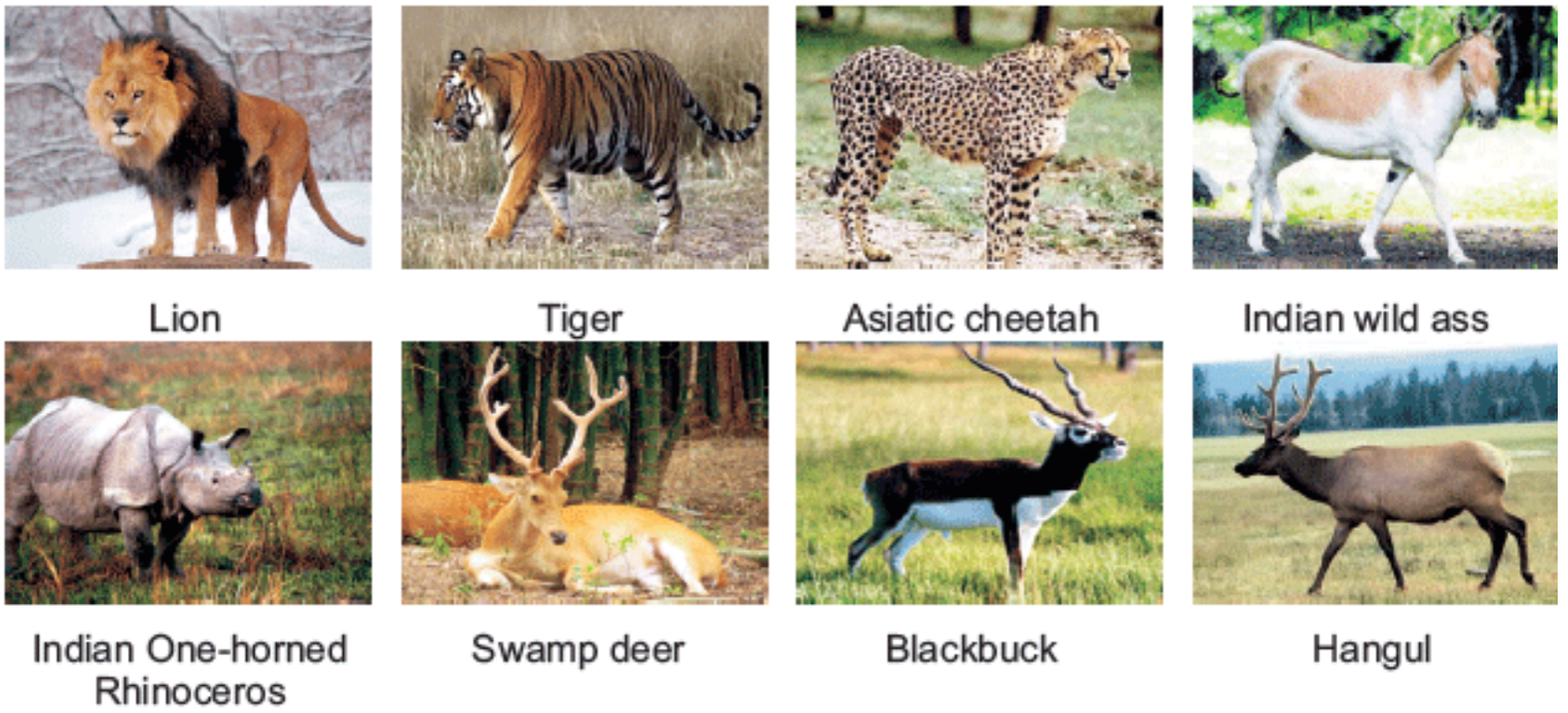


Figure 3.6: The animals that have gone extinct in Pakistan

3.6.1 Impact Of Human Beings On Biodiversity

By 10,000 years ago there were about 5 million people on Earth. With the advancement in agriculture and industry, human population began to grow rapidly. Today around 600 million people live on Earth.

To improve the living conditions for 600 million humans, we are imposing serious threats to the survival of biodiversity. Habitat loss, deforestation, over-hunting, introduction or removal of species, pollution and climate change are the major causes of species extinction.

In an ecosystem, a species is called extinct when there is no doubt that the last individual of that species has died in that ecosystem. A species is called endangered when it is at risk of extinction in near future.

More than 260,000 people are added to the world population each day, or more than 180 each minute!

Habitat loss is probably the greatest threat to biodiversity on Earth today.

Eucalyptus plants were imported from Australia and introduced in Pakistan. These plants consume more water and have disturbed the water table (level of underground water). It harms other small plants that grow near *Eucalyptus* trees.

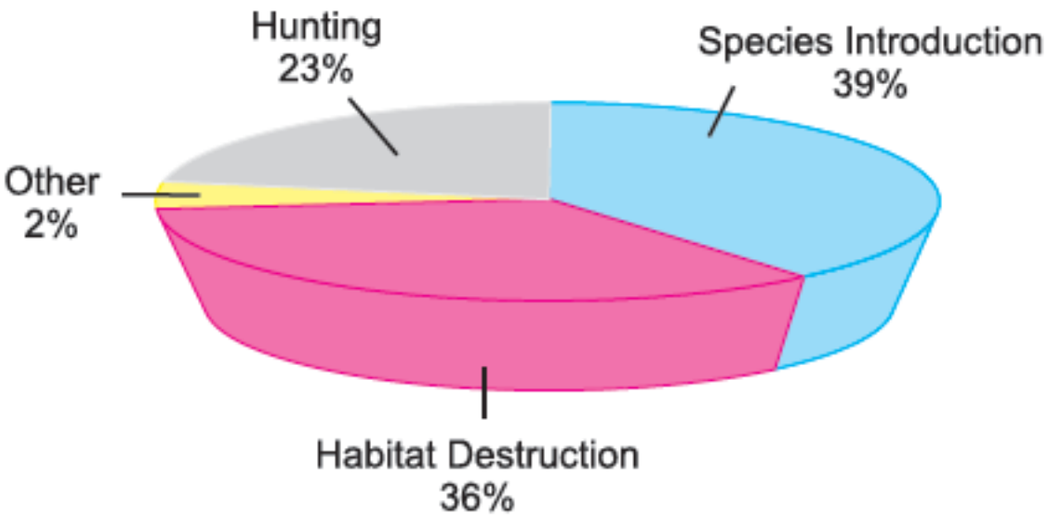


Figure 3.7: Known causes of species extinctions

Sea star (starfish) eats mussels. If sea stars are removed from a region in ocean, mussels rapidly increase in number. Large number of mussels prey on small animals and become dangerous for their existance.

The race to produce cash through fruits, spices, sugar, tobacco, soap, rubber, paper, and cloth has stimulated many to get them by using soil and by destroying the forests.

3.6.2 Deforestation And Over-Hunting

Deforestation means cutting down of trees for the conversion of a forest to non-forest land. The destruction of significant areas of forest has resulted in a degraded environment with reduced biodiversity.

Causes and effects of deforestation

Sometime there is slow forest degradation and sometime sudden and catastrophic clear-cutting for urban development. Deforestation can be the result of deliberate removal of forests for wood, agriculture or urban development.
Deforestation affects the amount of water in soil and moisture in atmosphere. When there are no trees to keep soil in place, there are more chances of soil erosion. Heavy rainfall washes soil into rivers (Figure 3.8). Essential nutrients are washed out of soil. Rivers become choked up with mud and silt, which can cause floods. The silted water gets stored in dams and it reduces their water storage capacity. Deforestation also contributes to decreased transpiration, which lessens cloud formation. This ultimately reduces the sources of rains.

In developing countries, almost 3 billion people rely on wood for heating and cooking.

Figure 3.8: Soil erosion

Figure 3.9: Chopping up of trees for the construction of roads

Forests support considerable biodiversity. The utilization of forest products, including timber and fuel wood, have played a key role in human societies. Today, developed countries continue to utilize timber for building houses and wood pulp for making paper.
The forest products industry is a large part of the economy in developed and developing countries. Short-term economic gains made by conversion of forest to agriculture often leads to loss of long-term income.

Forests extract carbon dioxide and pollutants from the air, thus contributing to biosphere stability. Forests are also valued for their aesthetic beauty and tourist attraction. These important aspects of forests are also harmed due to deforestation. In Pakistan too, deforestation is a great threat to biodiversity. In the province Khyber Pakhtunkhwa, the closed canopy forests are shrinking at approximately 1% per year.

Over-hunting

Over-hunting has been a significant cause of the extinction of hundreds of species and the endangerment of many more such as whales, ibex, urial, markhor (the national animal of Pakistan) etc. Commercial hunting, both legal and illegal, is the principal threat.

The threat to biodiversity is among the hot topics discussed at the UN World summits.

3.6.3 Steps For The Conservation Of Biodiversity

Conservation of biodiversity has become a global concern. Biologists urge the national policy makers to state a set of rules necessary to protect a species. They demand that laws should define species which are threatened by extinction and must be protected.

Though rich in biodiversity, Pakistan today faces severe threats to its animal and plant species. The greatest concern is the loss of natural habitats. Main causes of this loss are rapid growth in human population and the prevailing poverty in rural areas of Pakistan. In addition, low literacy rate is also a reason for the failure of conservation measures taken so far.
The International Union for the Conservation of Nature and Natural Resources **(IUCN)** and the World Wildlife Fund-Pakistan **(WWF-P)** work in close coordination with Pakistan's Ministry of Environment and other government and non-government institutions. The IUCN has prepared the first national Red List (list of endangered or threatened species).

Following are a few examples of environmental work that has been carried out in Pakistan in order to conserve species and associated habitats.

1. **National Conservation Strategy:** In 1980's, IUCN and the government of Pakistan formulated the National Conservation Strategy for Pakistan for the conservation of Pakistan's biodiversity.

2. **UN Convention on Combating Desertification (CCD):** This is an international treaty against damage and poverty in drylands. Pakistan signed this in 1997.

The northern areas provide habitats to Musk deer, Snow leopard, Astore markhor and Himalayan ibex, Woolly flying squirrel and the Brown bear.

It is estimated that about 200,000 of the one million migratory birds passing through Chitral are killed during migration.

3 **Himalayan Jungle Project (HJP):** It started in 1991 in the Palas Valley, in Khyber Pakhtunkhwa (KP). It aimed at protecting one of the richest areas of biodiversity in Pakistan.

4. **Conservation of biodiversity of the Suleiman Range, Balochistan:** Suleiman Range Chilghoza Forest is the largest Chilghoza forest in the world. In 1992, the WWF-P started its conservation program.

5. **Northern Areas Conservation Project:** The northern areas of Pakistan serve as a habitat for a number of wildlife species. The survival of these species is under threat. The NACP is a project of WWF-P which is successful in implementing a ban on the hunting of these species.

6. **Conservation of migratory birds in Chitral, KP:** Chitral lies on the migratory route of several important bird species. These birds face enormous hunting pressure. WWF-Pakistan initiated efforts to reduce the hunting pressure in 1992. The efforts proved successful.

7. **Conservation of Chiltan Markhor:** Hazarganji National Park is located close to Quetta and is the only remaining habitat of Chiltan Markhor in the country. WWF-Pakistan developed the management plan of the park.

8. **Ban on games:** Foreigners visit the northern areas and play many games in which bears are used. WWF-Pakistan has been successful in imposing a ban on this illegal practice.

The herders capture the bear cubs and sell them to the trainers who train them and sell to the foreigners.

3.6.4 Endangered Species In Pakistan

Due to human activities, the biodiversity in Pakistan is facing a great loss. Here are a few examples of endangered species in Pakistan.

Indus dolphin

According to WWF-P, only 600 animals of the species of Indus dolphin are left today in the Indus River. The population of this species declined due to water pollution, poaching, and destruction of habitat.

Marco Polo sheep

Marco Polo sheep are mostly found in the Khunjerab National Park and nearby areas. Their numbers have been rapidly decreasing in the last two decades and WWF-P has started projects for its conservation.

Houbara bustard

This bird flies to Pakistan in winter season from former Soviet territory and settles in Cholistan and Thar deserts. The decline in its population is due to hunting by foreigners and destruction of its habitats.

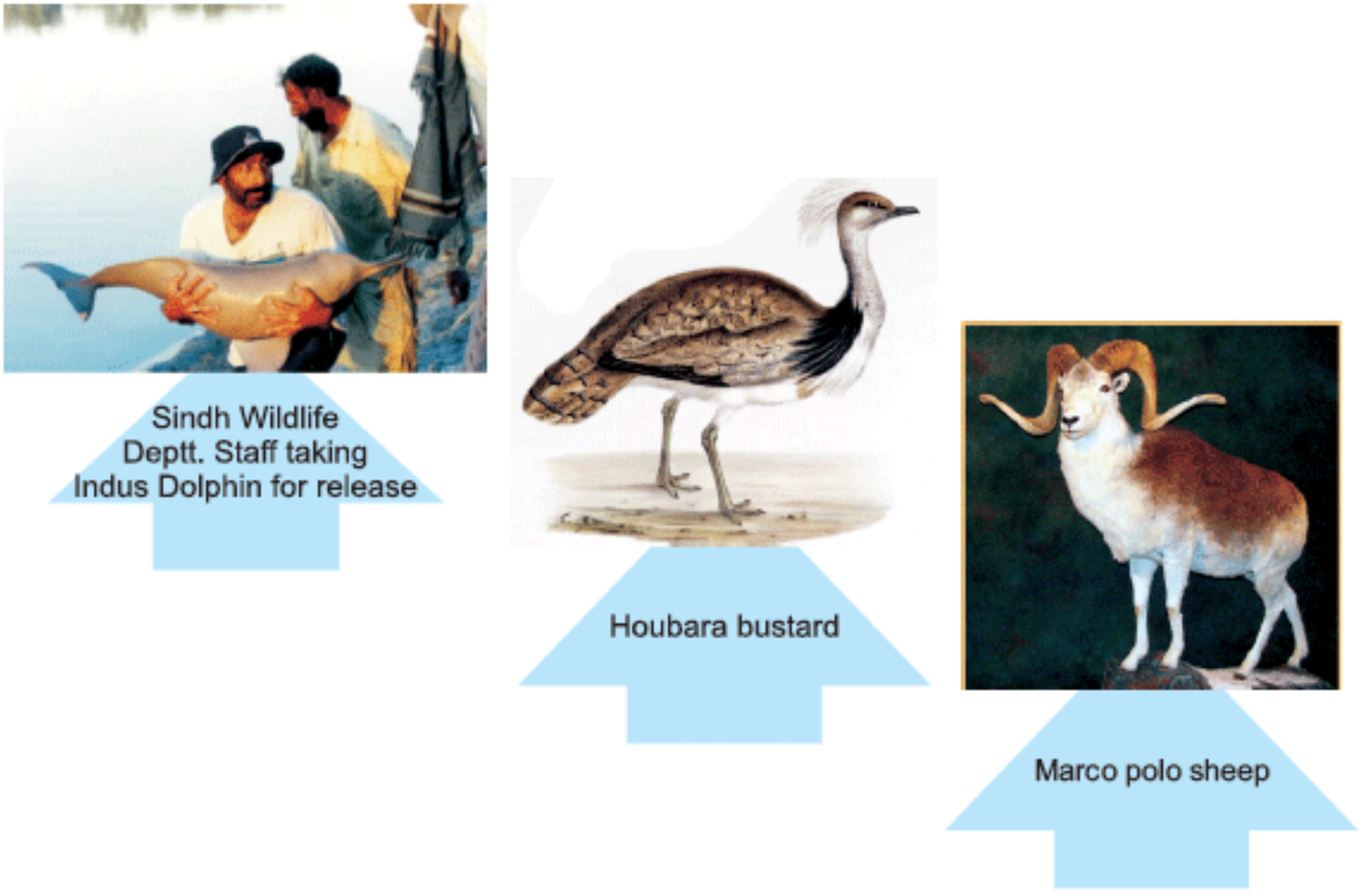
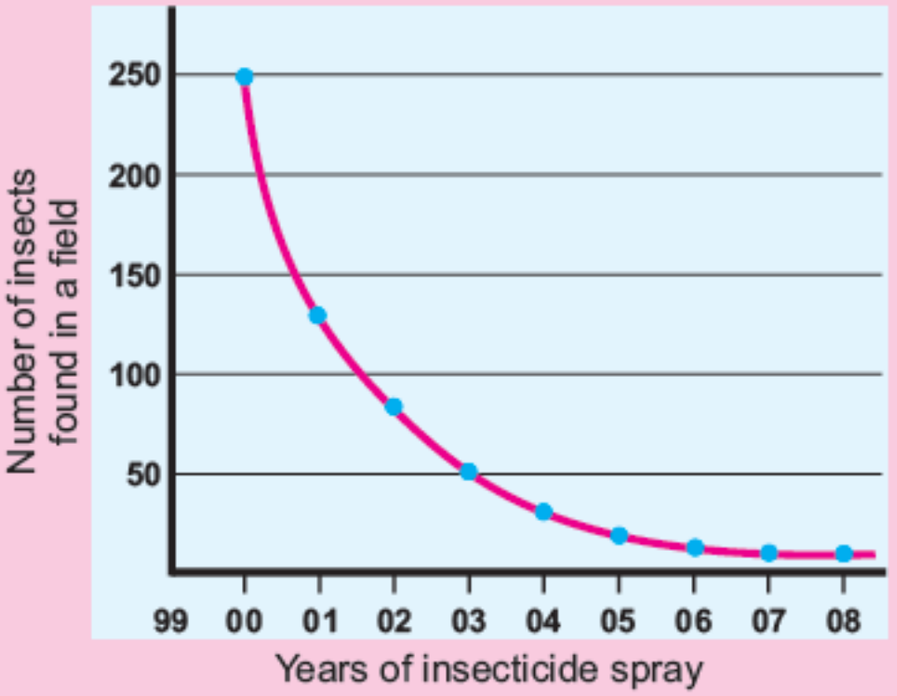


Figure 3.10: Indus Dolphin, Houbara and Marco polo sheep

Analyzing and Interpreting

Note: By this activity we will test our abilities of making a graph from available data. We should also be able to analyse and interpret the graph for drawing conclusions.

Most insecticides kill beneficial insects along with pest species. The following graph shows an example of the effect of an insecticide on an insect population of a field. Hypothesize whether the usage of insecticide may be the factor responsible for the endangered status of this insect.



Write a short article for publication in newspaper about endangered species.

Find out from books / internet the biological names of local plants and animals and sort out their generic and specific names.

Did you know?
Markhor is the National animal of Pakistan.

Did you know?
Chakor patridge is the National bird of Pakistan.

UNDERSTANDING THE CONCEPTS

1. Relate the importance of biodiversity with natural ecosystem through examples.
2. Explain the aims and principles of classification, keeping in view its historical background.
3. Explain the base for establishing five kingdoms of living organisms.
4. Justify why virus are excluded from the Five-Kingdom classification system.
5. Describe the aims and principles of binomial nomenclature.
6. Explain the impact of human beings on biodiversity.
7. Identify causes of deforestation and its effects on biodiversity.
8. Describe some of the programs running in Pakistan for the conservation of biodiversity.

SHORT QUESTIONS

1. What is the difference between the modes of nutrition of fungi and animals?
2. It is difficult to use the criterion of interbreeding to define species of unicellular organisms. Why?
3. How are taxonomy and systematics related?
4. Differentiate between the terms “extinct” and “endangered”.
5. What are the contributions of Whittaker, Margulis and Schwartz in taxonomy?

THE TERMS TO KNOW		
Acellular	Family	Prion
Animalia	Fauna	Protista
Binomial nomenclature	Flora	Soil erosion
Biodiversity	Fungi	Species
Class	Genus	Systematics
Classification	Monera	Taxon
Conservation	Order	Taxonomic hierarchy
Deforestation	Phylum	Viroid
Endangered species	Plantae	WWF

INITIATING AND PLANNING

1. Match the binomials of some common local organisms from a two column list on the basis of generic and specific names.
2. Describe ways in which society benefits from biodiversity.
3. Describe the reasons why an established animal species becomes endangered due to human interference. (e.g. Houbara bustard, Indus dolphin and Marco polo sheep).

ACTIVITIES

1. Observe the distinguishing taxonomic characters from fresh and preserved specimens and recognize plants and animals on the basis of these characters.

SCIENCE, TECHNOLOGY AND SOCIETY

1. Analyze the impact of human beings on biodiversity.
2. Associate advancements in scientific understanding with classification of organisms to develop a more reliable system.
3. Apply the knowledge of classification to assess the characteristics of different organisms when visit to zoos, herbaria, and gardens.
4. Explain the importance of binomial nomenclature in developing a more comprehendible sharing of scientific research.

ON-LINE LEARNING

1. http://www.pakistanwetlands.org/
2. http://hwf.org.pk
3. www.biodiversity.iucnp.org/
4. edu.iucnp.org/
5. www.wildlifeofpakistan.com/WildlifeBiodiversityofPakistan/
6. en.wikipedia.org/wiki/Biodiversity_Action_Plan

CHAPTER

4

Cells And Tissues

Animation 4: Cell Biology
Source and Credit: imm.eday

The wing of a butterfly is a thin sheet of cells, and so is the shiny layer of our eyes. The meat we eat is composed of cells and its contents soon become part of our cells. Our eyelashes, fingernails, orange juice, the wood of our pencil - all are produced by cells. In this chapter we will take a close look at cells and learn about their internal structure. We will also learn how specific cells group together to form tissues.

Recalling:

All organisms are composed of cells. Some are composed of a single cell, and some, like us, are composed of many cells.

4.1 Microscopy And The Emergence Of Cell Theory

The use of microscope is known as microscopy. The first compound microscope was developed by Zacharias Janssen, in Holland in 1595. It was simply a tube with lenses at each end and its magnification ranged from 3X to 9X.

Two important terms are used in microscopy i.e. magnification and resolving power. **Magnification** is the increase in the apparent size of an object and it is an important factor in microscopy. **Resolving power** or **resolution** is the measure of the clarity of an image. It is the minimum distance at which two objects can be seen as separate objects. Human naked eye can differentiate between two points, which are at least 0.1 mm apart. This is known as the resolution of human eye. If we place two objects 0.05 mm apart, human eye would not be able to differentiate them as two separate objects. Magnification and resolution can be increased with the help of lenses.

4.1.1 Light microscopy and electron microscopy

Now two types of microscope i.e. light microscope (LM) and electron microscope (EM) are used in microscopy.

Light Microscope

A light microscope works by passing visible light through a specimen. It uses two glass lenses. One lens produces an enlarged image of the specimen and the second lens magnifies the image and projects it into viewer's eye or on to photographic film. A photograph taken through a microscope is called a **micrograph**.

Animation 4.1: Microscope
Source & Credit: emaze

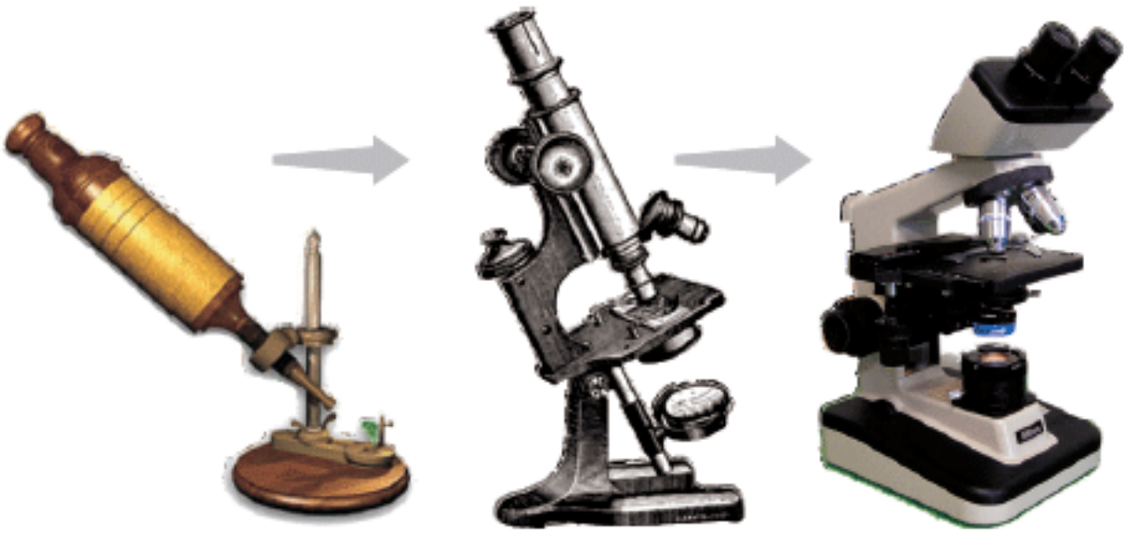


Figure 4.1: Light microscopes: From earlier (left) to the latest (right)

Figure 4.2: Light microscopic view; amoebae (left), unicellular algae (right)

When we see a micrograph on the page of a book, we see some words like "LM 109X" printed along the edge of the micrograph. It tells us that the photomicrograph was taken through a light microscope and that the image has been magnified 109 times.

A light microscope can magnify objects only about 1500 times without causing blurriness i.e. its magnification is **1500X**. Its resolving power is **0.2 micrometer** (µm) and 1µm = 1/1000 mm. In other words, the LM cannot resolve (distinguish) objects smaller than 0.2 µm. It is about the size of the smallest bacterium. The image of bacterium can be magnified many times, but light microscope cannot show the details of its internal structure.

Electron Microscope

It is the most advanced form of microscope. In EM, object and lens are placed in a vacuum chamber and a beam of electrons is passed through object. Electrons pass through or are reflected from object and make image. Electromagnetic lenses enlarge and focus the image onto a screen or photographic film.

Electron microscope has much higher resolving power than light microscope. The most modern EM can distinguish objects as small as **0.2 nanometer** (nm) and 1 nm = 1/1000,000 mm. It is a thousand-fold improvement over LM. EM can magnify objects about 250,000 times. Under special conditions EM can detect individual atoms. Cells, organelles and even molecules like DNA and protein are much larger than single atoms.

Biologists use two types of electron microscopes i.e. **Transmission Electron Microscope (TEM)** and **Scanning Electron Microscope (SEM)**. In TEM, electrons are transmitted through the specimen. TEM is used to study the internal cell structure (Figure 4. 3).

EM has revolutionized the study of cells and organelles but it cannot be used to study life processes, because the specimen must be held in a vacuum chamber i.e. all air must be removed. To study the life processes e.g. movement of Amoeba a light microscope is better.

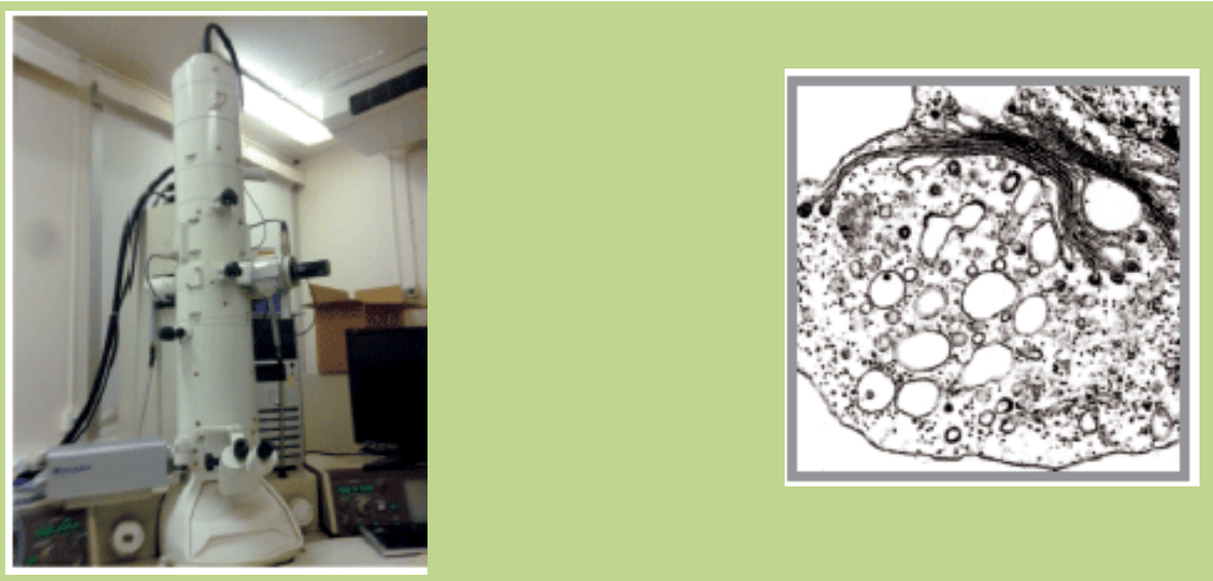


Figure 4.3: TEM (left) and view of an animal cell (right) through it

?

Which type of microscope would you use to study: (a) the change in shape of a human white blood cell; (b) the surface texture of human hair; (c) the detailed structure of a mitochondrion in the cell of human liver?

(a) LM; (b) SEM; (c) TEM

In SEM, electrons are reflected from the metal-coated surfaces. SEM is used to study the structure of cell surfaces (Figure 4.4).

Figure 4.4: SEM (left) and view of mosquito's head and eye (right) through it

4.1.2 History of the formulation of cell theory

In the history of biology, ancient Greeks were the first who organized the data of natural world. **Aristotle** presented the idea that all animals and plants are somehow related. Later this idea gave rise to questions like “is there a fundamental unit of structure shared by all organisms?”. But before microscopes were first used in 17th century, no one knew with certainty that living organisms do share a fundamental unit i.e. cell.

Cells were first described by a British scientist, **Robert Hooke** in 1665. He used his self-made light microscope to examine a thin slice of cork. Hooke observed a “honeycomb” of tiny empty compartments. He called the compartments in cork as “cellulae”. His term has come to us as cells (Figure 4.5). The first living cells were observed a few years later by Dutch naturalist **Antonie van Leeuwenhoek**. He observed tiny organisms (from pond water) under his microscope and called them as “animalcules”.

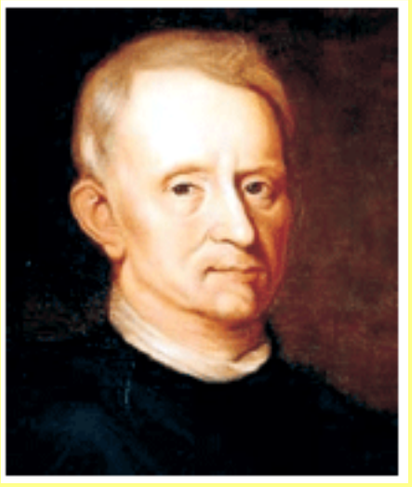


Figure 4.5: Robert Hooke

Robert Hooke was a chemist, mathematician and physicist. His remarkable engineering abilities enabled him to invent and improve many mechanical devices, including timepieces, the quadrant, and the Gregorian telescope. His observation about the section of cork is also illustrated here.

For another century and a half, the general importance of cells was not appreciated by biologists. In 1809, **Jean Baptist de-Lamarck** proposed that “no body can have life if its parts are not cellular tissues or are not formed by cellular tissues”.

In 1831, a British botanist **Robert Brown** discovered nucleus in the cell. In 1838, a German botanist **Matthias Schleiden** studied plant tissues and made the first statement of cell theory. He stated that all plants are aggregates of individual cells which are fully independent. One year later, in 1839, a German zoologist **Theodor Schwann** reported that all animal tissues are also composed of individual cells. Thus Schleiden and Schwann proposed cell theory in its initial form.

In 1855 **Rudolf Virchow**, a German physician, proposed an important extension of cell theory. He proposed that all living cells arise from pre-existing cells (“Omnis cellula e celula”). In 1862, **Louis Pasteur** provided experimental proof of this idea.

Cell theory is regarded as one of the most fundamental knowledge in biology. It has wide ranging effects in all fields of research. After the initial presentation of cell theory by Schleiden and Schwann, many details of cells were studied and cell theory was extended. Cell theory, in its modern form, includes the following principles;

1. All organisms are composed of one or more cells.
2. Cells are the smallest living things, the basic unit of organization of all organisms.
3. Cells arise only by divisions in previously existing cells.

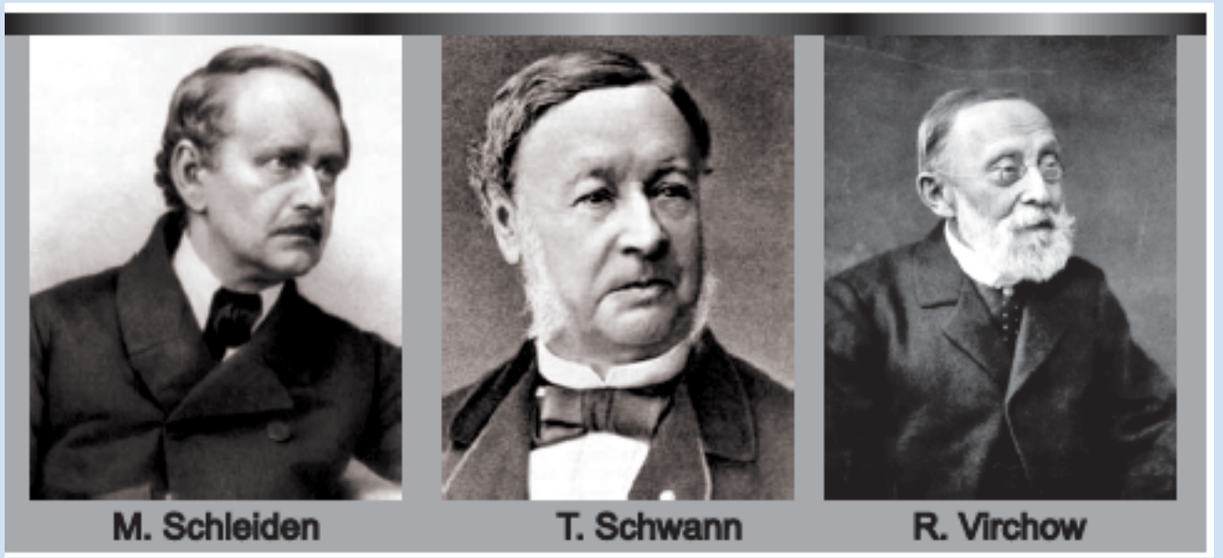
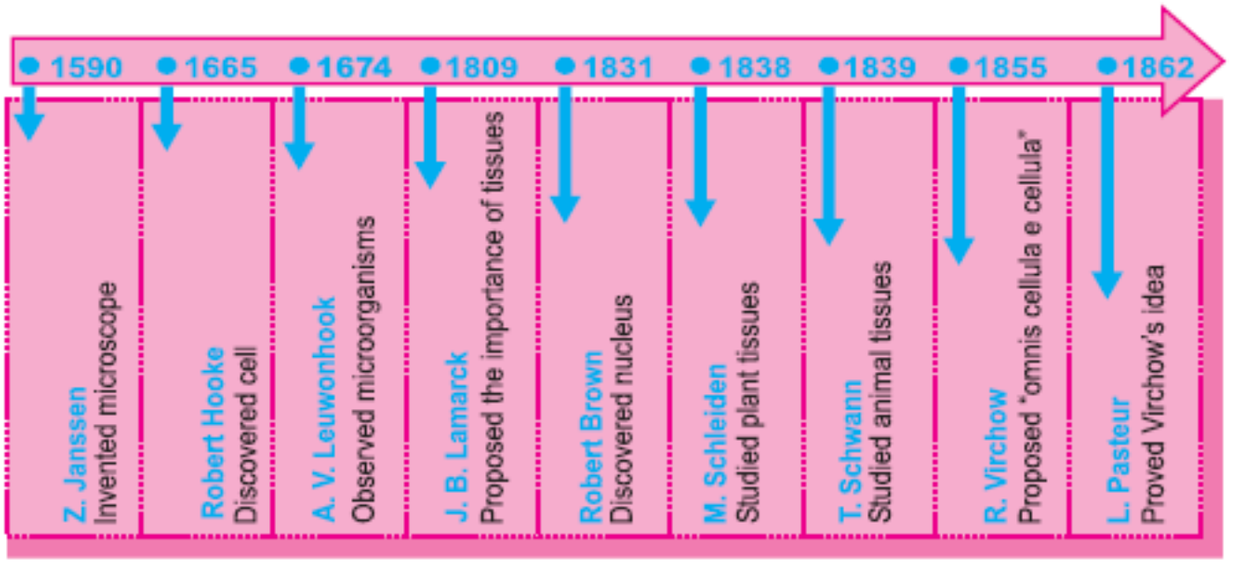


Figure 4.6: Three great German biologists

Sub-cellular or Acellular Particles: According to the first principle of the cell theory all organisms are composed of one or more cells. Virus, prions and viroids are not composed of cells; rather they are sub-cellular or acellular particles. They do not run any metabolism inside them. They show some characteristics of living organisms i.e. they can increase in number and can transmit their characters to next generations. We know that such acellular particles are not classified in any of the five kingdoms of organisms.



History of the formulation of cell theory

4.2 Cellular Structures And Functions

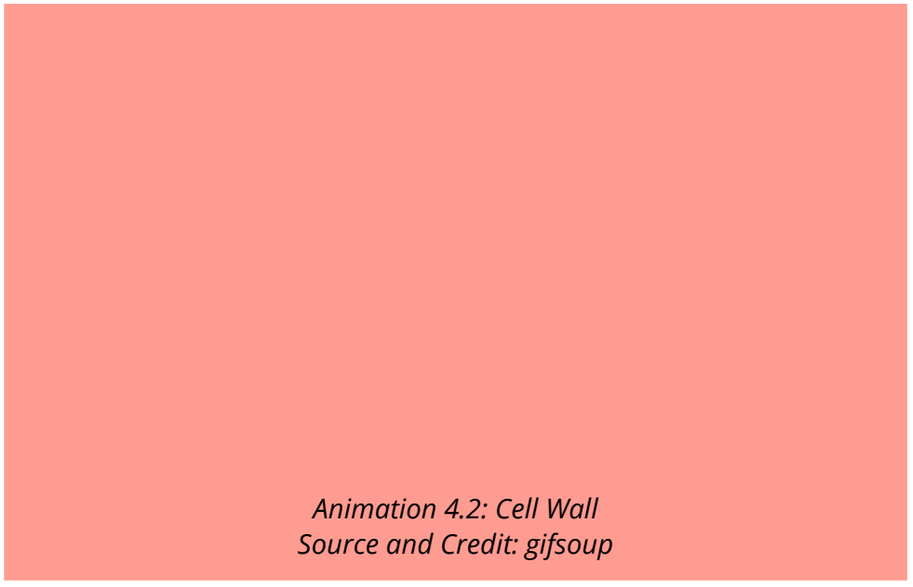
We are well familiar with the basic organization of a eukaryotic cell. Here we will get some detailed learning about cellular structure and functions. A cell is made by the assemblage of organelles. There are some structures in cell that are not organelles, but are still very important for cell. These structures are **cell wall, cell membrane, cytoplasm, and cytoskeleton.**

4.2.1 Cell Wall

We know that not all living organisms have cell walls around their cells, e.g. animals and many animal-like protists. Cell wall is a non-living and strong component of cell, located outside plasma membrane. It provides shape, strength, protection and support to the inner living matter (protoplasm) of cell.

Plant cells have a variety of chemicals in their cell walls. The outer layer of plant cell wall is known as **primary wall** and cellulose is the most common chemical in it. Some plant cells, for example xylem cells, also have **secondary walls** on the inner side of primary wall. It is much thicker and contains lignin and some other chemicals. There are pores in the cell walls of adjacent cells, through which their cytoplasm is connected. These pores are called **plasmodesmata**.

Fungi and many protists have cell walls although they do not contain cellulose. Their cell walls are made of a variety of chemicals. For example, **chitin** is present in the cell wall of fungi. Prokaryotes have a cell wall composed of **peptidoglycan** that is a complex of amino acids and sugars.



Animation 4.2: Cell Wall
Source and Credit: gifsoup

4.2.2 Cell Membrane

All prokaryotic and eukaryotic cells have a thin and elastic cell membrane covering the cytoplasm. Cell membrane functions as a semi-permeable barrier, allowing a very few molecules across it while fencing the majority of chemicals inside cell. In this way, cell membrane maintains the internal composition of cell.

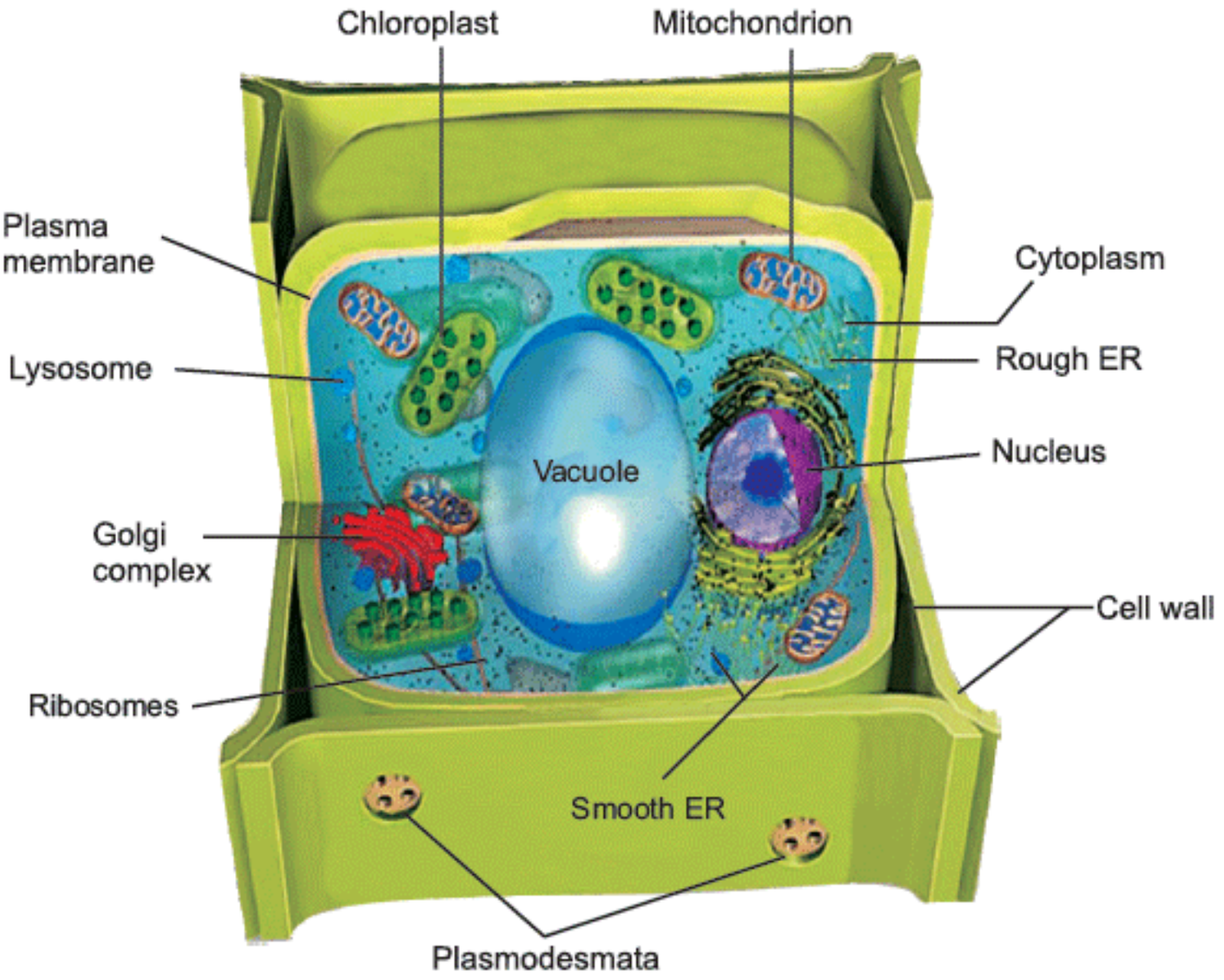


Figure 4.7: The ultra-structure of a plant cell

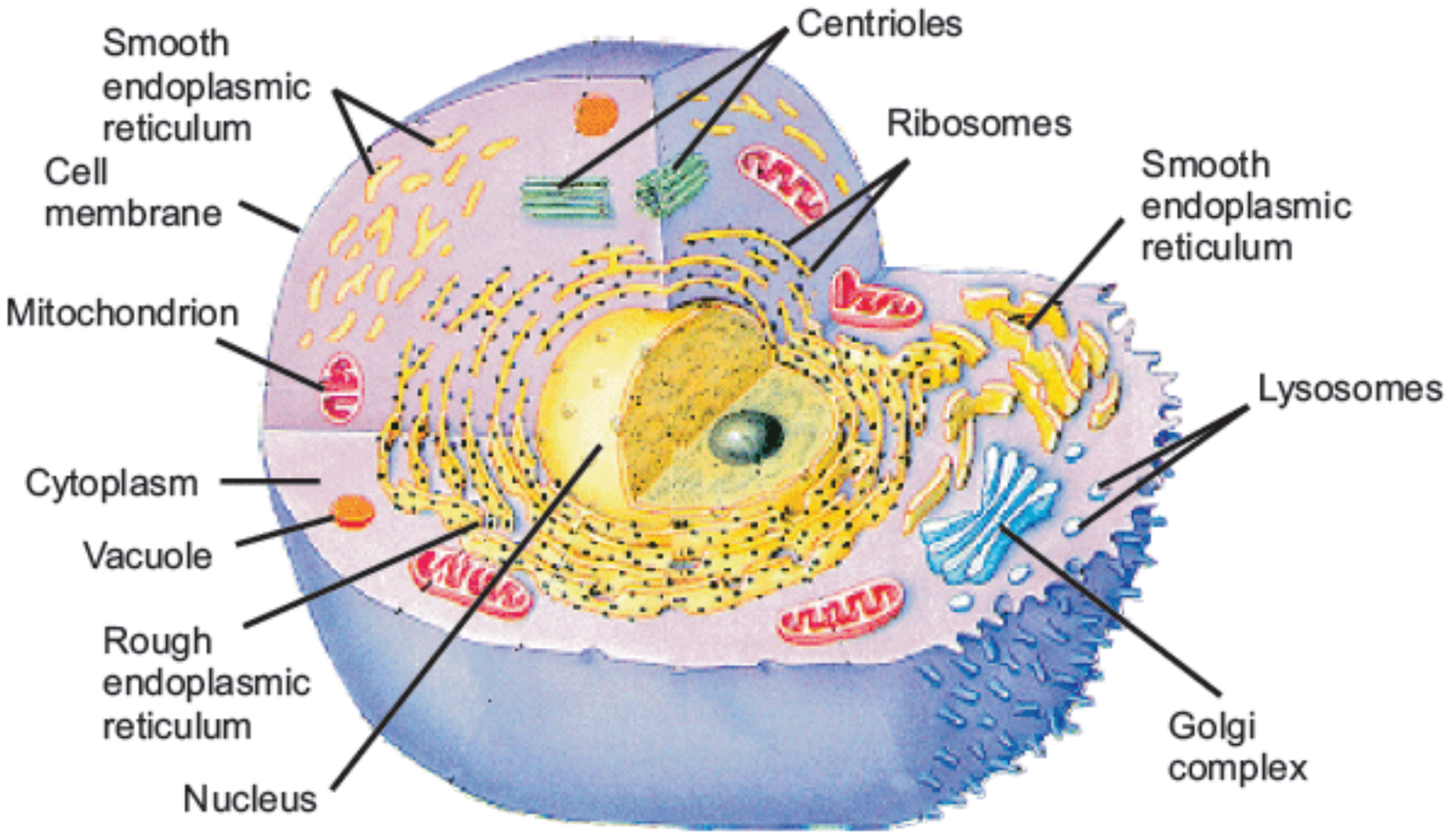


Figure 4.8: The ultra-structure of an animal cell

In addition to this vital role, cell membrane can also sense chemical messages and can identify other cells.

Chemical analysis reveals that cell membrane is mainly composed of **proteins** and **lipids** with small quantities of carbohydrates. Electron microscopic examinations of cell membranes have led to the development of **fluid-mosaic model** of cell membrane (Figure 4.9).

According to this model, there is a lipid bilayer in which the protein molecules are embedded. The lipid bilayer gives fluidity and elasticity to membrane. Small amounts of carbohydrates are also found in cell membranes. These are joined with proteins or lipids of membrane.

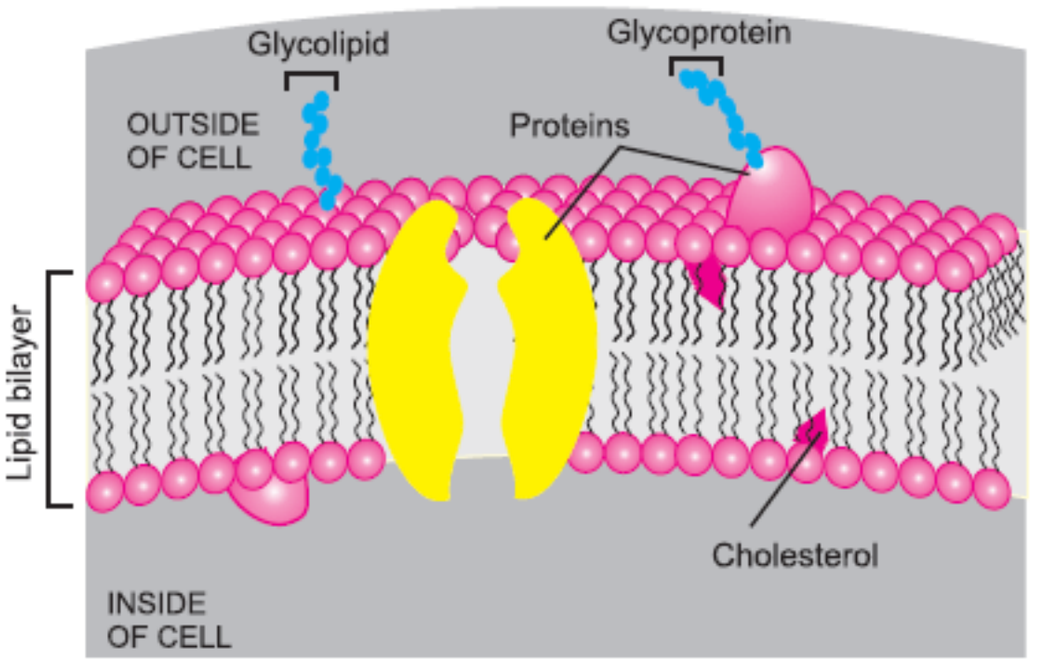


Figure 4.9: The fluid- mosaic model of cell membrane

In eukaryotic cells, cholesterol is also present in lipid bilayer. In eukaryotic cell many organelles e.g. mitochondria, chloroplasts, Golgi apparatus, and endoplasmic reticulum are also bounded by cell membranes.

When we talk about all the membranes of a cell, we say them as cell membranes.
When we talk about only the outer membrane of cell, we say it as plasma membrane.

4.2.3 Cytoplasm

Cytoplasm is the semi-viscous and semi-transparent substance between plasma membrane (cell membrane) and nuclear envelope. It contains water in which many organic molecules (proteins, carbohydrates, lipids) and inorganic salts are completely or partially dissolved.

Cytoplasm provides space for the proper functioning of organelles and also acts as the site for various biochemical (metabolic) reactions. For example, Glycolysis (breakdown of glucose during cellular respiration) occurs in cytoplasm.

4.2.4 Cytoskeleton

Cytoskeleton is a network of microfilaments and microtubules. Microtubules are made of **tubulin** protein and are used by cells to hold their shape. They are also the major component of cilia and flagella. Microfilaments are thinner and are made of **actin** protein. They help cells to change their shapes.

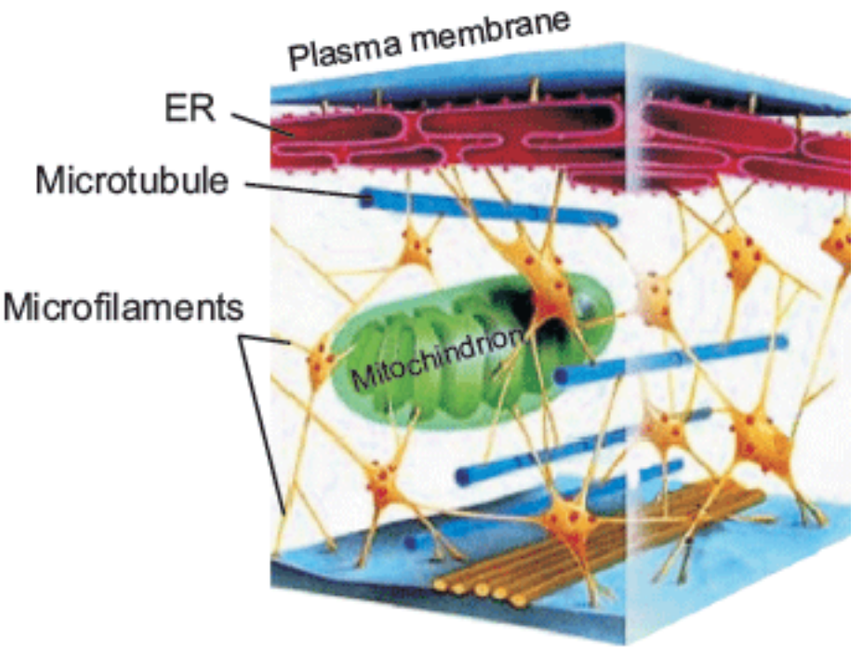


Figure 4.10: Cytoskeleton

4.2.5 Cell Organelles

Organelles are small structures within cells that perform dedicated functions. There are about a dozen types of organelles commonly found in eukaryotic cells. We will go through the basic facts about important cell organelles.

4.2.6 Nucleus

A prominent nucleus occurs in eukaryotic cells. In animal cells it is present in the centre while in mature plant cells, due to the formation of large central vacuole, it is pushed to side. Nucleus is bounded by a double membrane known as **nuclear envelope.** Nuclear envelope contains many small pores that enable it to act as a semi-permeable membrane. Inside nuclear envelope, a granular fluid i.e. **nucleoplasm** is present. Nucleoplasm contains one or two nucleoli (singular; nucleolus) and chromosomes (Figure 4.11).

Nucleolus is a dark spot and it is the site where ribosomal RNA are formed and assembled as ribosomes. **Chromosomes** are visible only during cell division while during interphase (non-dividing phase) of cell they are in the form of fine thread-like structures known as **chromatin**. Chromosomes are composed of Deoxyribonucleic acid (DNA) and proteins.

The prokaryotic cells do not contain prominent nucleus. Their chromosome is made of DNA only and is submerged in cytoplasm.

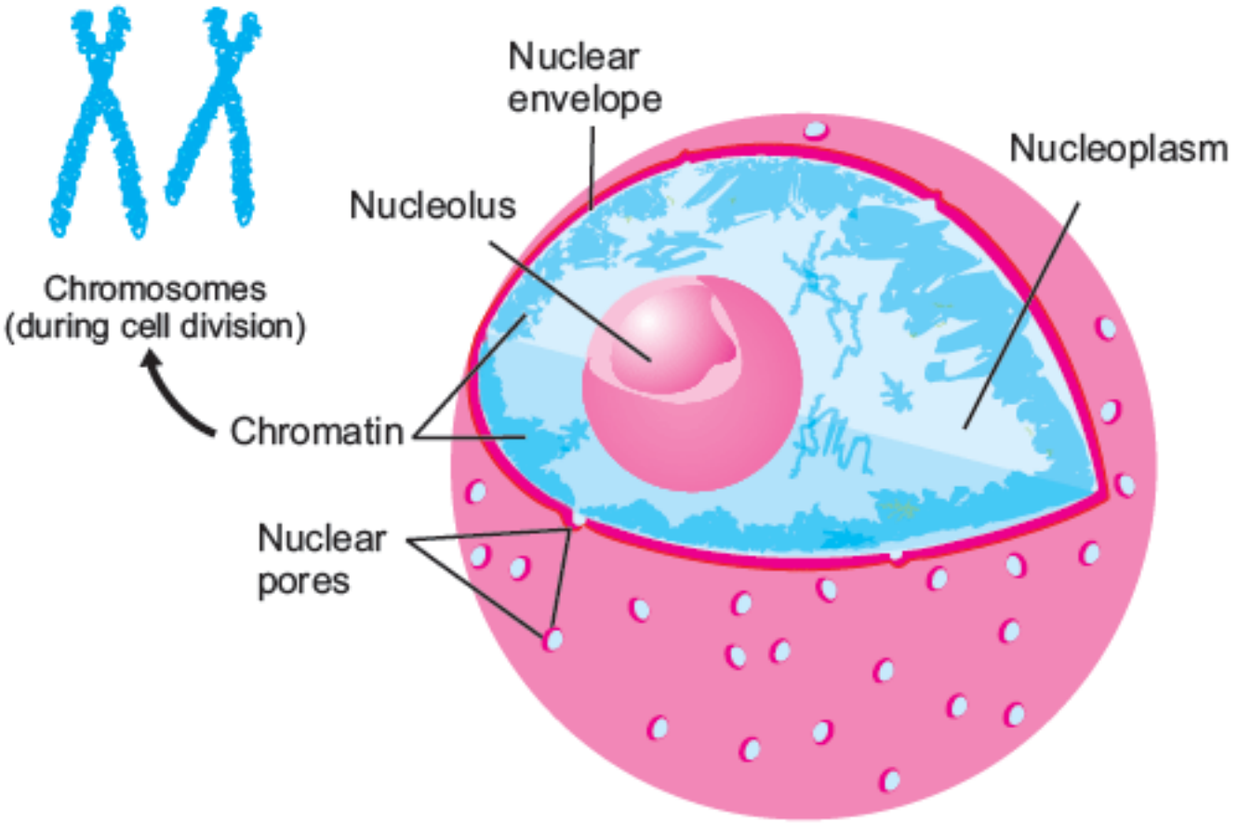


Figure 4.11: Structure of Nucleus

Animation 4.3: Nucleus
Source and Credit: Ameoba sisters

Ribosomes

Ribosomes are tiny granular structures that are either floating freely in cytoplasm or are bound to endoplasmic reticulum (ER). Each ribosome is made up of almost equal amounts of proteins and ribosomal RNA (rRNA). Ribosomes are not bound by membranes and so are also found in prokaryotes. Eukaryotic ribosomes are slightly larger than prokaryotic ones.

Ribosomes are the sites of protein synthesis. Protein synthesis is extremely important to cells, and so large numbers of ribosomes are found throughout cells. When a ribosome is not working, it disassembles into two smaller units (Figure 4.12) .

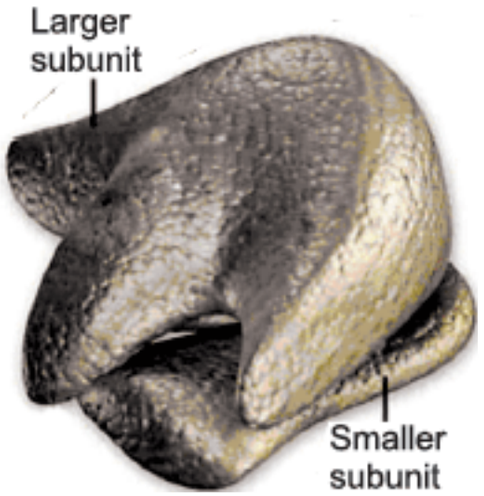


Figure 4.12: Ribosome

Animation 4.4: Ribosomes
Source and Credit: Nature

Animation 4.5: Ribosomes
Source and Credit: nature

Mitochondria

Mitochondria (singular: mitochondrion) are double membrane-bounded structures found only in eukaryotes. These are the sites of aerobic respiration, and are the major energy production centres. The outer membrane of a mitochondrion is smooth but the inner membrane forms many infoldings, called **cristae** (singular crista) in the inner mitochondrial matrix. This serves to increase the surface area of inner membrane on which membrane-bound reactions can take place (Figure 4.13). Mitochondria have their own DNA and ribosomes. The ribosomes of mitochondria are more similar to bacterial ribosomes than to eukaryotic ribosomes.

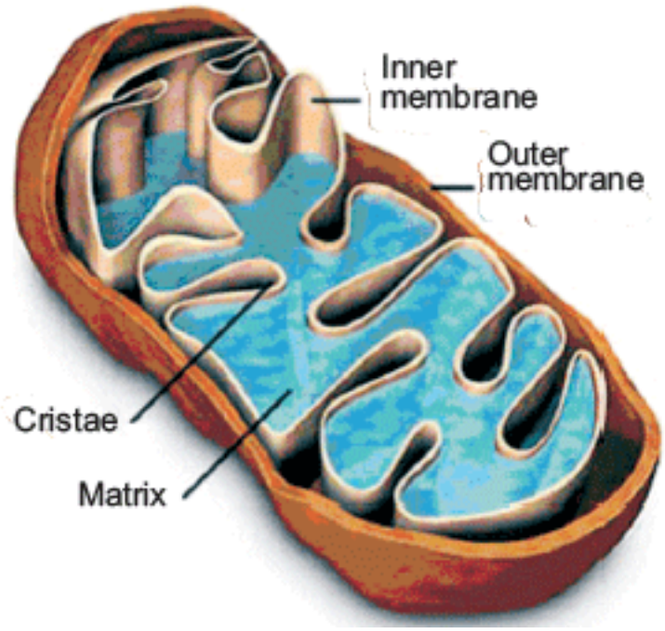


Figure 4.13: Mitochondrion

Animation 4.6: Mitochondria
Source and Credit: ibiblio

Plastids

Plastids are also membrane-bound organelles that only occur in the cells of plants and photosynthetic protists (algae). They are of three type i.e chloroplasts, leucoplasts and chromoplasts.
Like mitochondria, **chloroplast** is also bound by a double membrane. The outer membrane is smooth while the inner membrane gives rise to sacs called **thylakoids**. The stack of thylakoids is called granum (plural = grana).

Grana float in the inner fluid of chloroplast i.e. **stroma** (Figure 4.14). Chloroplasts are the sites of photosynthesis in eukaryotes. They contain chlorophyll (the green pigment necessary for photosynthesis) and associated pigments. These pigments are present in the thylakoids of grana.
The second type of plastids in plant cells are **chromoplasts**. They contain pigments associated with bright colors and are present in the cells of flower petals and fruits. Their function is to give colors to these parts and thus help in pollination and dispersal of fruit.
Leucoplasts are the third type of plastids. They are colourless and store starch, proteins and lipids. They are present in the cells of those parts where food is stored.

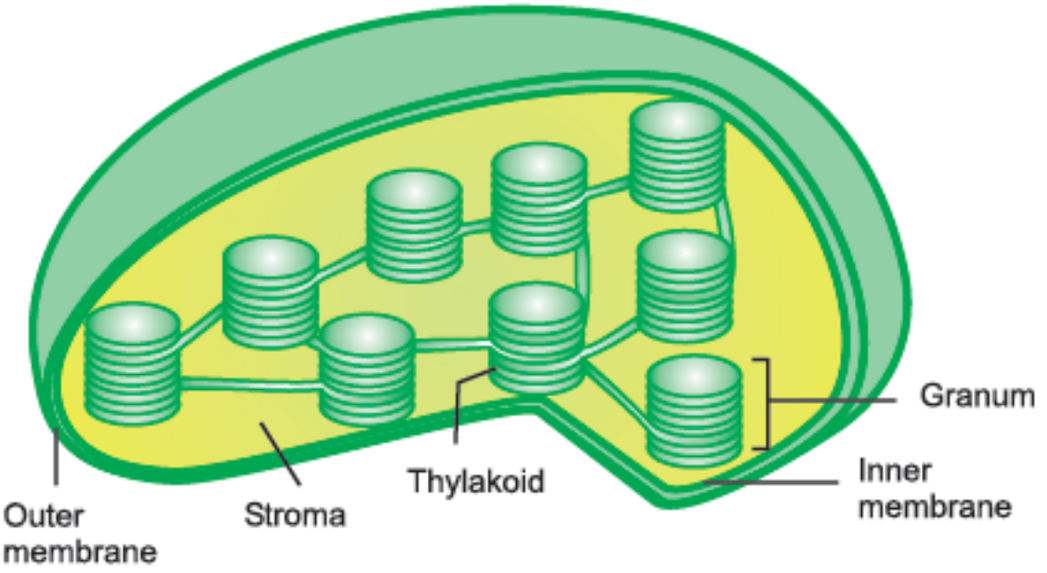


Figure 4.14: Chloroplast

Endoplasmic reticulum (ER)

Endoplasmic reticulum is a network of interconnected channels that extends from cell membrane to nuclear envelope. The network exists in two forms:

Rough Endoplasmic Reticulum (RER) is so-named because of its rough appearance due to numerous ribosomes that are attached to it (Figure 4.15). Due to the presence of ribosomes, RER serves a function in protein synthesis.

Smooth Endoplasmic Reticulum (SER) lacks ribosomes and is involved in lipid metabolism and in the transport of materials from one part of cell to other. It also detoxifies the harmful chemicals that have entered cell.

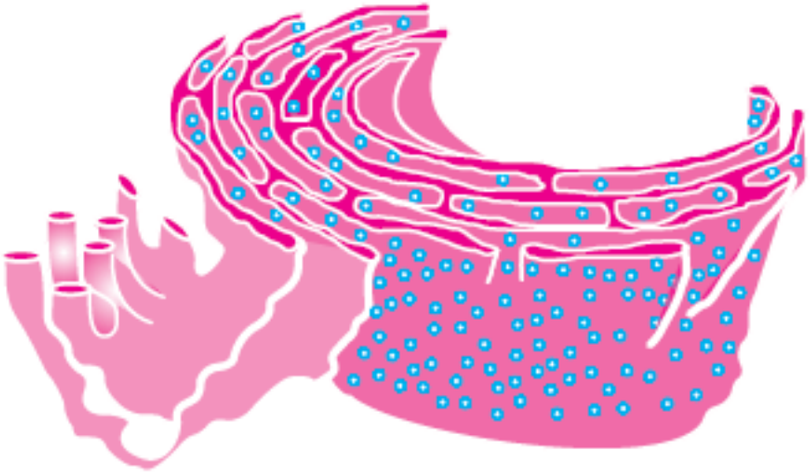


Figure 4.15: Smooth and Rough Endoplasmic Reticulum

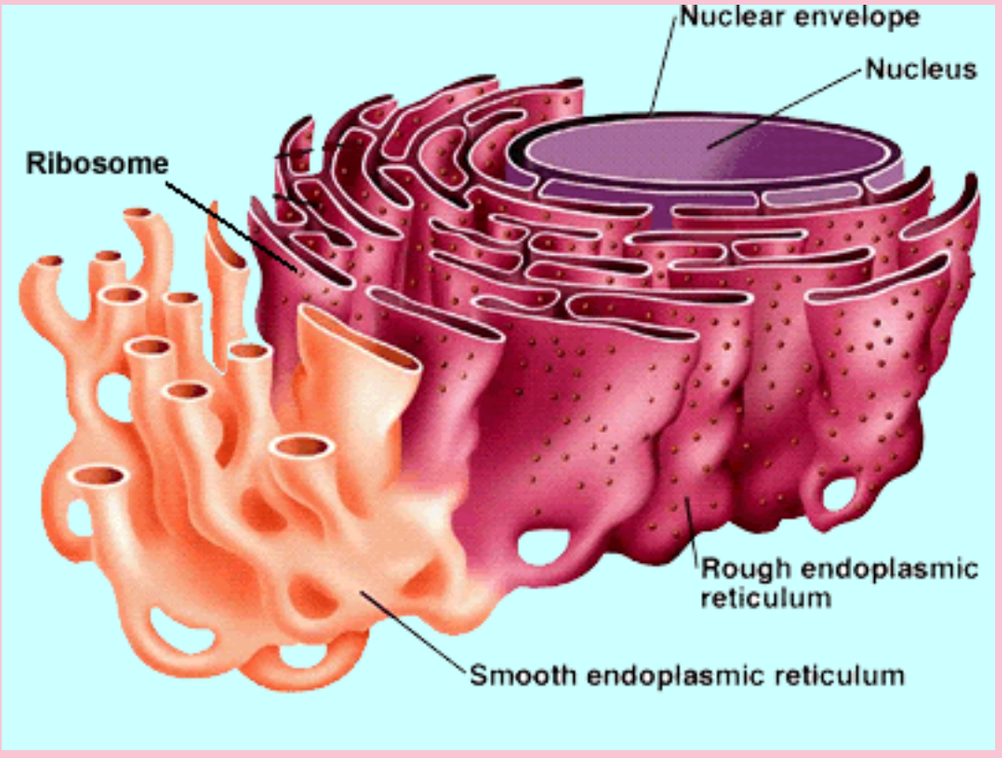
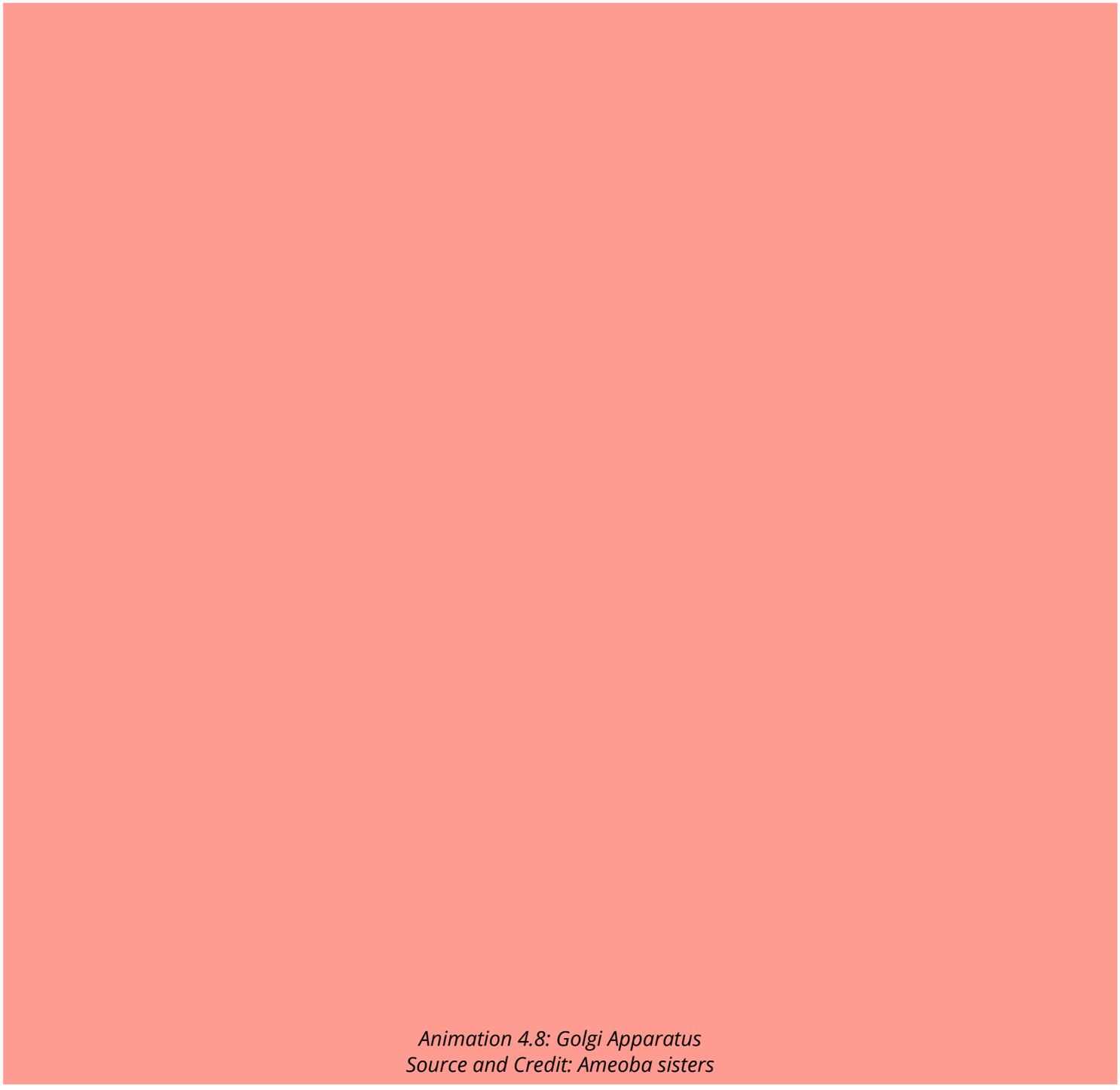


Image 4.1: Endoplasmic reticulum
Source and Credit: dynamicscience

Animation 4.7: Endoplasmic reticulum
Source and Credit: Ameoba sisters

Golgi Apparatus

An Italian physician **Camillo Golgi** discovered a set of flattened sacs **(cisternae)** in cell. In this set, many **cisternae** are stacked over each other. The complete set of cisternae is called Golgi apparatus or Golgi complex. It is found in both plant and animal cells. It modifies molecules coming from rough ER and packs them into small membrane bound sacs called **Golgi vesicles**. These sacs can be transported to various locations in cell or to its exterior, in the form of secretions (Figure 4.17).



Animation 4.8: Golgi Apparatus
Source and Credit: Ameoba sisters

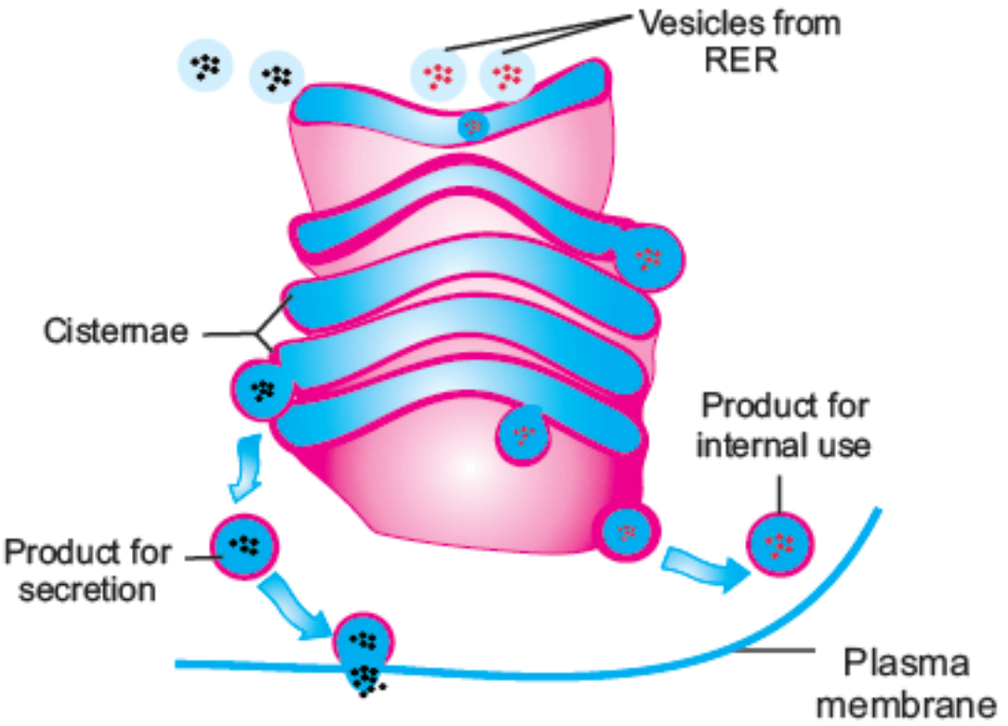


Figure 4.17: Functioning of the Golgi apparatus

De Duve won the 1974 Nobel Prize for physiology and medicine.

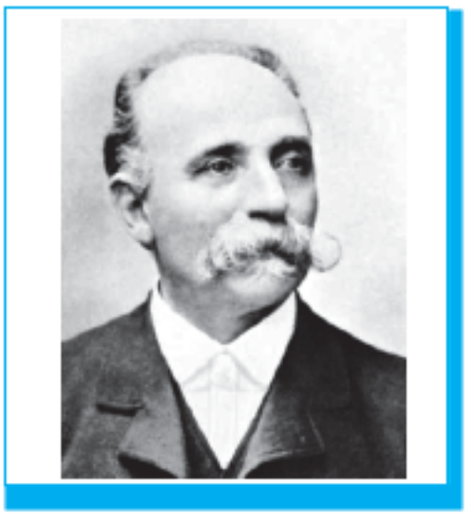


Figure 4.16: Camillo Golgi

In 1906, Golgi was awarded Nobel Prize for physiology and medicine.

Lysosomes

In the mid-twentieth century, a Belgian scientist **Christian René de Duve** discovered lysosomes. These are single-membrane bound organelles. Lysosomes contain strong digestive enzymes and work for the breakdown (digestion) of food and waste materials within cell. During its function, a lysosome fuses with the vacuole that contains the targeted material and its enzymes break down the material.

Let's think; What can happen when a lysosome bursts inside the cell and all its enzymes are released in the cytoplasm?

Animation 4.9: Lysosomes
Source and Credit: Ameoba sisters

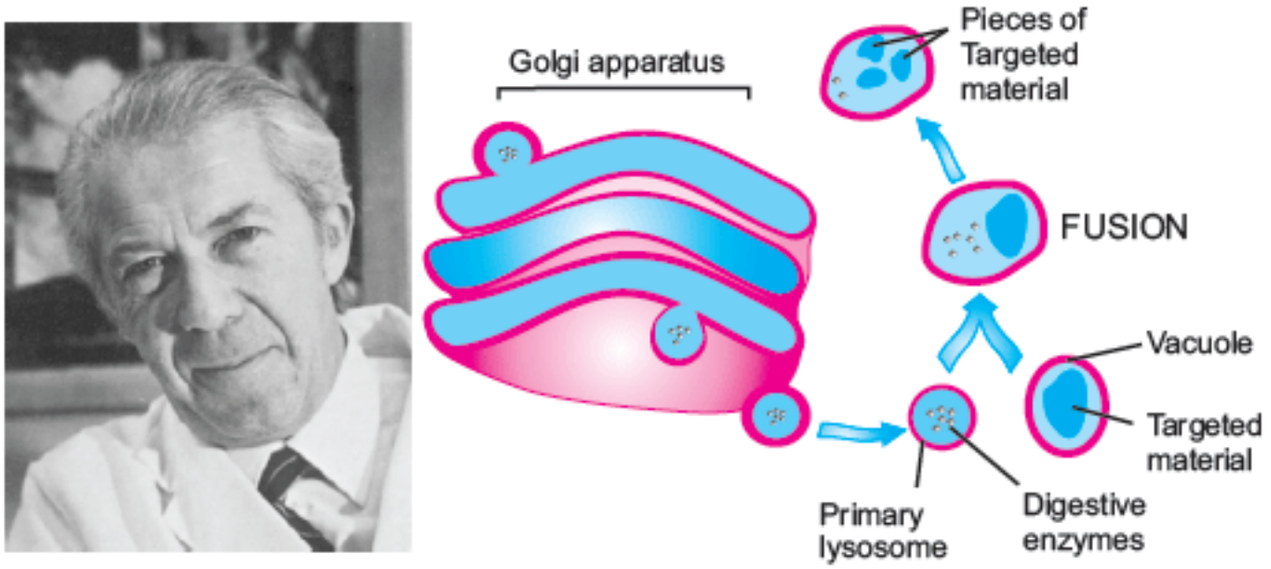


Figure 4.18: De Duve; Formation and Function of lysosome

Centrioles

Animals and many unicellular organisms have hollow and cylindrical organelles known as centrioles. Each centriole is made of nine triplets of microtubules (made up of tubulin protein). Animal cells have two centrioles located near the exterior surface of nucleus. The two centrioles are collectively called a **centrosome**. Their function is to help in the formation of spindle fibers during cell division. In some cells, centrioles are involved in the formation of cilia and flagella.

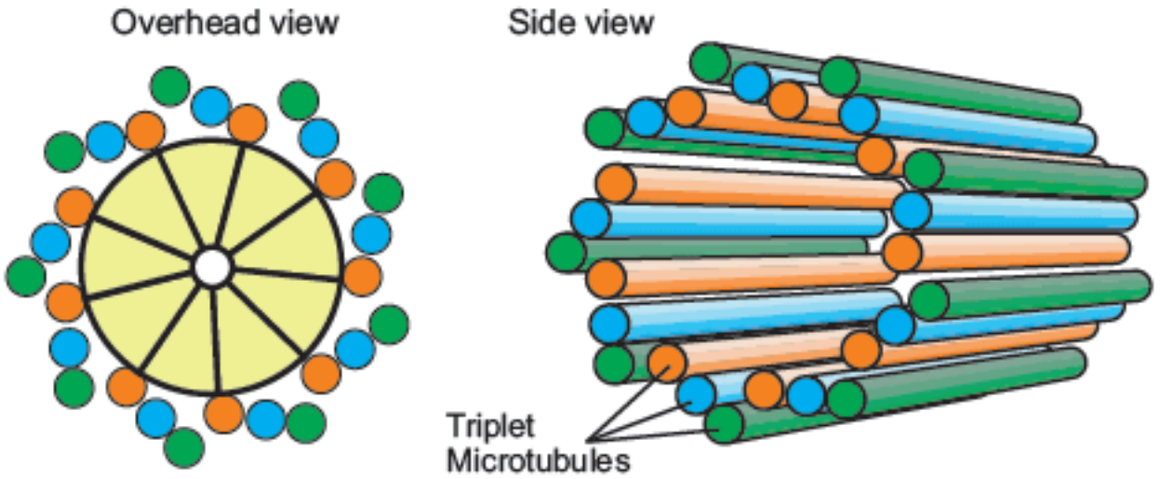
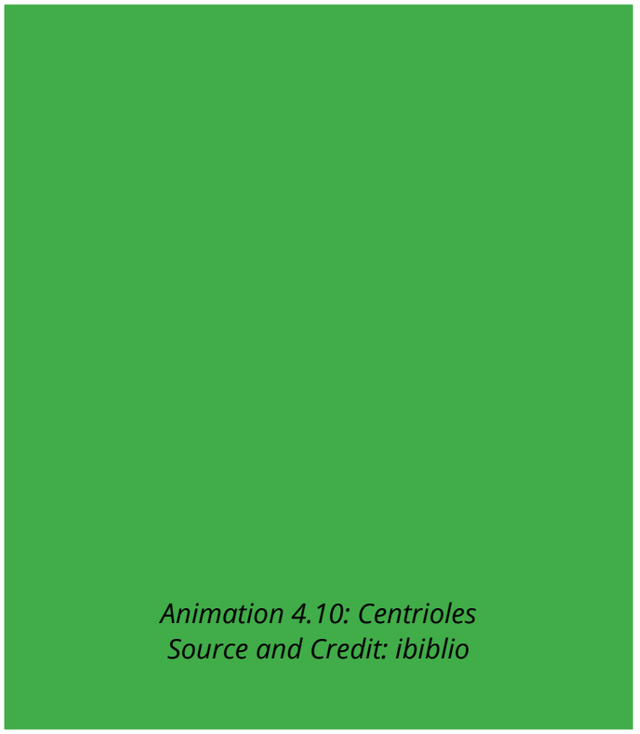


Figure 4.19: A Centriole



Animation 4.10: Centrioles
Source and Credit: ibiblio

Vacuoles

Vacuoles are fluid filled single-membrane bound organelles. Cells have many small vacuoles in their cytoplasm. However, when a plant cells matures its small vacuoles absorb water and fuse to form a single large vacuole in centre. Cell in this state becomes turgid. Many cells take in materials from outside in the form of food vacuole and then digest the material with the help of lysosomes. Some unicellular organisms use contractile vacuole for the elimination of wastes from their bodies.

? Which of the following organelles does not belong to others in the list: mitochondrion, chloroplast, ribosome, lysosome? Why?

Ribosome, because they are not membrane bounded.

Animation 4.11: Vacuole
Source and Credit: Ameoba sisters

4.2.6 Difference between Prokaryotic and eukaryotic cells

Prokaryotes possess prokayotic cells which are much simpler than the eukaryotic cells.The main differences between prokaryotic and eukaryotic cells are given next.

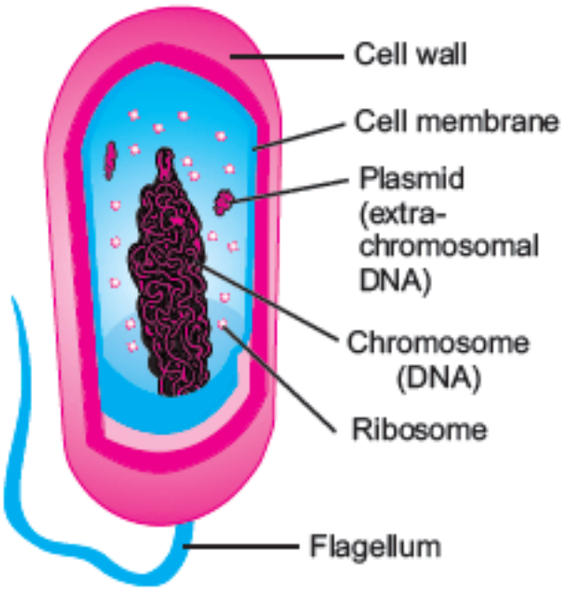


Figure 4.20: A general prokaryotic cell

Animation 4.12: Prokaryote vs. Eukaryote
Source and Credit: Ameoba sisters

Nucleus:	Eukaryotic cells have prominent nucleus (bounded by nuclear envelope) while prokaryotic cells do not have prominent nucleus. Their chromosome consists of DNA only and it floats in cytoplasm near centre. This region is called **nucleoid.**
Other Organelles:	Eukaryotic cells have membrane-bounded organelles like mitochondria, Golgi apparatus, endoplasmic reticulum etc while such membrane-bounded organelles are not present in prokaryotic cells. The ribosomes of eukaryotic cells are larger in size as compared to the ribosomes of prokaryotic cells.
Size:	Eukaryotic cells are, on average, ten times larger than prokaryotic cells.
Cell Wall:	The cell wall of eukaryotic cell is made of cellulose (in plants) or chitin (in fungi). All prokaryotic cells have cell wall, which is made of peptidoglycan (a large polymer of amino acids and sugars).

4.2.7 Relationship Between Cell Function And Cell Structure

The bodies of animals and plants are made of different cell types. Each type performs specific function and all coordinated functions become the life processes of organism. Cells of one type may differ from those of other types in the following respects.

Do you know?
Human body is made of about 200 types of cells.

Size and shape:	• Red blood cells are round to accommodate globular haemoglobin • Nerve cells are long for the transmission of nerve impulse • Xylem cells are tube-like and have thick walls for conduction of water and support
Surface area to volume ratio:	• Root hair cells have large surface area for the maximum absorption of water and salts
Presence or absence of organelles:	• Cells involved in making secretions have more complex ER and Golgi apparatus • Cells involved in photosynthesis have chloroplasts

Individual cells contribute in the functioning of the whole body. It can be explained by the following examples of the cells of human body:

- Nerve cells conduct nerve impulse and thus contribute in coordination in body.
- Muscle cells undergo contraction and share their role in movements in body.
- Red blood cells carry oxygen and white blood cells kill foreign agents and so contribute in the roles of blood in transportation and defence.
- Some skin cells act as physical barriers against foreign materials and some as receptors for temperature, touch, pain etc.
- The cells of bone deposit calcium in their extracellular spaces to make the bone tough and thus contribute to the supporting role of bones.

Cell as an Open System

A cell works as an **open system** i.e. it takes in substances needed for its metabolic activities through its cell membrane. Then it performs the metabolic processes assigned to it. Products and by-products are formed in metabolism. Cell either utilizes the products or transports them to other cells. The by-products are either stored or are excreted out of cell.

4.3 Cell Size And Surface Area To Volume Ratio

Cells vary greatly in size. The smallest cells are bacteria called mycoplasmas, with diameter between 0.1 µm to 1.0 µm. The bulkiest cells are bird eggs, and the longest cells are some muscle cells and nerve cells. Most cells lie between these extremes.

Cell size and shape are related to cell function. Bird eggs are bulky because they contain a large amount of nutrient for the developing young. Long muscle cells are efficient in pulling different body parts together. Lengthy nerve cells can transmit messages between different parts of body. On the other hand, small cell size also has many benefits. For example human red blood cells are only 8 µm in diameter and therefore can move through our tiniest blood vessels i.e. capillaries. Most cells are small in size. In relation of their volumes, large cells have less surface area as compared to small cells. Figure 4.21 shows this relationship using cube-shaped cells. The figure shows 1 large cell and 27 small cells. In both cases, the total volume is same:

Volume = 30 µm X 30 µm X 30 µm = 27,000 μm^3

In contrast to the total volume, the total surface areas are very different. Because a cubical shape has 6 sides, its surface area is 6 times the area of 1 side.

The surface areas of cubes are as follows:

- Surface area of 1 large cube = 6 X (30 µm X 30 µm) = 5400 μm^2
- Surface area of 1 small cube = 6 X (10 µm X 10 µm) = 600 μm^2 and
- Surface area of 27 small cubes = 27 X 600 μm^2 = 16, 200 μm^2

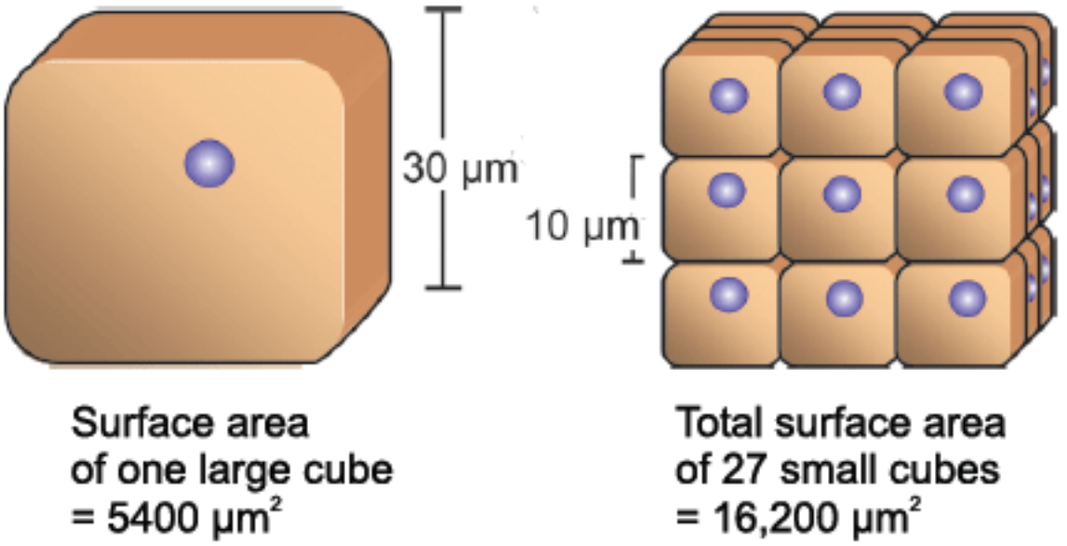


Figure 4.21: Effect of cell size on surface area

Need of nutrients and rate of waste production are directly proportional to cell volume. Cell takes up nutrients and excretes wastes through its surface cell membrane. So a large volume cell demands large surface area. But as the figure shows, a large cell has a much smaller surface area relative to its volume than smaller cells have. Hence we conclude that the membranes of small cells can serve their volumes more easily than the membrane of a large cell.

4.4 Passage Of Molecules Into And Out Of Cells

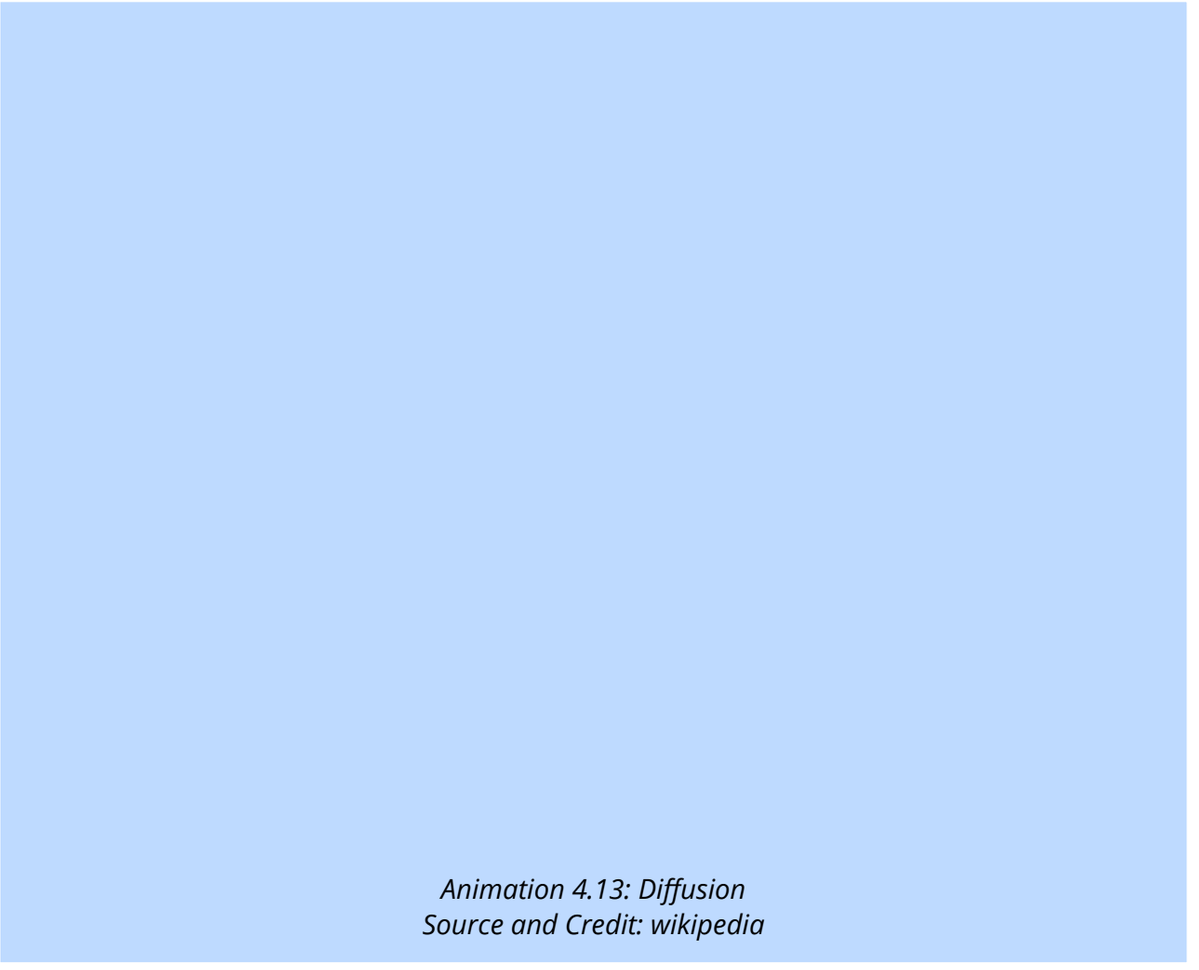
We know that cell membranes act as barriers to most, but not all, molecules. That is why cell membranes are called **semi-permeable** membranes. Cell membranes maintain equilibrium inside cell as well as outside by exchanging matter with cells' environment according to needs. Cell membranes do it through the phenomena of diffusion, facilitated diffusion, osmosis, filtration, active transport, endocytosis and exocytosis.

Diffusion

Diffusion is the movement of molecules from an area of higher concentration to the area of lower concentration i.e. along concentration gradient. The molecules of any substance (solid, liquid or gas) are in motion when that substance is above 0 degrees Kelvin or -273 degrees Centigrade. In a substance, majority of the molecules move from higher to lower concentration, although there are some that move from low to high. The overall (or net) movement is thus from high to low

concentration. Eventually, the molecules reach a state of equilibrium where they are distributed equally throughout the area.

Diffusion is one principle method of movement of substances within cells, as well as across cell membrane. Carbon dioxide, oxygen, glucose etc. can cross cell membranes by diffusion. Gas exchange in gills and lungs occurs by this process. Movement of glucose molecules from small intestine lumen into the blood capillaries of villi is another example of diffusion. Because a cell does not expend energy when molecules diffuse across its membrane, the diffusion is type of **passive transport.**



Animation 4.13: Diffusion
Source and Credit: wikipedia

Facilitated diffusion

Many molecules do not diffuse freely across cell membranes because of their size or charge. Such molecules are taken into or out of the cells with the help of transportproteins present in cell membranes. When a transport protein moves a substance from higher to lower concentration, the process is called facilitated diffusion. The rate of facilitated diffusion is higher than simple diffusion. Facilitated diffusion is also a type of passive transport because there is no expenditure of energy in this process (Figure 4.22).

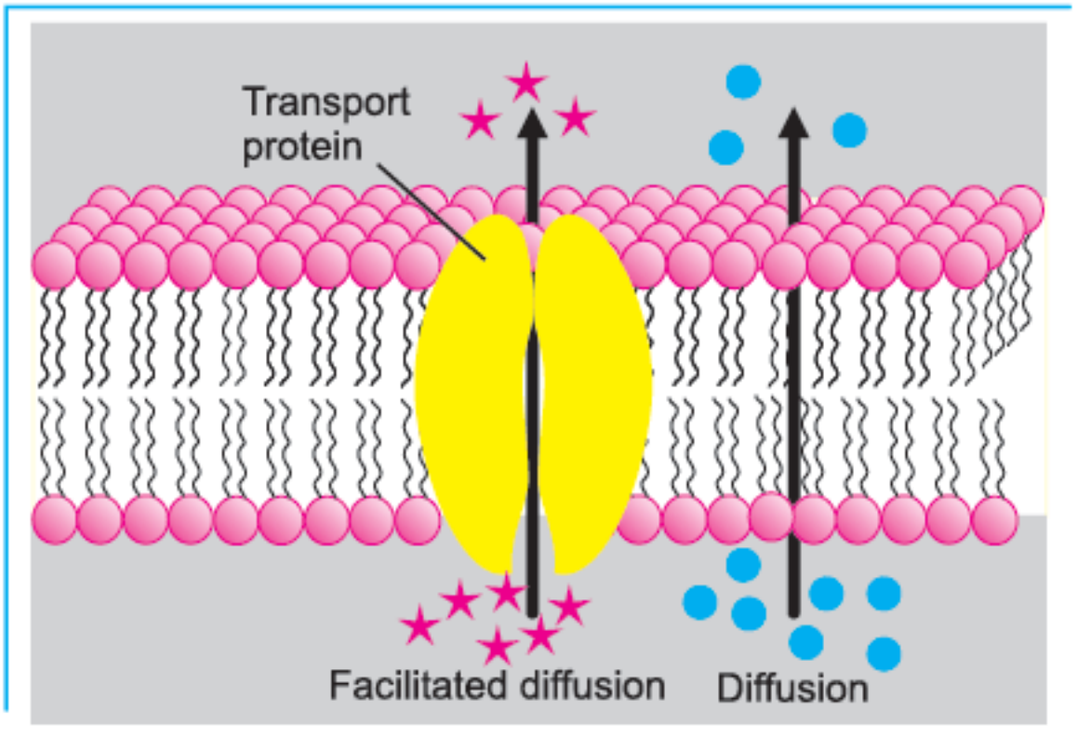


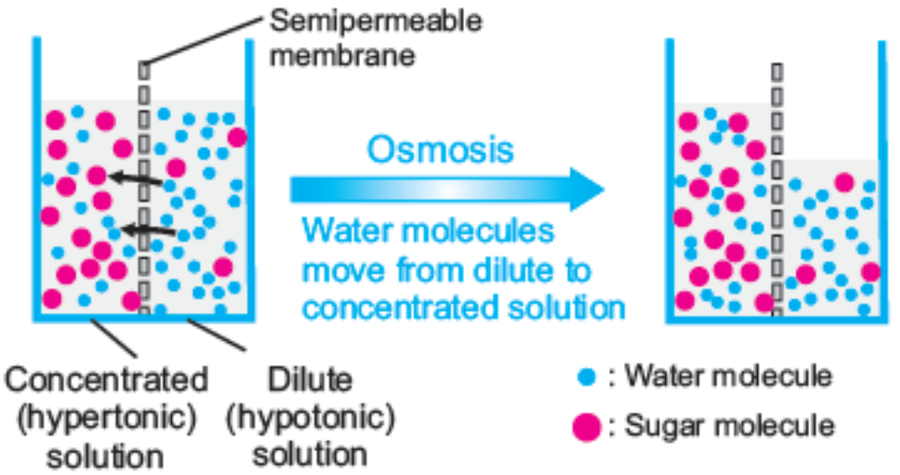
Figure 4.22: Diffusion and facilitated diffusion through cell membrane

Osmosis

Osmosis is the movement of water across a semi-permeable membrane from a solution of lesser solute concentration to a solution of higher solute concentration.

The rules of osmosis can be best understood through the concept of tonicity of solutions. The term tonicity refers to the relative concentration of solutes in the solutions being compared.

- A **Hypertonic solution** has relatively more solute.
- A **Hypotonic solution** has relatively less solute.
- **Isotonic** solutions have equal concentrations of solutes.



Animation 4.14: Osmosis
Source and Credit: majordifferences

Water balance problems

When an animal cell, such as red blood cell, is placed in an isotonic solution, the cell volume remains constant because the rate at which water is entering cell is equal to the rate at which it is moving out. When a cell is placed in a hypotonic solution, water enters and cell swells and may rupture like an over-filled balloon. Similarly, an animal cell placed in a hypertonic solution will lose water and will shrink in size. So in hypotonic environments (e.g. freshwater) animal cells must have ways to prevent excessive entry of water and in hypertonic environments (e.g. seawater) they must have ways to prevent excessive loss of water.

Water balance problems are somewhat different for plant cells because of their rigid cell walls. Most plant cells live in hypotonic environment i.e. there is low concentration of solutes in extracellular fluids than in cells. As a result, water tends to move first inside cell and then inside vacuole. When vacuole increases in size, cytoplasm presses firmly against the interior of cell wall, which expands a little. Due to strong cell wall, plant cell does not rupture but instead becomes rigid. In this condition, the outward pressure on cell wall exerted by internal water is known as **turgor pressure** and the phenomenon is **turgor**. In isotonic environment, the net uptake of water is not enough to make the cell turgid and it is flaccid (loose / not firm). In a hypertonic environment a plant cell loses water and cytoplasm shrinks. The shrinking of cytoplasm is called **plasmolysis.**

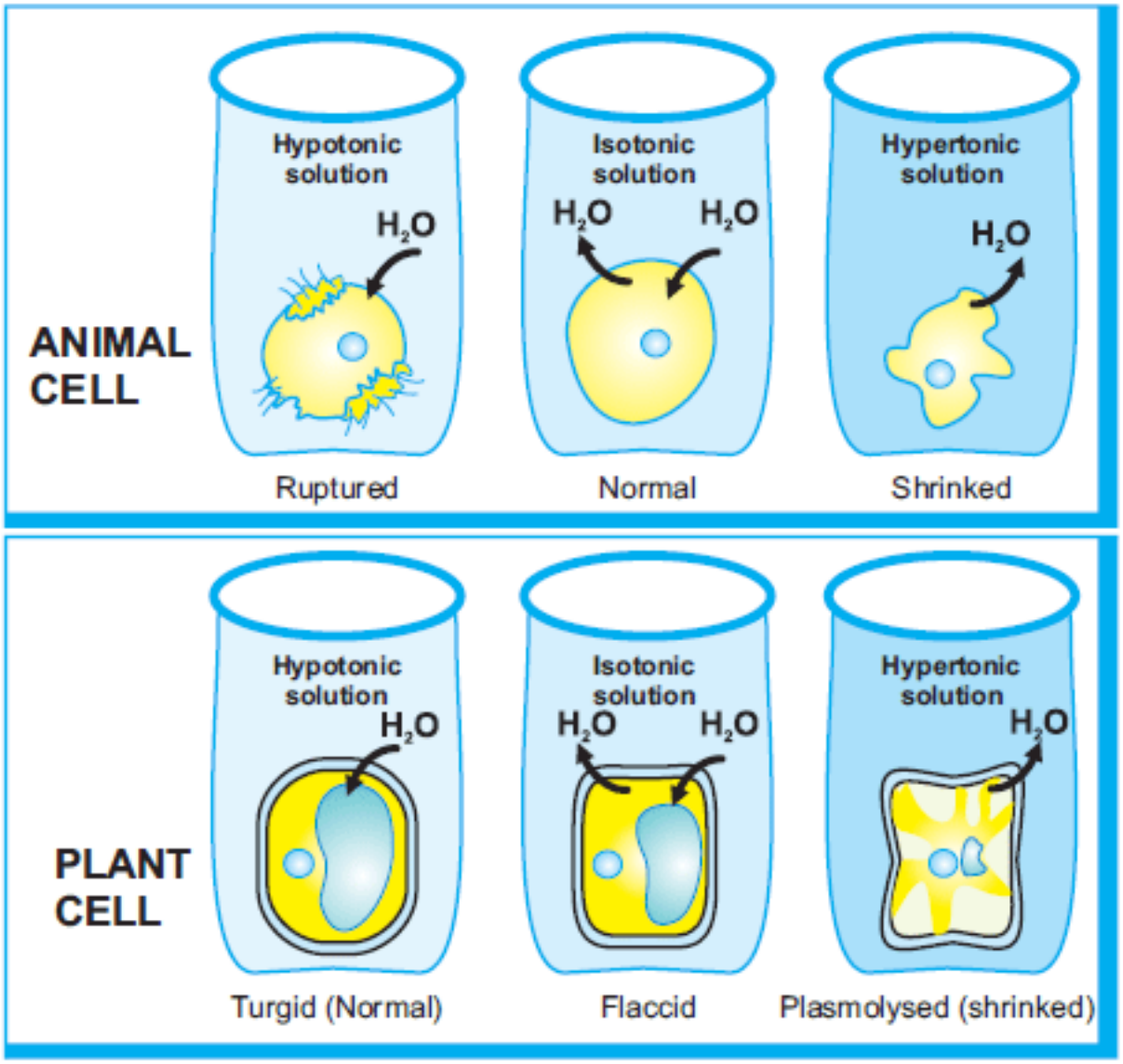


Figure 4.23: Effect of tonicity on animal and plant cell

Osmosis and Guard cells

Stomata (openings) in leaf epidermis are surrounded by guard cells. During daytime guards cells are making glucose and so are hypertonic (have higher concentration of glucose) than their nearby epidermis cells. Water enters them from other cells and they swell. In this form, they assume a rigid bowed shape and a pore is created between them. At night when there is low solute concentration in guard cells, water leaves them and they become flaccid. In this form, both guard cells rest against one another and the opening is closed.

Application of knowledge about semi-permeable membranes

The knowledge about semi-permeable membranes is applied for various purposes. We know that semi-permeable membrane is capable of separating substances. Artificially synthesized semi-permeable membranes are used for the separation of bacteria from viruses, because bacteria cannot cross a semi-permeable membrane. In advanced water-treatment technologies, membrane-based filtration systems are used. In this process, semi-permeable membranes separate salts from water **(reverse osmosis)**.

Filtration

Filtration is a process by which small molecules are forced to move across semipermeable membrane with the aid of hydrostatic (water) pressure or blood pressure.

The turgor of cells is responsible for maintaining shapes of non-woody plants and soft portions of trees and shrubs.

? Explain why it is not enough just to say that a solution is “hypertonoc“.

Hypertonic and hypotonic are relative terms. therefore you must say what the solution is compared to.

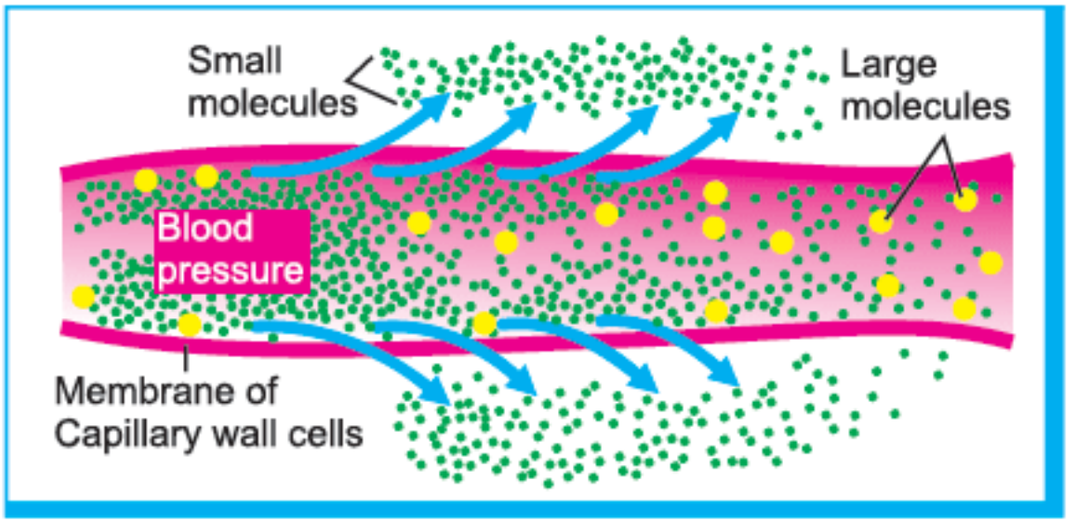


Figure 4.24: Filtration through the cell membrane of capillary wall

Active transport

Active transport is the movement of molecules from an area of lower concentration to the area of higher concentration. This movement against the concentration gradient requires energy in the form of ATP.

In this process, carrier proteins of cell membrane use energy to move the molecules against the concentration gradient. For example, the membranes of nerve cells have carrier proteins in the form of **"sodium-potassium pump"**. In a resting (not conducting nerve impulse) nerve cell, this pump spends energy (ATP) to maintain higher concentrations of K^+ and lower concentrations of Na^+ inside the cell. For this purpose, the pump actively moves Na^+ to the outside of the cell where they are already in higher concentration. Similarly this pumps moves K^+ from outside to inside the cell where they are in higher concentration (Figure 4.25).

?

In diffusion and filtration, only small molecules can pass across membrane. Which process would move the molecules faster?

Filtration

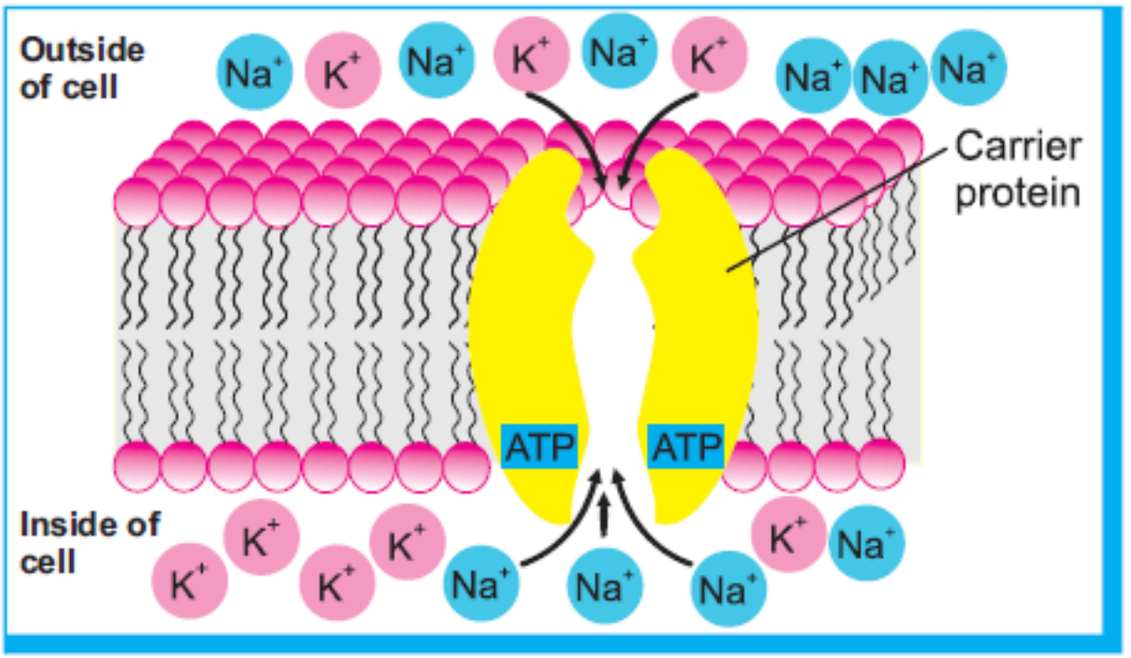


Figure 4.25: Sodium-potassium pump, showing active transport

Endocytosis

It is the process of cellular ingestion of bulky materials by the infolding of cell membrane (see the steps of endocytosis in Figure 4.26).

The two forms of endocytosis are **phagocytosis** (cellular eating) and **pinocytosis** (cellular drinking). In phagocytosis cell takes in solid material while in pinocytosis cell takes in liquid in the form of droplets.

In a colony of cells there are many cells and each cell performs all general functions on its own. Such a group does not get tissue level of organization because cells are not specific and there is no coordination among them.

Exocytosis

It is the process through which bulky material is exported (see the steps in Figure 4.26). This process adds new membrane which replaces the part of cell membrane lost during endocytosis.

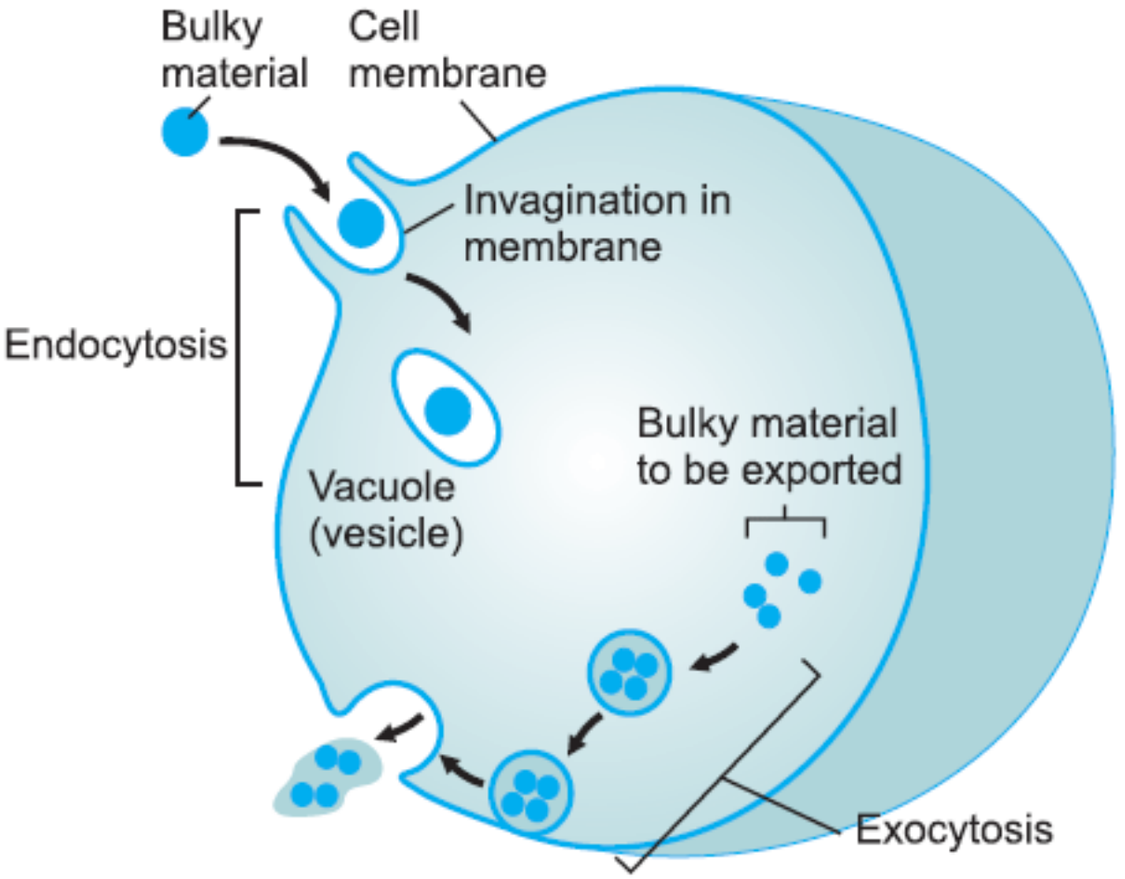


Figure 4.26: Endocytosis and Exocytosis

4.5 Animal And Plant Tissues

We are familiar with the levels of structural organization of life and recognize tissue as a group of similar cells specialized for the performance of a common function. In this topic we will learn about the major types of animal and plant tissues, with reference to their cell specificities, locations and functions.

4.5.1 Animal Tissues

In the bodies of animals, there are four major categories of tissues: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.

Epithelial tissue

Epithelial tissue covers the outside of body and lines organs and cavities. The cells in this tissue are very closely packed together. This tissue has many types on the basis of the shape of cells as well as the number of cell layers. Some types include:

Squamous epithelium consists of a single layer of flat cells. It is found in lungs, heart and blood vessels. Here, it allows the movement of materials across it.

Cuboidal epithelium consists of a single layer of cube-shaped cells. It is found in kidney tubes, small glands etc. where it makes secretions.

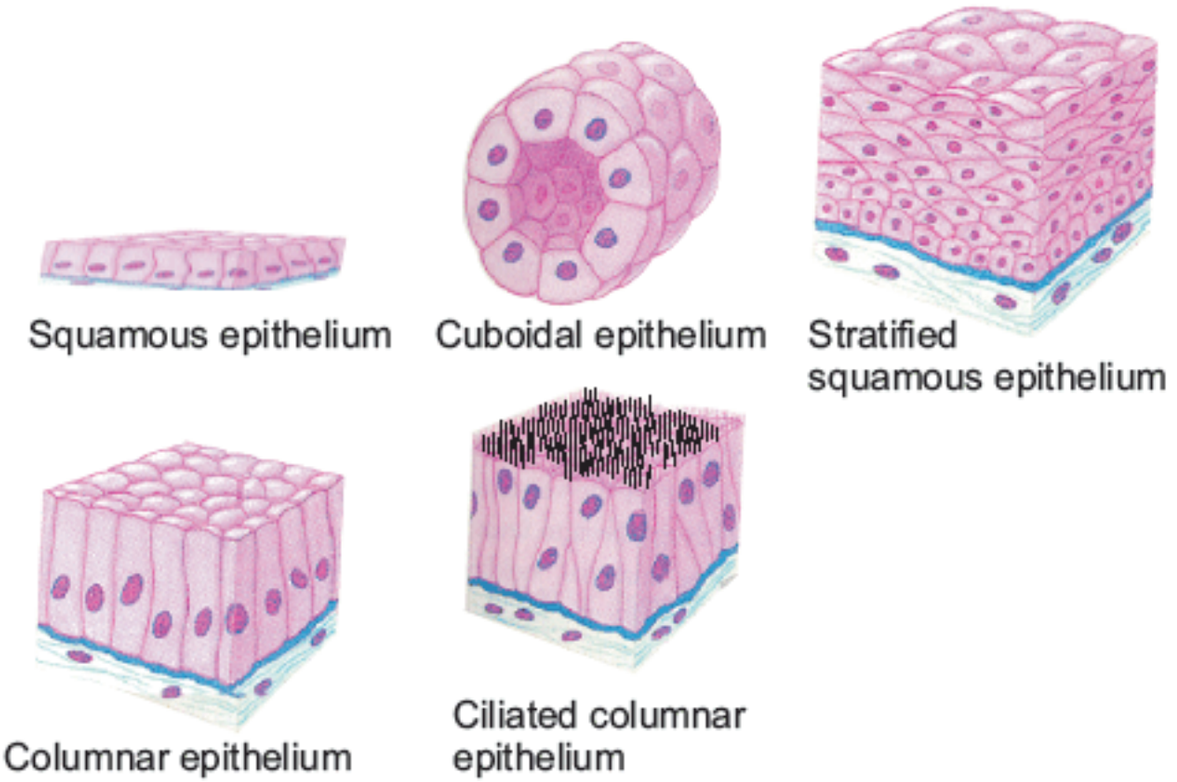


Figure 4.27: Epithelial tissues in animals

Columnar epithelium has elongated cells. It is found in alimentary canal, gall bladder etc. where it makes secretions.

Ciliated columnar epithelium has elongated cells with cilia. It is present in trachea and bronchi and propels mucous.

Stratified squamous epithelium has many layers of flat cells. It is present in the lining of oesophagus and mouth and also over the skin. It protects the inner parts.

Connective tissue

As the name shows, connective tissue serves a "connecting" function. It supports and binds other tissues. Unlike epithelial tissue, connective tissue has cells scattered throughout an extracellular matrix. Common examples of this tissue are cartilage (found around the ends of bones, in external ear, nose, trachea etc.), bone and blood. The adipose tissue (found around kidneys, under skin, in abdomen etc.) is also a type of connective tissue. It provides energy and support organs.

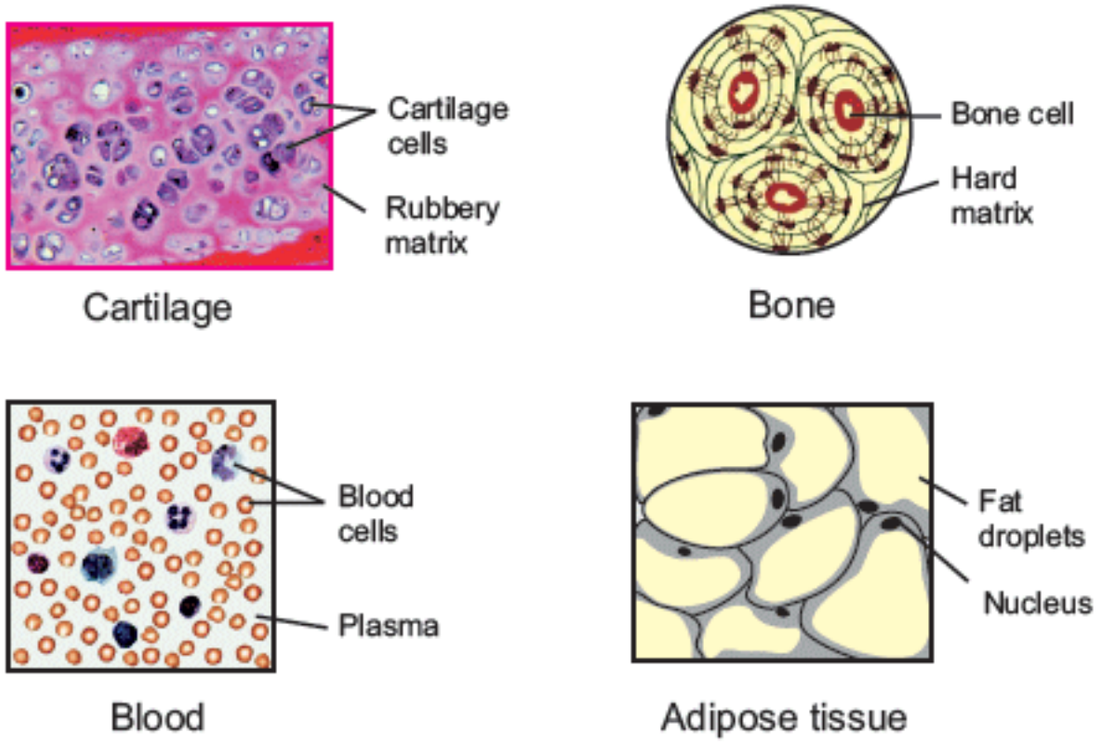


Figure 4.28: Connective tissues in animals

Do you know?

Exercise does not increase the numbers of our skeletal muscle cells; it simply enlarges those already present

Muscle Tissue

Muscle tissue consists of bundles of long cells called muscle fibers. It is the most abundant tissue in an animal. The cells of this tissue have ability to contract. There are three kinds of muscle tissue.

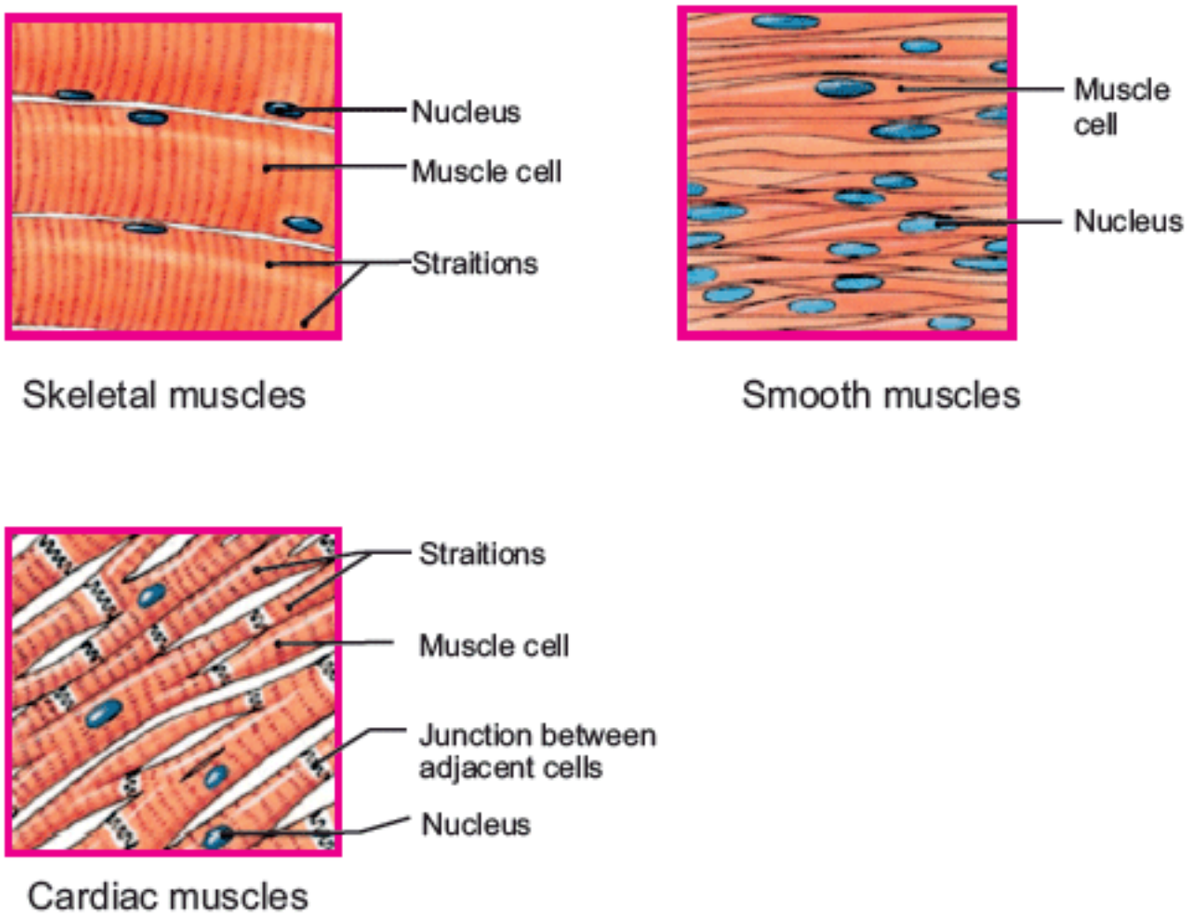


Figure 4.29: Types of muscle tissue

Skeletal muscles or striated muscles are attached to bones. Their cells are striated (striped) and contain many nuclei. They are responsible for the movements of bones.

Smooth muscles are found in the walls of alimentary canal, urinary bladder, blood vessels etc. They contain smooth (non-straited) cells, each with a single nucleus. They are responsible for the movement of substances.

Cardiac muscles are present in the wall of heart. Their cells are also striated but there is a single nucleus in each cell. They produce heartbeat.

Skeletal muscles are voluntary in action i.e. their contraction is under the control of our will. Smooth and cardiac muscles are involuntary in action i.e. their contraction is not under the control of our will.

Nervous tissue

We know that an animal's survival depends on its ability to respond appropriately to the stimuli from its environment. This ability requires the transmission of information among the parts of body. Nervous tissue forms a communication system and performs this task. This tissue is mainly composed of **nerve cells** or **neurons,** which are specialized to conduct messages in the form of **nerve impulses.** Nervous tissue is found in brain, spinal cord and nerves.

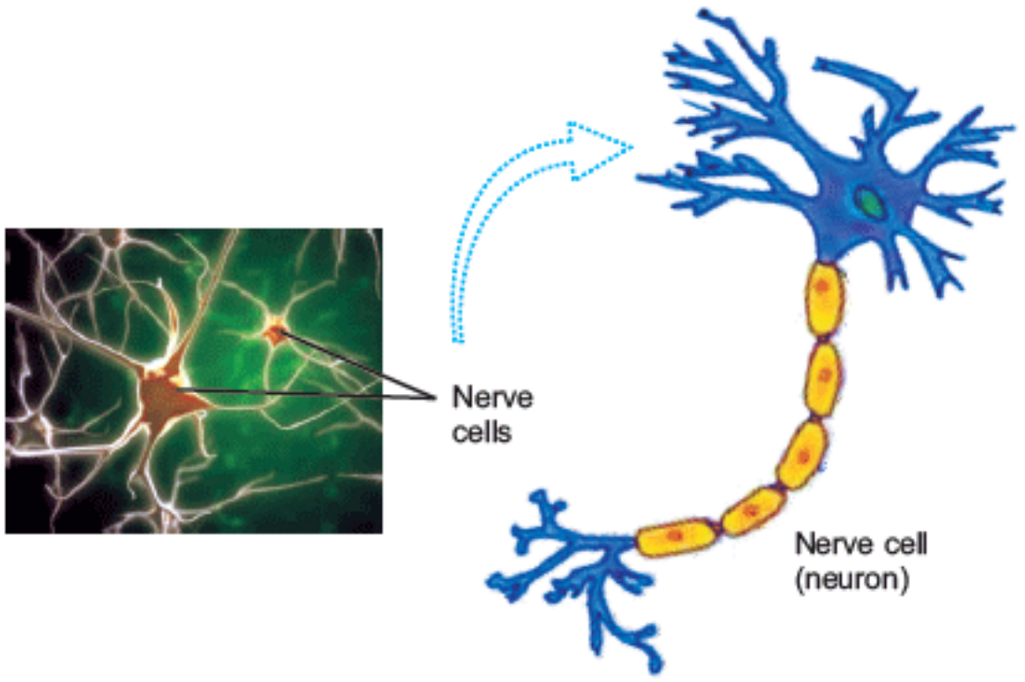


Figure 4.30: Nervous tissue

? When you hear that epithelial tissue has a tightly packed structure what function do you expect?

Barrier and protective function

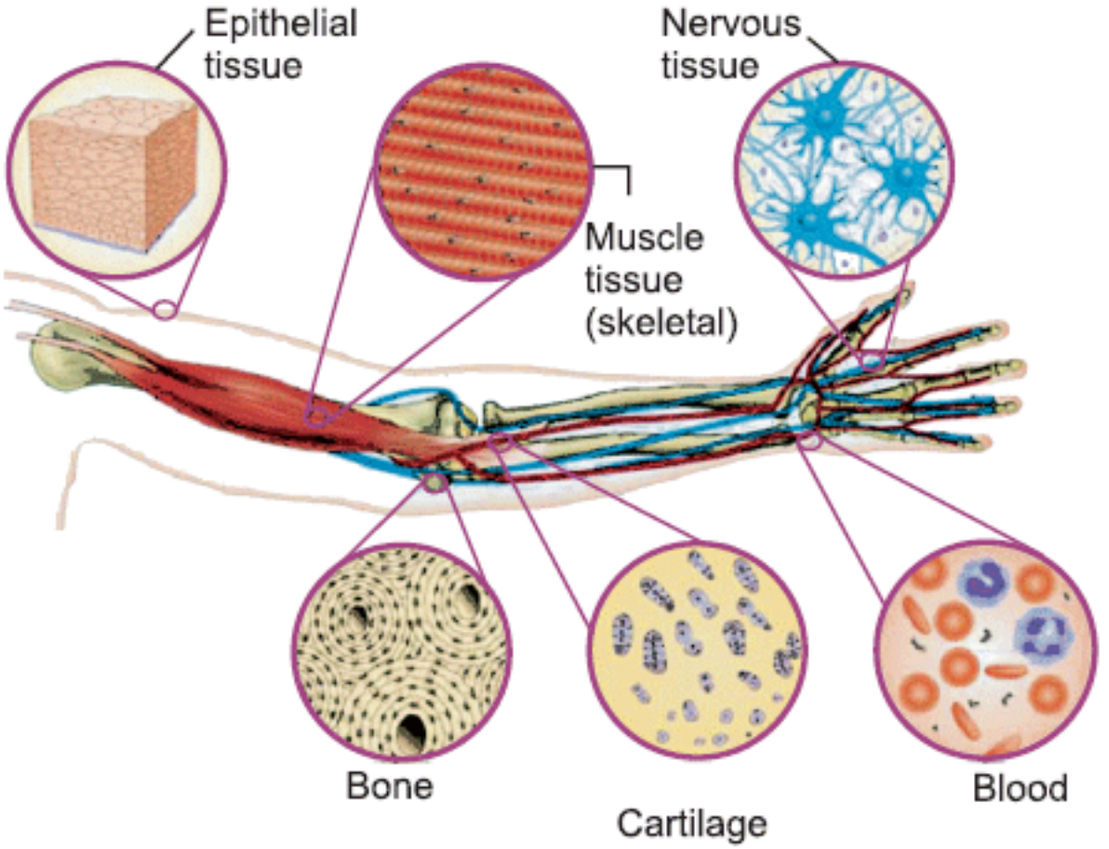


Figure 4.31: Different tissues in human body

4.5.2 Plant Tissues

As in animals, the cells of plants are grouped into tissues with characteristic functions such as photosynthesis, transport etc. There are two major categories of tissues in plants i.e. simple tissues and compound (complex) tissues.

Simple tissues

The tissues which are made of single type of cells, are called simple tissues. They are of two types i.e. meristematic tissues and permanent tissues.

A- Meristematic Tissues

These tissues are composed of cells, which have the ability to divide. The cells are thin walled, have large nucleus and small or no vacuoles. They do not have inter-cellular spaces among them. Two main types of meristematic tissues are recognized in plants.

i. **Apical meristems** are located at the apices (tips) of roots and shoot. When they divide they cause increase in the length of plant. Such growth is called primary growth.

ii. **Lateral meristems** are located on the lateral sides of roots and shoot. By dividing, they are responsible for increase in growth of plant parts. This growth is called secondary growth. They are further of two types i.e. **vascular cambium** (located between xylem and phloem) and cork cambium (in the outer lateral sides of plant).

Intercalary meristem is in the form of small patches among the mature tissues. These are common in grasses and help in the regeneration of parts removed by herbivores etc.

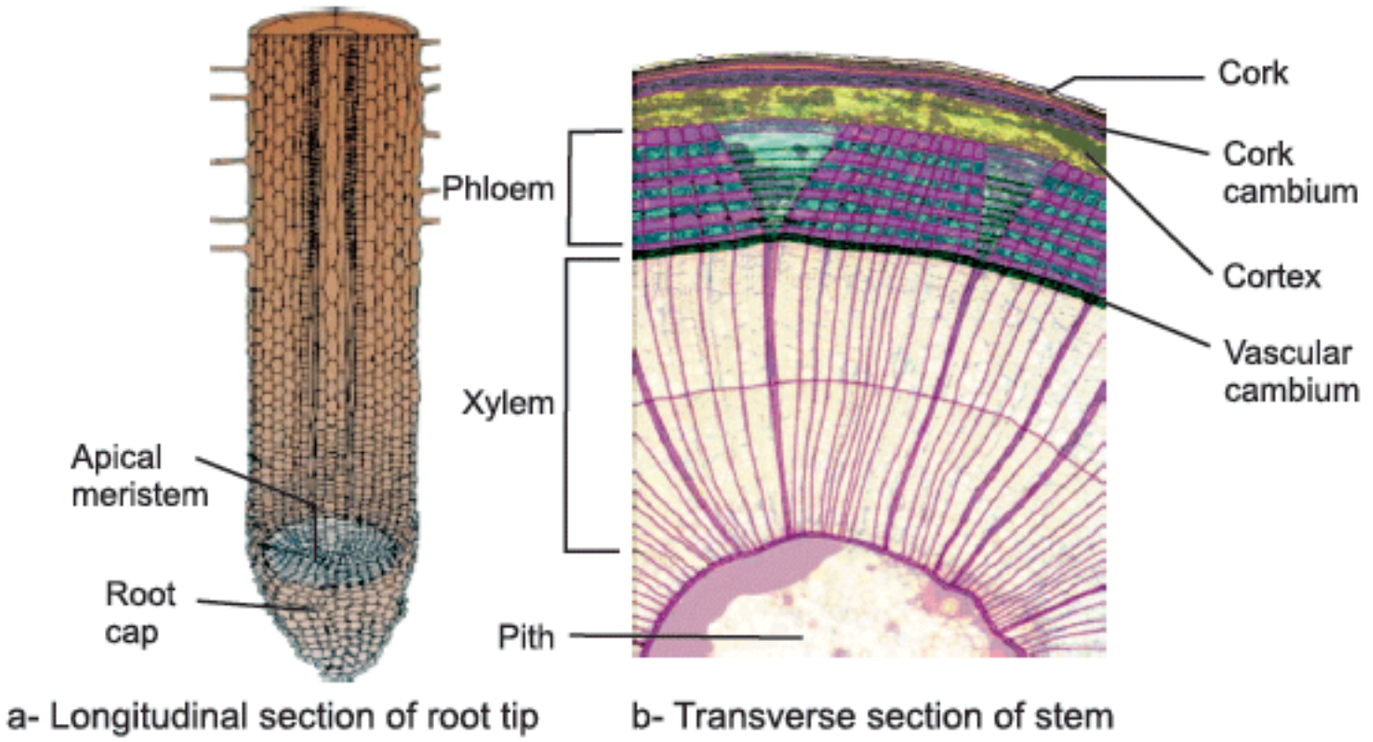


Figure 4.32: a- Apical meristem at root tip and b- Vascular and cork cambium in stem

B- Permanent Tissues

Permanent tissues originate from meristematic tissue. The cells of these tissues do not have the ability to divide. They are further classified into following types:

1. Epidermal Tissues

Epidermal tissues are composed of a single layer of cells and they cover plant body. They act as a barrier between environment and internal plant tissues. In roots, they are also responsible for the absorption of water and minerals. On stem and leaves they secrete cutin (the coating of cutin is called cuticle) which prevents evaporation.

Epidermal tissues also have some specialized structure that perform specific functions; for example **root hairs** and **stomata**.

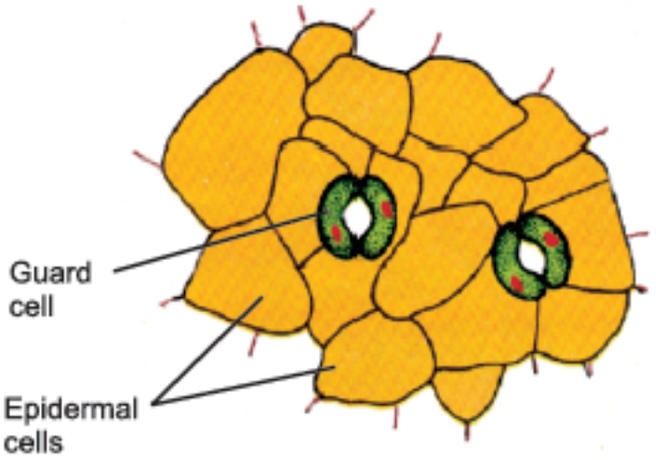


Figure 4.33: Epidermal tissue

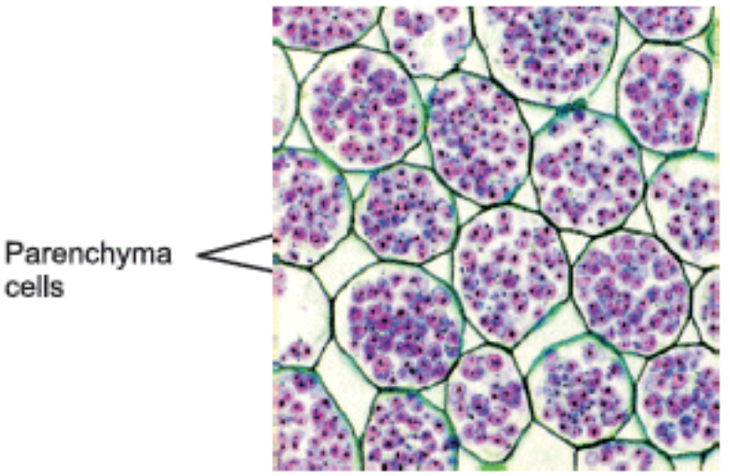


Figure 4.33-b : Ground tissue

2. Ground Tissues

Ground tissues are simple tissues made up of **parenchyma cells.** Parenchyma cells are the most abundant cells in plants. Overall they are spherical but flat at point of contact. They have thin primary cell walls and have large vacuoles for storage of food. In leaves, they are called **mesophyll** and are the sites of photosynthesis. In other parts, they are the sites of respiration and protein synthesis.

Do you know?

Most parenchyma cells can develop the ability to divide and differentiate into other types of cells and they do so during the process of repairing an injury.

3. Support Tissues

These tissues provide strength and flexibility to plants. They are further of two types.

i. Collenchyma Tissue

They are found in cortex (beneath epidermis) of young stems and in the midribs of leaves and in petals of flowers. They are made of elongated cells with unevenly thickened primary cell walls. They are flexible and function to support the organs in which they are found.

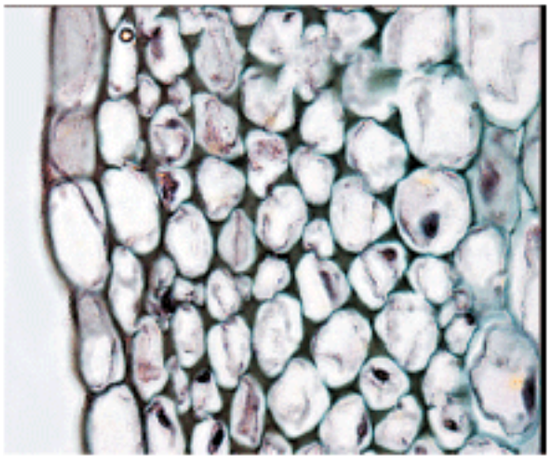


Figure 4.34: Collenchyma tissue

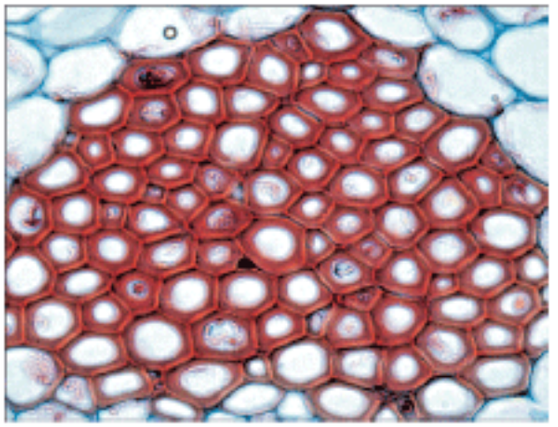


Figure 4.35: Schlerenchyma tissue

ii. Sclerenchyma Tissue

They are composed of cells with rigid secondary cell walls. Their cell walls are hardened with lignin, which is the main chemical component of wood. Mature sclerenchyma cells cannot elongate and most of them are dead.

Compound (Complex) Tissues

A plant tissue composed of more than one type of cell is called a compound or complex tissue. Xylem and phloem tissues, found only in vascular plants, are examples of compound tissues.

1. Xylem Tissue

Xylem tissue is responsible for the transport of water and dissolved substances from roots to the aerial parts. Due to the presence of lignin, the secondary walls of its cells are thick and rigid. That is why xylem tissue also provides support to plant body. Two types of cell are found in xylem tissue i.e. vessel elements and tracheids. **Vessel elements or cells** have thick secondary cell walls. They lack end walls and join together to form long tubes. **Tracheids** are slender cells with overlapping ends.

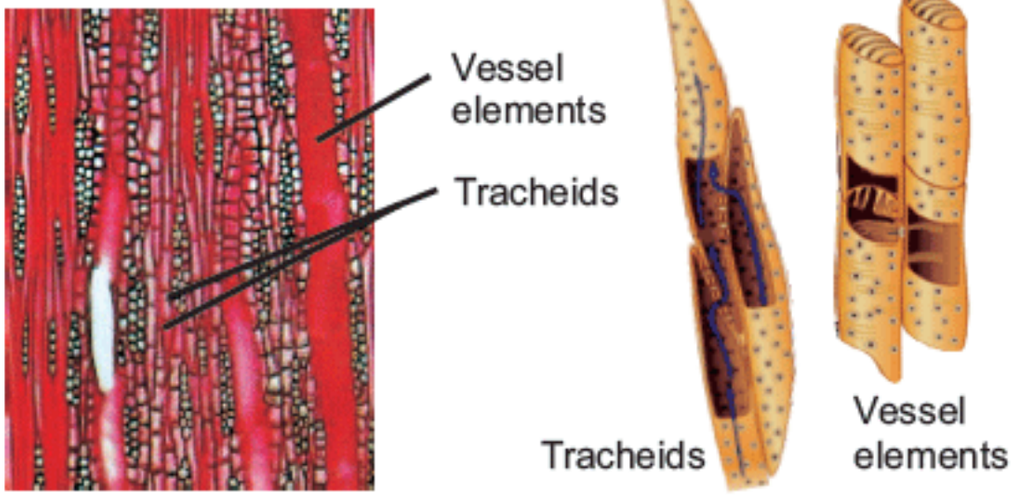


Figure 4.36: Xylem tissue

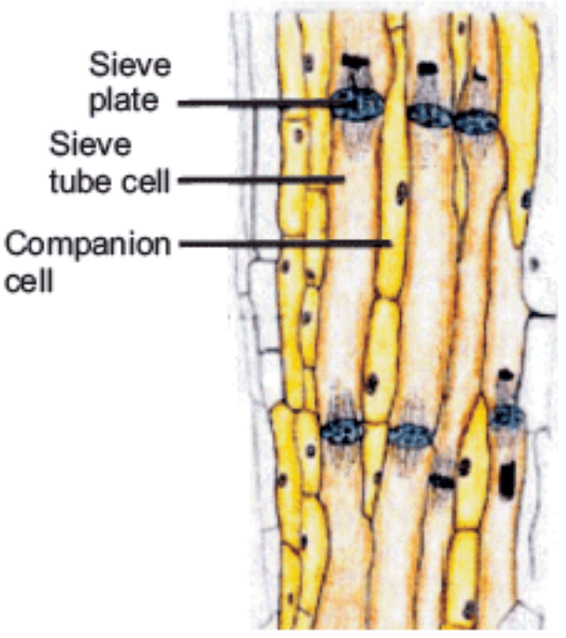


Figure 4.37: Phloem tissue

2. Phloem Tissue

Phloem tissue is responsible for the conduction of dissolved organic matter (food) between different parts of plant body. Phloem tissue contains sieve tube cells ands companion cells. **Sieve tube cells** are long and their end walls have small pores. Many sieve tube cells join to form long sieve tubes. **Companion cells** make proteins for sieve tube cells

? Birds fly by flapping their wings. What do you thing is the type of muscle responsible for wings flapping?

Skeletal

UNDERSTANDING THE CONCEPTS

1. Explain the functions of cell membrane.
2. Describe the structure of cell wall.
3. Discuss nucleus structure and function.
4. Describe the structure and function of endoplasmic reticulum and Golgi apparatus.
5. Describe the formation and function of lysosomes.
6. Explain what would happen when a plant and an animal cell is placed in a hypertonic solution.
7. Describe the internal structure of chloroplast and compare it with that of mitochondrion.
8. Explain the phenomena involved in the passage of matter across cell membrane.
9. Describe how turgor pressure develops in a plant cell.
10. State the relationship between cell function and cell structure.
11. Describe the differences in prokaryotic and eukaryotic cells.
12. Explain how surface area to volume ratio limits cell size.
13. Describe the major animal tissues in terms of their cell specificities, locations and functions.
14. Describe the major plant tissues in terms of their cell specificities, locations and functions.

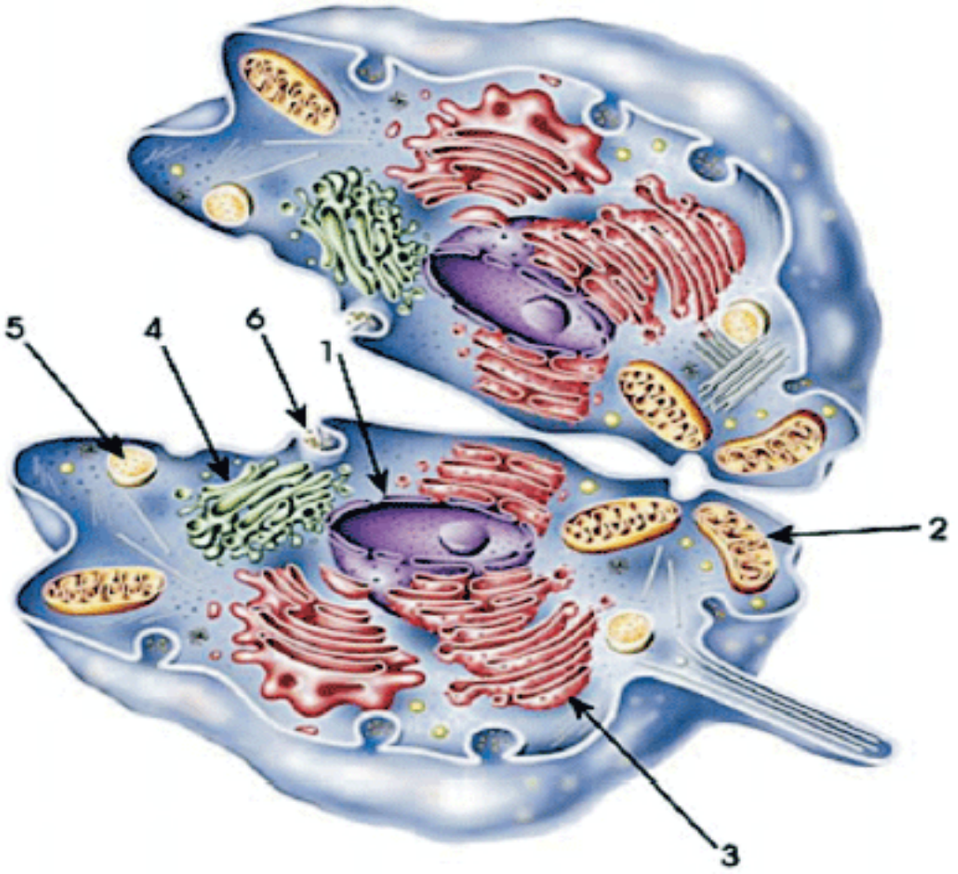
SHORT QUESTIONS

1. State the cell theory.
2. What are the functions of leucoplasts and chromoplasts?
3. Differentiate between diffusion and facilitated diffusion?
4. What is meant by hypertonic and hypotonic solutions?

THE TERMS TO KNOW		
Active transport	Epithelial tissue	Organelle
Cell	Facilitated diffusion	Osmosis
Cell membrane	Golgi apparatus	Passive transport
Cell theory	Hypertonic/Hypotonic solution	Phagocytosis
Cell wall	Isotonic solution	Pinocytosis
Centriole	Leucoplast	Plasmolysis
Chloroplast	Lysosome	Plastid
Chromoplast	Mitochondrion	Ribosome
Connective tissue	Muscle tissue	Selectively permeable
Cytoplasm	Nucleus	Tissue
Diffusion	Endoplasmic reticulum	Turgor pressure

Initiating And Planning

1. Assess the capabilities of animal and plant cell types owing to the presence or absence of chloroplasts and cell wall.
2. Assess the capabilities of prokaryotic and eukaryotic cells owing to the presence or absence of nucleus and mitochondria.
3. Label the six points given in the following diagram of a cell.



4. Justify why a colony of cells does not get tissue level of organization in spite of having many cells.
5. Formulate operational definitions of major variables e.g. Define concentration gradient; define osmosis in terms of hypotonic, hypertonic and isotonic solutions.

ON-LINE LEARNING

1. www.columbia.edu
2. www.agen.ufl.edu/.../lect/lect_15/lect_15.htm
3. http://sps.k12.ar.us/massengale/biology%20I%20page.htm
4. www.cell-research.com

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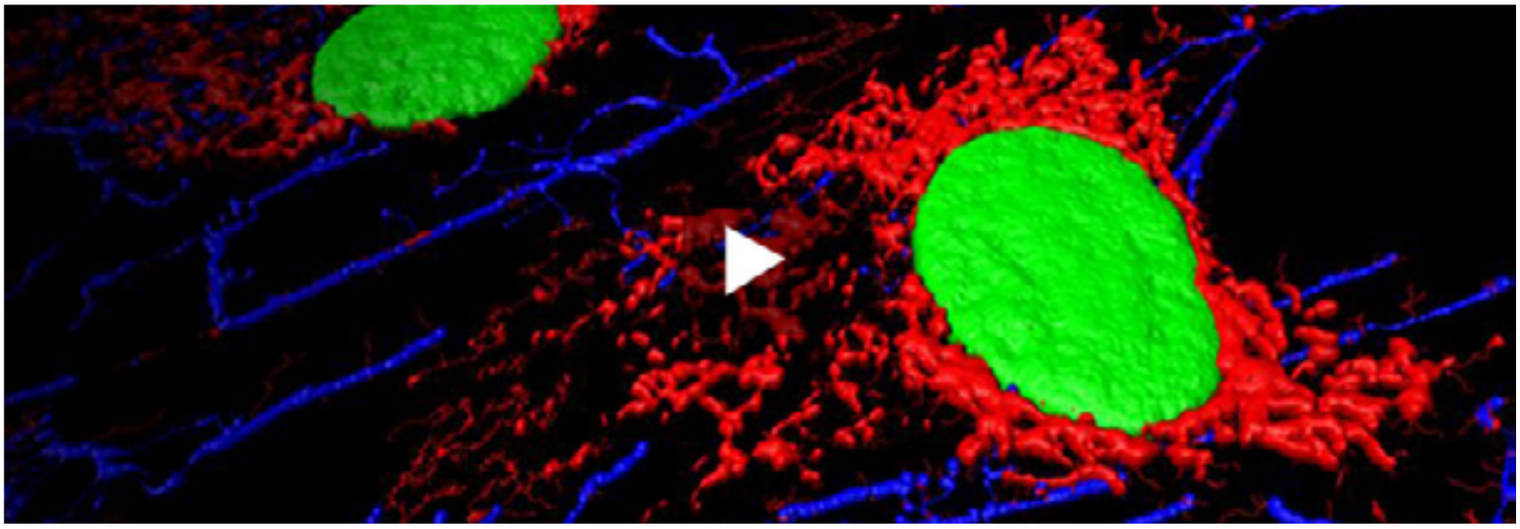


About this Course:

In Part 1, you will be learning about things like the cell, its structure, its functions, and the chemistry that drives all of the processes cells carry out on a daily basis.

As you work through this course, you will find lecture videos taught by expert AP Biology teachers, practice multiple choice questions and free response questions that are similar to what you will encounter on the AP exam and tutorial videos that show you step-by-step how to solve problems. By the end of the course, you should be ready to take on the AP exam!

CHAPTER

5

Cell Cycle

Animation 05: Mitosis
Source & Credit: Buffonescience.wikispaces

The most basic characteristic of life is reproduction. Reproduction occurs at different levels of organization. Parts of cell such as chromosomes produce new chromosomes, cells produce new cells and individuals produce offspring like themselves. If we recall from chapter 1, we should remember Rudolf Virchow. He proposed an important biological principle i.e. all cells come from cells. This principle tells us that the continuation of life, including all aspects of reproduction, is based on the reproduction of cells. We commonly refer cellular reproduction as cell division and it is a part of the whole life of a cell i.e. cell cycle.

5.1 Cell Cycle

Cell cycle is the series of events from the time a cell is produced until it completes mitosis and produces new cells. Cell cycle consists of two major phases i.e. interphase and mitotic phase (M phase). Mitotic phase is a relatively short period of cell cycle. It alternates with the much longer interphase, where cell prepares itself for division.
Interphase is the time when a cell's metabolic activity is very high, as it performs its various functions. It is divided into three phases, G1 (first gap), S (synthesis), and G2 (second gap).

G1 phase: After its production, a cell starts its cell cycle in G1 phase. During this phase, cell increases its supply of proteins, increases the number of its organelles (such as mitochondria, ribosomes), and grows in size. This phase is also marked by the synthesis of various enzymes that are required in next phase i.e. S phase for the duplication of chromosomes.

Typically,interphase lasts for at least 90% of the total time required for the cell cycle.

S phase: In this phase, cell duplicates its chromosomes. As a result, each chromosome consists of two sister chromatids.

G2 phase: In the G2 phase, cell prepares proteins that are essential for mitosis, mainly for the production of spindle fibres.

After the G2 phase of interphase, cell enters the division phase i.e. M phase. It is characterized by mitosis, in which cell divides into the two daughter cells.

Cells that have temporarily or permanently stopped dividing are said to have entered a state of quiescence, called G0 phase.

Animation 5.1: Cell cycle
Source & Credit: amersol

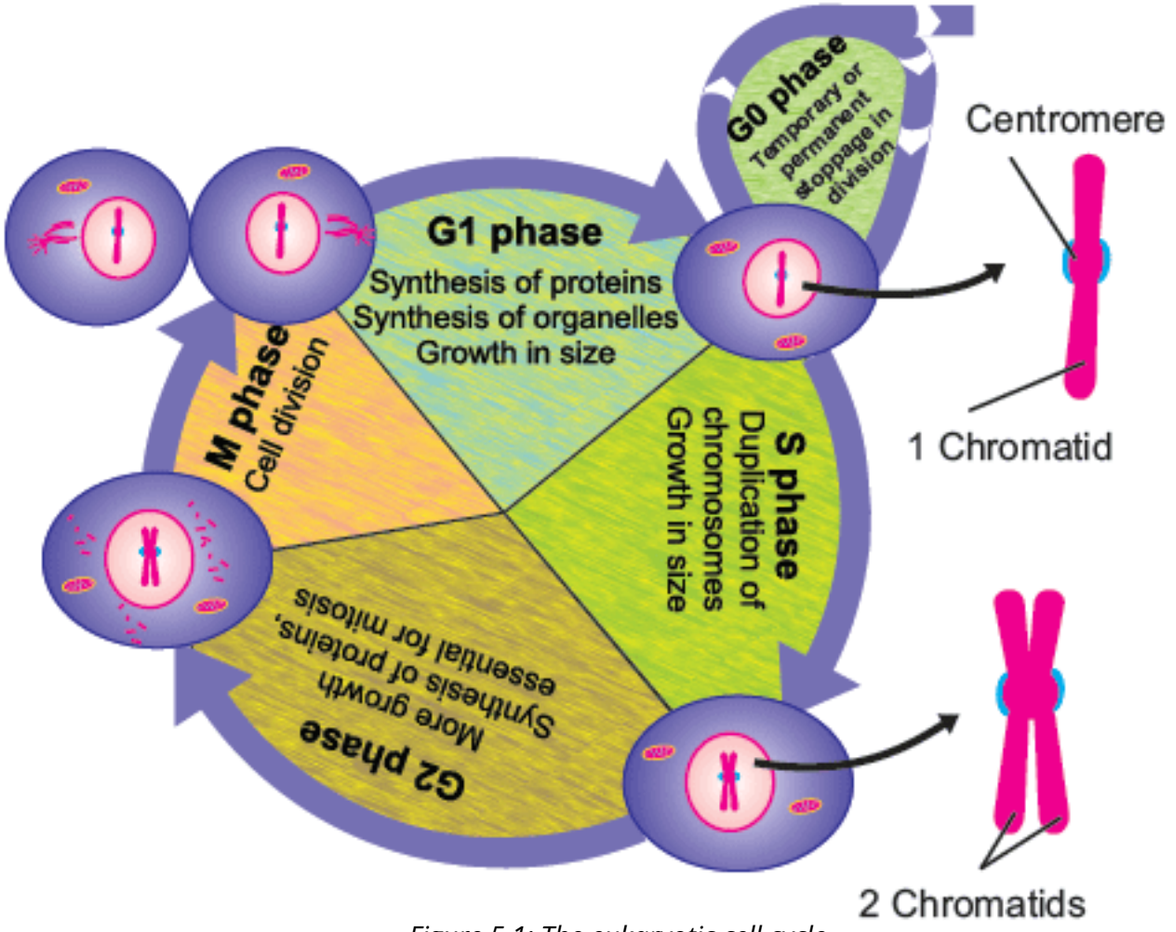


Figure 5.1: The eukaryotic cell cycle

Inhibition of protein synthesis during G2 phase prevents cell from undergoing mitosis.

G0 phase: In multicellular eukaryotes, cells enter G0 phase from G1 and stop dividing. Some cells remain in G0 for indefinite period e.g. neurons. Some cells enter G0 phase semipermanently e.g. some cells of liver and kidney. Many cells do not enter G0 and continue to divide throughout an organism's life, e.g. epithelial cells.

The events of cell cycle are ordered and directional i.e each event occurs in a sequential fashion and it is impossible to "reverse" the cycle.

5.2 Mitosis

In 1880s, a German biologist **Walther Flemming** observed that in a dividing cell, nucleus passes through a series of changes which he called mitosis. Mitosis is the type of cell division in which a cell divides into two daughter cells, each with the same number of chromosomes as were present in parent cell.

Mitosis occurs only in eukaryotic cells. In multicellular organisms, the somatic cells undergo mitosis. Prokaryotic cells undergo a process similar to mitosis called binary fission. They do not undergo proper mitosis. Why?

5.2.1 Phases Of Mitosis

The process of mitosis is complex and highly regulated. There are two major phases i.e. the division of nucleus known as karyokinesis; and the division of cytoplasm known as cytokinesis.

A. Karyokinesis: The division of nucleus is further divided into four phases i.e. prophase, metaphase, anaphase and telophase.

Somatic cells are those which form the body of organisms while germ line cells are those which give rise to gametes. Somatic cells undergo mitosis while germ line cells undergo meiosis.

i. Prophase

Normally, the genetic material in nucleus is in a loose thread-like form called chromatin. At the onset of prophase, chromatin condenses into highly ordered structures called chromosomes. Since the genetic material has already been duplicated earlier in S phase, each chromosome is made of two sister chromatids, bound together at the same centromere. Each chromosome also has kinetochore at centromere. Kinetochore is a complex protein structure that is the point where spindle fibers attach.

Prokaryotes do not have proper nucleus and do not form spindles during division. That is why their division is not called mitosis.

There are two centrioles (collectively called a centrosome) close to nucleus (recall from chapter 4: Figure 4.19). Each centriole duplicates and thus two daughter centrosomes are formed. Both centrosomes migrate to the opposite poles of cell. Here, they give rise to microtubules by joining tubulin proteins present in cytoplasm. The microtubules thus formed are called **spindle fibres.** Complete set of spindle fibres is known as **mitotic spindle.** By this time, nucleolus and nuclear envelope have degraded, and spindle fibres have invaded the central space.

In highly vacuolated plant cells, nucleus has to migrate to the centre of cell before prophase. The cells of plants lack centrioles. So, spindle fibres are formed by the aggregation of tubulin proteins on the surface of nuclear envelope during prophase.

Animation 5.2: Stages of Mitosis
Source and Credit: Ameoba sisters

ii. Metaphase

When spindle fibres have grown to sufficient length, some spindle fibres, known as kinetochore fibres, attach with the kinetochores of chromosomes. Two kinetochore fibres from opposite poles attach with each chromosome. Chromosomes arrange themselves along the equator of cell forming a **metaphase plate**. A number of other fibres (non-kinetochore) from the opposite centrosomes attach with each other.

iii. Anaphase

When a kinetochore spindle fibre connects with the kinetochore of chromosome, it starts to pull toward the originating centrosomes. The pulling force divides the chromosome's sister chromatids and they separate. These sister chromatids are now sister chromosomes, and they are pulled apart toward the respective centrosomes. The other spindle fibres (non-kinetochore) also elongate. At the end of anaphase, cell has succeeded in separating identical copies of chromosomes into two groups at the opposite poles.

iv. Telophase

Telophase is a reversal of prophase. A new nuclear envelope forms around each set of separated chromosomes. Both sets of chromosomes, now surrounded by new nuclear envelopes, unfold back into chromatin. Nuclear division is completed, but cell division has yet one more step to complete. (Figure 5.2)

B. Cytokinesis:

Cytokinesis is the division of cytoplasm. In **animal cells**, cytokinesis occurs by a process known as cleavage. A cleavage furrow develops where the metaphase plate used to be. The furrow deepens and eventually pinches the parent cell into two daughter cells.

Cytokinesis in **plant cells** occurs differently. Vesicles derived from the Golgi apparatus move to the middle of cell and fuse to form a membrane-bounded disc called cell plate or **phragmoplast**. The plate grows outward and more vesicles fuse with it. Finally, membranes of cell plate fuse with plasma membrane and its contents join the parental cell wall. The result is two daughter cells, each bounded by its own plasma membrane and cell wall (Figure 5.3)

?

Nucleus is visible only in interphase while chromosomes are only visible in cell division stage. Why is that?

Nuclear membrane breaks during cell division so there is no distinct nucleus. In interphase nuclear material is in the form of fine chromatin which condenses during prophase to get the shape of Chromosomes.

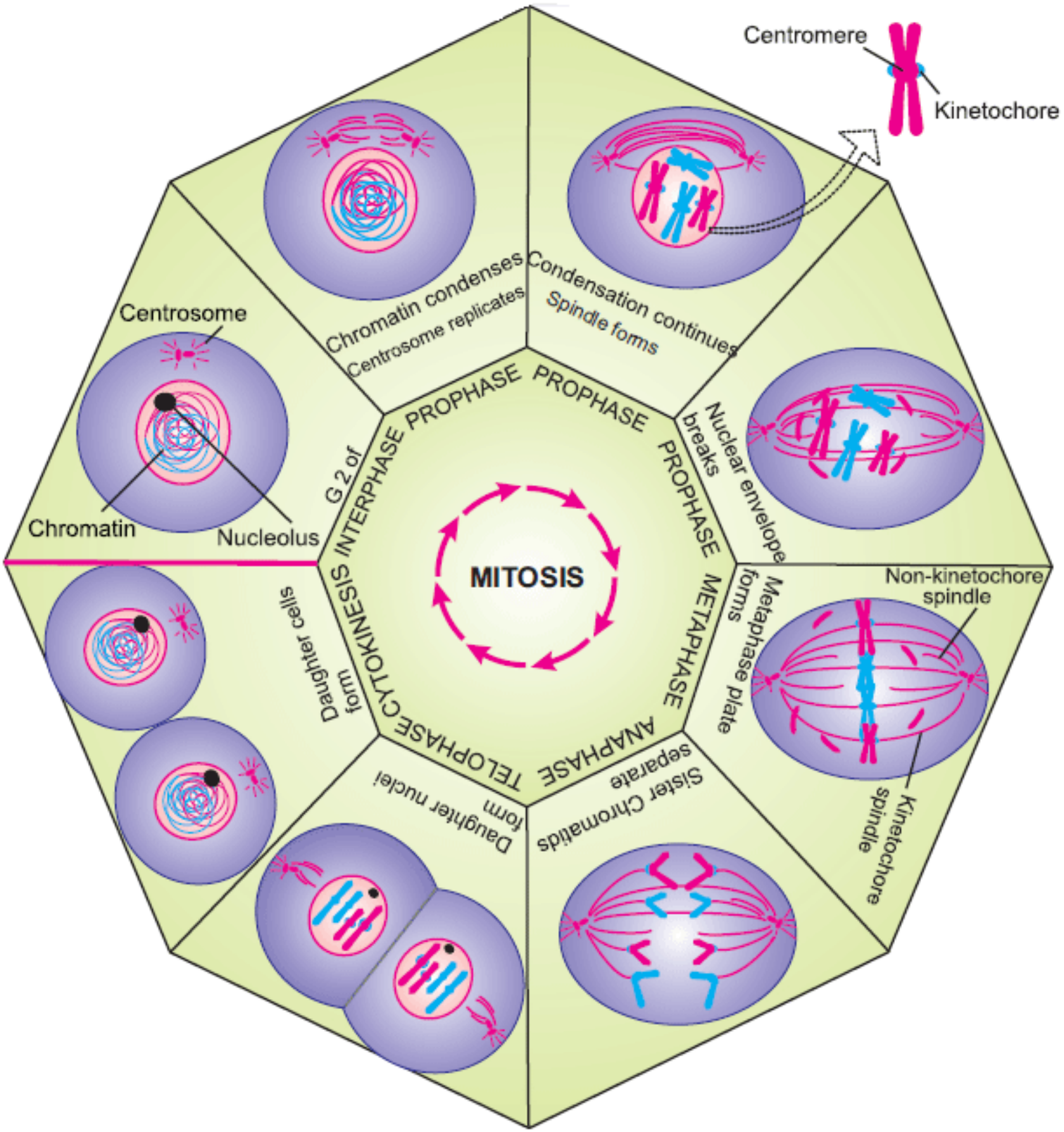


Figure 5.2: Stages in mitosis

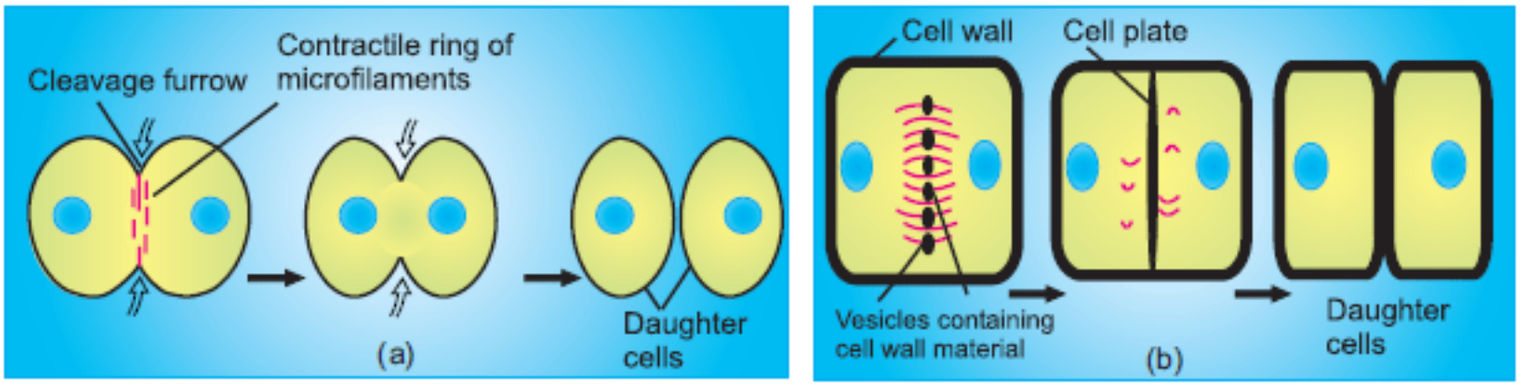


Figure 5.3: Cytokinesis; (a) in animal cell, (b) in plant cell

5.2.2 Significance Of Mitosis

Importance of mitosis is the maintenance of chromosomal set i.e. each daughter cell receives chromosomes that are a like in composition and equal in number to the chromosomes of parent cell.

Following are the occasions in the lives of organisms where mitosis happens.

Development and growth:

The number of cells within an organism increase by mitosis. This is the basis of the development of a multicellular body from a single cell i.e. zygote and also the basis of the growth of multicellular body.

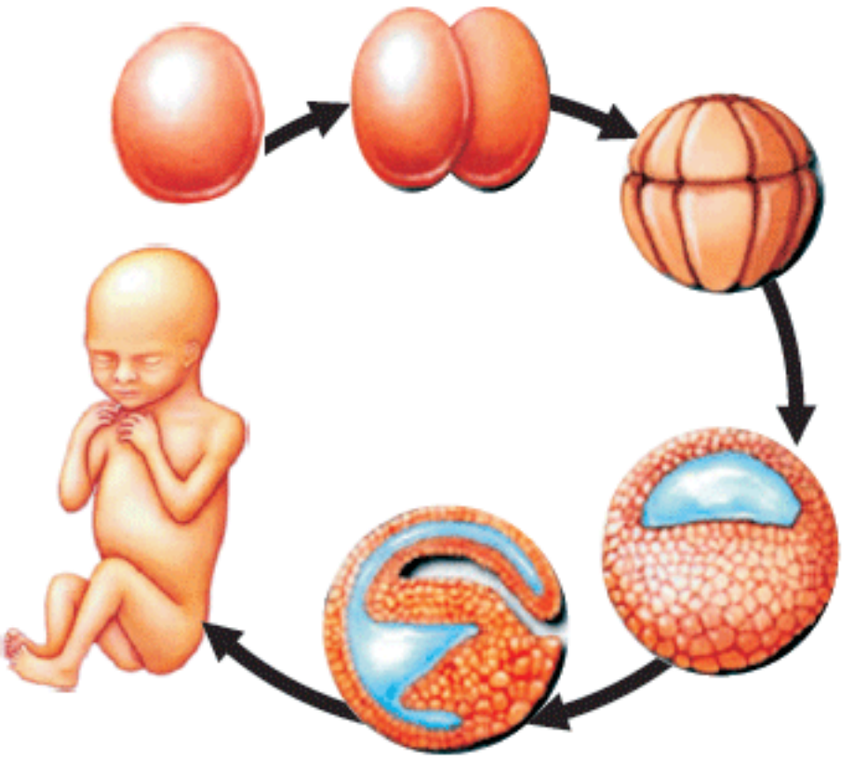


Figure 5.4: Development of a single cell (zygote) into a multicellular body

Cell replacement:

In some parts of body, e.g. skin and digestive tract, cells are constantly sloughed off and replaced by new ones. New cells are formed by mitosis and so are exact copies of the cells being replaced. Similarly, red blood cells have short life span (about 4 months) and new red blood cells are formed by mitosis.

Regeneration:

Some organisms can regenerate parts of their bodies. The production of new cells is achieved by mitosis. For example; sea star regenerates its lost arm through mitosis.

Figure 5.5: Regeneration in sea star

Asexual reproduction:

Some organisms produce genetically similar offspring through asexual reproduction. Mitosis is a mean of asexual reproduction. For example; hydra reproduces asexually by budding. The cells at the surface of hydra undergo mitosis and form a mass called bud. Mitosis continues in the cells of bud and it grows into a new individual. The same division happens during asexual reproduction (vegetative propagation) in plants.

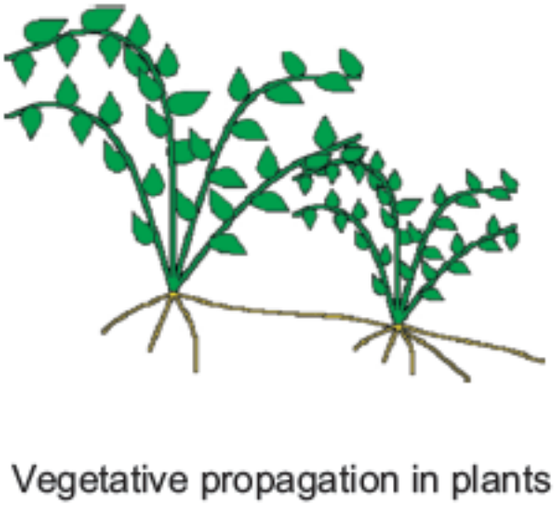


Figure 5.6: Asexual reproduction

Errors In Mitosis

Errors in the control of mitosis may cause cancer. All cells have genes that control the timing and number of mitosis. Sometimes mutations occur in such genes and cells continue to divide. It results in growths of abnormal cells called tumors. As long as these **tumors** remain in their original location, they are called **benign** tumours. But if they invade other tissues, they are called **malignant** (cancerous) tumors and their cells are called cancer cells. Such tumors can send cancer cells to other parts in body where new tumors may form. This phenomenon is called **metastasis** (spreading of disease).

Practical Work:

Preparation of root tip squashes and study of the stages of mitosis

The number of cells within an organism increases by mitosis and this is the basis of growth in multicellular organisms.

Problem:

While observing the cells from the tip of an onion root, can we identify cell in different stages of mitosis. (You may use your textbook to help you identify the stages of mitosis.)

Apparatus required:

Microscope, slides , fresh grown onion root tip, 5-10ml distilled water, 5ml 6M HCl, 1 ml Feulgen reagent in a vial, dropper pipette, beaker, and a pencil with eraser or small cork to squash the slide, toothpicks

Background information:

- Growth in organisms is carefully controlled by regulating the cell cycle.
- In plants, the roots continue to grow.
- The tips of roots are good for studying the cell cycle because at any given time, we can find cells that are undergoing mitosis.
- Slicing the onion root captures many cells in different phases of the cell cycle.
-

Procedure:

1. Take an onion and place it in a cup of water so that only the root portion is under water. (To do this, push toothpicks into the side of the onion which extend outward and hold it on the rim of the cup. New roots should grow within two days.)

2. Preheat about 10 ml of Hydrochloric acid in a small beaker to 60ºC using a waterbath.
3. Using scissors remove the last 2 mm from several growing root tips. Place them in the preheated acid and return to the waterbath for 4-5 minutes.
4. Gently transfer each root tip to a clean microscope slide containing water drop.
5. Gently blot dry with a piece of soft tissue. It is important to remove as much water as possible.
6. Using a dissection needle, thoroughly chop up the root tip and spread over an area equivalent to the size of a 01 rupee coin. (Alternatively you can place another microscope slide at right angles to the original slide to form a cross, and squash the tip between the two slides.)
7. Place a coverslip over the broken tissue trying not to get air bubbles under it.
8. Press down firmly onto the coverslip with a small cork or pencil eraser to spread the cells in a very thin layer
9. For staining, remove the coverslip and add one drop of the stain to the macerated root tip and immediately cover with a coverslip.
10. Place the slide on the compound microscope.
11. Locate growth zone, which is just above the root cap at the very end of the tip.
12. Focus in on low power, and then switch to medium or high power.
13. Find textbook diagrams of the four stages of mitosis and use them to help you to identify the stages on the microscope slide.

Observation:

Each slide shows a number of cells in different stages and the darkly stained areas can be easily distinguished.

Evaluation:

i. Copy this table onto a paper. You can enter data in this table as you go along, or at the end of the activity.

	Prophase	Metaphase	Anaphase	Telophase	Total
Number of Cells					

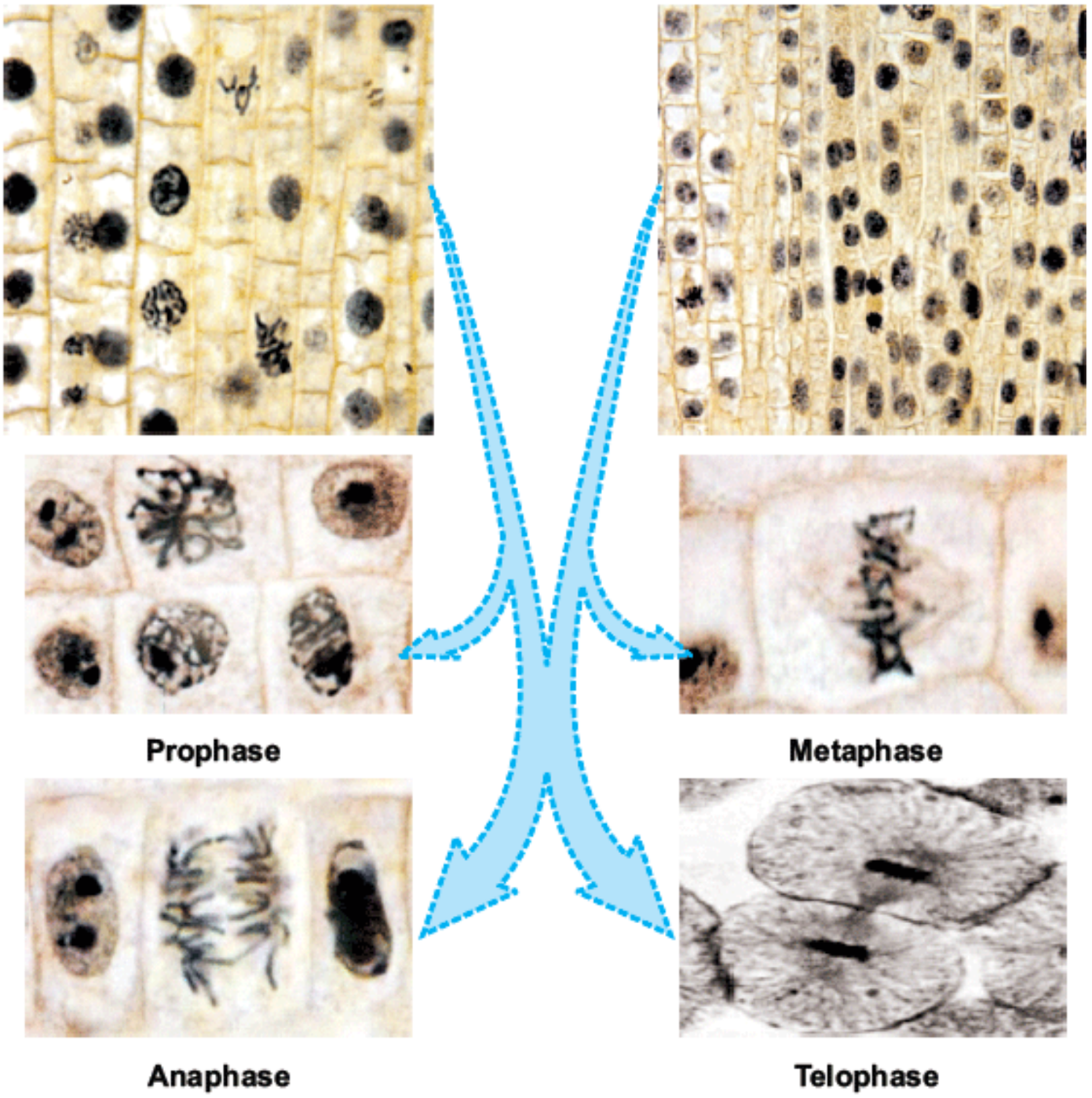


Figure 5.7: Cells in different stages of cell cycle

5.3 Meiosis

Meiosis is the process by which one diploid (2n) eukaryotic cell divides to generate four haploid (1n) daughter cells. Diploid means the cells in which chromosomes are in pairs (homologous pairs) while haploid means the cells with half the number of chromosomes i.e. chromosomes are not in the form of pairs.

The word meiosis comes from Greek word 'meioun', meaning "to make smaller," since it results in a reduction in chromosome number.

5.3.1 Phases Of Meiosis

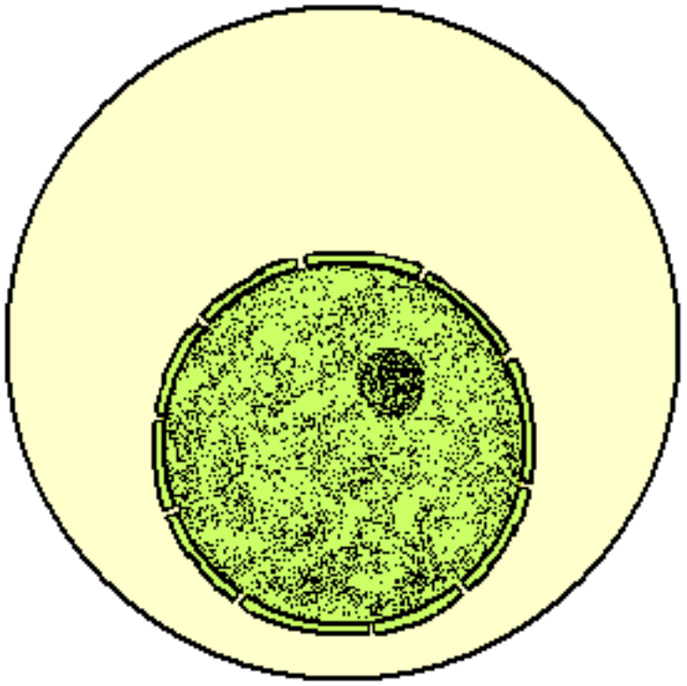
Meiosis was discovered and described for the first time in 1876, by a German biologist **Oscar Hertwig**. The preparatory steps of meiosis are identical to the interphase of mitosis. Interphase is divided into the same three phases i.e. G1, S phase, and G2. Interphase is followed by meiosis I and meiosis II.

Meiosis I

In meiosis I, the homologous chromosomes in a diploid cell separate and so two haploid daughter cells are produced. It is the step in meiosis that generates genetic variations. Meiosis I occurs in two main steps i.e. karyokinesis and cytokinesis. The karyokinesis of Meiosis I is subdivided into prophase I, metaphase I, anaphase I, and telophase I.

Prophase I

Prophase I is the longest phase in meiosis. During this stage, chromatin condenses into chromosomes. The homologous chromosomes line up with each other and form pairs by a process called **synapsis**. Each pair of homologous chromosomes is called bivalent. Each **bivalent** has four chromatids, so it may also be called a **tetrad**. The two non-sister chromatids of homologous chromosomes join each other at certain points along their length. These points of attachment are called **chiasmata.** In the next stage, the non-sister chromatids of homologous chromosomes exchange their segments and the phenomenon is known as **crossing over** (Figure 5.8).



Animation 5.3: Meiosis
Source & Credit: geocities

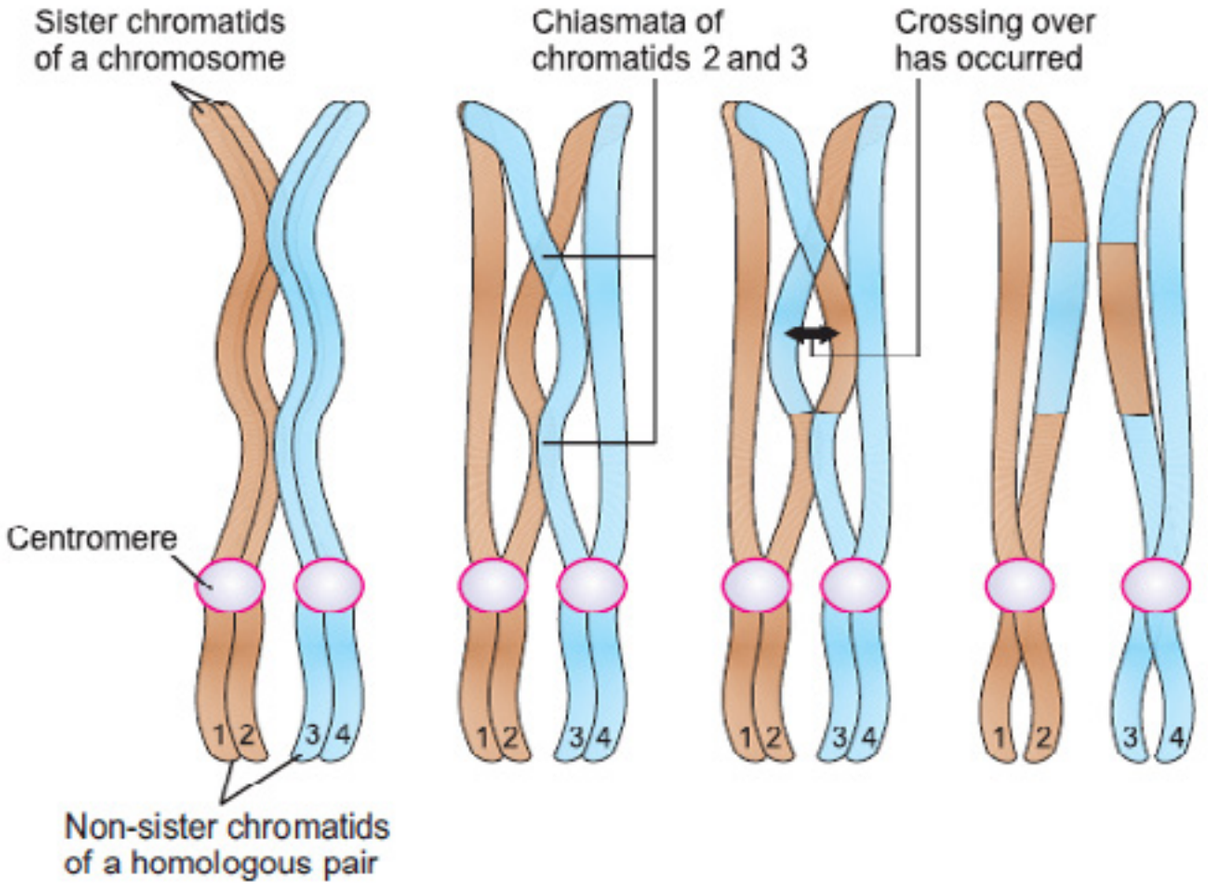


Figure 5.8: Crossing over

The exchange of segments results in the recombination of genetic information. After crossing over, each pair of homologous chromosomes remain as a bivalent.
Chromosomes condense further, the nucleoli disappear, and the nuclear envelope disintegrates. Centrioles, which were duplicated during interphase, migrate to the two poles and form spindle fibres. The kinetochore spindle fibres attach with the kinetochores of chromosomes. While the non-kinetochore spindle fibres from both sides interact with each other. Two kinetochore spindle fibres (from the opposite poles) attach with a pair of chromosomes. In mitosis, we have seen that two kinetochore spindle fibres attach with one chromosome.

Metaphase I

The pairs of homologous chromosomes align along equatorial plane forming the metaphase plate.

In 1911, the American geneticist Thomas Hunt Morgan observed the phenomenon of crossing over in fruit fly Drosophila melanogaster.

Anaphase I

Kinetochore spindle fibres shorten. It results in pulling apart the chromosomes of each pair. Since one chromosome is pulled toward one pole, two haploid sets are formed. Each chromosome still contains a pair of sister chromatids.

Telophase I

Chromosomes arrive at the poles. Each pole now has half the number of chromosomes but each chromosome still consists of two chromatids. Spindle network disappears, and nuclear envelope is formed around each haploid set. Chromosomes uncoil back into chromatin.

Cytokinesis (the pinching of the cell membrane in animal cells or the formation of the cell wall in plant cells) occurs and the creation of two haploid daughter cells is completed (Figure 5.9).

After meiosis I both haploid daughter cells enter a period of rest known as **interkinesis** or **interphase II.** The interphase II is different from the interphase of mitosis and meiosis I. There is no S-phase and so there is no duplication of chromosomes during this stage.

? During crossing over, genetic material is exchanged between sister/non-sister chromatids of homologous /non-homologous chromosomes.

Non-sister chromatids of homologous chromosomes.

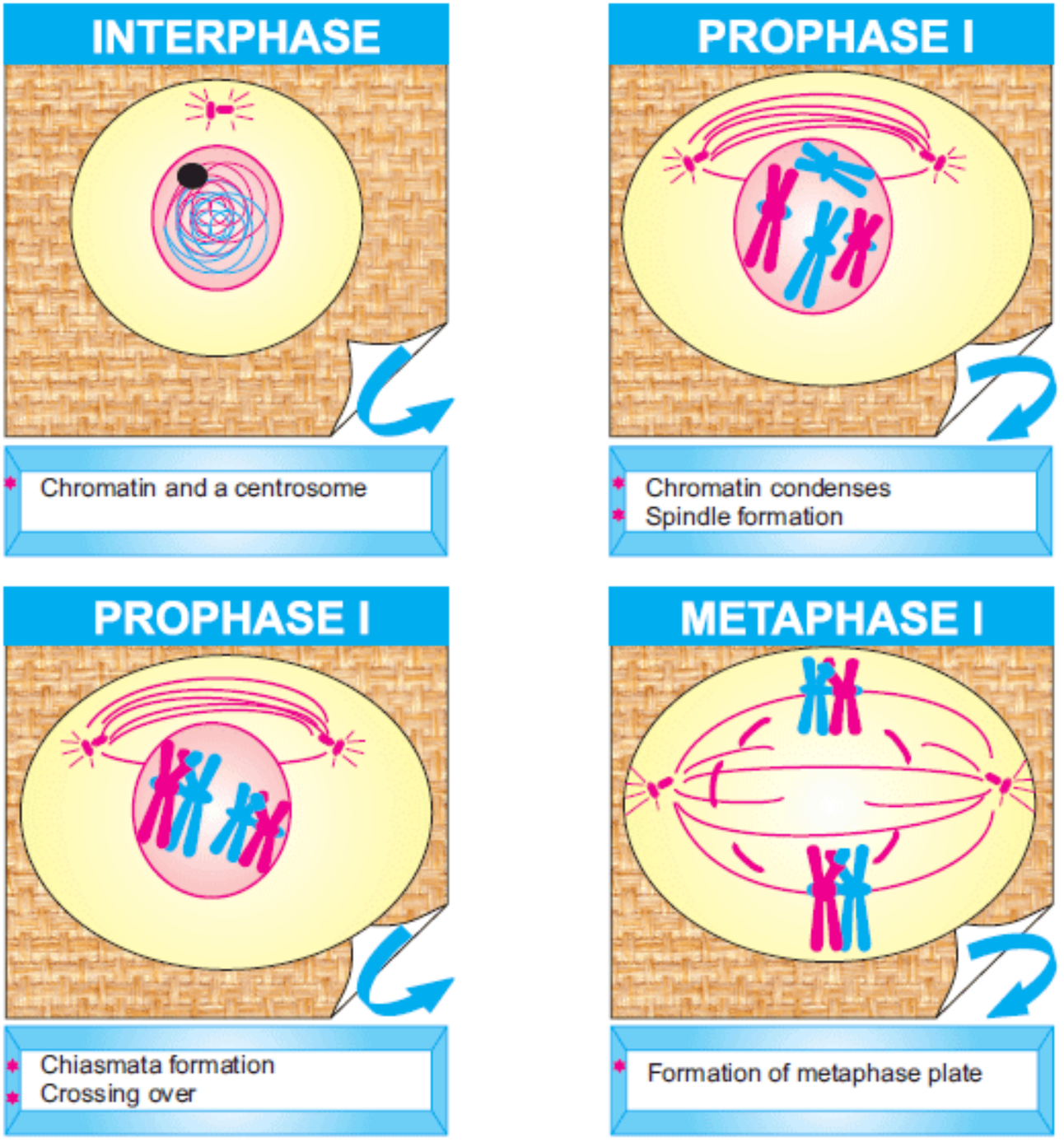


Figure 5.9: Stages in Meiosis-I (a)

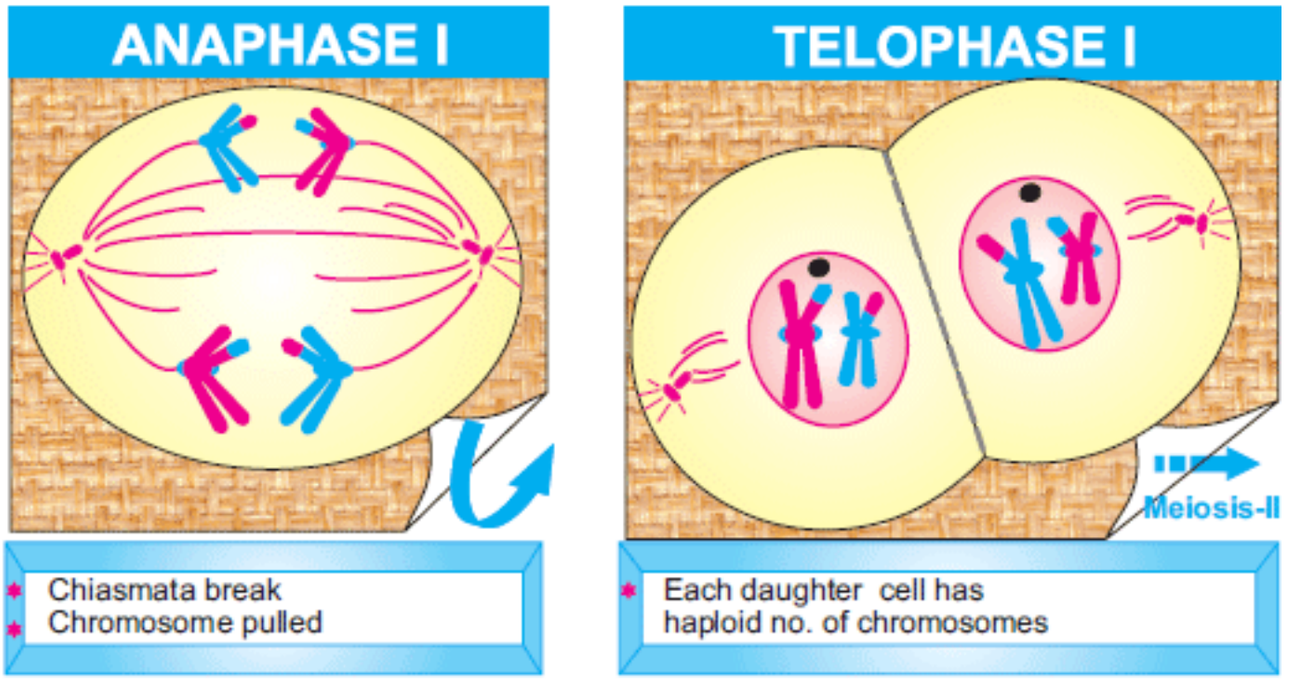


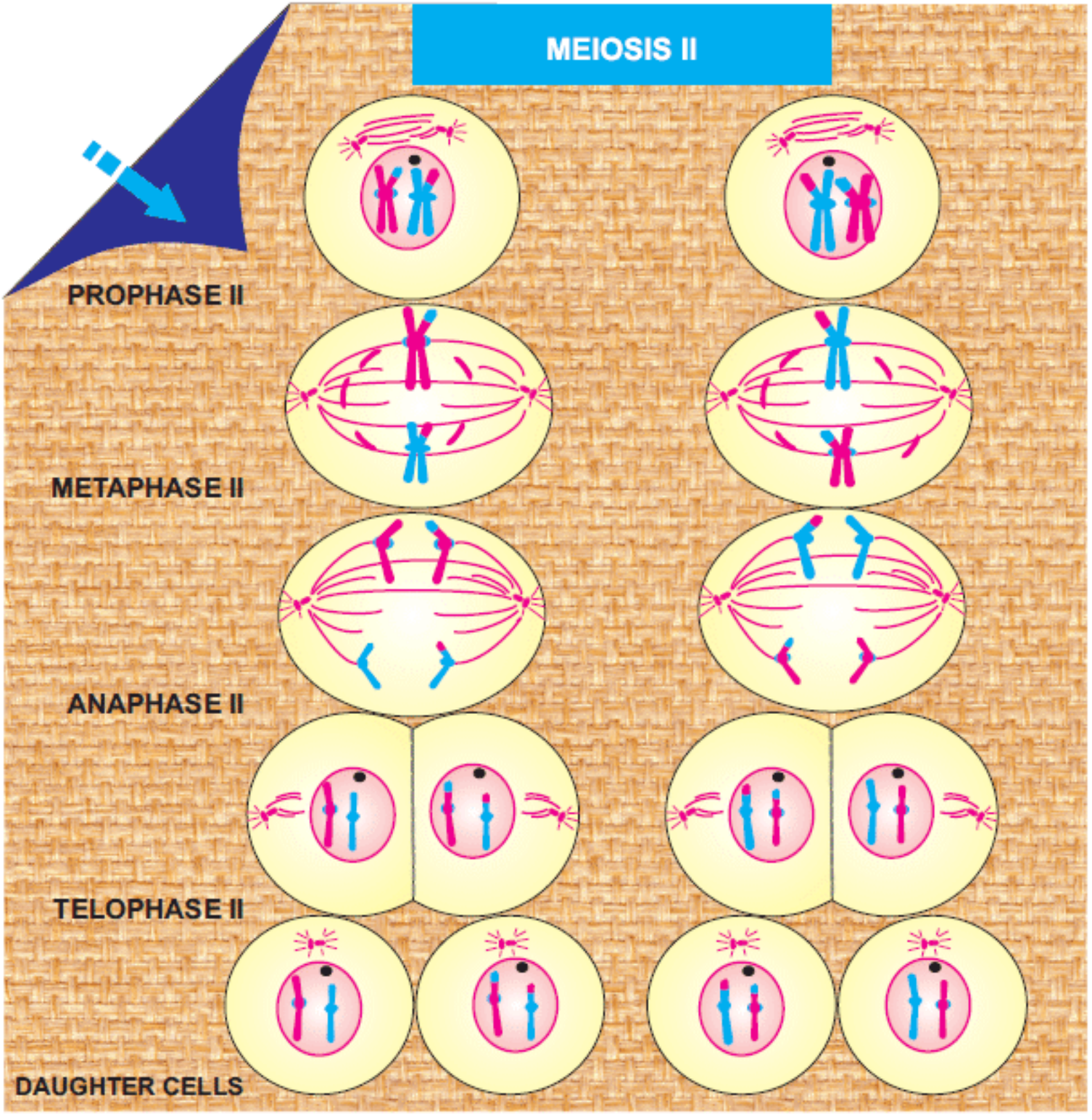
Figure 5.9: Stages in Meiosis-I (b)

Meiosis II

It is the second part of meiosis and is similar to mitosis. It is subdivided into prophase II, metaphase II, anaphase II, and telophase II.

Prophase II takes much less time compared to prophase I. In this prophase, nucleoli and nuclear envelope disappear and chromatin condenses. Centrioles move to the polar regions and make spindle fibres. In metaphase II, chromosomes attach with kinetochore spindle fibers and align at the equator of cell.

This is followed by anaphase II, where centromeres are cleaved and sister chromatids are pulled apart. The sister chromatids are now called sister chromosomes, and they are pulled toward opposing poles. Telophase II is marked with uncoiling of chromosomes into chromatin. Nuclear envelopes reform; cleavage or cell wall formation eventually produces a total of 4 daughter cells, each with a haploid set of chromosomes (Fig. 5.10).



Each daughter cell has haploid number of chromosomes

Figure 5.10: Stages in Meiosis-II

5.3.2 Significance Of Meiosis

The significance of meiosis for reproduction and inheritance was described in 1890 by German biologist August Weismann. He pointed out that meiosis was necessary not only to maintain the number of chromosomes in the next generation but also to produce variations in next generation.

Maintenance of the chromosome number in next generation

Meiosis is essential for sexual reproduction. In humans, diploid gamete-mother cells or germ line cells undergo meiosis to produce haploid gametes. Male and female gametes unite to form diploid zygote, which undergoes repeated mitosis and develops into a new diploid human. Many haploid fungi and protozoans produce haploid gametes through mitosis. Plants' life cycle shows alternation of generations. The cells of diploid sporophyte generation undergo meiosis to produce haploid spores, which grow into haploid gametophyte generations. Gametophyte generation produces haploid gametes through mitosis. The gametes combine to produce diploid zygote. Zygote undergoes repeated mitosis to become diploid sporophyte.

Production of variations in next generations

The chromosome pairs of each parent undergo crossing over during meiosis. So daughter cells i.e. gametes have genetic variations. When gametes fuse and form zygote, its genetic make up is different from both parents. Thus meiosis allows a species to bring variations in the next generations. Beneficial variations help organisms to adapt to the changes in environment.

Errors in meiosis

During anaphase I, chromosomes separate and go to opposite poles while during anaphase II sister chromosomes separate. It is called **disjunction**. Sometimes the separation is not normal and it is called **non-disjunction**. This results in the production of gametes which have either more or less than the normal number of chromosomes. If such abnormal gamete fuses with a normal gamete, it results abnormal chromosome number in next generation, for example 47 or 45 chromosomes in humans.

5.3.3 Comparison Between Mitosis And Meiosis

Meiosis II is similar to mitosis while meiosis I makes the actual difference between these two cell divisions. The following chart describes the main differences between mitosis and meiosis I.

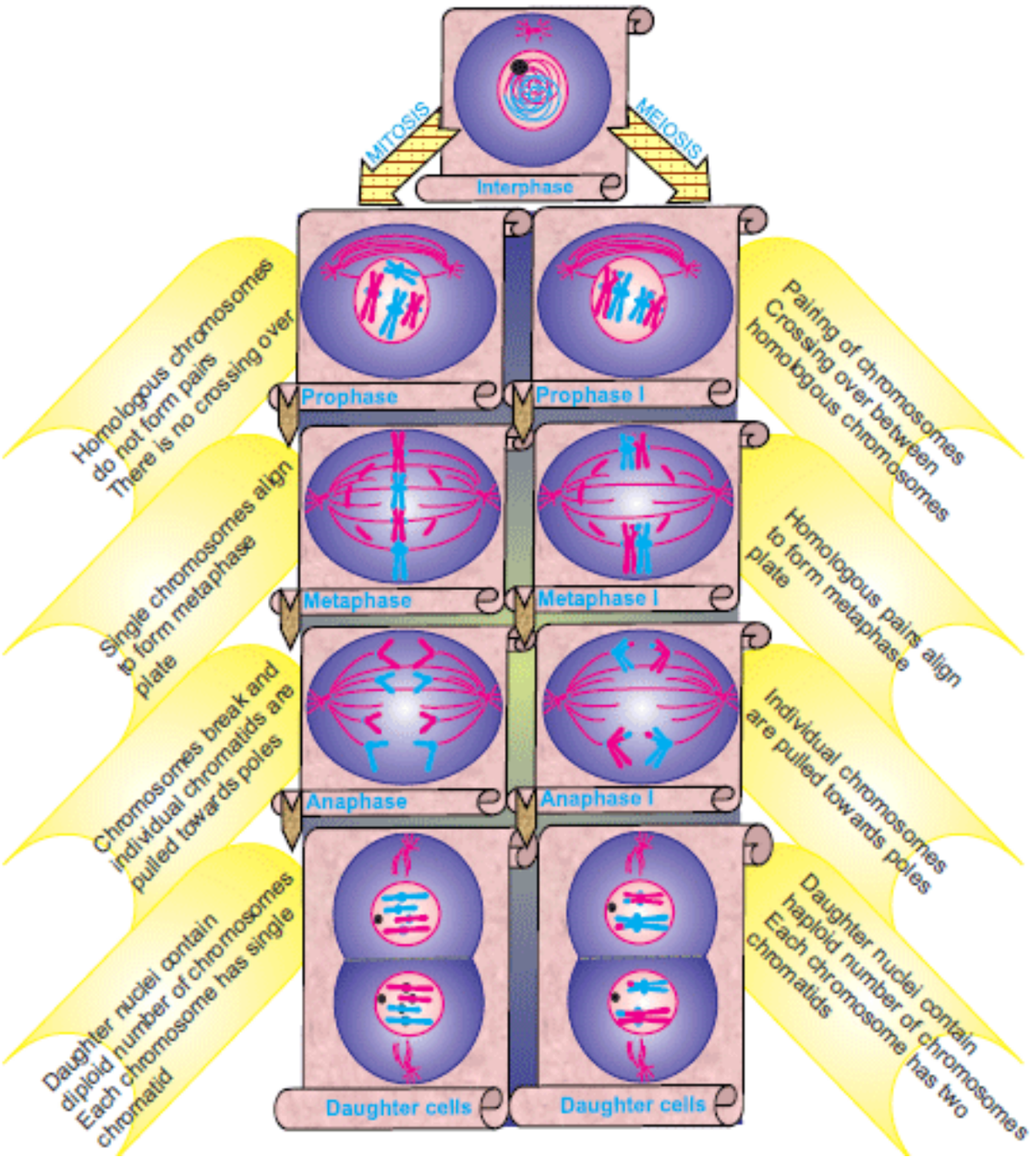


Figure 5.11: Mitosis and Meiosis; a comparison

Practical Work:

Observation of various stages of mitosis and meiosis by slides, models and charts.

Mitosis and meiosis are sequential events in which a parent cell divides.

Problem:

Can we recognize the stage of mitosis or meiosis by finding some hints in the slide or diagram?

Background information:

- We should have a comprehensive knowledge of the events that occur in each stage of mitosis and meiosis.

Procedure:

1. Observe the given material (slide, model or chart). Slide must be observed under microscope.
2. Draw illustration on your notebook and try to label different components.
3. Point out important features of your illustration and recall the events that occur during mitosis and meiosis.
4. Indicate the stage of cell division which you think may be.

Evaluation:

1. If you found that the given specimen was taken from an animal tissue and the cells were undergoing meiosis, what would be the daughter cells?
2. What is the main feature of prophase-I of meiosis, which differentiates it from the prophase of mitosis?
3. Chromosomes are only visible during cell division and not visible during interphase. Why?

5.4 Apoptosis And Necrosis

Apoptosis and necrosis are two phenomena of cell death.

Apoptosis

Apoptosis is one of the main types of programmed cell death. During apoptosis, cell shrinks and becomes rounded due to the breakdown of cytoskeleton by enzymes. Its chromatin undergoes condensation and nuclear envelope breaks. In this way, nucleus spreads in the form of several discrete chromatin bodies. Cell membrane makes irregular buds known as **blebs**. Blebs break off from the cell and are now called **apoptotic bodies**, which are then phagocytosed by other cells.

In an adult human,50 to 70 billion cells die each day by apoptosis.

Apoptosis can occur when a cell is damaged or undergoes stress conditions. Apoptosis removes the damaged cell, preventing it from getting further nutrients, or to prevent the spread of infections. Apoptosis also gives advantages during development. For example during the formation of fingers, the cells between them undergo apoptosis and the digits separate.

Necrosis

Necrosis is the accidental death of cells and living tissues. Necrosis is less sequential than apoptosis. There are many causes of necrosis including injury, infection, cancer etc. Necrosis may occur when a cell is given hypoxic (with less oxygen) environments.

During necrosis, there is a release of special enzymes from lysosomes. Lysosomal enzymes break cellular components and may also be released outside cell to break surrounding cells. Cells that die by necrosis may also release harmful chemicals that damage other cells.

Spider bites also cause necrosis in some areas.

Necrosis may be due to lack of proper care to a wound site.

UNDERSTANDING THE CONCEPTS

1. What is cell cycle and what are its main phases?
2. The S-phase of interphase is important and a cell can never divide without it. Justify.
3. How would you state the events of prophase of mitosis?
4. Make a list of the events of mitosis.
5. How is mitosis significant?
6. Describe the events that occur during the phases of meiosis-I.
7. Describe the significance of meiosis.
8. Contrast mitosis and meiosis, emphasizing the events that lead to different outcomes.
9. Describe necrosis and apoptosis.

Short Questions

1. A nerve cell does not divide after its formation. In which phase of cell cycle it is?
2. How is cytokinesis different in plant cells as compared to animal cell?
3. What type of cell division occurs when our wounds are healed?
4. Plants do not make their gametes by meiosis. How is that?

TERMS TO KNOW

Anaphase	Chromosomes	Non-sister chromatids
Apoptosis	Interphase	Phragmoplast
Benign	Karyokinesis	Prophase
Budding	Kinetochore	S phase
Cell cycle	M phase	Sister chromatids
Chiasmata	Malignant	Spindle
Crossing over	Metaphase	Synapsis
G 0 phase	Metaphase plate	Telophase
G 1 phase	Mitosis	
G 2 phase	Necrosis	
Homologous	Necrosis	

Activities

1. Observe various stages of mitosis and meiosis through slides, models and charts.

Science, Technology And Society

1. Describe the inability of some mature cells (nerve cells) to divide and the uncontrolled division of certain cells (tumors).

ON-LINE LEARNING

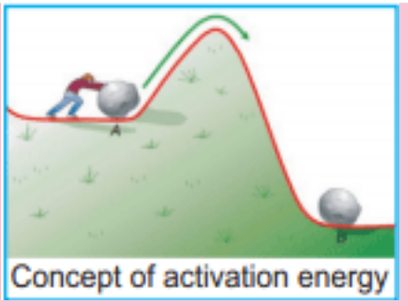
1. www.columbia.edu
2. www.agen.ufl.edu/.../lect/lect_15/lect_15.htm
3. http://sps.k12.ar.us/massengale/biology%20I%20page.htm
4. www.cell-research.com

CHAPTER

6 Enzymes

Animation 6: Enzymes
Source & Credit : greydefence

The life of living organisms is a reflection of what is going on in their bodies. Metabolism is the set of biochemical reactions that occur in living organisms in order to maintain life.These processes allow organisms to grow and reproduce maintain their structures, and respond to their environments. Anabolism includes the biochemical reactions in which larger molecules are synthesized while catabolism includes the biochemical reactions in which larger molecules are broken down. Usually, energy is released in catabolism and it is utilized in anabolism. In this way the biochemical reactions are actually energy transfers. During metabolism, chemicals are transformed from one form to the other by enzymes. Enzymes are crucial to metabolism because they act as **biocatalysts** and speed up and regulate metabolic pathways.



Concept of activation energy

The term metabolism is derived from a Greek word meaning “change . The concept of metabolism was first of all given by Ibn-e-Nafees, who stated that “the body and its parts are always undergoing change.

Enzymes are proteins that catalyze (i.e. speed up) biochemical reactions and are not changed during the reaction. The molecules at which enzymes act are called **substrates,** and enzyme converts them into different molecules, called **products**.

All chemical reactions require **activation energy.** It is defined as minimum energy required to start a reaction. The need for activation energy acts as a barrier to the beginning of reaction as symbolized in the diagram). Enzymes lower such barriers by decreasing the requirement of activation energy. Thus, in the presence of enzymes, reactions proceed at a faster rate (Figure 6.1)

Enzymes lower the activation energy in several ways. They may alter the shape of substrate and reduce the requirement of energy for this change. Some enzymes do so by disrupting the charge distribution on substrates. Enzymes may also lower activation energy by bringing substrates in the correct orientation to react.

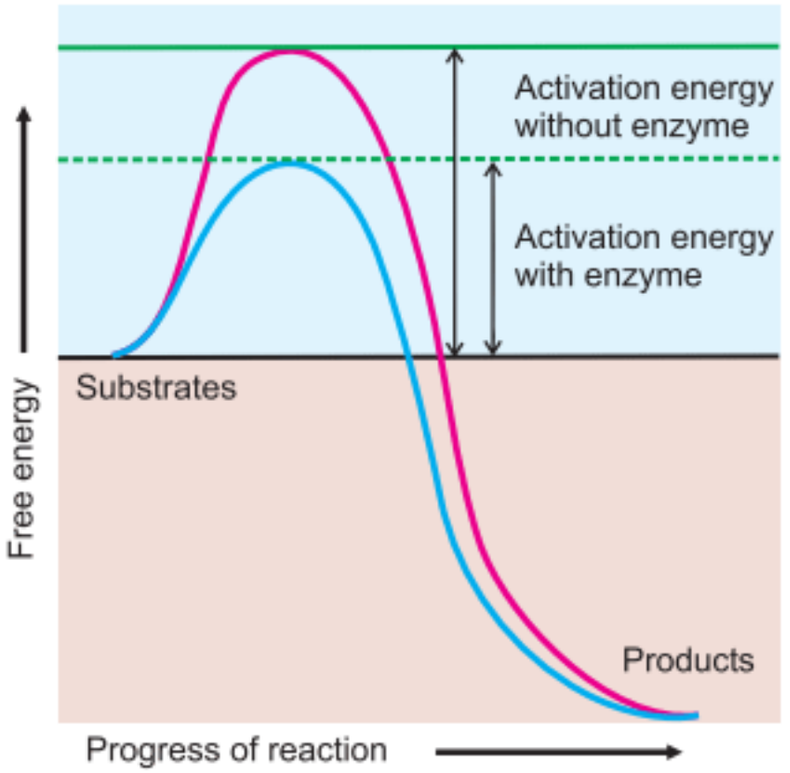


Figure 6.1: Enzymes lower the activation energy

Enzymes can be categorized on the basis of the site where they work i.e. they may be **intracellular enzymes** (e.g. enzymes of glycolysis working in the cytoplasm) or may be **extracellular enzymes** (e.g. pepsin enzyme working in the stomach cavity)

? statement 1: All enzymes are catalysts.Statement 2: All catalysts are enzymes.Which one is correct?

Statement 1

All biochemical catalysts are not proteins for example some RNA molecules also catalyze reactions.

6.1 Characteristics Of Enzymes

In 1878, German physiologist **Winhelm Kuhne** first used the term enzyme. Enzymes are globular proteins Like all proteins, enzymes are made of long linear chains of amino acids that fold to produce a three-dimensional molecule.

- Almost all enzymes are proteins i.e. they are made of amino acids.
- Most enzyme reaction rates are millions of times faster than those of comparable uncatalyzed reactions. As with all catalysts, enzymes are not consumed by the reactions they catalyze.
- Enzymes are usually very **specific** for the type of reaction and for the nature of their substrates.
- Only a small portion of enzyme molecule is directly involved in catalysis. This catalytic region is known as **active site** It recognizes and binds substrate and then carries out reaction.
- Enzyme production can be enhanced or diminished by a cell according to needs. Enzyme activity can also be regulated by **inhibitors** and **activators.**
- Some enzymes do not need any additional component to work. However, others require non-protein molecules or ions called **cofactors**. Cofactors can be either inorganic (e.g. metal ions) or organic (e.g. flavin and heme).If organic cofactors are tightly bound to enzyme, they are called **prosthetic groups**. If organic cofactors are loosely attached with enzyme, they are called **co-enzymes**. Coenzymes transport chemical groups from one enzyme to another. Some important vitamins (e.g. riboflavin, thiamine and folic acid) act as coenzymes.
- Several enzymes can work together in a specific order, creating **metabolic pathways** In a metabolic pathway**,** one enzyme takes the product of another enzyme as a substrate. After the reaction, the product is passed on to the next enzyme.

Animation 6.1: Enzyme
Source & Credit: dynamicscience

Uses of enzymes

Enzymes are extensively used in different industries for fast chemical reactions. For example;

1. **Food industry:** Enzymes that break starch into simple sugars are used in the production of white bread, buns etc.
2. **Brewing industry:** Enzymes break starch and proteins. The products are used by yeast for fermentation (to produce alcohol).
3. **Paper industry:** Enzymes break starch to lower its viscosity that aids in making paper.
4. **Biological detergent:** Protease enzymes are used for the removal of protein stains from clothes. Amylase enzymes are used in dish washing to remove resistant starch residues.

6.1.1 Factors Affecting The Rate Of Enzyme Action

Enzymes are very sensitive to the environment in which they work. Any factor that can change the chemistry or shape of enzyme molecule, can affect its activity. Some of the factors that can affect the rate of enzyme action are being discussed next.

Temperature

Increase in temperature speeds up the rate of enzyme catalyzed reactions, but only to a point (Figure 6.2). Every enzyme works at its maximum rate at a specific temperature called as the **optimum temperature** for that enzyme.

When temperature rises to a certain limit, heat adds in the activation energy and also provides kinetic energy for the reaction. So reactions are accelerated. But when temperature is raised well above the optimum temperature, heat energy increases the vibrations of atoms of enzyme and the globular structure of enzyme is lost. This is known as the **denaturation** of enzyme. It results in a rapid decrease in rate of enzyme action and it may be blocked completely.

The optimum temperature for the maximum working speed of human enzymes is 37°C.

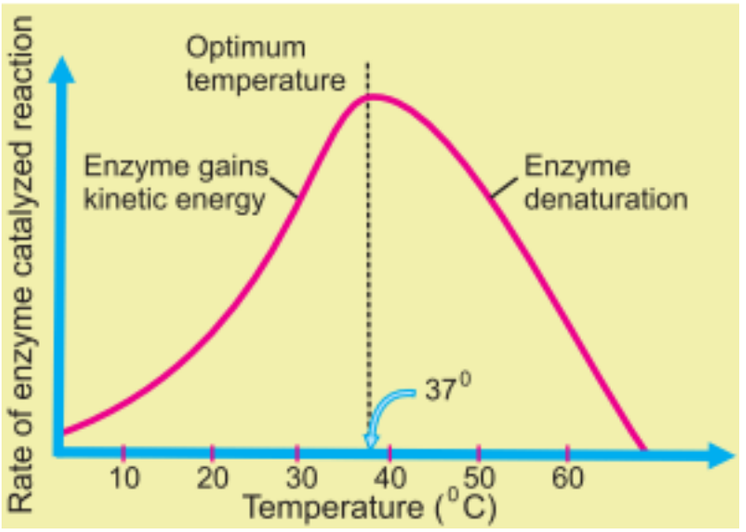


Figure 6.2: Effect of temperature on enzyme activity

?

Birds have higher body temperature than mammals.What would happen to the activity of a bird's enzyme if it is given temperature of 37° C?

Reaction will slow down

Substrate concentration

If enzyme molecules are available in a reaction, increase in substrate concentration increases the rate of reaction. If enzyme concentration is kept constant and amount of substrate is increased, a point is reached where any further increase in substrate does not increase the rate of reaction any more. When the active sites of all enzymes are occupied (at high substrate concentration), any more substrate molecules do not find free active sites. This state is called **saturation** of active sites and reaction rate does not increase (Figure 6.3).

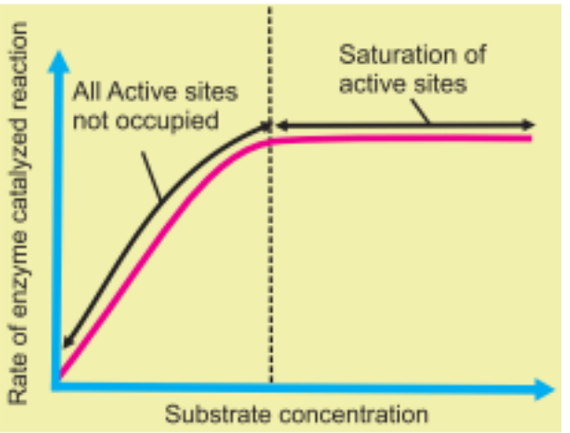


Figure 6.3: Effect of substrate concentration on enzyme activity

pH

All enzymes work at their maximum rate at a narrow range of pH, called as the **optimum pH** (Figure 6.4). A slight change in this pH causes retardation in enzyme activity or blocks it completely. Every enzyme has its specific optimum pH value. For example pepsin (working in stomach) is active in acidic medium (low pH) while trypsin (working in small intestine) shows its activity in alkaline medium (high pH). Change in pH can affect the ionization of the amino acids at the active site.

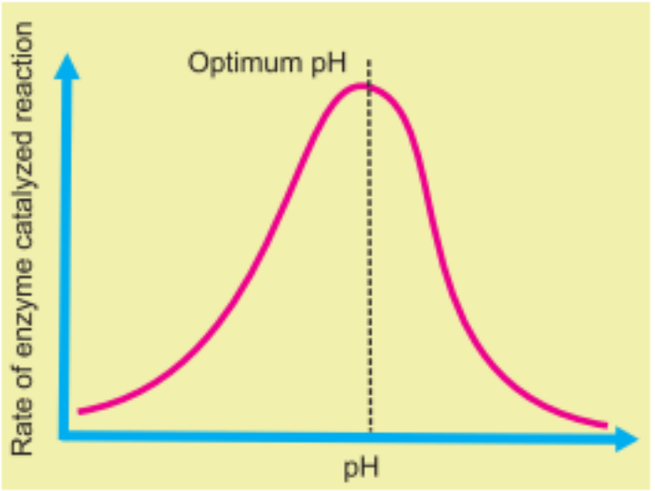


Figure 6.4: Effect of pH on enzyme activity

6.2 Mechanism Of Enzyme Action

When enzyme attaches with substrate, a temporary enzyme-substrate (ES) complex is formed. Enzyme catalyzes the reaction and substrate is transformed into product. After it, the ES complex breaks and enzyme and product are released.

$$E + S \longrightarrow ES\ complex \longrightarrow E + P$$

In order to explain the mechanism of enzyme action a German chemist **Emil Fischer**, in 1894, proposed **lock and key model**. According to this model, both enzyme and substrate possess specific shapes that fit exactly into one another. This model explains enzyme specificity (Figure 6.5).

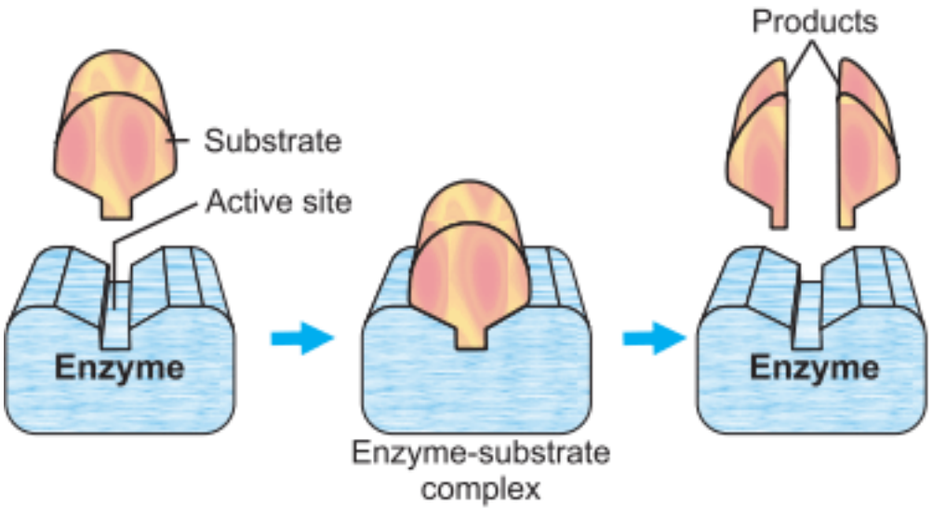


Figure 6.5: Lock and key model of enzyme action

In 1958, an American biologist **Daniel Koshland** suggested a modification to lock and key model and proposed **induced-fit model.** According to this model, active site is not a rigid structure rather it is molded into the required shape to perform its function. Induced fit model is more acceptable than "lock and key" model of enzyme action.

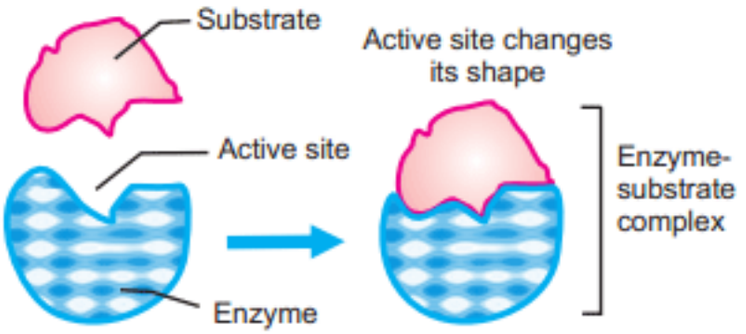


Figure 6.6: Induced-Fit model of enzyme action

6.3 Specificity Of Enzymes

There are over 2000 known enzymes, each of which is involved in one specific chemical reaction. Enzymes are also substrate specific. The enzyme protease (which breaks peptide bonds in proteins) will not work on starch (which is broken down by an enzyme amylase . Similarly lipase enzyme acts only on lipids and digests them into fatty acids and glycerol. Specificity of different enzymes is determined by the shapes of their active sites. Active sites possess specific geometric shapes that fit with specific substrates.

See in Figure 6.7 how the geometric shape of active site of enzyme determines its specificity for substrate **(point out which substrate can exactly fit in the active site).**

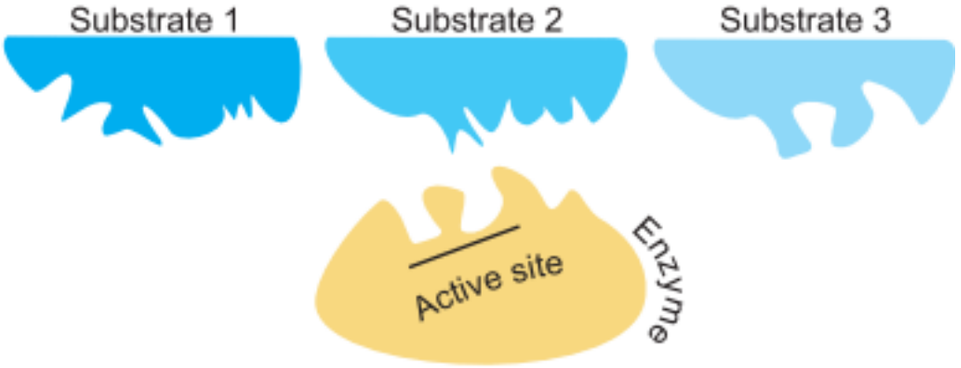


Figure 6.7: Specificity of enzyme due to the geometric shape of active site

Practical Work:

Perform an experiment to show the working of an enzyme in vitro

Enzymes can catalyze in-vivo and in-vitro reactions. We can design an experiment to observe the in-vitro enzyme activity. For this purpose we will select meat proteins as substrate and pepsin as the protein digesting enzyme.

Problem: Can pepsin digest the proteins present in meat?

Apparatus required: Meat, Test tube, pepsin solution, HCl, Biuret reagent

Background information:

- In-vitro means outside living body (in artificial environment) while in-vivo means inside living body
- Animal flesh (meat) contains lot of proteins.
- Pepsin enzyme is produced in stomach (in its inactive form pepsinogen). It acts on protein molecules and digests them to peptides.

Procedure:

- Take a small piece of meat in two test tubes and pour 15 ml of pepsin in one of them the and pour 15 ml water in the second tube (for comparison).
- Add 10 drops of HCl in both test tubes and place them at 37° C in incubator.

Observation: Observe the piece of meat after four hours. Perform the Biuret test to confirm the presence of proteins in both tubes. Go to chapter 8 (section 8.2) for the procedure of Biuret test.

Results: The Biuret test gives negative results in the tube in which pepsin was added. It confirms that no proteins are present in this test tube and all have been digested by the enzyme pepsin.

Evaluation:

- What effect did pH have on pepsin activity?
- What is the optimum pH for pepsin?
- An organism lives in a hot springs. What will be the effect on its enzymes if it is placed in cold water?

Practical Work:

Perform an experiment to show the working of amylase in vitro

Amylase is an enzyme that catalyses the breakdown of the polysaccharide starch to the disaccharide maltose. It is present in saliva, plant tissues and also in seeds. To observe the in-vitro enzyme activity we can select starch as substrate and amylase as the starch digesting enzyme.

Problem: Can amylase digest starch?

Apparatus required: Meat, Test tube, pepsin solution, HCl, Biuret reagent

Background information:

- Starch turns iodine solution dark purple/black while disaccharides do not react with the iodine.

Procedure:

1. Prepare 1% solution of amylase and put some of it in a test tube.

2. Add 2 ml of starch solution in the test tube.

3. Incubate the test tube at 37^0 C for 15 minutes.

Observation: Observe the test tube after 15 minutes. Perform iodine test to confirm the presence of starch. This can be done by putting few drops of iodine solution in the test tube. Observe the color change in the test tube.

Results: Iodine test gives negative results. There was no color change. It confirms that no starch is present in the test tube and all have been digested into disaccharides.

Evaluation:

i. What color appears when iodine test is positive?

ii. Why was the experimental test tube incubated at 37^0 C?

iii. If we perform the iodine test on starch solution before putting it in amylase, what would be the results?

UNDERSTANDING THE CONCEPTS

1. How would you define enzymes? Describe their characteristics.
2. What do you mean by activation energy and why it is referred in the definition of enzymes?
3. In a range of 0-35°C, the rate of reaction of an enzyme is proportional to temperature. Above 35°C and below 0°C, enzyme activity slows down and eventually stops. Explain why?
4. How does pH affect enzyme activity?
5. What characteristic of enzymes makes them specific for substrates?
6. Briefly describe the factors that affect the activity of enzymes.
7. Describe the lock and key mechanism of enzyme action.

Short Questions

- Define cofactor and coenzyme.
- What is the main use of enzymes in paper industry?

THE TERMS TO KNOW		
Activation energy Active site Amylase Anabolism Biocatalyst, Enzyme Catabolism Catalyst	Coenzyme Cofactor Denaturation Optimum pH Optimum temperature Enzyme-substrate	Lipase Lock-and-key model Metabolism Product Saturation Substrate

Initiating And Planning

- Draw graphs showing the effects of temperature, pH, and concentration of substrate on the rate of enzyme-catalyzed reactions.
- Illustrate through a diagram, the lowering of activation energy by enzyme.

Activities

1. Perform experiment to show the in-vitro working (in test tube) of pepsin on meat.
2. Perform experiment to show the in-vitro working (in test tube) of amylase on starch.

Science, Technology And Society

1. List the uses of enzymes in different industries.

ON-LINE LEARNING

en.wikipedia.org/wiki/Enzyme
www.biology-online.org/dictionary/Enzyme
encarta.msn.com/encyclopedia_761575875/enzyme.html
www.brooklyn.cuny.edu/bc/ahp/BioWeb/

CHAPTER

7

Bioenergetics

Animation 7.1: Photosynthesis
Source & Credit : 6bhaverfordgarden11.wikispaces

Chapter 4 described the structure of cell and chapter 6 mentioned the role of enzymes in cellular functions. A living cell exhibits ceaseless chemical activities.
We studied that cells are like “open systems” i.e. substances are entering and leaving the cell all the times. Inside cells, substances are broken down and new substances are formed. Energy drives all these processes in a cell. In living organisms, energy exists in two forms: kinetic energy is actively involved in doing work, and potential energy is stored for future use. Potential energy is stored in chemical bonds and is released as kinetic energy when these bonds break.

7.1 Bioenergetics And The Role Of ATP

Bioenergetics is the study of energy relationships and energy transformations (conversions) in living organisms. Organisms obtain energy by metabolizing the food they eat or prepare. Food contains potential energy in its bonds. When these bonds are broken down, a large amount of kinetic energy is usually released. Some of this energy is stored in the form of potential energy in the bonds of ATP molecules while the rest escapes as heat. The potential energy stored in ATP is again transformed into kinetic energy to carry out life activities (Fig 7.1).

Recalling

Plants and some microorganisms (e.g. photosynthetic bacteria and algae) prepare their own food from carbon dioxide and water in the presence of light by a process called photosynthesis. Whereas animals, fungi and many microorganisms (non-photosynthetic bacteria and protozoans) get the prepared food.

Animation 7.2 : Bioenergetic
Source and Credit: introbiol

Oxidation-Reduction Reaction

Various life processes in organisms involve constant flow of energy. This energy flow comprises the acquisition, transformation and use of energy for various life processes like growth, movement, reproduction etc.

For all life processes, oxidation-reduction reactions (redox reactions) are the direct source of energy. Redox reactions involve exchange of electrons between atoms. The loss of electrons is called **oxidation** while the gain of electrons is called **reduction**.

Electrons can be an energy source. It depends upon their location and arrangement in atoms. For example; when they are present in oxygen, they make stable association with oxygen atom and are not good energy source. But if electrons are dragged away from oxygen and attached to some

other atom e.g. carbon or hydrogen, they make unstable association. They try to move back to oxygen and when this happens, energy is released.

In living organisms redox reactions involve the loss and gain of hydrogen atoms. We know that a hydrogen atom contains one proton and one electron. It means that when a molecule loses a hydrogen atom, it actually loses an electron (oxidation) and similarly when a molecule gains hydrogen atom, it actually gains an electron (reduction).

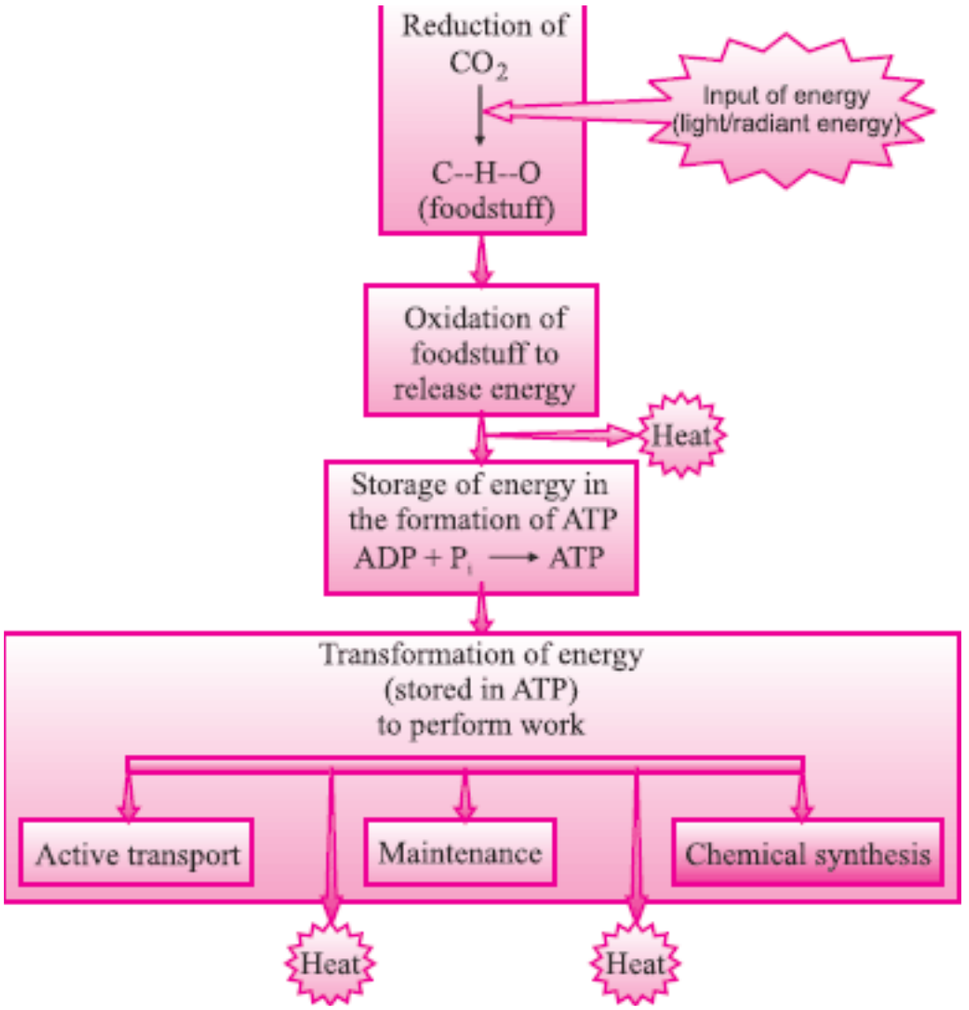


Figure 7.1: Some energy transformations in living organisms. Note that heat is lost in every transformation

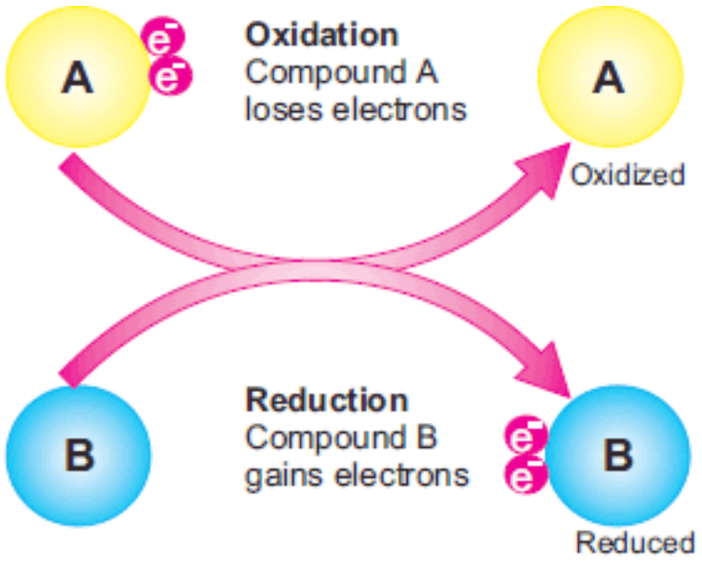


Figure 7.2: Redox reactions

ATP was discovered in 1929 by **Karl Lohmann,** and was proposed to be the main energy-transfer molecule in the cell by the Nobel prize winner, Fritz Lipmann in 1941.

ATP: The Cell's Energy Currency

The major energy currency of all cells is a nucleotide called adenosine triphosphate (ATP). It is the main energy source for majority of the cellular functions like synthesis of macromolecules (DNA, RNA, and proteins), movement, transmission of nerve impulses, active transport, exocytosis and endocytosis etc.

The ability of ATP to store and release energy is due to its molecular structure. Figure 7.3 shows a simplified diagram of ATP. Each ATP molecule has three subunits: (a) adenine - a double-ringed nitrogenous base; (b) a ribose - a five-carbon sugar; and (c) three phosphate groups in a linear chain.

The ability of ATP to store and release energy is due to its molecular structure. Figure 7.3 shows a simplified diagram of ATP. Each ATP molecule has three subunits: (a) adenine a double-ringed nitrogenous base; (b) a ribose - a five-carbon sugar; and (c) three phosphate groups in a linear chain.

The covalent bond connecting two phosphates is indicated by the "tilde" (~) and it is a high-energy bond. The energy in this bond is released as it breaks and inorganic phosphate (Pi) gets separated from ATP. The breaking of one phosphate bond releases about 7.3 kcal (7,300 calories) per mole of ATP as follows:

$ATP + H_2O \rightarrow ADP + P_i$ + energy (7.3 kcal/mole)

In common energy reactions only the outermost of the two high-energy bonds breaks. When this happens, ATP becomes ADP (adenosine diphosphate) and one Pi is released. In some cases, ADP is further broken down to AMP (adenosine monophosphate) and P as follows:

$ADP + H_2O \rightarrow AMP + P_i$ + energy (7.3 kcal/mole)

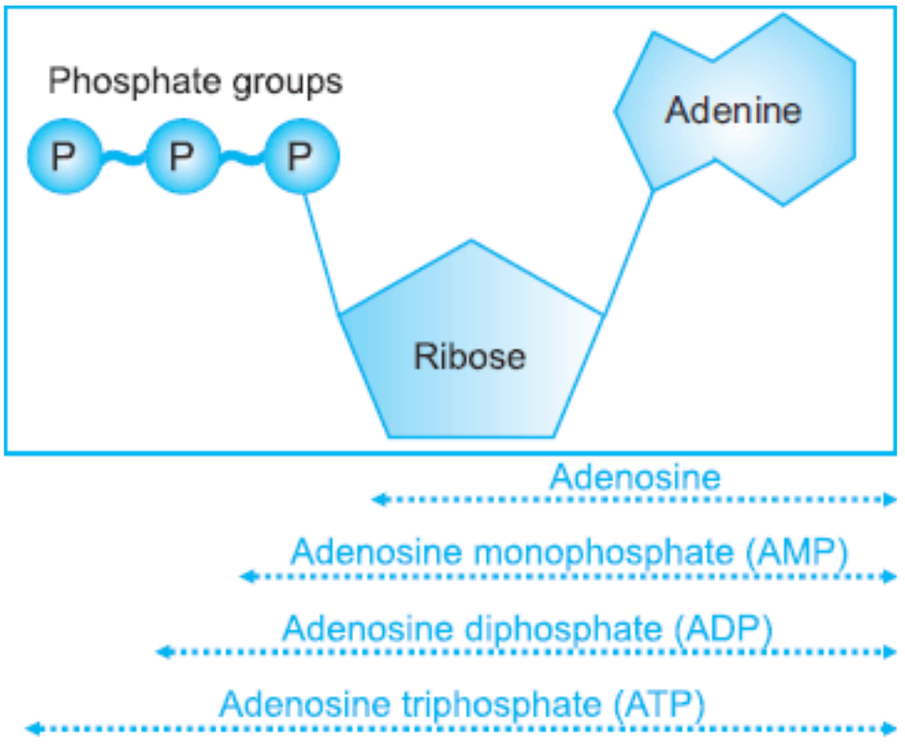


Figure 7.3: Molecular structure of ATP

Cells constantly recycle ADP by recombining it with P_i to form ATP.The synthesis of ATP from ADP and P_i requires the expenditure of 7.3 kcal of energy per mole. This energy is obtained from the oxidation of foodstuff. So we can summarize that ATP is generated by energy-releasing processes and is broken down by energy-consuming processes. In this way ATP transfers energy between metabolic reactions.

Because ATP plays a central role as energy currency in all organisms, it must have appeared in the early history of life.

7.2 Photosynthesis

Photosynthesis is the synthesis of glucose from carbon dioxide and water in the presence of sunlight and chlorophyll, with oxygen as a by-product. Photosynthesis is an anabolic (building) process and is an important component of bioenergetics in living systems.

It is the most important biochemical pathway and nearly all life depends on it. It comprises many coordinated biochemical reactions that occur in plants, some protists (algae), and some bacteria. A simple general equation for photosynthesis is as follows:

$$6CO_2 + 12H_2O + \text{Light energy} \xrightarrow{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

When cells use energy to build ATP from ADP, or ADP from AMP, they are really storing energy as we put money in a bank

Animation 7.3 : Photosynthesis
Source and Credit: agarciahawkins.weebly

Animation 7.4 : Photosynthesis
Source and Credit: mocomi

Intake of Water and Carbon dioxide

Water and carbon dioxide are the raw materials of photosynthesis. Plants have mechanisms for the intake and transport of these raw materials.

Water, present in soil, is absorbed by roots and root hairs through osmosis. This water is eventually transported to leaves through xylem vessels.

The air that enters leaf through tiny pores (stomata) reaches into the air spaces present around mesophyll cells. This air carries CO_2 , which gets absorbed in the thin layer of water surrounding mesophyll cells. From here, the carbon dioxide diffuses into mesophyll cells.

Recalling

Osmosis is the movement of water from a dilute solution to the concentrated one, through a membrane.

Animation 7.5 : Photosynthesis
Source and Credit: solpass

Animation 7.6 : Photosynthesis
Source and Credit: cas.miamioh

7.2.1 Mechanism Of Photosynthesis

Photosynthesis occurs in two phases (Fig 7.4). During first phase, light energy is captured and is used to make high-energy molecules (ATP and NADPH). These reactions, which are known as **light reactions**, take place on the thylakoid membranes of chloroplasts. During second phase, carbon dioxide is reduced to make glucose. In this phase, the energy from high energy molecules (ATP and NADPH) is utilized. Since these reactions do not use light directly, they are known as dark reactions.

The **dark reactions** take place in the stroma of the chloroplasts.

Stomata cover only 1-2% of the leaf surface but they allow much air to pass through them.

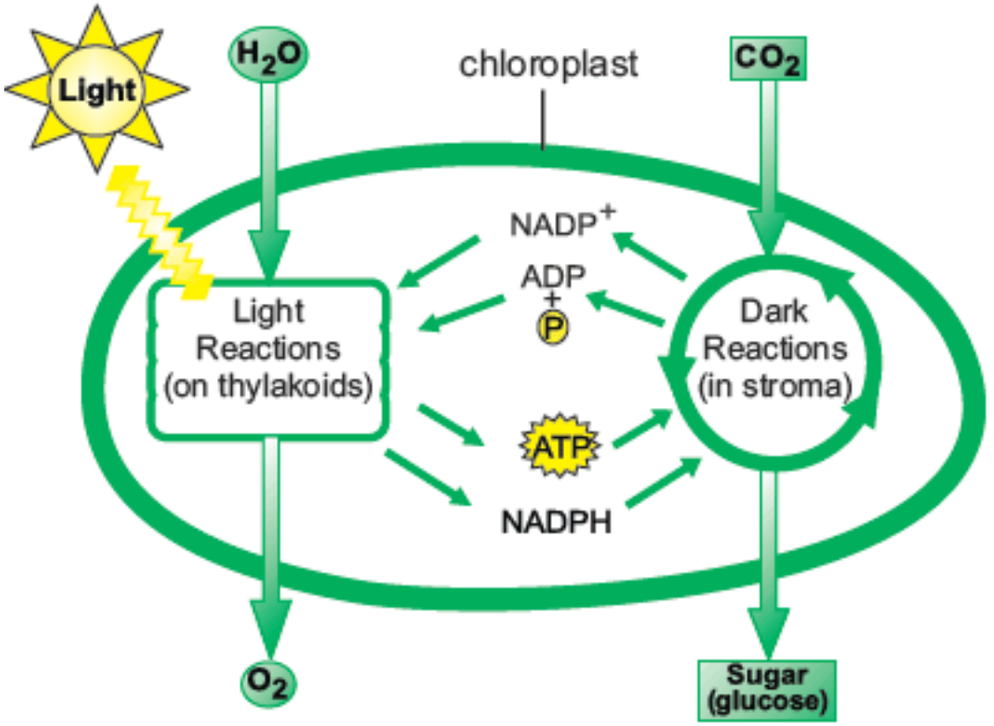


Figure 7.4: Summary of Photosynthesis

Animation 7.7 : Photosynthesis
Source and Credit: mocomi

Light Reactions

The summary of the events of light reactions is as follows;

- When chlorophyll molecules absorb light, their energy level increases and their electrons are emitted.
- Electrons are passed to electron transport chain to produce ATP.
- Light also breaks water molecule (photolysis) and oxygen is released. The hydrogen atoms of water give electrons to chlorophyll and become ions.
- The electrons of chlorophyll, after the production of ATP, and the hydrogen ions of water are used for the reduction of $NADP^+$ into NADPH.

The whole series of light reactions is called Z-scheme due to its Z-shaped flow chart.

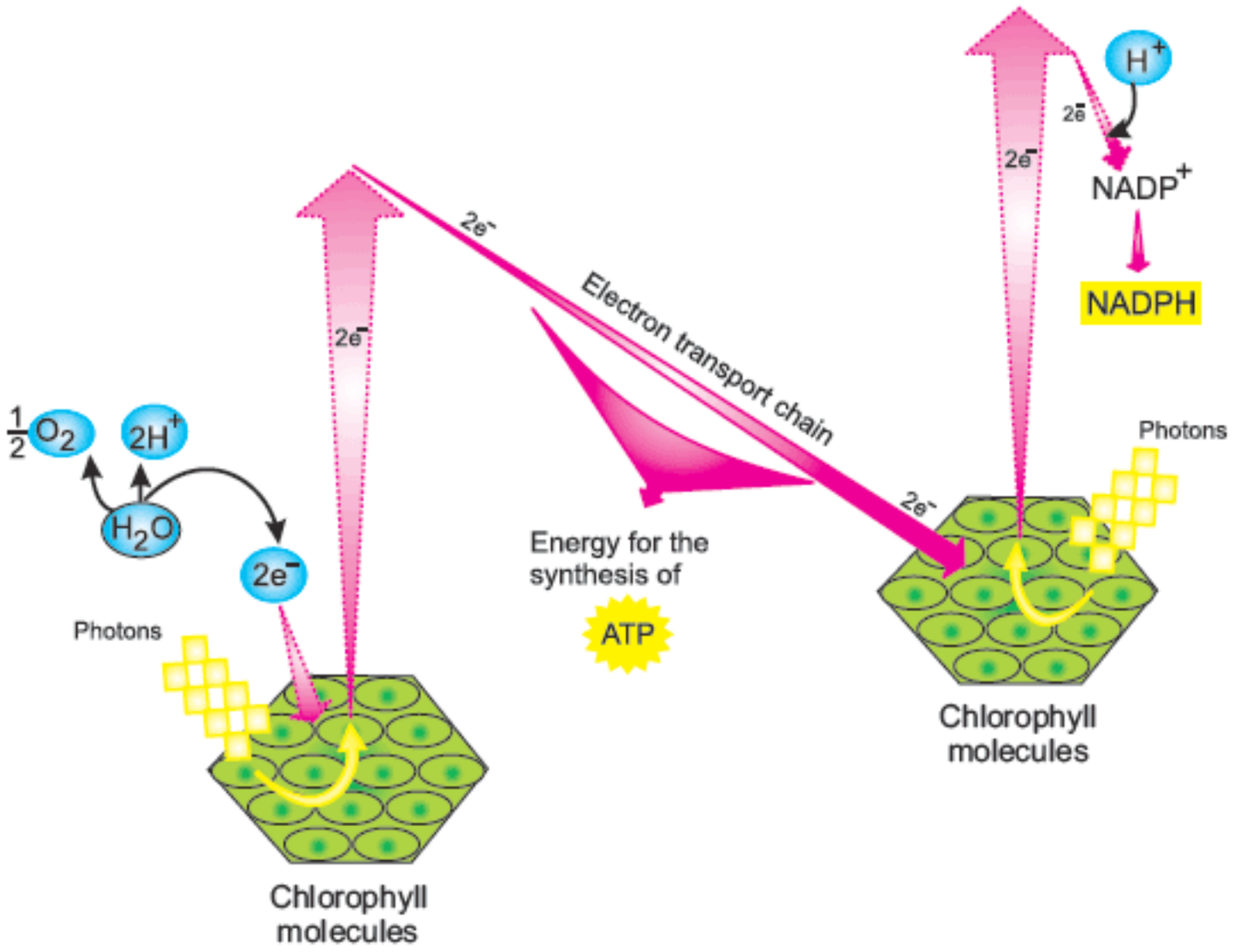
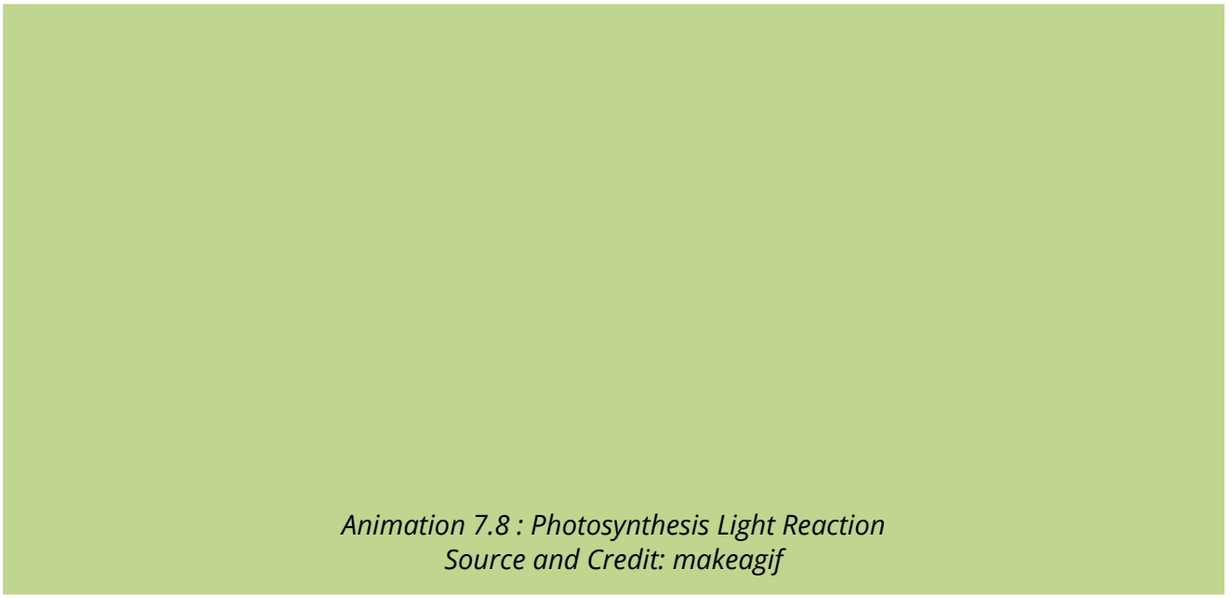


Figure 7.5: Light reactions of photosynthesis

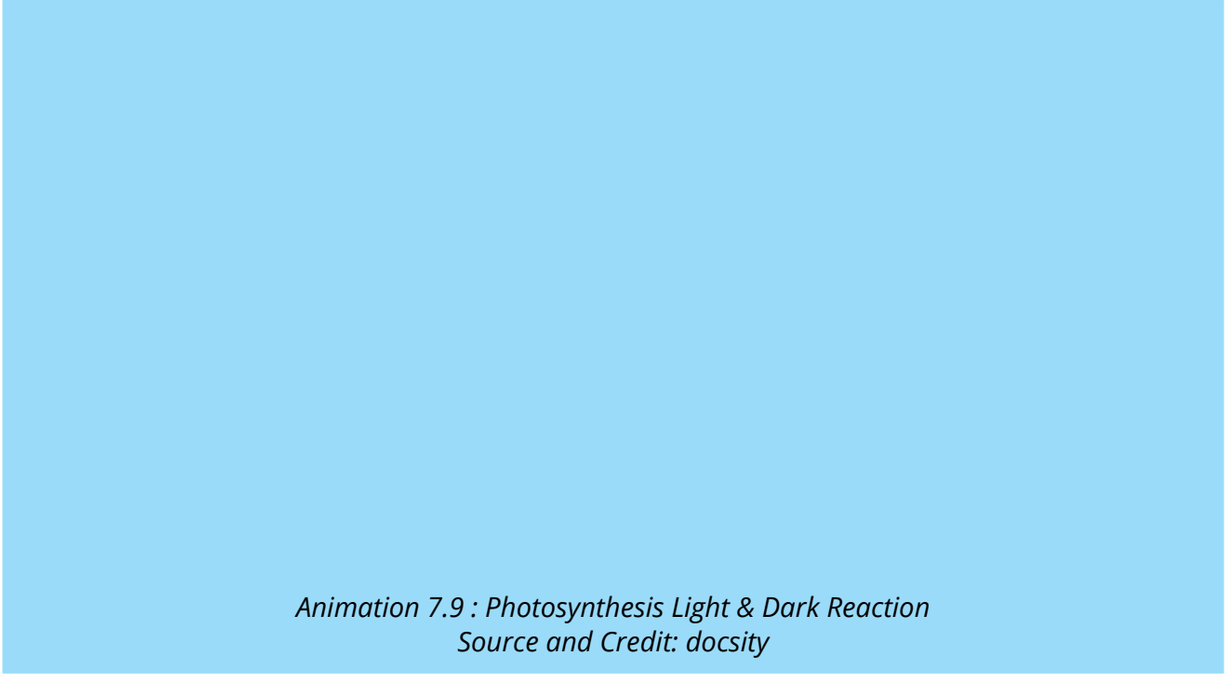


Animation 7.8 : Photosynthesis Light Reaction
Source and Credit: makeagif

Nicotinamide adenine dinucleotide (NAD^+) is a coenzyme that takes electrons and hydrogen ions and is thus reduced to NADH. One form of this coenzyme also carries phosphate with it, so is called $NADP^+$.

Dark Reactions (Calvin Cycle)

The details of dark reactions were discovered by **Malvin Calvin** and his colleagues at the University of California. The summary of the events of dark reactions, also known as Calvin cycle (Fig 7.6) is as follows;



Animation 7.9 : Photosynthesis Light & Dark Reaction
Source and Credit: docsity

- CO_2 molecules are combined with 5-carbon compounds to form 2 temporary 6-carbon compounds, each of which splits into two 3- carbon compounds.
- The 3-carbon compounds are reduced to 3-carbon carbohydrates by using ATP and hydrogen from NADPH. The 3-carbon carbohydrates are used to manufacture glucose.
- The 3-carbon carbohydrates are also used to regenerate the original 5-carbon compounds. This step also utilizes ATP.

7.2.2 Role Of Chlorophyll And Light

Sunlight energy is absorbed by chlorophyll. It is then converted into chemical energy, which drives the photosynthetic process. Only about one percent of the light falling on the leaf surface is absorbed, the rest is reflected or transmitted. The light rays of different wavelengths are not only differently absorbed by photosynthetic pigments but are also differently effective in photosynthesis. The blue and red lights carry out more photosynthesis.

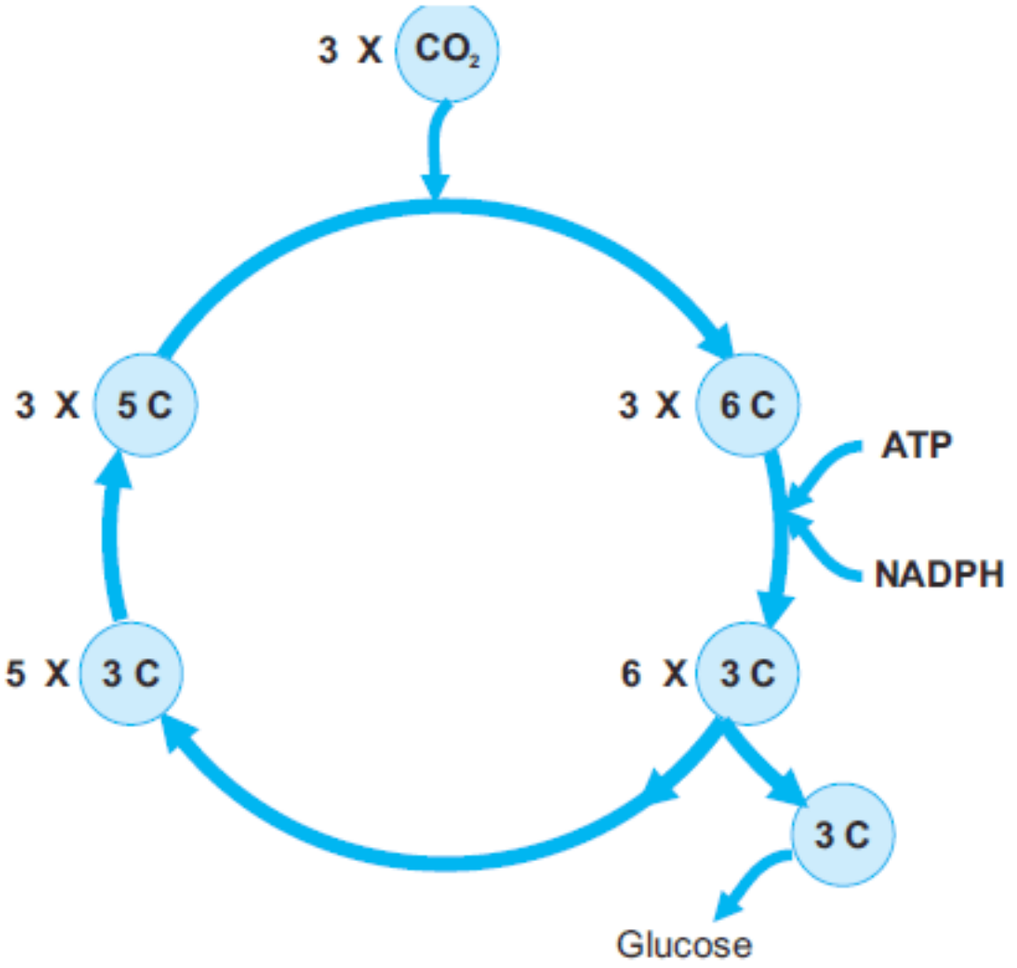
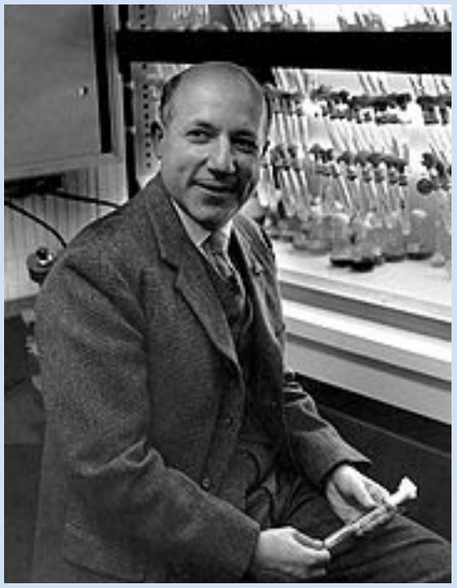


Figure 7.6: Dark reactions of photosynthesis (The Calvin cycle)



Calvin was awarded Nobel prize, in 1961, for his work on the details of photosynthesis.

Photosynthetic pigments are organized in the form of clusters, called **photosystems,** in thylakoid membranes of chloroplasts. Chlorophyll-a is the main photosynthetic pigment. Others are called accessory pigments and include chlorophyll-b and carotenoids. Chlorophylls absorb mainly blue and red lights. Some wavelengths not absorbed by chlorophyll 'a' are very effectively absorbed by accessory pigments and vice-versa.

? In dark reactions, 3-carbon compounds are reduced to form carbohydrates. What is the ultimate source of these hydrogen for this reduction?

Water

7.2.3 Limiting Factors In Photosynthesis

Any environmental factor the absence or deficiency of which can decrease the rate of a metabolic reaction, is called limiting factor for that reaction. Many factors like light intensity, temperature, concentration of carbon dioxide and availability of water act as limiting factors for photosynthesis.

Effect of light intensity and temperature

The rate of photosynthesis varies with light intensity. It decreases as light intensity decreases and increases as intensity increases. However at much higher light intensity, the rate of photosynthesis becomes constant.

The rate of photosynthesis decreases with decrease in temperature. It increases as temperature is increased over a limited range. But if light intensity is low, increasing the temperature has little influence on the rate of photosynthesis.

Effect of carbon dioxide concentration

As carbon dioxide concentration rises, the rate of photosynthesis goes on increasing until limited by other factors. Increase in carbon dioxide concentration beyond a certain level causes the closure of stomata and it decreases the rate of photosynthesis.

Practical Work:

Demonstration of photosynthesis

The phenomenon of photosynthesis can be demonstrated by using an aquatic plant, like Hydrilla. You know that in the process of photosynthesis, oxygen gas is evolved as a byproduct.So release of oxygen from a set up would provide an evidence of photosynthesis.

Problem:

Does Hydrilla carry out photosynthesis when provided by all the essential factors?

Hypothesis:

Hydrilla is an aquatic plant that carries out photosynthesis, using CO_2 and water and releases oxygen at the same time.

Deduction:

Release of O_2 from the plant body would be a proof of photosynthesis.

Material required:

Fresh Hydrilla branches, 500 ml beaker, funnel, test tube, potassium bicarbonate, match box, water tub.

Background information:

Carbon dioxide and water are the raw materials for photosynthesis. When potassium bicarbonate is dissolved in water, it is ionized into carbonate and hydrogen ions. The carbonate ions release carbon dioxide.

Procedure:

1. Fill about half of the 500-ml beaker with water.
2. Take some fresh branches of Hydrilla and place them in the broader side of a funnel and set the funnel as shown in Fig 7.7.
3. Put an inverted test tube on the tubular part of the funnel. (Perform step 1, 2 and 3 by putting all the apparatus in a water tub, so that no external air would enter the test tube. After step 3, bring the set-up out of water tub.)
4. Put some quantity of potassium bicarbonate in the water of beaker.
5. Put all the set up in light and observe.

Observation:

Bubbles would be created in test tube water and these will accumulate in the top portion of the tube.

Results: T

he branches have released oxygen gas in the form of bubbles.

Confirmation:

When enough gas bubbles have accumulated in the test tube, pick up the tube by putting thumb on its mouth. Take a burning match-stick inside the tube. It flares up when it touches gas bubbles. It confirms that the test tube contains oxygen gas.

Error analysis:

The experimental work would not give the expected results if any of the limiting factors of photosynthesis i.e. light, CO_2 , water, and chlorophyll are not present. Similarly, if gas bubbles are not observed the branches used may be dead and decayed.

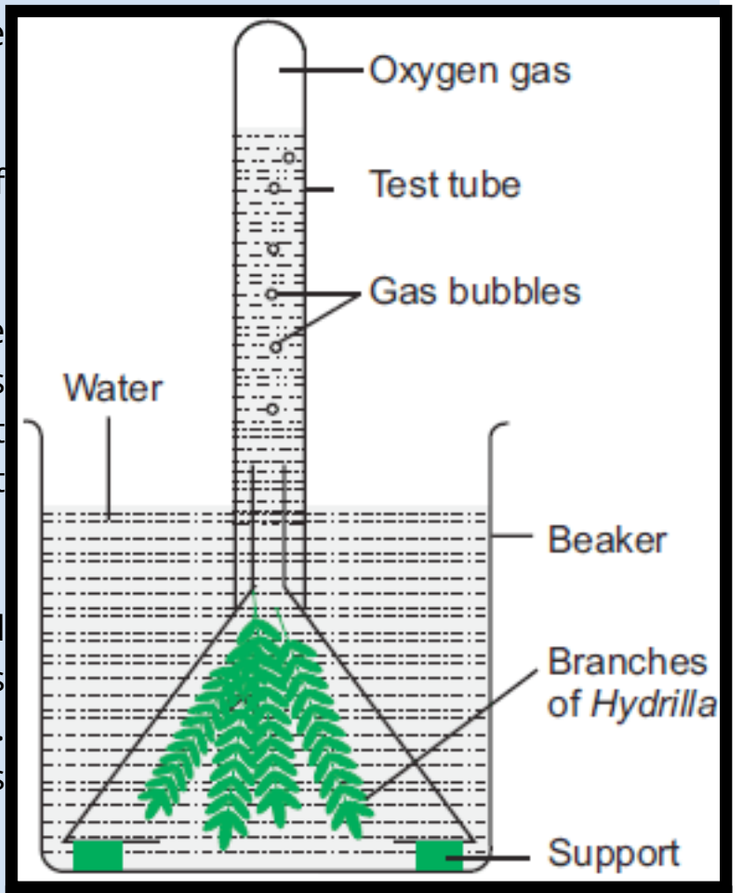


Figure 7.7: Experiment set up for the demonstration of photosynthesis

Evaluation:

1. There are two phases of photosynthesis i.e. light reactions and dark reactions.During which of these phases oxygen is produced?
2. Why was it necessary to do experiment with fresh branches of Hydrilla?
3. Why did you use a burning match-stick for confirmatory test?
4. What products (other than oxygen) are produced during photosynthesis?

Practical Work:

Investigation for the presence of starch

We know that in the process of photosynthesis, plants synthesize glucose by reducing CO_2 and for this reduction hydrogen is obtained from water. In many plants the synthesized glucose is converted into starch. So presence of starch in a leaf confirms that the plant has carried out photosynthesis. The presence of starch is investigated through starch test.

Problem:

How would it be proved that starch is present in a leaf?

Hypothesis:

A fresh leaf has carried out photosynthesis and has accumulated starch in its cell.

Deduction:

If the experimental leaf is processed for starch test, it would give positive results for starch.

Material required:

Fresh leaves, a 500 ml beaker, a forceps, a test tube, ethanol, dilute iodine solution, dropper, petri dish.

Background information:

- When a leaf is dipped in boiling water for sometime, it is killed and becomes soft.
- A soft and decolourized leaf can be tested in starch test. When soft leaf is boiled in ethanol it loses chlorophyll but retains starch in it.
- Starch turns blue when treated with dilute iodine solution (Fig 7.8).

Procedure:

1. Dip a leaf in a beaker of boiling water for about ten seconds.
2. Take the leaf out of boiling water and put it in a test tube of ethanol.
3. Put the test tube in a beaker of hot water for ten minutes. The ethanol starts boiling and the leaf in it gets decolourized.
4. Wash the leaf by moving it up and down in water in a beaker and put the washed leaf in a petri dish.
5. Perform starch test with the leaf. It is done by putting drops of iodine solution on the leaf.

Observation:
Leaf will turn blue-black.
Results:
Leaf contains starch.
Error analysis:
If leaf is retained in boiling water for long, it breaks the starch molecules present in it. Such a leaf will not give the expected results of the starch test.
Evaluation:
i. From where did the leaf get starch?
ii. Why was leaf placed in ethanol?
iii. What was the purpose of washing the leaf before performing the starch test?

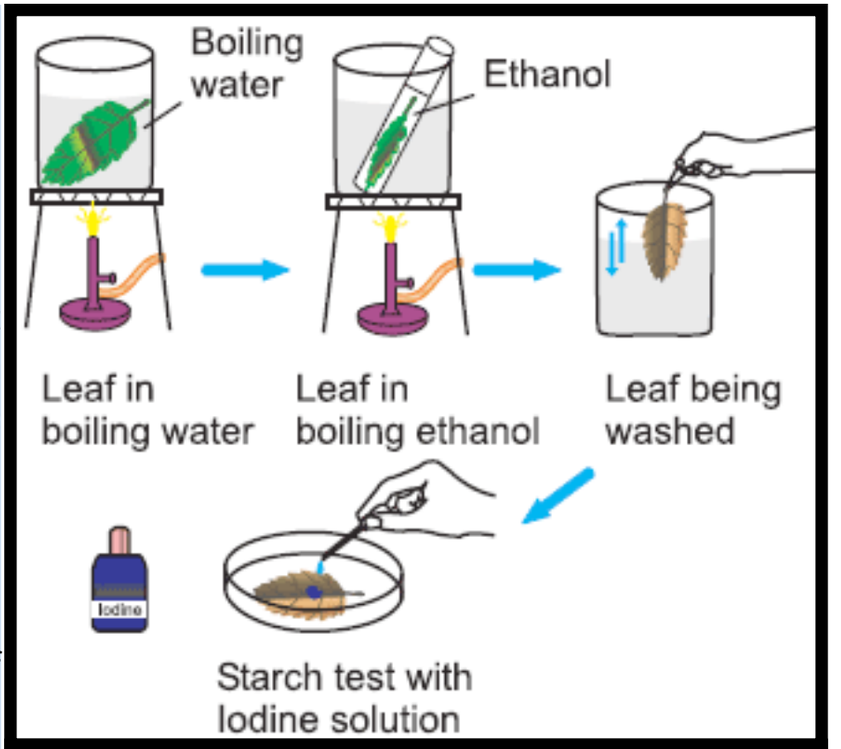


Figure 7.8: Experiment steps for starch test

Practical Work:

Investigation to find out that chlorophyll is necessary for photosynthesis
Chlorophyll is present in the chloroplasts of mesophyll cells. Leaves which lose their chlorophyll due to some diseases or salt deficiencies, fail to perform photosynthesis and eventually die.
Problem:
Is chlorophyll necessary for photosynthesis?
Hypothesis:
Chlorophyll is necessary for photosynthesis.
Deduction:
There will be no photosynthesis in the parts of the leaf that do not have chlorophyll and so there will be no starch production in these parts.
Material required:
A variegated leaf e.g. leaf of Geranium, a 500 ml beaker, a forceps, a test tube, ethanol, dilute iodine solution, dropper, petri dish.

Background information:

- Some leaves have yellow areas on their green surface. These areas mark the absence of chlorophyll (chloroplasts) containing cells. Such spotted leaves are called variegated leaves.
- Occurrence of photosynthesis can be confirmed by the presence of starch, through starch test.

Procedure:

1. Take a potted plant with variegated leaves e.g. Geranium.
2. Put the potted plant in light for several days so that it carries out photosynthesis (Fig 7.9).
3. Detach one of the variegated leaves and draw its upper surface on paper. The drawing should clearly distinguish the green and non-green areas.
4. Perform starch test on whole leaf.

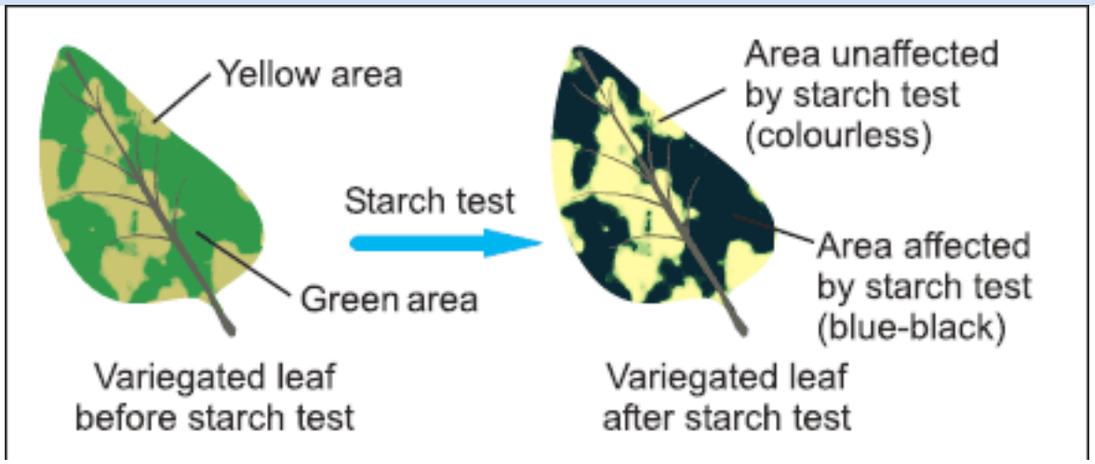


Figure 7.9: Test to prove the necessity of chlorophyll for photosynthesis

Observation:

The green parts of leaf will turn blue-black while the non-green parts will remain colourless.

Results:

There is no starch present in the non-green parts of leaf. In other words, these nongreen parts do not carry out photosynthesis.

Error analysis:

If non-green as well as green parts of leaf do not show the presence of starch, it means that the potted plant did not get any of the other required variables e.g. light, CO_2 , water etc.

Evaluation:

1. If there is no photosynthesis in the non-green parts of leaf, how they are alive?
2. In which phase of photosynthesis, chlorophyll plays its role?
3. Chlorophyll-a is the principal pigment. What are the accessory pigments?

Practical Work:

Investigation to find out that light is necessary for photosynthesis

Light energy is used for exciting the electrons of chlorophyll which in turn produce ATP and are also used for the reduction of CO_2. Thus light energy is incorporated in glucose in the form of bond energy.

Problem:

Is light necessary for photosynthesis?

Hypothesis:

Light is necessary for photosynthesis.

Deduction:

There will be no photosynthesis in the parts of leaf that do not get sufficient light and so there will be no starch production in these parts.

Apparatus required: A potted plant with healthy leaves, black paper, paper clips, a 500 ml beaker, a forceps, a test tube, ethanol, dilute iodine solution, dropper, petri dish.

Background information:

- If a plant is kept in darkness for several days, it utilizes its stored starch and is said to be de-starched.
- Black paper can check the light falling on a leaf.
- Occurrence of photosynthesis can be confirmed by the presence of starch, through starch test.

Procedure:

1. Take a potted plant and keep it in darkness for at least three days so that its leaves are de-starched.
2. Attach a strip of black paper to both the upper and lower sides of a leaf as shown in Figure 7.10.
3. Put the potted plant in a well-lit place for at least five hours.
4. Remove the experimental leaf and perform the starch test to observe the presence and/or absence of starch. Make a drawing to how the results.

Observation:

The part of the leaf having black paper strip will remain colourless while the other parts will turn blue-black.

Results:

There is no starch present in the parts of leaf, which were covered by black paper. In other words, these parts did not carry out photosynthesis.

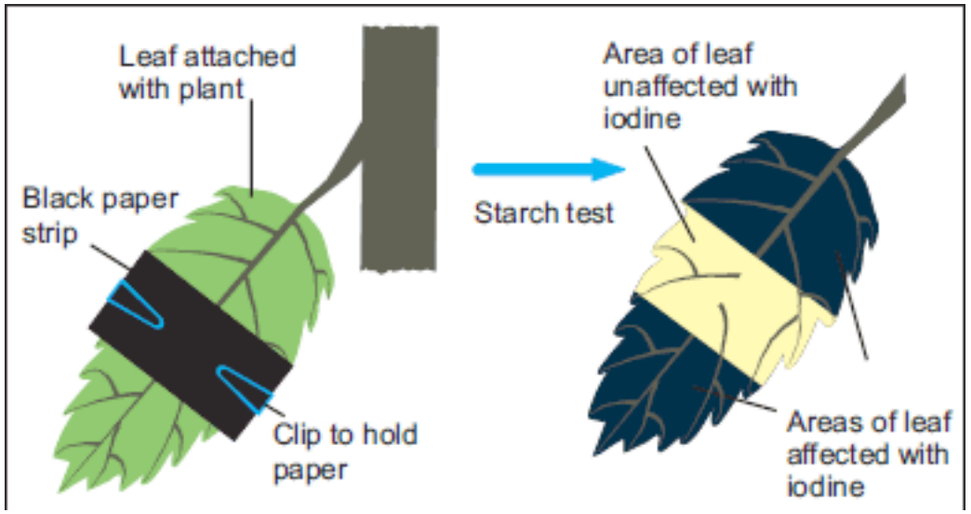


Figure 7.10: Experiment to show the necessity of light for photosynthesis

Error analysis:

If the covered parts show the presence of starch, it means that the plant could not be de-starched while it was kept in darkness. It may be due to the reason that plant was not given enough time to consume its stored starch.

Evaluation:

1. If light is necessary for photosynthesis, why the other parts of the plant do not photosynthesize, which receive light?
2. What adaptations leaves possess for maximum absorption of light?
3. Which colours of light are least absorbed by the leaves?

Practical Work:

Investigation to find out that CO_2 is necessary for photosynthesis

In photo synthesis, CO_2 is reduced to form carbohydrates (glucose). Water acts as the hydrogen source for this reduction while sunlight is the energy source for it. Plants get CO_2 from air which enters in their leaves through stomata.

Problem:

Is carbon dioxide necessary for photosynthesis?

Hypothesis:

Carbon dioxide is necessary for photosynthesis.

Deduction:

There will be no photosynthesis in the parts of leaf that do not get carbon dioxide and so there will be no starch production in these parts.

Apparatus required:

A potted plant with healthy leaves, a 500 ml beaker, a forceps, a test tube, ethanol, dilute iodine solution, dropper, petri dish, potassium hydroxide solution, a glass flask with rubber cork.

Background information:

- If a plant is kept in darkness for several days, it utilizes its stored starch and is said to be de-starched.
- Potassium hydroxide absorbs CO_2 from its surroundings.
- Occurrence of photosynthesis can be confirmed by the presence of starch, through starch test.

Procedure:

1. Take a potted plant and keep it in darkness for at least three days so that its leaves are de-starched.
2. Take potassium hydroxide solution in a glass flask and fit a cork in the mouth of the flask. The cork should be cut longitudinally
   before fitting.
3. Select a leaf of the de-starched plant (but do not remove it from plant). Pass half of the leaf from the cut of cork so that half portion of leaf is inside flask and other half is outside (Fig 7.11).
4. Put the potted plant in a well-lit place for at least five hours.
5. Remove the experimental leaf and perform starch test to observe the presence and/or absence of starch. Make a drawing to show the results.

Observation:

The portion of leaf present inside flask will remain colourless while the other portion that remains in fresh air will turn blue-black.

Results:

Carbon dioxide present in the air inside flask was absorbed by KOH and so the portion of leaf present here could not carry out photosynthesis and could not make starch.

Error analysis:

If the portion of leaf inside flask shows the presence of starch, it means that the cut in the rubber cork was wide to allow some air to enter the flask.

Evaluation:

1. Why the portion inside the flask could not make starch?
2. Where had the CO_2 gone that was present in the air inside flask?

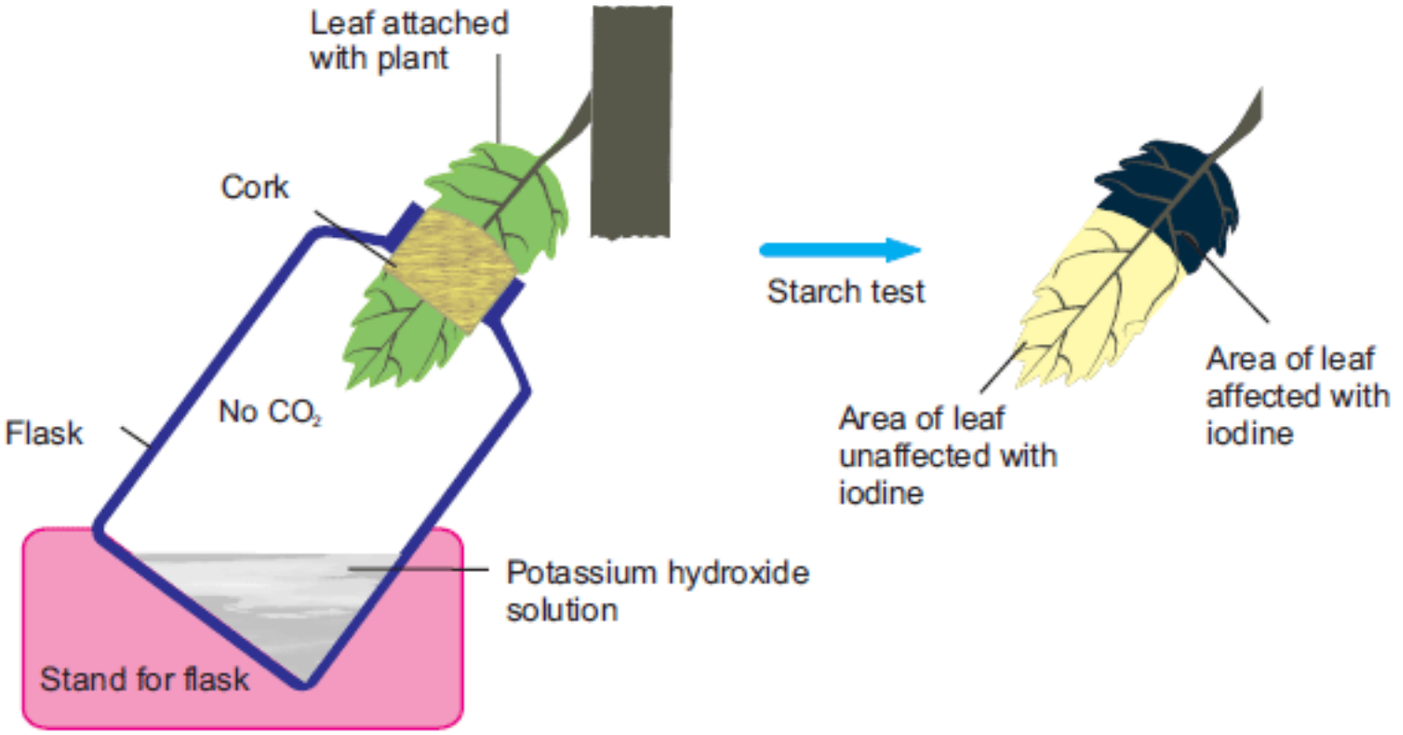


Figure 7.11: Experiment to show the necessity of CO_2 in Photosynthesis

? There are more chloroplasts in the palisade mesophyll than in the spongy mesophyll. Why?

Because the palisade cells are on the upper surface and receive more light. So they should be able to absorb more light.

7.3 Respiration

When we burn a fuel, it utilizes oxygen and yields energy in the form of light, heat, etc. In this burning process, oxygen is used to break the C-H bonds present in fuel molecules. In the same way, organisms utilize oxygen for the breakdown of C-H bonds present in the food in their cells. This break down yields energy which is transformed into ATP. During this process the C-H bonds are broken by oxidation-reduction reaction and so carbon dioxide and water are also produced. The cellular energy-yielding process is called **cellular respiration.**

In cellular respiration, food is oxidized to CO_2 while O_2 is reduced into H_2O.

7.3.1 Aerobic And Anaerobic Respiration

The most common fuel used by cell to get energy by cellular resp ration is glucose. The way glucose is oxidized depends on the availability of oxygen. The cellular respiration occurring in the presence of oxygen is called aerobic respiration while the one that occurs in the absence of oxygen is called anaerobic respiration.

i. Aerobic Respiration

In the presence of oxygen, complete oxidation of glucose occurs with maximum release of energy. In the first phase of aerobic respiration, a molecule of glucose (6-C) is broken down into two molecules of pyruvic acid (3-C).
In the second phase, molecules of pyruvic acid are completely oxidized (all C-H bonds are broken) to CO_2 and water and all energy is released.The overall reaction is as follows.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

ii. Anaerobic Respiration (Fermentation)

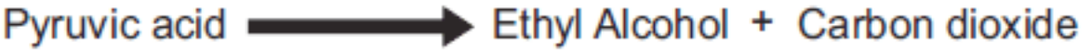
In the absence of oxygen, glucose is incompletely oxidized with less amount of energy released. In anaerobic respiration, the first phase is exactly similar to that of aerobic respiration. A molecule of glucose is broken down into two molecules of pyruvic acid. But in the second phase, pyruvic acid is not completely oxidized (due to the absence of oxygen).

Animation 7.10 : Anaerobic Respiration
Source and Credit: biobook.kuensting

It is transformed into ethyl alcohol or lactic acid. In this way many of the C-H bonds are left unbroken in the products. Anaerobic respiration is further classified as alcoholic fermentation and lactic acid fermentation.

A- Alcoholic fermentation:

It occurs in bacteria, yeast etc. In this type of anaerobic respiration, pyruvic acid is further broken down into alcohol (C_2H_5 OH) and CO_2 .



B- Lactic acid fermentation:

It occurs in skeletal muscles of humans and other animals during extreme physical activities. This also happens in the bacteria present in milk. In this type of anaerobic respiration, each pyruvic acid molecule is converted into lactic acid ($C_2H_6O_3$).

Importance of Fermentation

When life evolved on the Earth, the early land or water habitats did not have any supply of free oxygen (O_2). In these anaerobic conditions, early organisms respired anaerobically and got energy for their life activities. Even today when free oxygen is available, some organisms including some bacteria and some fungi get energy from anaerobic respiration and are called **anaerobes**. Humans can also provide energy to their skeletal muscle cells through anaerobic respiration. It happens when skeletal muscles have to work hard (during exercise etc.) but oxygen supply cannot be increased to fulfil the demand.

Scientists have used the fermenting abilities of fungi and bacteria for the benefit of mankind. For example, the fermenting powers of bacteria are used for making cheese and yogurt. Fermentation in yeasts is used in brewing and baking industries. Similarly, the soy sauce is made through the fermentation by a fungus Aspergillus.

7.3.2 Mechanism Of Respiration

The process of respiration involves complex series of reactions. For the study of all the reactions of glucose oxidation, we will go into the mechanism of aerobic respiration. Aerobic respiration is a continuous process, but for convenience we can divide it into three main stages; 1- glycolysis, 2- Krebs cycle and 3- electron transport chain.

Glycolysis occurs in cytoplasm and oxygen is not involved in this stage. That is why, it occurs in both types of respiration i.e. aerobic and anaerobic. In glycolysis, glucose (6C) molecule is broken into two molecules of pyruvic acid (3C).

In Krebs cycle, the pyruvic acid molecules are completely oxidized, along with the formation of ATP, NADH and $FADH_2$. Before entering in Krebs cycle, pyruvic acid is changed into a 2-carbon compound called acetyl-CoA.

Electron transport chain is the final step of cellular respiration. It is the transfer of electron on an electron transport chain. In this step, NADH and $FADH_2$ release electrons and hydrogen ions. These electrons are taken up by a series of electron carriers. When electrons move through the series of electron carriers they lose energy, which is used to synthesize ATP. At the end of chain, electrons and hydrogen ions combine with molecular oxygen and form water.

?

Why it is incorrect to say that the energy releasing step of respiration is electron transport chain?

Energy released in glycolysis and kerbs cycle in the form of NADH and $FADH_2$. Electron transport chain transforms the energy present in these components to ATP.

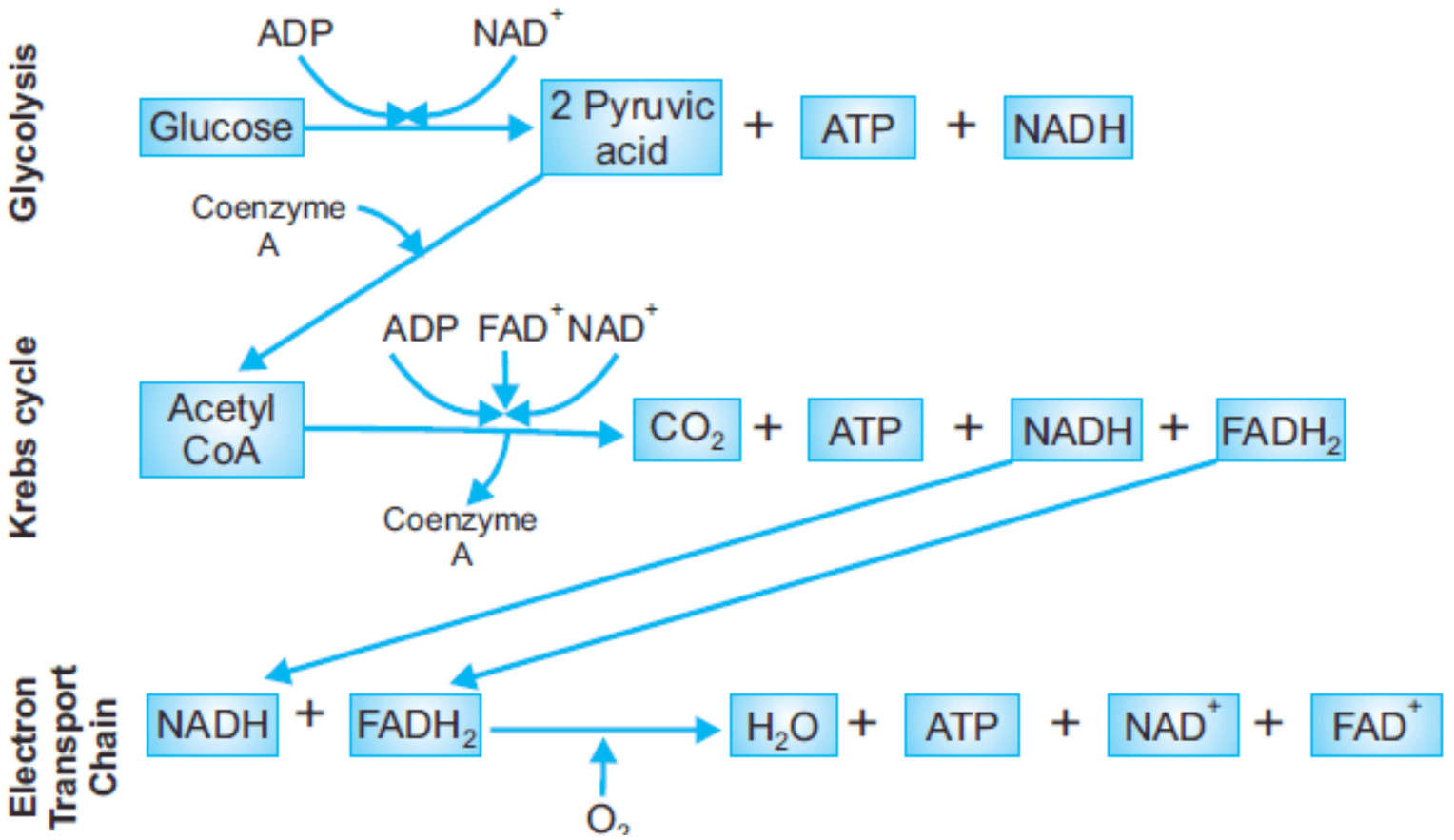


Figure 7.12: Mechanism of respiration

7.3.3 The Energy Budget Of Respiration

Each NADH produces 3 ATP in electron transport chain. The NADH generated in glycolysis gives 2 ATP because 1 ATP is spent to transport it across the mitochondrial membrane. Each $FADH_2$ produces 2 ATP. The total output of ATPs can be calculated from the following data (Fig 7.13). Note that during anaerobic oxidation of a glucose molecule only 2 ATP molecules are gained as the net profit. It is because there is no Krebs cycle and electron transport chain in anaerobic respiration.

A British biochemist, **Sir Hans Krebs** discovered this series of reactions that is why it is called the Krebs cycle.

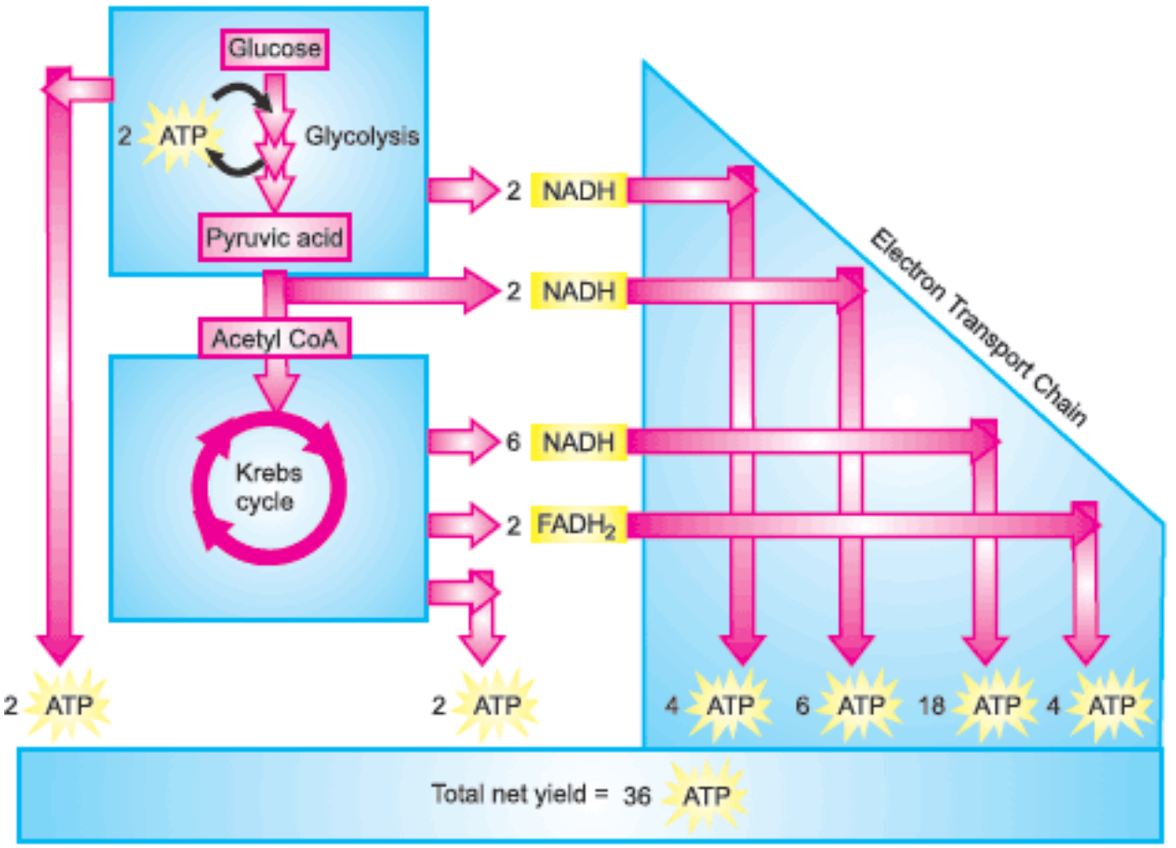


Figure 7.13: Energy chart of Respiration

Practical Work:

Investigation to find out that carbon dioxide is released during aerobic respiration

In aerobic respiration, the C-H bonds of glucose are broken. The hydrogen released in this breakage is taken by oxygen to produce water and CO_2 is left behind.

Problem:

Does the process of respiration produce CO_2 ?

Hypothesis:

CO_2 is produced as one of the end products of aerobic respiration.

Deduction:

An organism carrying out aerobic respiration will release CO_2

Apparatus required:

Flasks, potassium hydroxide, lime water, an animal.

Background information:

- Lime water readily absorbs CO_2 .

Procedure:

Set the apparatus as Figure 7.14 and observe the changes in lime water.

Observation:

Color changes would be observed in lime water.

Results:

CO_2 is produced during respiration.

Evaluation:

i. What color changes occurred in lime water?

ii. Why did we use potassium hydroxide and lime water?

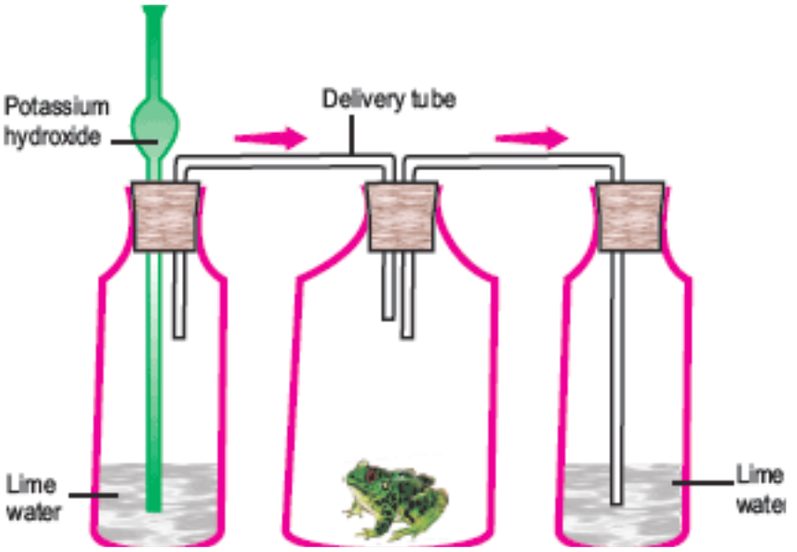


Figure 7.14: Experiment set up to investigate the release of carbon dioxide during aerobic respiration

Practical Work:

Investigation to find out that heat is given out during aerobic respiration

In respiration, lot of energy is released and some of this is stored in the form of ATP while the rest evolves out in the form of heat energy.

Problem:

Is there any production of heat energy during respiration?

Hypothesis:

Heat is produced during respiration.

Deduction:

A thermometer placed in the apparatus where respiration is being carried out,would show a rise in temperature.

Apparatus required:

Pea seeds, 01% chlorine or sodium hypochlorite solution, 02 beaker,02 flasks, 02 thermometers, cotton.

Background information:

- Seeds contain embryos of plants which consist of many cells.
- Boiling of seeds kills their cells.
- High temperature causes decay of dead cells.

Procedure:

1. Take pea seeds and keep them in water for 24 hours.
2. Wash the seeds with some germicide (e.g. 01% chlorine or sodium hypochlorite solution)to kill the bacteria present on their surface.
3. Boil some seeds for ten minutes so that their cells die. Cool these seeds so that these should not decay.
4. Put both sets of seeds (alive and dead) in separate flasks and label them as ‘a and ‘b’respectively. (Do not fill the flask up to their mouths.)
5. Insert a thermometer in the mouth of each flask and seal the mouth with cotton as in Figure 7.15.
6. Invert the flasks and fix them with stands and note the temperatures on both thermometers.
7. Keep the apparatus for about 4 hours.

Observation:

The temperature reading in the thermometer put in flask ‘a’ rises but there is no rise in the temperature reading in the second thermometer.

Results:

Respiration in the live cells of seeds in flask ‘a’ results in the release of heat.

Error analysis:

If there is rise in temperature in the apparatus flask ‘b”, it may be due to some rise in room temperature. In such conditions, the temperature in flasks ‘a’ will raise more than the temperature in flask ‘b’.

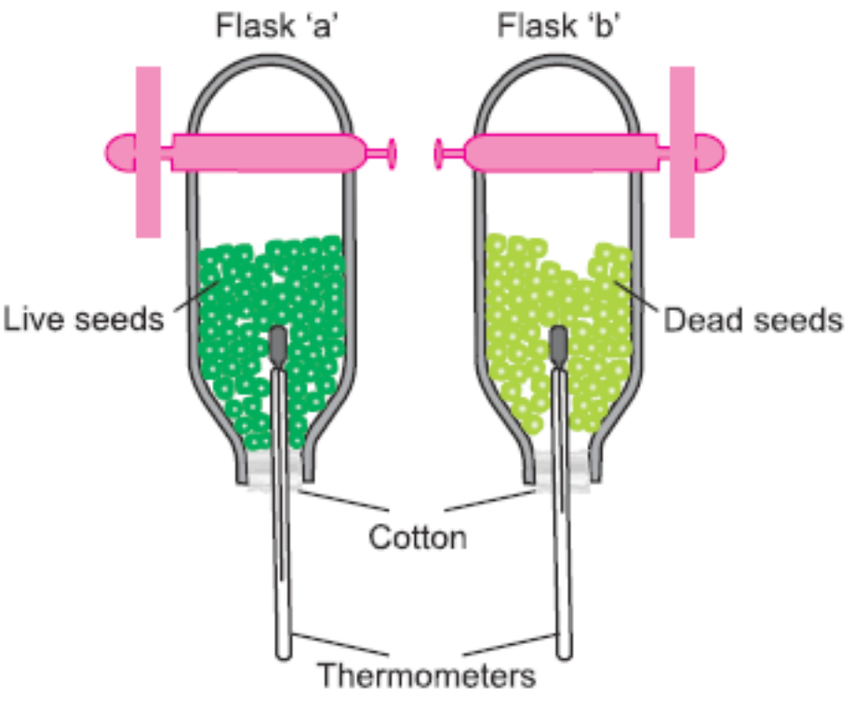


Figure 7.15: Experiment set up to investigate the release of heat during respiration

Evaluation:

i. Why were the flasks not filled up to their mouths?
ii. Why did the temperature in flask ‘a’ rise and why did not in flask ‘b’?
iii. Is there any heat released during respiration in our bodies?

TABLE 7.1: Difference between photosynthesis and respiration

Characteristics	Photosynthesis	Respiration
Metabolism	Anabolism	Catabolism
Energy investment / production	Investment of light energy to store it in the form of bond energy	Bond energy transformed into chemical energy of ATP
Organisms capable of;	Some bacteria, all algae all plants	All organisms
Site of occurrence	Chloroplasts	In cytoplasm and mitochondria
Time of occurrence	In daytime only, in the presence of light	All the time

TABLE 7.2: Difference between Aerobic and Anaerobic Respiration

Properties	Aerobic respiration	Anaerobic respiration
Presence of Oxygen	Yes	No
Number of ATP as net profit	36	2
Final products	CO_2 , H_2O	Lactic acid or Ethanol + CO_2
Site of occurrence	Gycolysis in cytoplasm and Krebs cycle and electron transport chain in mitochondria	In cytoplasm
Importance	Major source of energy for most organisms	• Source of energy for anaerobic organisms • Source of energy for aerobic organisms in short supply of O_2 • Source of many products (ethanol, cheese etc)

UNDERSTANDING THE CONCEPTS

1. How would you define bioenergetics while relating it to the oxidation reduction reactions in living systems?
2. Interpret that ATP is the chief energy currency of all cells.
3. What is the role of chlorophyll and light in photosynthesis?
4. Outline the processes involved in photosynthesis?
5. State how the varying light intensity carbon dioxide concentration and temperature affect the rate of photosynthesis?
6. Outline the mechanism of respiration while defining glycolysis, Krebs cycle and electron transport chain.
7. Draw a comparison of aerobic and anaerobic respiration.
8. How will you compare respiration and photosynthesis?

SHORT QUESTIONS

1. Why is it said that all life forms are dependent on photosynthesis?
2. What structures and phenomena are involved in the intake of carbon dioxide and water by plants?
3. In what ways the respiratory energy is used in the body of organisms?
4. What is the importance of anaerobic respiration?

TERMS TO KNOW

Acetyl-CoA	Chlorophyll	NADPH
Adenine	Coenzyme-A	Oxidation
ADP	Electron transport chain	Photolysis
Aerobic respiration	FAD	Photosynthesis
Alcoholic fermentation	Glycolysis	Photosystem
AMP	Krebs cycle	Pigments
Anabolism	Lactic acid fermentation	Pyruvic acid
Anaerobic respiration	Light-dependent reactions	Reduction
ATP	Limiting factors	Respiration
Autotrophic	Mesophyll	Stroma
Bioenergetics	Metabolism	Thylakoid
Calvin cycle	Chlorophyll	Z-scheme

Initiating And Planning

1. Design the molecular model of ATP using low-cost no-cost materials.
2. Design a model of light and dark reactions by low-cost no-cost materials.

Activities

1. Demonstrate the process of photosynthesis using an aquatic plant, like Hydrilla.
2. Identify and label the cellular and tissue structures in the CS of a leaf through observation under the microscope.
3. Investigate the necessity of chlorophyll, light, carbon dioxide, using appropriate controls.
4. Demonstrate the process of respiration in germinating seeds by using limewater.
5. Investigate the release of carbon dioxide and heat during aerobic respiration in germinating seeds.

ON-LINE LEARNING

1. en.wikipedia.org/wiki/Bioenergetics
2. photoscience.la.asu.edu/
3. www.sambal.co.uk/respiration.html
4. www.fi.edu/learn/heart/systems/respiration.html

CHAPTER

8 Nutrition

Animation 8.1: Nutrition
Source & Credit: Wikispace

Recalling

Every organism needs food for growth and energy and to function normally.

The process in which food is obtained or prepared, absorbed and converted into body substances for growth and energy, is called nutrition. Nutrients are the elements and compounds that an organism obtains and uses for energy or for the synthesis of new materials.

We know that **autotrophic** organisms obtain water, carbon dioxide and minerals from their environment and prepare their food which is then used for growth and energy. On the other hand **heterotrophic** organisms obtain their food from other organisms and use it for growth and energy.

8.1 MINERAL NUTRITION IN PLANTS

Plants have the most efficient mechanisms for autotrophic mode of nutrition. Plants get carbon, hydrogen and oxygen from carbon dioxide and water. In addition to these elements, plants also require mineral elements for various activities and structures. The nutrients which are required in large quantities are called **macronutrients** e.g. carbon, hydrogen, oxygen, nitrogen, magnesium, potassium etc. Similarly, the nutrients which are required in small quantities are called **micronutrients** e.g. iron, molybdenum, boron, chlorine, zinc etc. If any of these nutrients is not available to plant, they show abnormalities and do not grow normally. Table 8.1 describes the roles of important macro and micronutrients in plants.

Animation 8.2: Nutritions
Source & Credit: spokaneschools

Animation 8.3: Minral Nutrition in Plants
Source & Credit: sites

Table 8.1: Role of important nutrients in plant life

Macronutrients	Role in plant life
Phosphorus	Component of ATP, nucleic acids, and coenzymes, necessary for seed germination, photosynthesis, protein formation etc
Potassium	Regulates the opening and closing of the stoma, reduces water loss from the leaves
Sulphur	Component of proteins, vitamins and enzymes
Calcium	Activates enzymes, is a structural component of cell wall, influences water movement in cells

Micronutrients	Role in plant life
Iron	Necessary for photosynthesis, activates many enzymes
Molybdenum	Component of the enzyme that reduces nitrates to ammonia, important in building amino acids
Boron	Important in sugar transport, cell division, and synthesizing certain enzymes
Copper	Component of several enzymes
Manganese	Involved in enzyme activity for photosynthesis, respiration, and nitrogen metabolism
Zinc	Required in a large number of enzymes
Chlorine	Involved in osmosis of water
Nickel	Required in a nitrogen metabolism

Carnivorous plants have evolved mechanisms for trapping and digesting small animals. The products of this digestion are used to supplement the plant's supply of nitrogen.

Roles of Nitrogen and Magnesium

Plants get nitrogen in the form of nitrates. Nitrogen is a major component of proteins, hormones, chlorophyll, vitamins and enzymes essential for plant life. Nitrogen metabolism is a major factor in stem and leaf growth. Too much nitrogen can delay flowering and fruiting. Deficiencies of nitrogen can reduce yields, cause yellowing of the leaves and stunt growth.

Magnesium is a structural component of chlorophyll. It is also necessary for the functioning of plant enzymes to produce carbohydrates, sugars and fats. It is used for fruit and nut formation and essential for germination of seeds. Deficiency of magnesium causes yellowing and wilting of leaves.

IMPORTANCE OF FERTILIZERS

As humans cultivated plants, it was learned that addition of certain materials to soil sometimes resulted in plants with desirable characteristics (e.g., more fruit, faster growth, more attractive flowers). Such materials were named as fertilizers. Fertilizers are broadly classified as organic or inorganic.

Naturally occurring inorganic fertilizers include rock phosphate, elemental sulfur and gypsum. These are not chemically modified. If nitrogen is the main element, they are called nitrogen fertilizers. Most inorganic fertilizers dissolve readily in water and are immediately available to plants for uptake.

Organic fertilizers are derived from plant and animal materials. They are more complex and take time to be broken down into forms usable by plants. Manure and compost are used as organic fertilizers. They can also increase soil drainage, aeration and the ability of the soil to hold nutrients.

The distinction between the organic and inorganic fertilizers is not always clear-cut. Urea, for example, is an organic compound, but chemically synthesized urea is generally grouped with inorganic fertilizers.

Animation 8.4: Importance of Fertilizers
Source & Credit: boerenbritaccommodation

Environmental hazards related to fertilizer's use

The massive quantities of inorganic fertilizers affect the soil nutrient-holding capacity. Their high solubilities also degrade ecosystems through **eutrophication** (increase in chemical nutrientsin an ecosystem). Storage and application of some nitrogen fertilizers may cause emissions of the greenhouse gas nitrous oxide. Ammonia gas may be emitted from the inorganic fertilizers. This extra ammonia can also increase soil acidity. Excessive nitrogen fertilizers can lead to pest problems by increasing their reproduction rate.

For these reasons, it is recommended that the nutrient content of the soil and nutrient requirements of the crop should be calculated before the application of inorganic fertilizers.

Excessive amounts of organic fertilizers cause environmental problems due to nitrate leaching or run off of soluble organic compounds.

If we supply inorganic and organic fertilizers to a plant, which one would be first available to the plant for uptake?

Inorganic fertilizer

8.2 COMPONENTS OF HUMAN FOOD

The nutritional requirements of human and other animals are relatively complex as compared to plants. Like other animals, the nutrients used by humans include carbohydrates, lipids, nucleic acids, proteins, minerals, vitamins. Besides these nutrients, they also require water.

CARBOHYDRATES

Carbohydrates are the basic source of energy for all animals. About half to 2/3 of the total calories every animal consumes daily are from carbohydrates. Glucose is the most often used carbohydrate for energy. Other useful carbohydrates are maltose, lactose, sucrose and starch. Carbohydrates contain 04 kilocalories per gram. Humans get carbohydrates from the foods like bread, pastas, beans, potatoes, bran, rice and cereals.

Carbohydrates are the most common source of energy. Proteins and lipids are vital building components for body but they can also be used for energy.

Saturated fatty acids can increase a person's cholesterol level. An increased cholesterol level may eventually result in the clogging of arteries and, ultimately, heart disease.

LIPIDS

The lipids present in food are composed of **fatty acids** bonded to **glycerol**. The fatty acids of lipids may be saturated or unsaturated.

Saturated fatty acids have all of their carbon atoms bonded to hydrogen atoms.

Unsaturated fatty acids have some of their carbon atoms double-bonded in place of a hydrogen atom. Generally, the lipids containing saturated fatty acids are solid at room temperature. The lipids containing unsaturated fatty acids are liquid at room temperature. For example butter contains nearly 70% saturated and 30% unsaturated fatty acids. On the other hand, sunflower oil contains nearly 75% unsaturated fatty acids. Lipids are used to form membranes, the sheaths surrounding neurons, and certain hormones. Lipids are also extremely useful energy sources. One gram of lipids contains 09 kilocalories of energy. Important sources of lipids include milk, butter, cheese, eggs, mutton, fish,mustard seeds, coconut and dry fruits etc

PROTEINS

Proteins are composed of amino acids. Proteins are essential components of the cytoplasm, membranes and organelles. They are also the major components of muscles, ligaments, and tendons. So we use proteins for growth. Many proteins play role as enzymes. Proteins can also be used for gaining energy. One gram of proteins contains 04 kilocalories of energy. Dietary sources of proteins are meat, eggs, grains, legumes, and dairy products such as milk and cheese.

Proteins can be converted into carbohydrates

MINERALS

Minerals are inorganic elements that originate in the Earth and cannot be made in body. They play important roles in various body functions and are necessary to maintain health. Most of the minerals in human diet come directly from plants and water, or indirectly from animal foods. Minerals are categorized into major and trace minerals. **Major minerals** are required in the amounts of 100 mg (milligrams) or more per day, while **trace minerals** are required in amounts less than 100 mg per day. The roles of major and minor minerals in human body are given in Table 8.2.

On the nutritional label of a packaged food the word “Calorie” is equal to a kilocalorie.

Table 8.2: Important minerals in human diet and their roles

Minerals	Role in body
Major minerals	
Sodium	Fluid balance in the body Helps in absorption of other nutrients Important for muscle contraction, nerve impulse transmission, heart function, and blood pressure
Potassium	Fluid balance in the body Acts as cofactor for enzymes
Chloride	Fluid balance in the body Component of hydrochloric acid
Calcium	Development and maintenance of bones and teeth blood clotting
Magnesium & Phosphorus	Development and maintenance of bones and teeth
Trace minerals	
Iron	Oxygen transport and storage Act as enzyme cofactors support immune function
Zinc	Aids insulin action Helps in growth and reproduction
Copper	Acts as enzyme cofactor
Chromium	Helps in insulin action
Fluoride	Stabilizes bone mineral and hardens tooth enamel
Iodine	Essential for normal thyroid function

Role of Calcium and Iron

Calcium is essential for the development and maintenance of bones and teeth. It is also needed for maintaining cell membranes and connective tissues and for the activation of several enzymes. Calcium also aids in blood clotting. Humans get calcium from milk, cheese, egg yolk, beans, nuts, cabbage etc. Deficiency of calcium causes spontaneous discharge of nerve impulses which may result in tetany, bones also become soft, blood clots slowly and wounds heal slowly.

Iron plays a major role in oxygen transport and storage. It is a component of haemoglobin in red blood cells and myoglobin in muscle cells. Cellular energy production also requires iron. It acts as cofactor for many enzymes of cellular respiration. Iron also supports immune function. Humans get iron from red meat, egg yolk, whole wheat, fish, spinach, mustard etc. Its deficiency is the most common nutrient deficiency worldwide. Iron-deficiency causes anaemia.

Good calcium nutrition, along with low salt and high potassium intake, prevents from hypertension and kidney stones.

? Which of the major components of food is needed as the main structural componet of the body

proteins

VITAMINS

Vitamins are the chemical compounds that are required in low amounts but are essential for normal growth and metabolism. Vitamins may be divided into two groups: the fat-soluble vitamins (vitamins A, D, E, and K) and the water-soluble vitamins (vitamins B and vitamin C).

Vitamin A

Vitamin A was the first fat-soluble vitamin identified (in 1913). It combines with a protein called **opsin** to form **rhodopsin** in rod cells of the retina of eye. When vitamin A is inadequate, the lack of rhodopsin makes it difficult to see in dim light. It is also involved in cell differentiation, a process through which embryonic cells transform into mature cells with specific functions. Vitamin A also supports bone growth and immune function

Cooking or heating destroys the water soluble vitamins more readily than the fat-soluble vitamins.

Fat-soluble vitamins are much less excreted from the body as compared to water-soluble vitamins. This means that levels of water-soluble vitamins in the body can decrease more quickly, leading to vitamin deficiency.

Table 8.3: Functions, deficiencies and sources of important vitamins

Vitamin	Sources	Functions	Deficiency symptoms
Vitamin A	Leafy vegetables (spinach, carrots) Yellow fruits Fish Liver Egg, milk and butter	Vision in dim light Cell differentiation Growth Immunity	Poor growth Blindness Dry skin
Vitamin C	Citrus fruits Leafy green vegetables Beef liver	Collagen formation Healing of wounds Functioning of immune system	Scurvy: Fatigue, poor wound healing Bleeding gums & joints
Vitamin D	Fish liver oil Milk Ghee and butter Synthesized by skin	Maintenance of the concentrations of calcium and phosphorous	Rickets in children Osteomalacia in adults

Minute quantities of vitamin C are present in muscles.Since meat consists of muscles so it is not a good source of vitamin C.

Humans get vitamin A from leafy vegetables (spinach, carrots), yellow/orange fruits (mango), liver, fish, egg, milk, butter etc. Deficiency of vitamin A is the leading cause of blindness in children worldwide. One of the symptoms of vitamin-A deficiency is **night blindness**. It is a temporary condition, but if left untreated it can cause permanent blindness. Vitamin-A deficiency can also cause a condition in which hair follicles become plugged with keratin, giving dry texture to skin.

Vitamin C: (Ascorbic Acid)

Vitamin C participates in many reactions. It is needed to form collagen (a fibrous protein) that gives strength to connective tissues. Collagen is also needed for the healing of wounds. Vitamin C in white blood cells enables the immune system to function properly.

We get vitamin C from citrus fruits (e.g. oranges, lemons, and grape fruit), leafy green vegetables, beef liver etc. Deficiency of vitamin C causes connective tissue changes throughout the body. The disease known as **scurvy** results from lack of vitamin C. In this condition the synthesized collagen is unstable. Symptoms of scurvy include muscle and joint pain, swollen and bleeding gums, slow wounds healing, and dry skin.

Vitamin D

The best-known function of vitamin D is to help regulate blood levels of calcium and phosphorous. Vitamin D increases the absorption of these minerals from intestine and their deposition in bones. Vitamin D is mainly found in fish liver oil, milk, ghee, and butter etc. It is also synthesized by skin when ultraviolet (UV) radiations from the Sun are used to convert a compound into vitamin D. Long-term deficiency of vitamin D affects bones. In children, vitamin-D deficiency leads to **rickets**, a condition in which bones weaken and bow under pressure. In adults, vitamin-D deficiency causes **osteomalacia**, or "softening of bones,"increasing the risk for fractures in bones.

Practical work:

Tests for starch (iodine test); reducing sugars (Benedict's test); protein (Biuret test); and lipids (ethanol emulsion test).

The food of animals contains organic macromolecules e.g. lipids, proteins, carbohydrates and nucleic acids.

Problem:

Test a variety of food samples for the presence of starch, simple reducing sugars, proteins and lipids.

Material required: Biuret reagent, test tubes, pipettes, various items (milk, yogurt, cheese,meat, bread, table sugar, flour, corn starch, various oils and fats etc), Sudan red solution,Benedict solution, iodine solution

Problem:

Test a variety of food samples for the presence of starch, simple reducing sugars, proteins and lipids.

Material required: Biuret reagent, test tubes, pipettes, various items (milk, yogurt, cheese,meat, bread, table sugar, flour, corn starch, various oils and fats etc), Sudan red solution,Benedict solution, iodine solution

Background information:

- Testing for the presence of starch is done through iodine solution, which changes from yellowish-brown to dark purple/black.
- Testing for simple carbohydrates (reducing sugars) is done through Benedict's solution. It is a blue colored liquid that contains copper ions. When Benedict's solution and simple carbohydrates are heated, the solution changes to orange red/ brick red.
- Starch does not react positive with the Benedict's test unless they are broken down through heating.
- Table sugar (disaccharide) is a non-reducing sugar and does not react with iodine and Benedict solution.
- Testing for proteins is done through Buiret test. Buiret solution is a blue liquid that changes to purple when proteins are present and to pink in the presence of short chains of polypeptides.
- Lipids are organic compounds that can supply as much as double the amount of energy as carbohydrates or proteins. Testing for lipids can be done through Sudan red test. Sudan red is a fat-soluble dye that stains lipids red. Using Sudan red can show the amount and the location of lipids.

Procedure:

Put on safety goggles and a lab apron.

1. Iodine Test:

i. To perform the iodine test, select three clean test tubes. With a wax pencil, label the tops of the test tubes "1", "2" and "3".

- To test tube 1, add 40 drops of glucose
- To test tube 2, add 40 drops of starch
- To test tube 3, add 40 drops of water

ii. Add iodine solution to the three test tubes.

In test tube "2" a dark purple / black colour will appear which indicates a positive result for starch.

2. Benedict's Test:

i. Get the three empty test tubes. Label the tops of the test tubes "1", "2" and "3".

- To test tube 1, add 40 drops of glucose.
- To test tube 2, add 40 drops of starch
- To test tube 3, add 40 drops of water

ii. Add 10 drops of Benedict's solution to each test tube.

The solution in test tube "1" will look blue and then it will make an orange to red-brick precipitate, which indicates a positive result for reducing sugars.

3. Biuret Test:

i. Select two clean test tubes. With a wax pencil, label the tops of the test tubes "1" and "2".

- To test tube 1, add 40 drops of albumin solution (a protein)
- To test tube 2, add 40 drops of water

ii. Add 3 drops of Buiret solution to each test tube.

The positive - purple or pink color in test tube "1" indicates the presence of protein.

4. Sudan Red Test:

i. To perform the Sudan red test, select two clean test tubes. With a wax pencil, label the tops of the test tubes "1" and "2".

- To test tube 1, add 5 drops of vegetable oil
- To test tube 2, add 40 drops of water

ii. Add 3 drops of Sudan red solution to each test tube. Sudan red will stain the lipid molecules in test tube "1".

5. Dispose of your materials according to the directions from teacher

Observation: Record your observation regarding the color changes in the experimental and the control test tubes. (Figure 8.1)

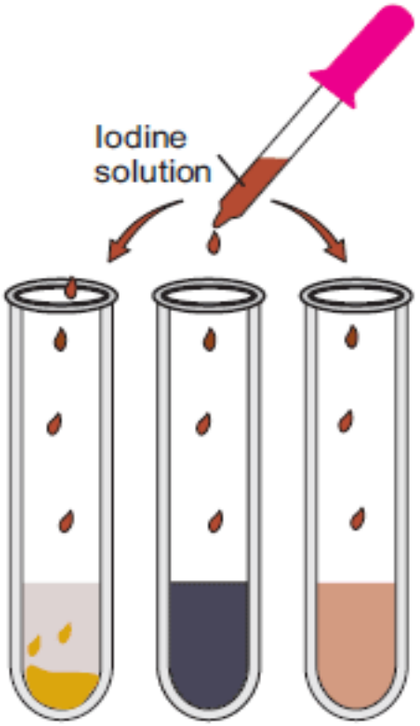
Evaluation:

I. What color changes did you observe in the presence of glucose, starch, protein, and lipids.

ii. Which test tubes contain standards that you could use for comparing tests on unknown substances?

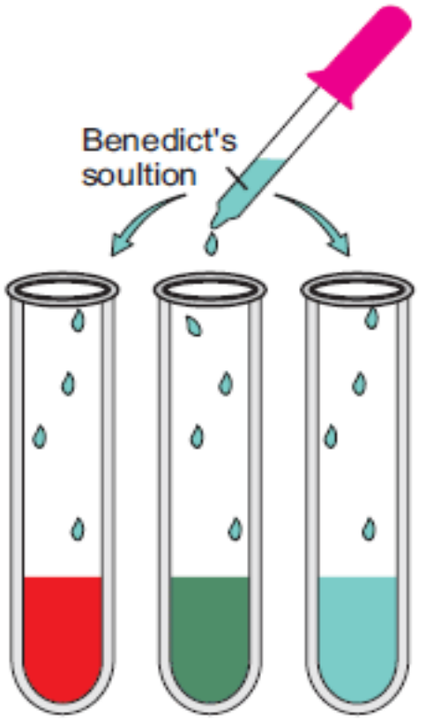
iii. What are the controls in this lab?

iv. You are asked to analyze and compare a food substance with standards for organic compounds. You observe a positive response with iodine solution and Biuret solution. What can you conclude about this food?



TEST FOR STARCH

1: No results with glucose
2: Dark purple/black colour with starch
3: No result with water

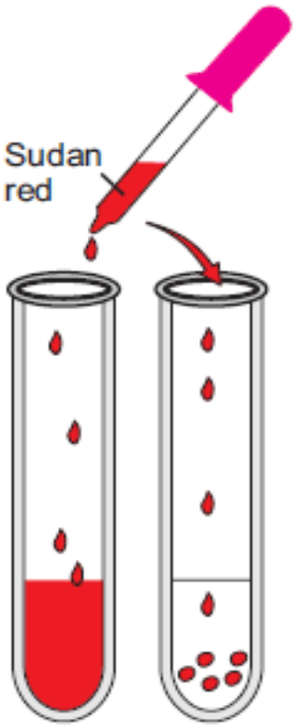


TEST FOR GLUCOSE

1: Red-brick colour with glucose
2: Starch does not make red colour
3: No result with water

TEST FOR PROTEINS

1: Purple colour with egg albumin (protein)
2: No result with water



TEST FOR LIPIDS

1: Red stain with vegetable oil (lipids)
2: No result with water

Analyzing and Interpreting

Investigate your daily food intake and present it in a tabulated data form (in terms of nutrients and calories).

8.2.1 EFFECTS OF WATER AND DIETARY FIBRE

Strictly speaking, water and dietary fibre are not considered as nutrients, but they do play important role in life.

WATER

Approximately 60% of the adult human body is composed of water. Nearly all life sustaining chemical reactions require an aqueous (watery) environment. Water also functions as the environment in which water-soluble foodstuff is absorbed in the intestines and the waste products are eliminated in urine. Another essential role of water is to maintain body temperature through evaporation, as in sweating. Severe dehydration may result in cardiovascular problems. The estimated water requirement of an average adult is two litres per day. Important sources of daily water intake are natural water, milk, juicy fruits and vegetables.

DIETARY FIBRE

Dietary fibre (also known as “roughage”) is the part of human food that is indigestible. It is found only in plant foods and it moves undigested through stomach and small intestine and into colon. The **insoluble dietary fibre** travels quickly through small intestines. Its sources are wheat bran, cereals and skins of many fruits and vegetables. The **soluble dietary fibre** breaks down as it passes through alimentary canal. Its sources are oats, beans, barley, and many fruits and vegetables.

Fibre prevents and relieves constipation by stimulating the contraction of intestinal muscles. Avoiding constipation reduces the risk of many other diseases. Soluble fibre helps in lowering blood cholesterol and sugar levels. Insoluble fibre speeds up the movement of carcinogens (cancer causing agents) from intestine.

Fibre supplements (such as Ispaghol husk) should be used only with a physician’s recommendations. Taken properly, these supplements may help in constipation and in lowering cholesterol levels.

8.2.2 BALANCED DIET

Humans require various types of nutrients in order to keep them healthy and fit. These nutrients should be taken appropriately in diet. A balanced diet may be defined as the one which contains all the essential nutrients in correct proportion for the normal growth and development of body. A balanced diet is related to one's age, gender and activity. It should include different types of nutrients and should be according to the energy requirements. The following chart shows some of the common foods, taken in Pakistan, and the percentage of carbohydrates, lipids and proteins in each of them.

Common foods and the percentage of nutrients

Food	Carbohydrates	Lipids	Proteins
Bread (Roti)	52%	03%	09%
Rice	23%	0.1%	2.2%
Potato	19%	0.1%	02%
Apple	12.8%	0.5%	0.3%
Eggs	0.7%	12%	13%
Milk	04%	04%	03%
Butter	0.4%	81%	0.6%
Chicken	0	11%	20%

Relation of balanced diet with age, gender and activity

During growth period of the body, there is higher metabolic rate in body cells and so body needs a balanced diet that contains more energy. Adults need less proteins per kilogram body weights, but a growing boy or girl needs more proteins per kilogram weight. Similarly, children need more calcium and iron for their growing bones and red blood cells respectively.

"Let thy food be thy medicine":
Hippocrates

Gender has an impact on the requirements of a balanced diet. Women have comparatively less metabolic rate than men of the same age and weight. So men need a balanced diet that provides comparatively more energy.

Different people have different lifestyles and varied nature of work. A man with sedentary habits does not require as much energy as the man who is on his feet for most of the day.

Table 8.4: Estimated energy requirements (in Kilocalories) according to age, gender and activity

Gender	Age (years)	Activity Level		
		Sedentary	Moderately active	Active
Child Male/ Female	2-3	1,000	1,000-1,400	1,000-1,400
Female	4-8	1,200	1,400-1,600	1,400-1,800
	9-13	1,600	1,600-2,000	1,800-2,200
	14-18	1,800	2,000	2,400
	19-30	2,000	2,000-2,200	2,400
	31-50	1,800	2,000	2,200
	50+	1,600	1,800	2,000-2,200
Male	4-8	1,400	1,400-1,600	1,600-2,000
	9-13	1,800	1,800-2,200	2,000-2,600
	14-18	2,200	2,400-2,800	2,800-3,200
	19-30	2,400	2,600-2,800	3,000
	31-50	2,200	2,400-2,600	2,800-3,000
	50+	2,000	2,200-2,400	2,400-2,800

Analyzing and Interpreting:
What do we eat?
Record everything we eat and drink daily in a chart like this and calculate the amount of energy got from carbohydrates, lipids and proteins. Compare the results with the energy requirements given in Table 8.4.

Time	Sun	Mon	Tues	Wed	Thur	Fri	Sat
Breakfast							
Mid-morning							
Lunch							
Mid-afternoon							
Tea							
Dinner							
Extra							

?

A physician advises us; " you should start taking whole wheat bread instead of enriched white bread." The purpose of this advice is that we should take more------(component of food)

Dietary fibre

8.2.3 PROBLEMS RELATED TO NUTRITION (MALNUTRITION)

Problems related to nutrition are grouped as malnutrition. It often refers to undernutrition resulting from inadequate consumption, poor absorption, or excessive loss of nutrients. Malnutrition also includes over-nutrition, resulting from overeating or excessive intake of specific nutrients.

Most commonly, malnourished people either do not have enough calories in their diet, or eat a diet that lacks protein, vitamins, or trace minerals. Malnutrition weakens the immune system, impairs physical and mental health, slows thinking, stunts growth and affects fetal development.

Common forms of malnutrition include protein-energy malnutrition (PEM), mineral deficiency disease (MDD), and over-intake of nutrients (OIN).

According to the United Nations Children's Fund (UNICEF), malnutrition contributes to the deaths of more than 6 million children (under age five) each year.

a- Protein-Energy Malnutrition

Protein-energy malnutrition means inadequate availability or absorption of energy and proteins in the body. It is the leading cause of death in children in developing countries. It may lead to diseases such as Kwashiorkor and marasmus.

1. Kwashiorkor is due to protein deficiency at the age of about 12 months when breast feeding is discontinued. It can also develop at any time during a child's growing years. Children may grow to normal height but are abnormally thin.

2. Marasmus usually develops between the ages of six months and one year. Patients lose all their body fat and muscle strength, and acquire a skeletal appearance. Children with marasmus show poor growth and look small for their age

b- Mineral Deficiency Diseases

Diseases resulting from the deficiency of a mineral are relatively rare among humans. Some examples are given below;

1. Goiter is a condition caused by an insufficient amount of iodine in diet. Iodine is used by thyroid gland to produce hormones that control the body's normal functioning and growth. If sufficient iodine is not available in a person's diet, thyroid gland becomes enlarged and it results in swelling in neck. This condition is known as goitre.

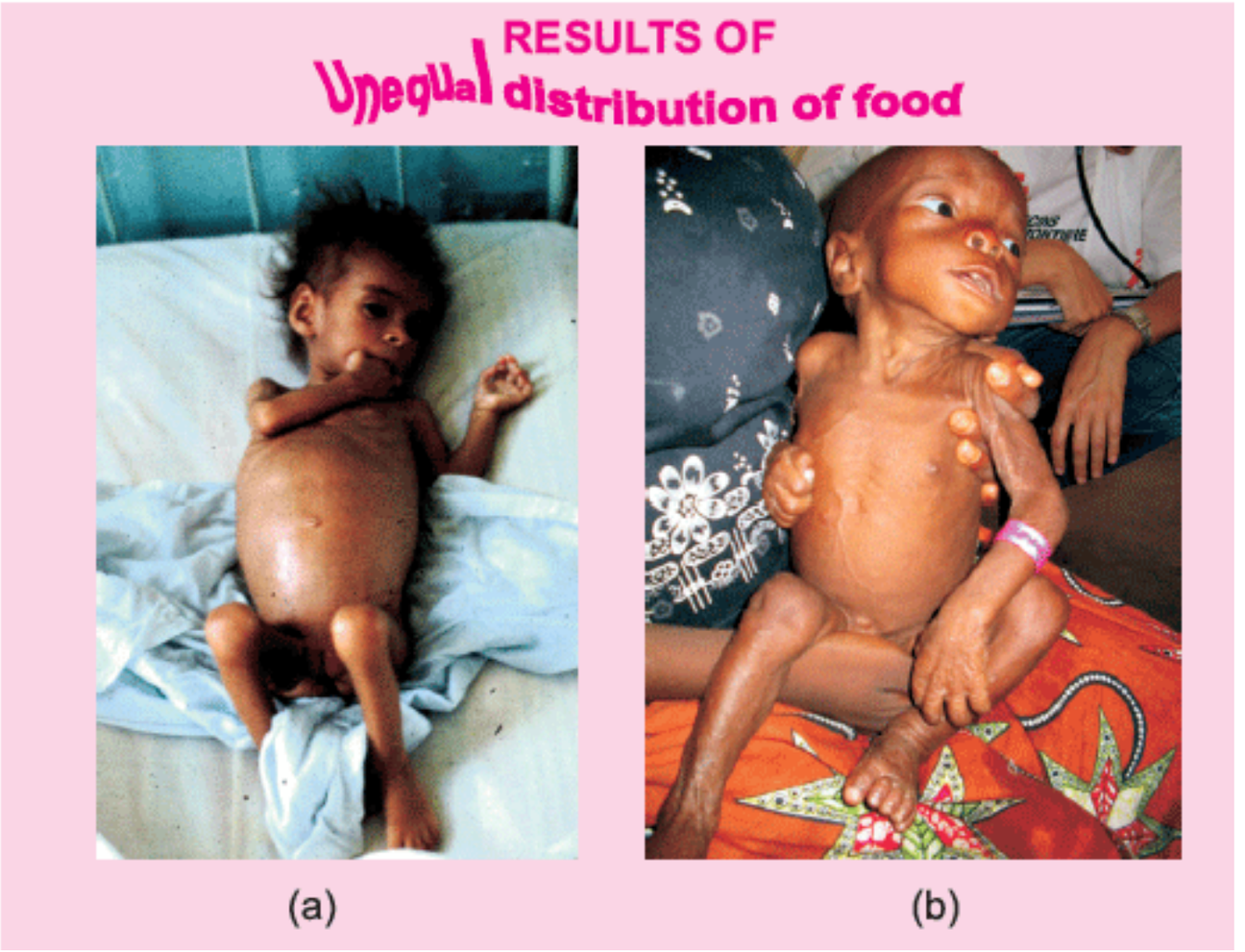


Figure 8.2: Children suffering from (a) Kawshiorkar, (b) Marasmus

2. Anemia is the most common of all mineral deficiency diseases. The term anemia literally means "a lack of blood." It is caused when the number of red blood cells is reduced than the normal. Haemoglobin molecule contains a single atom of iron at its centre. If body fails to receive sufficient amounts of iron, adequate number of haemoglobin molecules are not formed. In this case, there are not enough functioning of red blood cells. The patient is weak and there is shortage of oxygen supply to body's cells.

c- Over-Intake of Nutrients

Over-intake of nutrients (OIN) is a form of malnutrition in which more nutrients are taken than the amount required for normal growth, development and metabolism. The effects of over-intake of nutrients are usually intensified when there is reduction in daily physical activity (decline in energy expenditure).

Over-intake of nutrients causes a number of health problems. For example high intake of carbohydrates and fats leads to obesity, diabetes and cardiovascular problems. Similarly, high dose of vitamin A causes loss of appetite and liver problems. Excess intake of vitamin D can lead to deposition of calcium in various tissues.

EFFECTS OF MALNUTRITION

An extended period of malnutrition can lead to problems like starvation, heart diseases, constipation and obesity.

Starvation is a severe reduction in nutrient and energy intake and is the most horrible effect of malnutrition. In humans, prolonged starvation causes permanent organ damage and eventually results in death.

Heart diseases are also increasing on the global level. One of the causes of heart diseases is malnutrition. People who take unbalanced diet (high in fats) are more exposed to heart problems.

Constipation: Malnutrition often leads to situations where people cannot schedule their meals. This irregularity results in many health problems including constipation.

Obesity means becoming over-weight and it may also be due to malnutrition. People who take food that contains energy more than their requirement and do very little physical work can become obese. Obesity is known as the mother-disease and may lead to heart problems, hypertension, diabetes etc

According to the Food and Agriculture Organization of the United Nations, more than 25,000 people die of starvation every day. On average, every five seconds a child dies from starvation.

The World Health Organization (WHO)estimates that, within the next few years, diseases due to malnutrition will become the principal global causes of mortality.

FAMINE - THE MAJOR CAUSE OF MALNUTRITION

Famine means the lack of enough food to feed all people living in an area. The most terrible famines of the twentieth century are the Ethiopian famine (1983-85) and the North Korean famine (1990s). The major causes of famine are unequal distribution of food, drought, flooding or increasing population.

Unequal distribution of food

The achievements in science have enabled human beings to produce better food in terms of quality and quantity. Today the agricultural practices produce more than enough food that can be supplied to every one on the Earth. But due to political and administrative problems, food is not equally distributed to different regions of the world. The result is that there is always surplus food in countries like America, UK, and Canada etc. and at the same time people have nothing to eat in countries like Ethiopia, Somalia etc.

Famines may also be due to the problems created by humans e.g. wars and wrong economic policies

The World Food Program (WFP) is the food aid branch of the United Nations. It is the world's largest agency providing food to more than 90 million people in 80 countries.

Drought

A drought is a period of time when there is not enough water to support agricultural and human needs. Drought is usually due to a long period of below-normal rainfall. Droughts decrease or even stop the crop yields and it results in famine.

Analyzing and Interpreting

In the comparative chart of daily diet and balanced diet requirements, mention the visible symptoms caused by nutrient deficiencies.

Flooding

It occurs due to more than normal rainfall or due to weak water distribution system. Rivers and canals overflow their banks and destroy the soil quality of agricultural lands. It becomes impossible to grow crops immediately after flooding. In this way, flooding may be a reason for short-term famine.

Increasing population

In spite of the global increase in food production, millions of human beings are undernourished. In the over-populated regions of world, large populations overuse natural resources to grow maximum food in order to meet the problems of food shortage. It leads to dry and infertile lands and depletion of resources. In such situations crops can no longer be grown and famines result.

8.3 DIGESTION IN HUMAN

Our cells require oxygen, water, salts, amino acids, simple sugars, fatty acids, and vitamins. These can cross cell membranes to enter cells. Amino acids, simple sugars and fatty acids are rare in our environment. Such substances are usually parts of larger molecules like proteins, polysaccharides and lipids, which cannot cross the membranes. There is a need of converting such large and non-diffusible molecules into smaller and diffusible molecules (that can cross the membranes). This is achieved through the process of digestion.

After digestion, the diffusible molecules from the digestive system reach body cells through blood. Here, they are assimilated (to get energy and to synthesize our own structures). At the same time, the indigestible part of food is eliminated out of body through the process of defecation. In simple words, the nutrition in humans comprises of the following phases.

1- Ingestion	The process of taking in food.
2- Digestion	The process of breaking up complex substances into simpler substances.
3- Absorption	Diffusion of digested food into blood and lymph.
4- Assimilation	Conversion or incorporation of absorbed simple food into the complex substances constituting the body.
5- Defecation	Elimination of undigested food from the body.

We eat mutton and digest its proteins into amino acids. These amino acids are used to synthesize our proteins.

8.3.1 HUMAN ALIMENTARY CANAL

The digestive system of human consists of a long tube that extends from mouth to anus.This tube is called alimentary canal. Its main sections are oral cavity, pharynx,oesophagus, stomach, small intestines and large intestine. In addition, there are many glands associated with alimentary canal. These are in the form of three pairs of salivary glands, a pancreas and a liver.

We will go through the structure and functioning of digestive system by assuming how a bite of bread 'roti' taken with some dish (like mutton) is digested and how small molecules like amino acids, simple sugars, fatty acids, vitamins, salts and water are provided to cells.

Oral cavity - Selection, grinding, partial digestion

Oral cavity is the space behind mouth and has many important functions in the whole process of digestion. **Food selection** is one of them. When food enters oral cavity, it is tasted and felt. If the taste of mutton suggests that it is old, we reject it. If teeth or tongue detect some hard object, such as dirt, we also reject that bite. The senses of smell and vision also help oral cavity in the selection of food.

The second function of oral cavity is the grinding of food by teeth. It is known as chewing or **mastication**. This is useful because oesophagus can pass only small pieces. Enzymes also cannot act on large pieces of food. They require small pieces with large surface areas to attack.

The third and fourth function of oral cavity are **lubrication** and **chemical digestion** of food. The chewing process stimulates the three pairs of salivary glands (under tongue, behind jaws, and in front of ears) to release a juice called **saliva** in oral cavity. Saliva adds water and mucous to food which act as lubricant to ease the passage of food through oesophagus. Saliva also contains an enzyme **salivary amylase**, which helps in the semi-digestion of starch.

During the processes of chewing, lubrication and semi-digestion, the pieces of food are rolled up by the tongue into small, slippery, spherical mass called bolus. We swallow **bolus** and push it in oesophagus through pharynx.

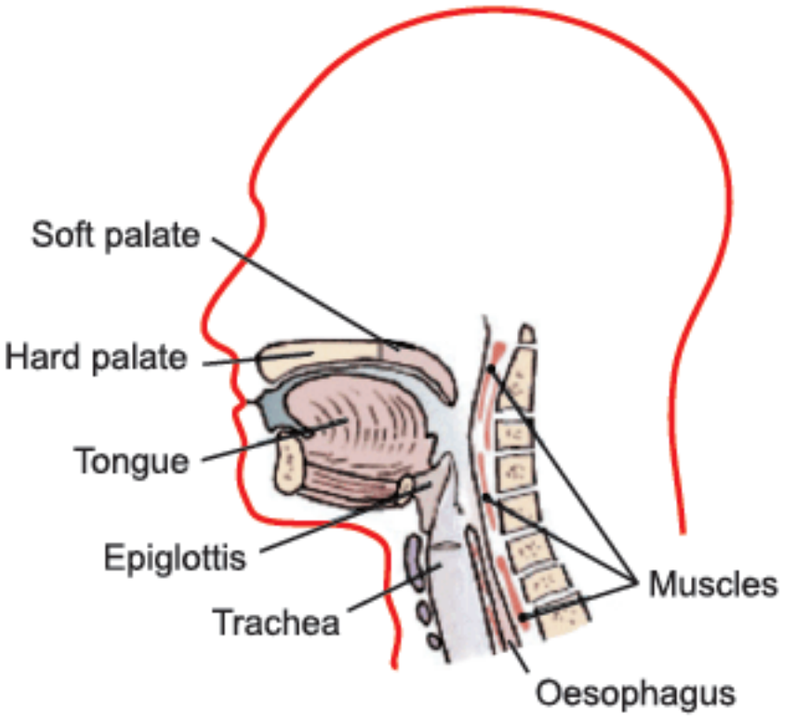


Figure 8.4: Steps in swallowing

Pharynx and Oesophagus - Swallowing and Peristalsis

During swallowing, bolus is pushed to the back of mouth by tongue. When tongue pushes bolus, the soft palate also moves upward and to rear. In this way, the opening of nasal cavity is closed. When swallowed, the bolus passes pharynx to enter oesophagus. Pharynx has adaptations to prevent the entry of bolus particles in trachea (wind pipe to lungs).

In adult human, oesophagus is about 25 cm long.

During swallowing, larynx (the top of trachea) moves upward and forces the epiglottis (a flap of cartilage) into horizontal position. Thus glottis i.e. the opening of trachea is closed. The beginning of swallowing action is voluntary, but once food reaches the back of mouth, swallowing becomes automatic.

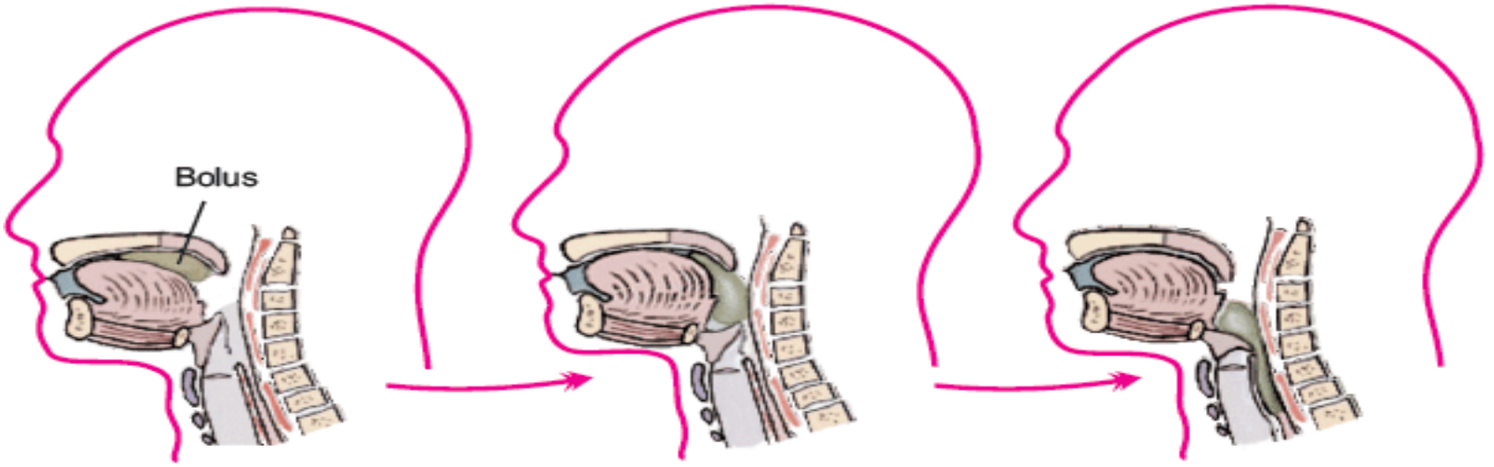


Figure 8.4: Steps in swallowing

After being swallowed, food enters the tube called oesophagus, which connects pharynx to stomach. Neither pharynx nor oesophagus contributes to digestion and the previous digestive actions of saliva continue.

Peristalsis moves food from oral cavity to rectum. **Peristalsis** is defined as the waves of contraction and relaxation in the smooth muscles of alimentary canal walls.

? If due to any reason, the direction of peristalsis reverses,what would be the result?

Vomiting

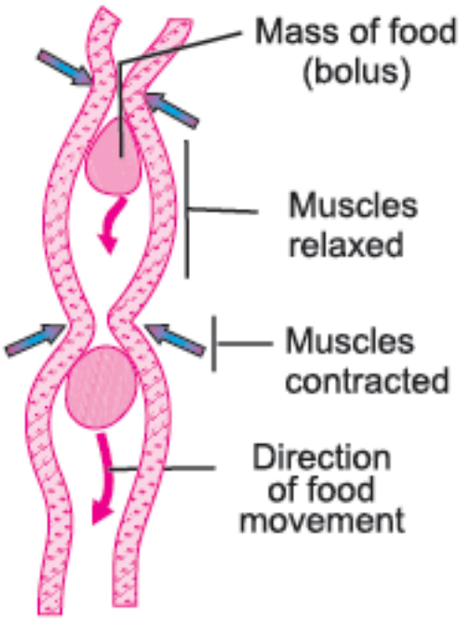
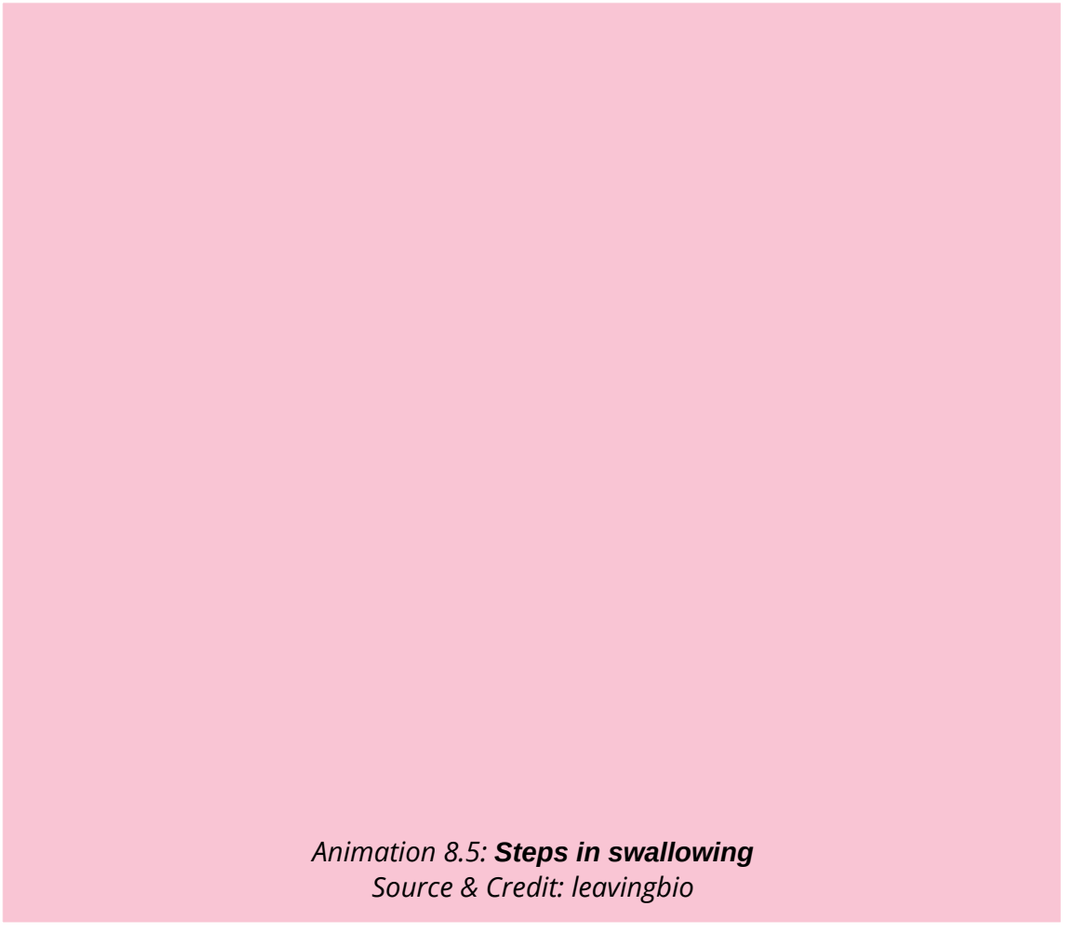


Figure 8.5: Peristalsis



Animation 8.5: ***Steps in swallowing***
Source & Credit: leavingbio

Animation 8.6: ***Steps in swallowing***
Source & Credit: sciencealert

Stomach - Digestion, churning and melting

Stomach is a dilated part of alimentary canal. It is J-shaped, located in the left of abdomen, just beneath diaphragm. Stomach has two main portions. **Cardiac portion** of stomach is present immediately after oesophagus and **pyloric portion** is located beneath cardiac portion. Stomach has two sphincters (openings which are guarded by muscles). **Cardiac sphincter** is between stomach and oesophagus while **pyloric sphincter** is between stomach and small intestine. Bolus enters stomach from oesophagus through cardiac sphincter.

When food enters stomach, the **gastric glands** found in the stomach wall are stimulated to secrete **gastric juice.** Gastric juice is composed chiefly of mucous, hydrochloric acid, and a protein-digesting enzyme **pepsinogen**. Hydrochloric acid converts the inactive enzyme pepsinogen into its active form i.e. **pepsin.** HCl also kills microorganisms present in food. Pepsin partially digests the protein portion of food (bulk of mutton) into polypeptides and shorter peptide chains.

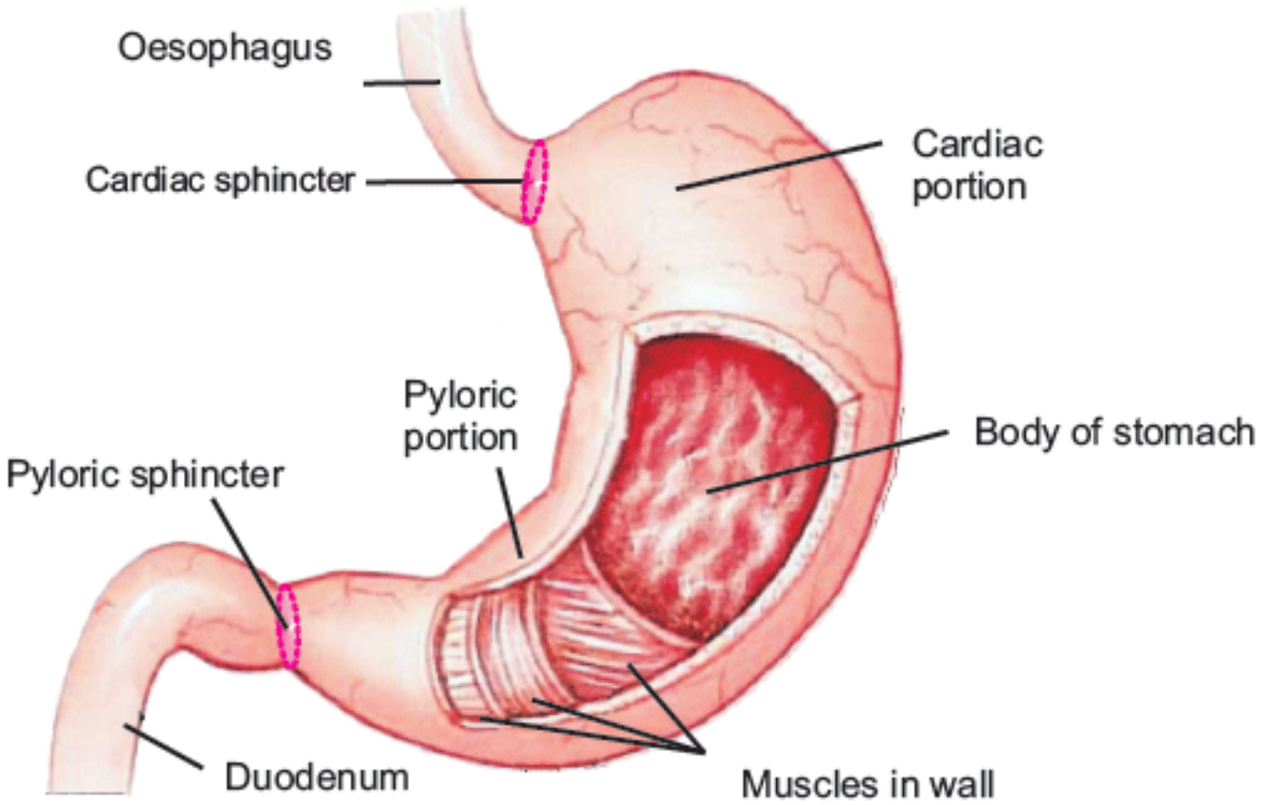


Figure 8.6: Structure of stomach

Animation 8.7: Stomach - Digestion
Source & Credit: gifsoup

An interesting problem is raised here. Pepsin is a powerful protein-digesting enzyme. Why does not it digest the stomach walls, which are mostly proteins? We saw that pepsin is not released in its active form. Rather it is secreted as inactive pepsinogen, which requires HCl for activation. The mucous of gastric juice forms a thick coating over the inner walls of stomach and neutralizes the HCl there. It makes pepsinogen difficult to be activated and to attack stomach walls.

In stomach, food is further broken apart through a process of **churning**. The walls of stomach contract and relax and these movements help in thorough mixing of gastric juice and food. The churning action also produces heat which helps to melt the lipid content of food.

The starch in our bite of bread and the protein in mutton have been partially digested and the food has been converted to a soup-like mixture called **chyme.** After it, the pyloric sphincter allows a little mass of chyme to enter duodenum.

Some quantity of gastric juice is always present in stomach. When bite is in oral cavity, brain sends messages to stomach walls to secrete some gastric juice. When food reaches stomach, more gastric juice is secreted according to needs. If there is little or no protein in food, stomach does not secrete more gastric juice. On the other hand, if more proteins are present in food, abundant gastric juice is secreted. In this case, already present gastric juice begins the digestion of huge proteins into peptides. These peptides stimulate some cells of stomach walls to release a hormone called **gastrin.** This hormone enters blood and is distributed to all parts of body. In stomach, it has specific effect and stimulates the gastric glands to secrete more gastric juice.

Bile also contains pigments that are the by-products of red blood cell destruction in liver; these bile pigments are eliminated from body with faeces.

Small Intestine - Complete digestion and absorption

Duodenum comprises of the first 10 inches (25 cm) of small intestine and it is the part of alimentary canal where most of the digestive process occurs. Here, food is further mixed with 3 different secretions:

1. **Bile** from liver helps in the digestion of lipids through **emulsification** i.e. by keeping the lipid droplets separate from one another.
2. **Pancreatic juice** from pancreas contains enzymes **trypsin**, **pancreatic amylase** and **lipase** which digest proteins, carbohydrates and lipids respectively.
3. **Intestinal juice** from intestine walls contains many enzymes for the complete digestion of all kinds of food.

Next to the duodenum is 2.4 meters long **jejunum**. It is concerned with the rest of the digestion of proteins, carbohydrates and lipids of our bite.

Last 3.5 meters long part of small intestine is **ileum**. It is concerned with the absorption of digested food. There are circular folds in the inner wall of ileum. These folds have numerous finger-like projections called **villi** (singular: villus). **Villi** increase the surface area of the inner walls and it helps a lot in the absorption of digested food.

Each villus is richly supplied with blood **capillaries** and a vessel of lymphatic system, called **lacteal**. The walls of villus are only single-cell thick. The digested molecules i.e. simple sugars and amino acids are absorbed from intestine into the blood capillaries present in villi.Blood carries them away from small intestine via the hepatic portal vein and goes to liver for filtering. Here, toxins are removed and extra food is stored. From liver, the required food molecules go towards heart via the hepatic vein. Fatty acids and glycerol, present in small intestine, are absorbed into the lacteal of villus. Lacteal carries them to the main lymphatic duct, from where they enter in bloodstream.

A non-functional finger-like process called **appendix** arises from the blind end of caecum. Inflammation of appendix due to infection causes severe pain. The infected appendix must be removed surgically otherwise it may burst and inflammation may spread in abdomen.

Large intestine - Absorption of water and defecation

After the digested products of our bite have been absorbed in blood, the remaining mass enters large intestine. It has 3 parts; caecum (or pouch that forms the T-junction with small intestine), colon and rectum. From colon, water is absorbed into blood.As water is absorbed, the solid remains of food are called **faeces**.

Faeces mainly consists of the undigested material. Large number of bacteria,sloughed off cells of alimentary canal, bile pigments and water are also part of faeces.

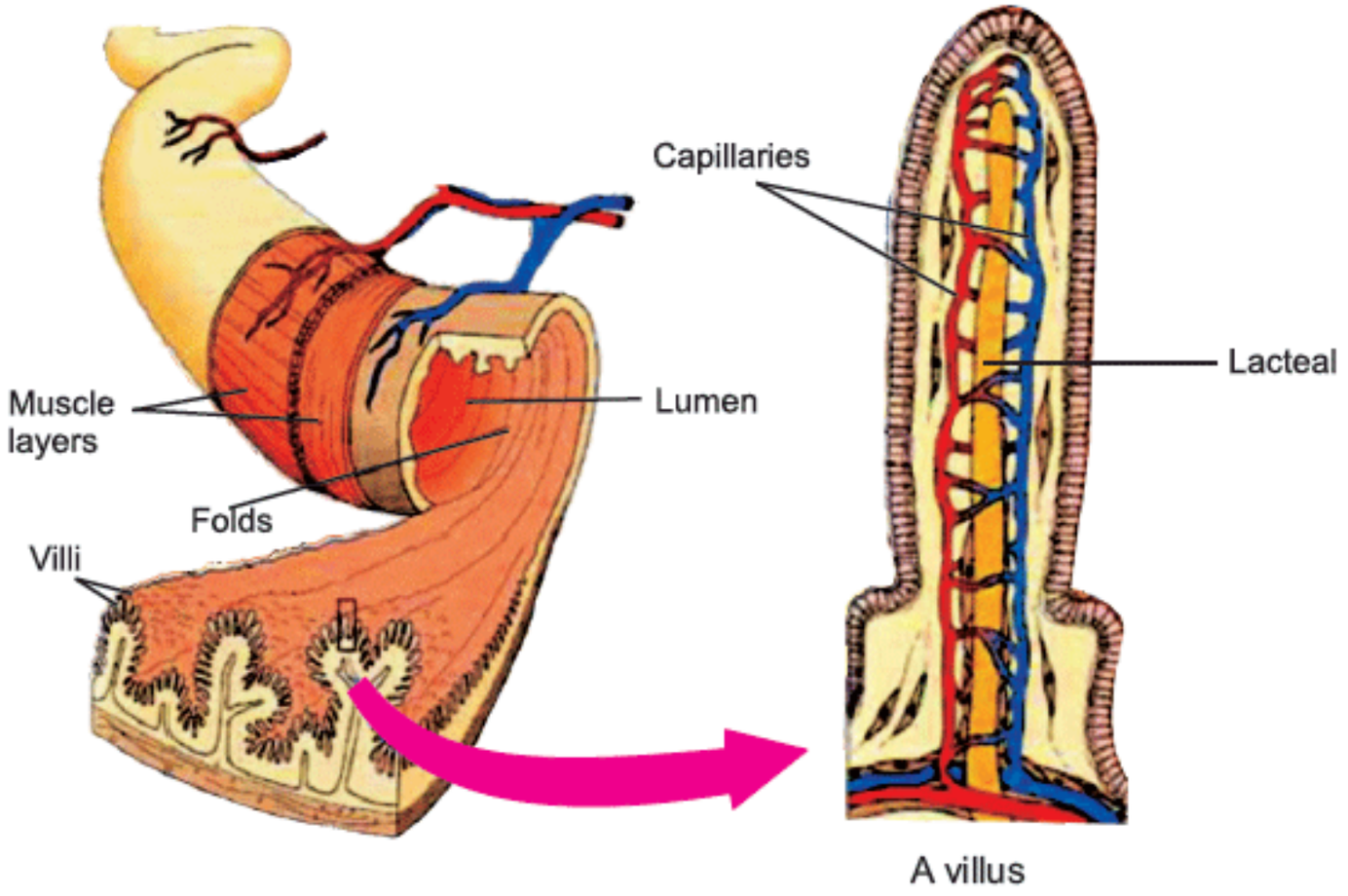


Figure 8.7: Folds and villi in small intestine

Faeces are temporarily stored in rectum, which opens out through anus. Under normal conditions when the rectum is filled up with faeces, it gives rise to a reflex and anus is opened for defecation. This reflex is consciously inhibited in adults but in infants it is controlled involuntarily. During growth, child learns to bring this reflex under voluntary control.

? Functions of large intestine include the elimination of faeces and .....

Absorption of water and salts

8.3.2 ROLE OF LIVER

Liver is the largest gland of body. It is multi-lobed and dark reddish in appearance. It lies beneath the diaphragm on the right side of abdomen. In an adult human, it weighs about 1.5 kg and is the size of a football. A pear-shaped greenish yellow sac i.e. **gallbladder** lies along the right lobe of liver on ventral side.

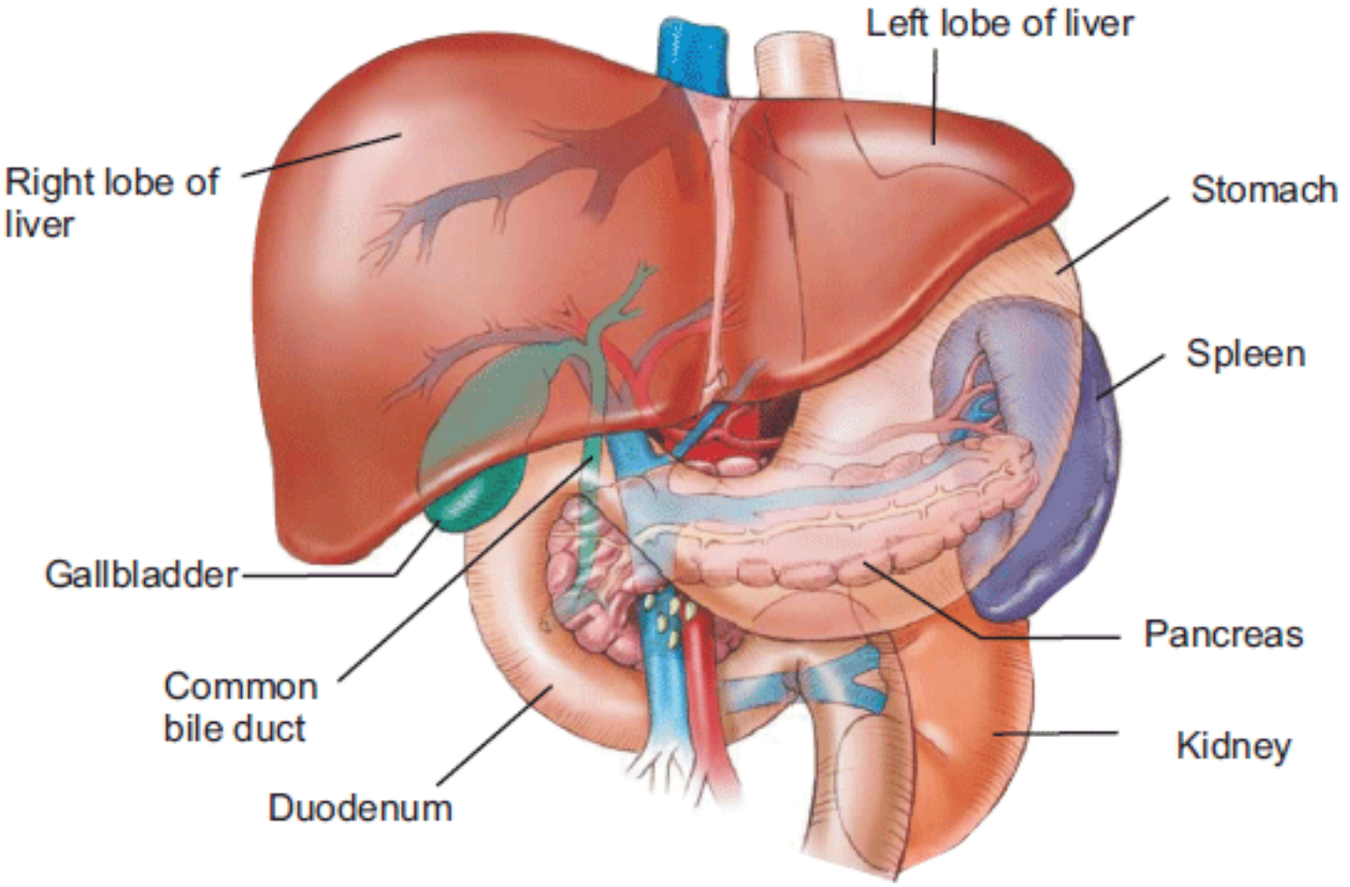


Figure 8.8: Liver and associated organs

Many bacteria live in colon.They produce vitamin K, which is necessary for the coagulation of blood.

Animation 8.8: ***Liver***
Source & Credit: wikipedia

Animation 8.9: ***Liver Rotating***
Source & Credit: emaze

Liver secretes bile, which is stored in gallbladder. When gallbladder contracts, bile is released into duodenum through **common bile duct**. Bile has no enzymes but contains bile salts for the **emulsification** of lipids. It helps the lipid-digesting enzymes to attack on lipids. Besides digestion, liver carries out a number of other functions, some of which are summarized here;

- Removes amino groups from amino acids **(de-amination).**
- Converts ammonia to a less toxic form i.e **urea.**
- Destroys the old red blood cells.
- Manufactures blood clotting proteins called **fibrinogen.**
- Converts glucose into glycogen and, when required, breaks glycogen into glucose.
- Converts carbohydrates and proteins into lipids and produces cholesterol.
- Produces heat to maintain body temperature.
- Stores fat-soluble vitamins (A, D, E, and K) and mineral ions, such as iron.

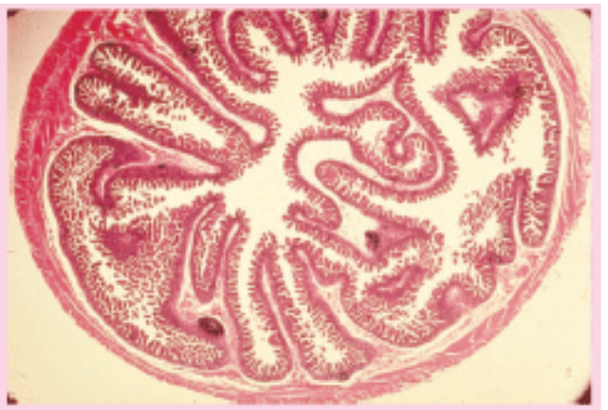
?

In which part of the alimentary canal,the maximum absorption of nutrients occurs?

small intestine

There is a growing concern about the harmful effects of carbonated soft drinks. They are very acidic and make our bodies poor in oxygen. They contain phosphoric acid which dissolves calcium out of the bones. This results in bones weakening. The caffeine present in colas increases the heart rate and raises blood pressure.

Analyzing and Interpreting:
Identify the villus, epithelium, capillary network and lacteal while examining the transverse sections of small intestine (like the one given on right).



?

Write in correct sequence the parts of the alimentary canal where digestion of proteins,lipids and carbohydrates begins.

Stomach,small intestine,oral cavity

8.4 DISORDERS OF GUT

Diarrhoea, constipation and ulcer are the most common disorders of the gut that affect a number of people in Pakistan.

DIARRHOEA

Diarrhoea is a condition in which the sufferer has frequent watery, loose bowel movements. This condition may be accompanied by abdominal pain, nausea and vomiting. It occurs when required water is not absorbed in blood from colon.

The main causes of diarrhoea include lack of adequate safe water. Diarrhoea is also caused by viral or bacterial infections of large intestine. If sufficient food and water is available, the patient of diarrhoea recovers in a few days.

However, for malnourished individuals diarrhoea can lead to severe dehydration and can become life-threatening. The treatment for diarrhoea involves consuming adequate amounts of water (to replace the loss), preferably mixed with essential salts and some amount of nutrients. Antibiotics may be required if diarrhoea is due to bacterial infection. Preventions of diarrhoea include taking clean water and essential salts, eating regularly and taking hygienic measures.

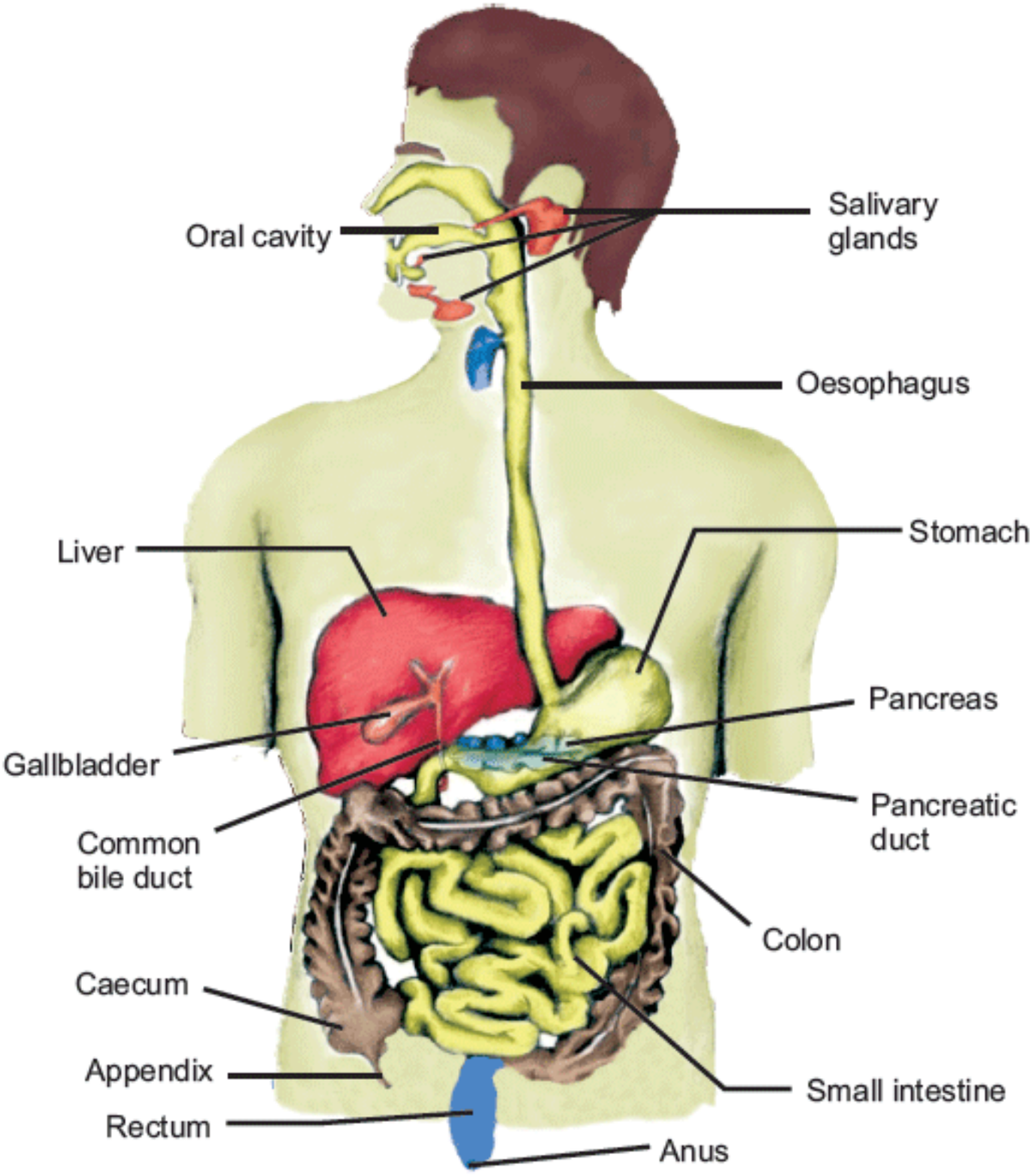


Figure 8.9: Human digestive system

Animation 8.10: Human Digestive System
Source & Credit: wikia

Animation 8.11: Human Digestive System
Source & Credit: makeagif

CONSTIPATION

Constipation is a condition where a person experiences hard faeces that are difficult to eliminate. The main causes of constipation include excessive absorption of water through colon, insufficient intake of dietary fibre, dehydration, use of medicines (e.g. those containing iron, calcium, and aluminium) and tumours in rectum or anus. Treatment of constipation is with a change in dietary and exercise habits. The medicines called laxatives (e.g. paraffin) are used for treatment. Constipation is usually easier to prevent than to treat. One should take the required quantities of water and dietary fibres.

ULCER

Ulcer (peptic ulcer) is a sore in the inner wall of gut (in oesophagus, duodenum or stomach). In ulcer, the acidic gastric juice gradually breaks down the tissue of the inner wall. Ulcer of stomach is called gastric ulcer. The causes of ulcer include excess acid, infection, long term use of anti-inflammatory medicines (including aspirin), smoking, drinking coffee, colas, and eating spicy foods.

The signs and symptoms of ulcer include abdominal burning after meals or at midnight. Severe ulcers may cause abdominal pain, rush of saliva after an episode of regurgitation, nausea, loss of appetite and weight loss. Ulcer is treated with medicines, which neutralize the acidic affects of gastric juice. Spicy, acidic foods and smoking should be avoided as preventive measures.

UNDERSTANDING THE CONCEPTS

1. What are the effects of the lack of nitrate and magnesium ions on plant growth?
2. How are inorganic and organic fertilizers important in agriculture?
3. Draw a table that can show sources, energy values and functions of carbohydrates, proteins and fats.
4. How are vitamins A, C and D important in our diets?
5. Which foods contain calcium and iron and what role these minerals play in our bodies?
6. Why are water and dietary fibres considered important in our diets?
7. Define balanced diet. How would you relate it with age, gender and activity?
8. Describe how protein energy malnutrition, mineral deficiency diseases and over intake of nutrients are the major forms of malnutrition?
9. How would you advocate the unequal distribution of food as the major factor that contribut to famine.

10. Describe structures and functions of the main regions of alimentary canal.
11. Describe swallowing and peristalsis.
12. Briefly give the signs and symptoms, causes, treatments and prevention of diarrhoea, constipation, and ulcer.

SHORT QUESTIONS

1. What are the health risks if we take more saturated fatty acids in our diet?
2. How can the deficiency of vitamin A cause blindness?
3. How will you differentiate between bolus and chyme?
4. Which sphincters play role in the movement of food in and out of stomach?
5. Stomach is an organ of the digestive system, but it also secretes a hormone. What hormone is it and what function it performs?

ACTIVITIES

- Perform tests for starch, reducing sugars, proteins and fats.

INITIATING AND PLANNING

1. Investigate and present in a tabulated data from your daily food intake (in terms of nutrients and calories).
2. Identify the villus; epithelium, capillary network and lacteal while examining the transverse section of small intestine.

TERMS TO KNOW

Amylase	Gastrin	Pharynx
Anemia	Goiter	Protein energy malnutrition
Appendix	Ileum	Pyloric sphincter
Assimilation	Intestinal juice	Rectum
Balanced diet	Jejunum	Saliva
Bolus	Kwashiorkor	Starvation
Cardiac sphincter	Lacteal	Stomach
Chyme	Laxatives	Swallowing
Colon	Lipase	Trace minerals
Constipation	Liver	Trypsin
Diarrhoea	Malnutrition	Ulcer
Dietary fibre	Marasmus	Villus
Digestion	Nutrition	Vitamins
Duodenum	Oesphagus	
Emulsification	Oral cavity	
Epiglottis	Pancreas	
Famine	Pancreatic juice	
Fat soluble vitamins	Pepsin	
Fertilizer	Peristalsis	
Gastric juice		

SCIENCE, TECHNOLOGY AND SOCIETY

1. Explain why farmers use chemical fertilizers for better growth of their plants.
2. Describe ways in which research about nutrition has brought about improvements in human health (e.g., development of nutritional supplements, and diets based on the needs of age, gender and activity).
3. Exemplify the societies suffering from famine due to unequal distribution of food and due to over-population.
4. Explain how the customary food habits contribute to digestive tract disorders (e.g. diarrhoea, constipation).

ON-LINE LEARNING

1. nutrition.about.com/od/foodpyramid/
2. www.enchantedlearning.com/subjects/anatomy/digestive/
3. kitses.com/animation/swfs/digestion.swf
4. healthresources.caremark.com/topic/digestivesystem

CHAPTER

9 Transport

Animation 9.1: Mineral uptake
Source & Credit: Plant transport system

We know that life of organisms is the product of complex metabolic processes occurring in them. In order to run their metabolism, cells need some materials from environment and also need to dispose some materials into environment. For this purpose, materials are transported to and from cells.

One method for the movement of molecules is diffusion but it alone cannot fulfill the needs. It takes much time for materials in solution to diffuse even a few inches. For the molecules of materials, diffusion can work only in unicellular and simple multicellular organisms, because every corner of their body is in close and direct contact with environment. In complex multicellular bodies, cells are far apart from environment and such bodies need a comprehensive system for the transport of materials.

9.1 TRANSPORT IN PLANTS

Water is vital to plant life. It is necessary not just for photosynthesis and turgor, but much of the cellular activities occur in the presence of water molecules. Internal temperature of plant body is also regulated by water. Land plants get water and minerals from soil. After absorption by roots, water and minerals have to be transported to the aerial parts of body. Similarly food is manufactured in leaves (by photosynthesis). This food is transported to other parts of body for utilization and storage.

Recalling:

Cells are the primary sites for metabolic processes. That is why they are regarded as the units of life.

Animation 9.2: Transport in plant
Source & Credit: ontrack-media

All land plants (except mosses and liverworts), have developed complex vascular tissues (xylem and phloem) that move water and food throughout plant body.

Recalling

Xylem tissue is responsible for the transport of water and dissolved substances from roots to aerial parts. It consists of vessel elements and tracheids. Phloem tissue is responsible for the conduction of dissolved organic matter (food) between different parts of plant body. It consists of sieve tube cells and companion cells.

Water always moves from an area of higher water potential to an area of lower water potential. The relationship between the concentration of solute and water potential is inverse. When there is a lot of solute (i.e. hypertonic solution), the water potential is low and vice versa.

9.1.1 WATER AND ION UPTAKE

In addition to anchor the plant, roots perform two other vital functions. First; they absorb water and salts from soil. Second; they provide conducting tissues for distributing these substances to the tissues of stem.

The **conducting tissues** (xylem and phloem) of root are grouped in the centre to form a rod-shaped core. This rod extends throughout the length of root. Outside the conducting tissues, there is a narrow layer of thin-walled cells, the **pericycle**.

A single layer of cells i.e. **endodermis** surrounds this pericycle. External to this, there is a broad zone of **cortex**. It consists of large and thin-walled cells.Cortex is bounded on outside by a single layer of **epidermal cells.** Roots also have clusters of tiny **root hairs**, which are actually the extensions of epidermal cells.
Root hairs provide large surface area for absorption. They grow out into the spaces between soil particles where they are in direct contact with water. The cytoplasm of root hairs has higher concentration of salts than soil water, so water moves by osmosis into root hairs. Salts also enter

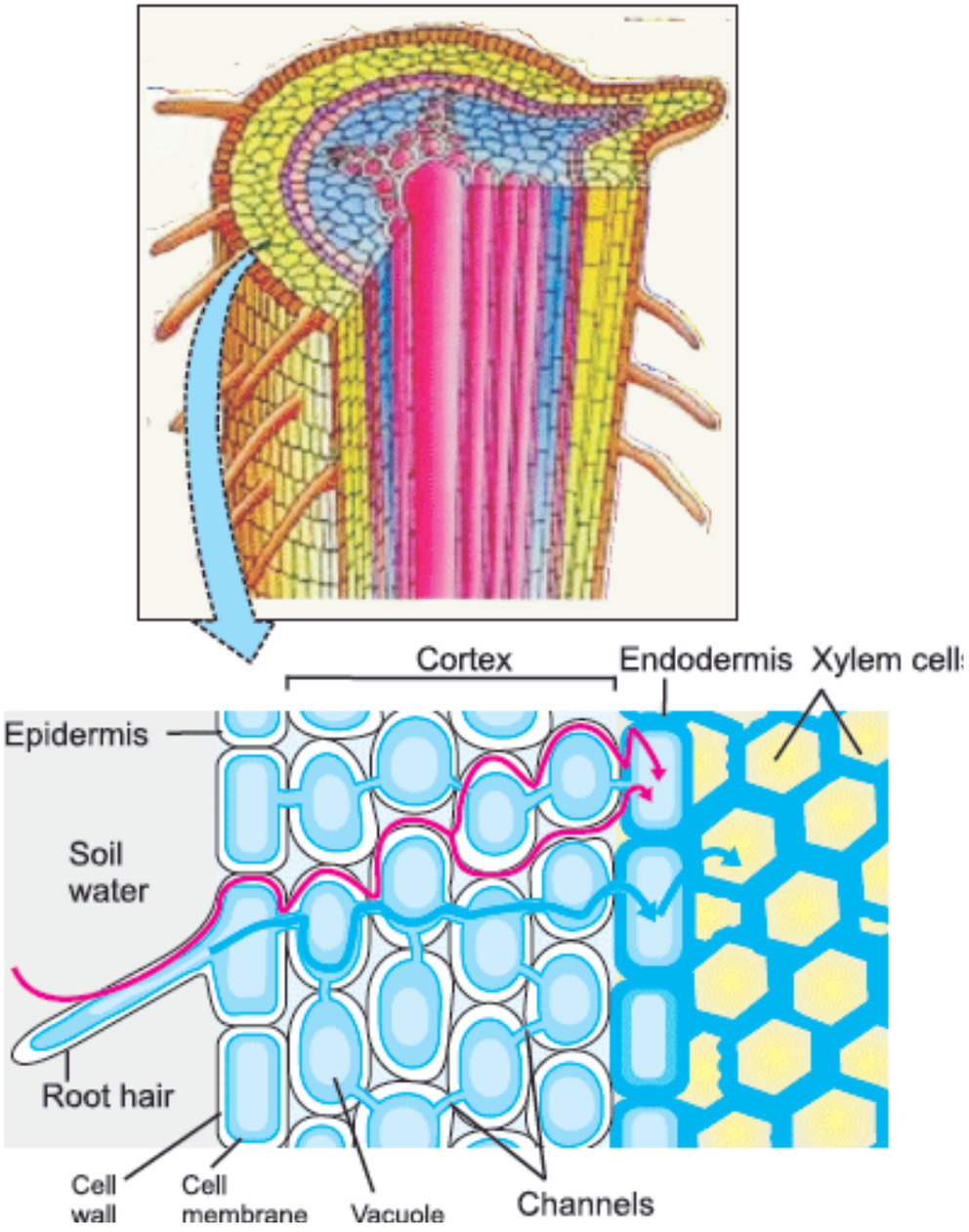


Figure 9.1: Uptake of water and ions by root

root hairs by diffusion or active transport. After their entry into root hairs, water and salts travel through intercellular spaces or through cells (via channels, called plasmodesmata) and reach xylem tissue. Once in xylem, water and salts are carried to all the aerial parts of plant.

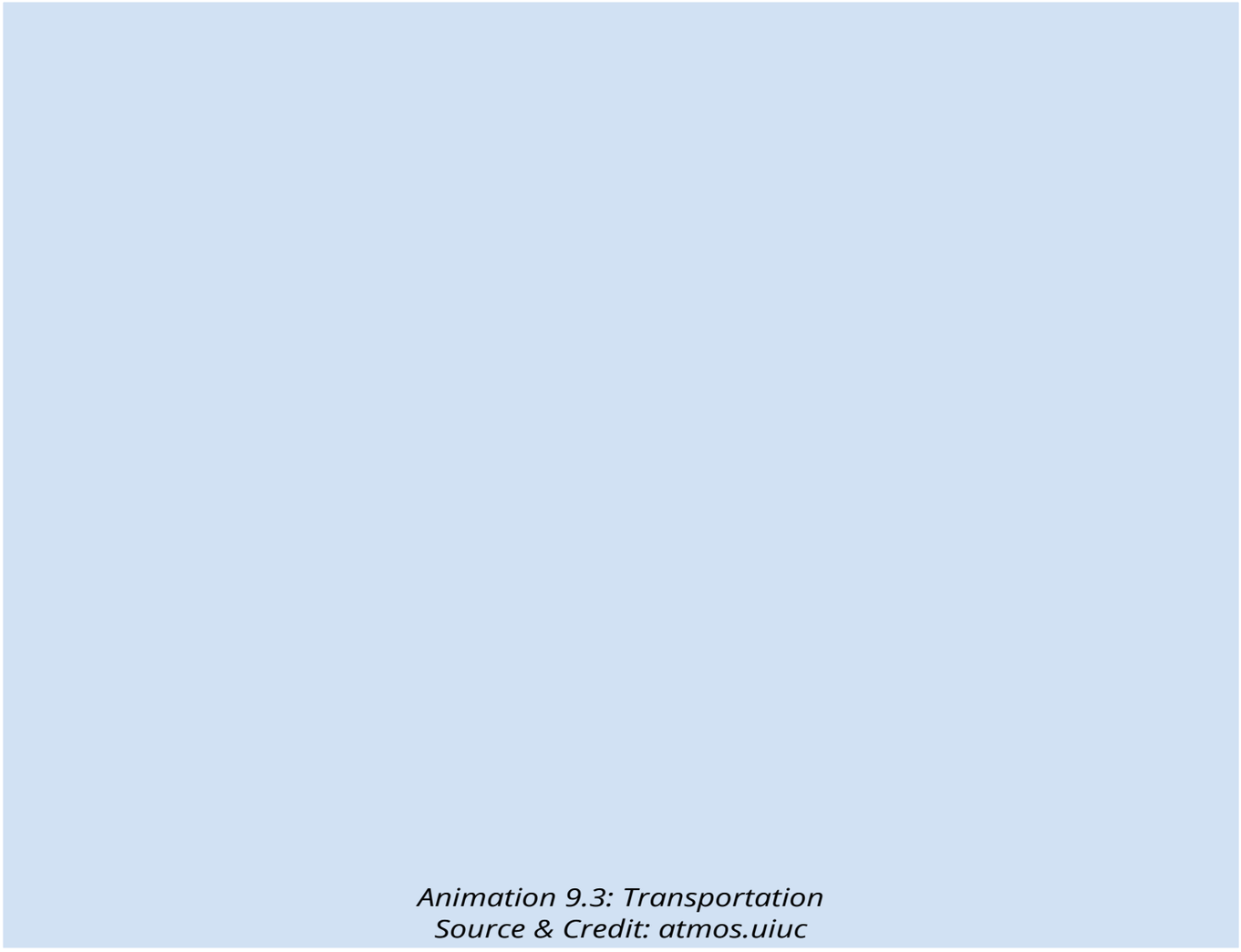
Plants also form beneficial relationships with soil bacteria and fungi in order to increase absorption of minerals.

Analyzing and Interpreting:
Identify root hairs on the growing roots of onion, carrot, radish etc.

9.1.2 TRANSPIRATION

Transpiration is the loss of water from plant surface through evaporation. This loss may occur through stomata in leaves, through the cuticle present on leaf epidermis, and through special openings called **lenticels** present in the stems of some plants.

Most of the transpiration occurs through stomata and is called **stomatal transpiration**. The mesophyll cells of leaf provide large surface area for the evaporation of water. Water is drawn from xylem into mesophyll cells, from where it comes out and makes a water-film on the cell walls of mesophyll. From here, water evaporates into the air spaces of the leaf. Water vapours then diffuse from air spaces towards stomata and then pass to outside air (Figure 9.2).



Animation 9.3: Transportation
Source & Credit: atmos.uiuc

Animation 9.4: Absorptive Root
Source & Credit: cas.miamioh

Roughly 90% of the water that enters a plant is lost via transpiration.

Video 9.5: Transpiration pull
Source & Credit: gifsoup

Opening and closing of stomata

Most plants keep their stomata open during the day and close them at night. It is the responsibility of stomata to regulate transpiration via the actions of guard cells. The two guard cells of a stoma are attached to each other at their ends. The inner concave sides of guard cells that enclose a stoma are thicker than the outer convex sides. When guard cells get water and become turgid, their shapes are like two beans and the stoma between them opens. When guard cells loose water and become flaccid, their inner sides touch each other and stoma closes.

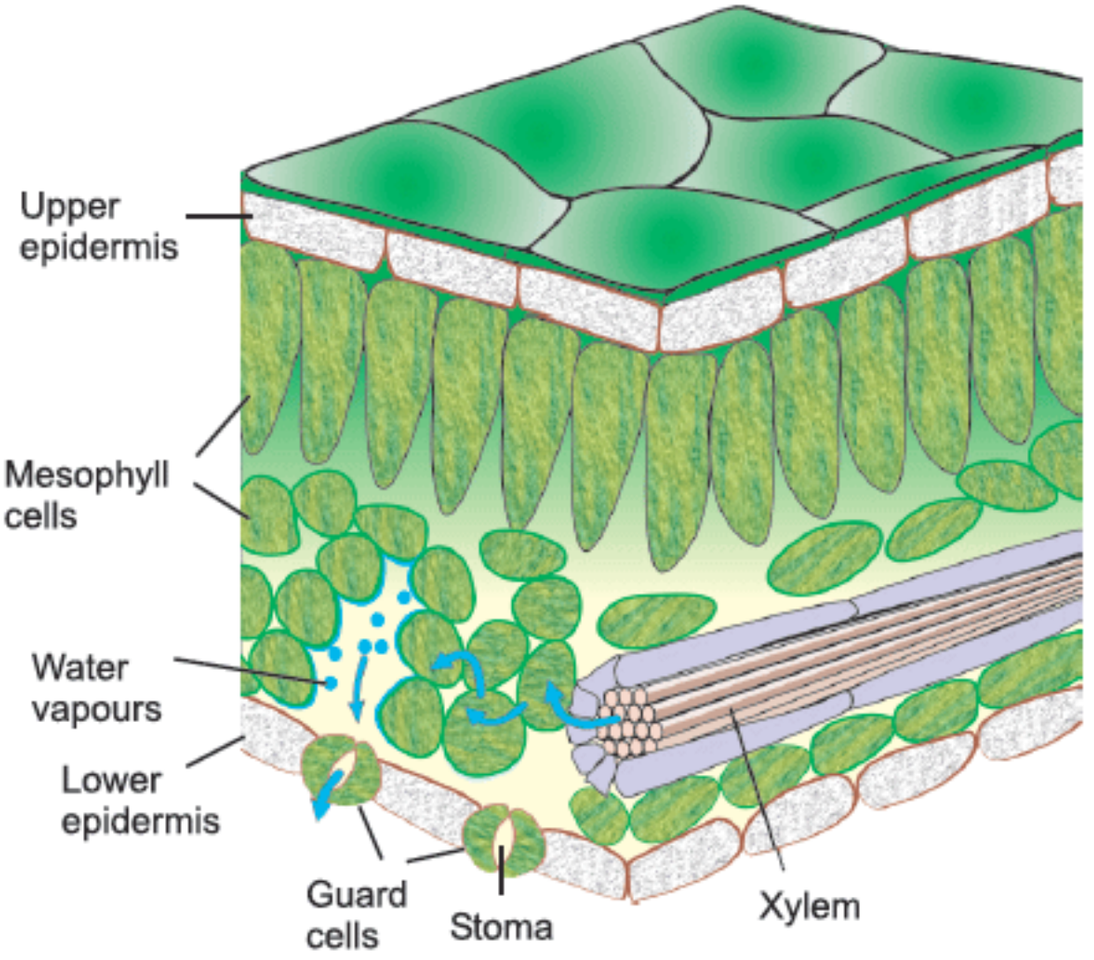


Figure 9.2: Events of transpiration shown in the section of a leaf

Some plants open their stomata during night when overall water stress is low.

In chapter 4 we have studied that the concentration of solutes (glucose) in guard cells is responsible for the opening and closing of stomata. Recent studies have revealed that light causes the movement of potassium ions from epidermal cells into guard cells. Water follows these ions and enters guard cells. Thus their turgidity increases and stoma opens. As the day progresses, guard cells make glucose i.e. become hypertonic. So water stays in them. At the end of the day, potassium ions flow back from guard cells to epidermal cells and the concentration of glucose also falls. Due to it, water moves to epidermal cells and guard cells loose turgor. It causes the closure of stoma.

Video 9.6: Opening and Closing Stomata
Source & Credit: blood.gq

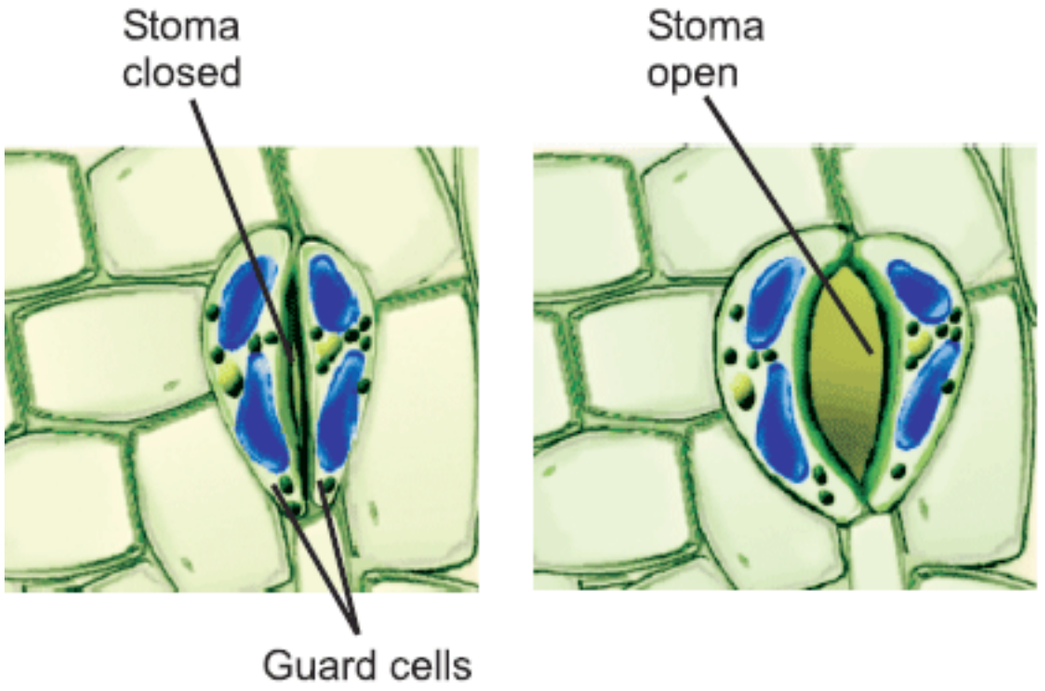


Figure 9.3: Opening and closing of stoma

FACTORS AFFECTING THE RATE OF TRANSPIRATION

The rate of transpiration is directly controlled by the opening and closing of stomata and it is under the influence of light. In strong light, the rate of transpiration is very high as compared to dim light or no light. Other factors which affect the rate of transpiration are given below.

Temperature

Higher temperature reduces the humidity of surrounding air and also increases the kinetic energy of water molecules. In this way it increases the rate of transpiration. The rate of transpiration doubles with every rise of 10 ^{o}C in temperature. But, very high temperatures i.e. 40-45 ^{o}C cause closure of stomata, so transpiration stops and plant does not loose the much needed water.

Air humidity

When air is dry, water vapours diffuse more quickly from the surface of mesophyll cells into leaf air spaces and then from air spaces to outside. This increases the rate of transpiration. In humid air, the rate of the diffusion of water vapours is reduced and the rate of transpiration is low.

Air movement

Wind (air in motion) carries away the evaporated water from leaves and it causes an increase in the rate of evaporation from the surfaces of mesophyll. When air is still, the rate of transpiration is reduced.

Leaf surface area

The rate of transpiration also depends upon the surface area of leaf. More surface area provides more stomata and there is more transpiration .

There is strong evidence that even mild water stress results in reduced growth rate in plants.

SIGNIFICANCE OF TRANSPIRATION

Transpiration is called a necessary evil. It means that transpiration is a potentially harmful process but is unavoidable too. Transpiration may be a harmful process in the sense that during the conditions of drought, loss of water from plant results in serious desiccation, wilting and often death.

On the other hand, transpiration is necessary too. It creates a pulling force called **transpirational pull** which is principally responsible for the conduction of water and salts from roots to the aerial parts of plant body. When water transpires from the surfaces of plant, it leaves a cooling effect on plant. This is especially important in warmer environments. Moreover, the wet surfaces of leaf cells allow gaseous exchange.

Practical Work:

To describe the structure and number of stomata present on the epidermal peel of a leaf

Stomata are the microscopic pores in the epidermis of leaves. They are the passageways for gases and water vapours.

Problem:

Observe the stomata on the epidermal peel of a leaf and describe their structure and number.

Apparatus required:

Petri dish, water, glass slides and cover slips, methylene blue, light microscope

Background information:

- A stoma is an opening through which leaves exchange gases and loose water (transpire).
- Each stoma is surrounded by two bean-shaped guard cells.
- The epidermis of leaves has stomata among its epidermal cells.

Procedure:

1. Take a thick leaf and peel off a thin layer (epidermis) from its surface.
2. Place the thin layer in water in a Petri dish.
3. Cut a piece of the peeled off epidermis and place it in a drop of water on a glass slide.
4. Pour a drop of methylene blue and place a cover slip on the material.
5. Observe under the low and high powers of the microscope.

Observation:

Observe the epidermis and point out the stomata present in it. Count the total stomata and count how many of these are open. Draw observation on notebook.

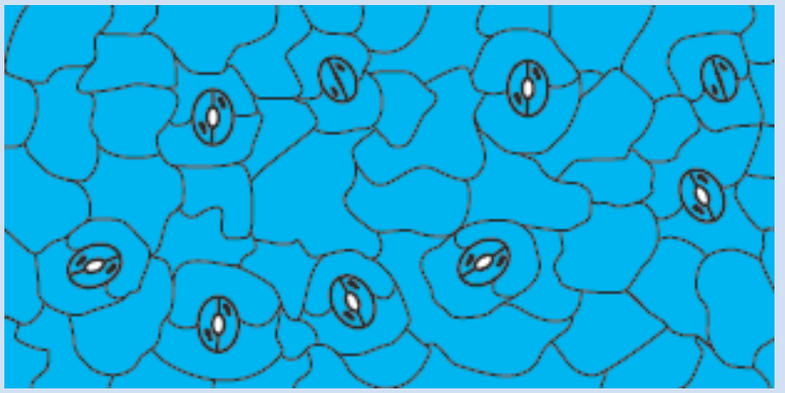


Figure 9.4: Microscopic view of the epidermis of a leaf

Evaluation:

i. How many stomata did you observe?

ii. What is the structure of guard cells and how does it help in the opening and closing of stomata?

Analyzing and Interpreting:

Wilting in a potted plant:

Due to non-availability or extra loss of water, the cells of herbaceous plants loose their turgidity and wilt. Wilting is defined as the loss of rigidity of non-woody parts of plants. This phenomenon can be observed by keeping a herbaceous plant without watering for a few days.

(a)

(b)

Figure 9.5: (a) Normal plant, (b) same plant in wilting stage

Practical work:

Investigation of the transpiration in a potted plant

Problem:

Explore the occurrence of transpiration.

Apparatus required:

A potted plant, 2 bell-jars, polythene bag, copper sulphate

Background information:

- Transpiration is the loss of water from plant surface.
- Polythene bag stops the escape of water vapours.

Hypothesis:

Transpiration occurs in plants which are given adequate supply of water and are placed in light.

Deduction:

A plant placed in light would transpire and water vapours can be observed.

Procedure:

1. Take a potted plant and cover the pot and base of stem with polythene bag.
2. Place the potted plant on a glass plate and invert a dry bell-jar over the pot and plant.
3. Leave the apparatus in sunlight.
4. Set up a control experiment with no plant.

Observation:

After an hour, drops of colourless liquid are seen inside the bell-jar with the plant. To show that these drops are water, touch them with anhydrous copper sulphate (white) and its colour changes to blue. No drops of water are found in the control experiment where there was no plant (Figure 9.6).

Results:

The water droplets on the inside of the jar containing the plant came from the leaves because the rest of the plant body and the soil were covered with polythene bag. Thus the potted plant present in the bell-jar showed the phenomenon of transpiration.

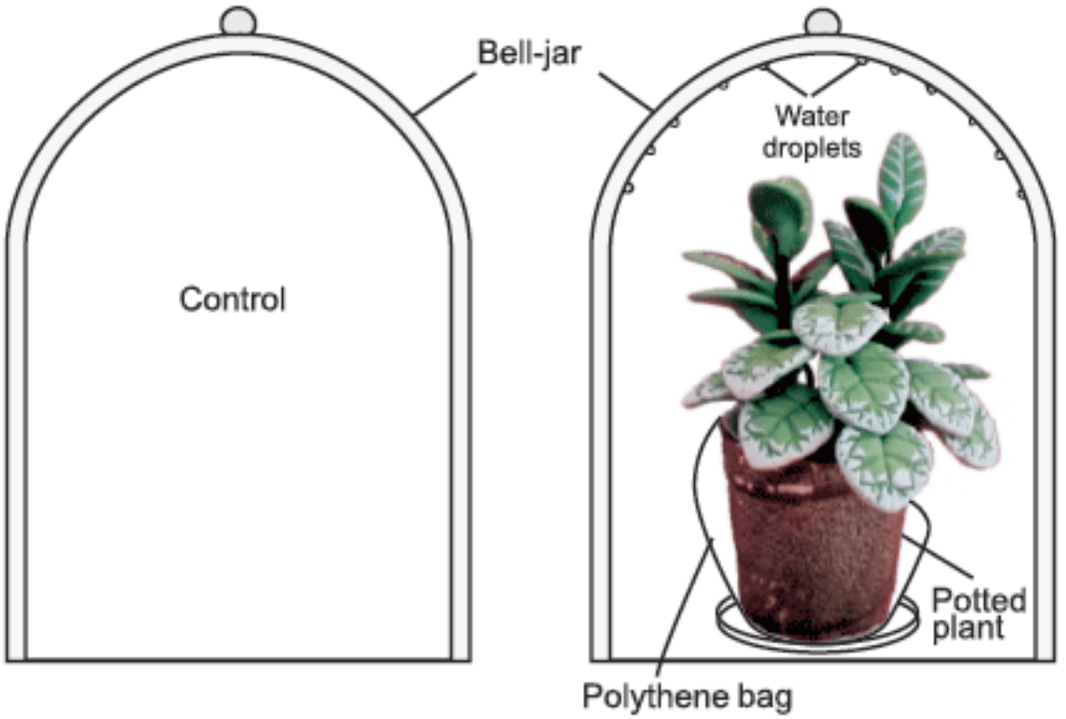


Figure 9.6: Experiment set up for transpiration in potted plant

Analyzing and Interpreting:

Identification of xylem and phloem in the prepared slides. See the photomicrographs and identify the xylem and phloem tissues by observing the prepared slides available in the school laboratory.

Practical work:

Investigation of the pathway of water in a cut stem

Transport of water and salts from roots to the aerial parts of plant body is termed as ascent of sap.

Problem:

Explore the pathway adopted by water during its transport in stem.

Background information:

- Xylem tissue consists of vessel elements and tracheids. Vessel elements form long tubes while tracheids are long cells with overlapping ends.
- Transpirational pull is the major force responsible for ascent of sap.

Hypothesis:

Water moves through the xylem tissue of stem.

Deduction:

If a plant is given water with some stain added, the transverse section of stem will show the same colour in the xylem region.

Procedure:

1. Fill a beaker with dilute eosin solution.
2. Place the shoot of a herbaceous plant (e.g. white coloured Petunia) inside the beaker as shown in the Figure 9.7. The lower end of the shoot must be completely submerged in the solution.
3. Keep the apparatus for a night.
4. Cut the longitudinal sections of stem. Examine and observe it under microscope.

Observation:

The white stem of the plant will show red lines. When examined under the light microscope, the longitudinal section of stem will also show that the xylem portions have become red.

Results:

The water along with the red eosin stain was absorbed by the stem and was transported through xylem tissues.

Practical work:

Investigation of the rate of water loss (transpiration) at two surfaces of a leaf

Leaves have different rates of water loss (transpiration) from the upper and lower surfaces.

Problem:

Explore the difference in the rate of transpiration at two surfaces of a leaf.

Apparatus required:

A potted plant, cobalt chloride filter papers, forceps, glass slides, rubber bands, filter paper discs

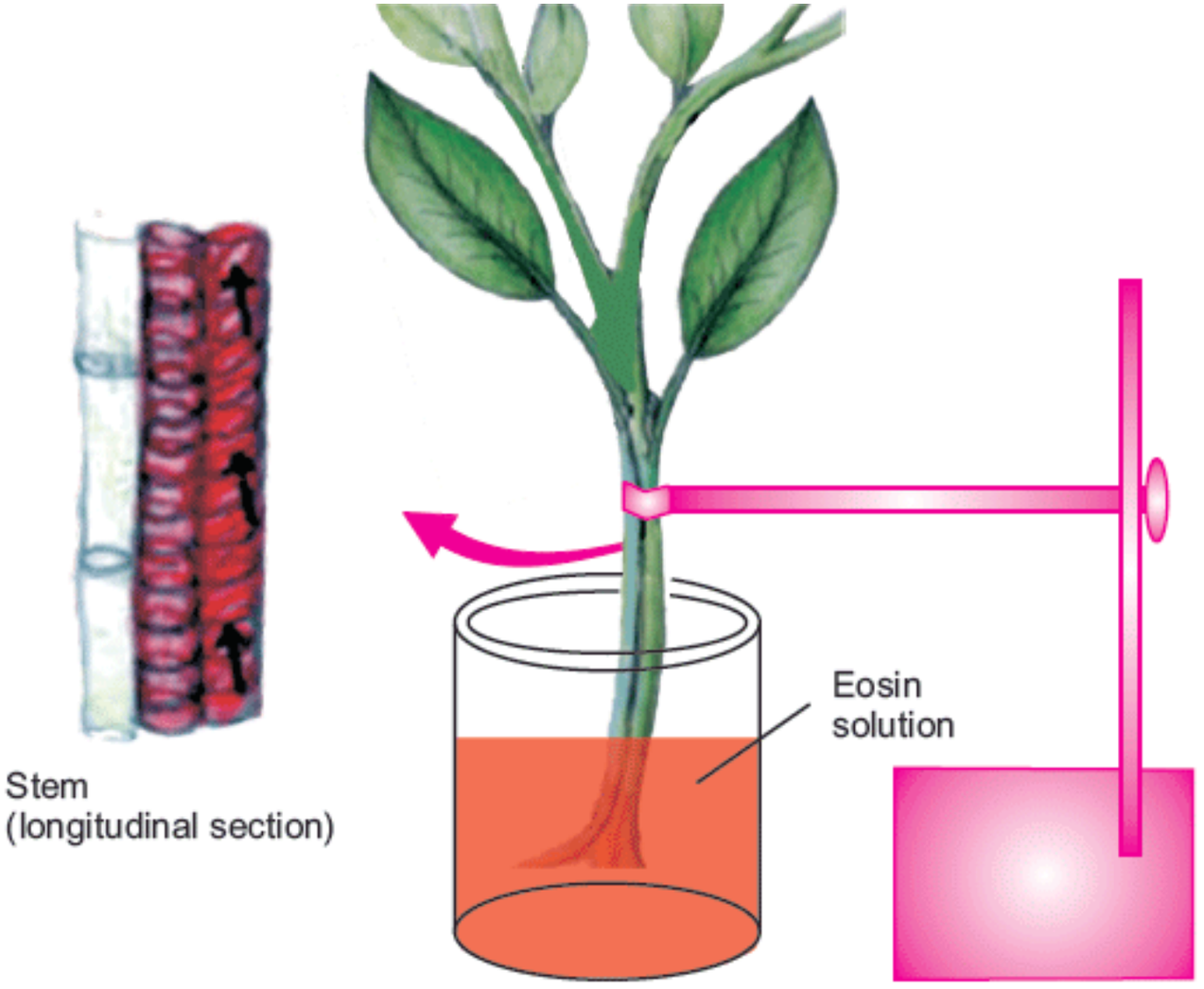


Figure 9.7: Experimental set up to explore the pathway of water

Background information:

- Cobalt chloride paper is blue when dry and it turns pink when it comes in contact with water vapours.
- Leaves of terrestrial plants have more stomata on their lower surface as compared to the upper ones.

Hypothesis:

There is more transpiration from the lower leaf surface as compared to the upper one.

Deduction:

If there is more transpiration from the lower surface, the cobalt chloride paper placed on the lower surface will show more colour change as compared to the paper placed on the upper surface.

Procedure:

1. Prepare dry cobalt chloride papers. For this, treat filter paper discs with slightly acidic cobalt chloride solution and dry the treated discs. Now, the dark blue filter paper discs will be called cobalt chloride paper.
2. Take a potted plant. Water the plant and leave it for an hour.
3. Take two equal size cobalt chloride papers and with the help of forceps place one piece of cobalt chloride paper on the upper surface and the other paper on the lower surface of a leaf.
4. Place dry glass sides on the upper and the lower cobalt chloride papers and fix them with a rubber band. (The glass slides will prevent the cobalt chloride papers to come in contact with atmospheric humidity.) Figure 9.8.

Observation:

Note changes in the colour of the two cobalt chloride papers. Both papers will start turning pink. Note that the paper placed at the lower surface of the leaf takes less time in turning pink.

Results:

Cobalt chloride paper placed on the lower surface of leaf contacted more water as compared the paper placed on the upper surface. It means that there is more water loss (transpiration) from the lower surface of leaf. The reason is that leaves have more stomata on their lower surfaces.

Evaluation:

i. What does it show when blue cobalt chloride paper starts turning pink?

ii. What is the relationship between the rate of transpiration and the number of stomata?

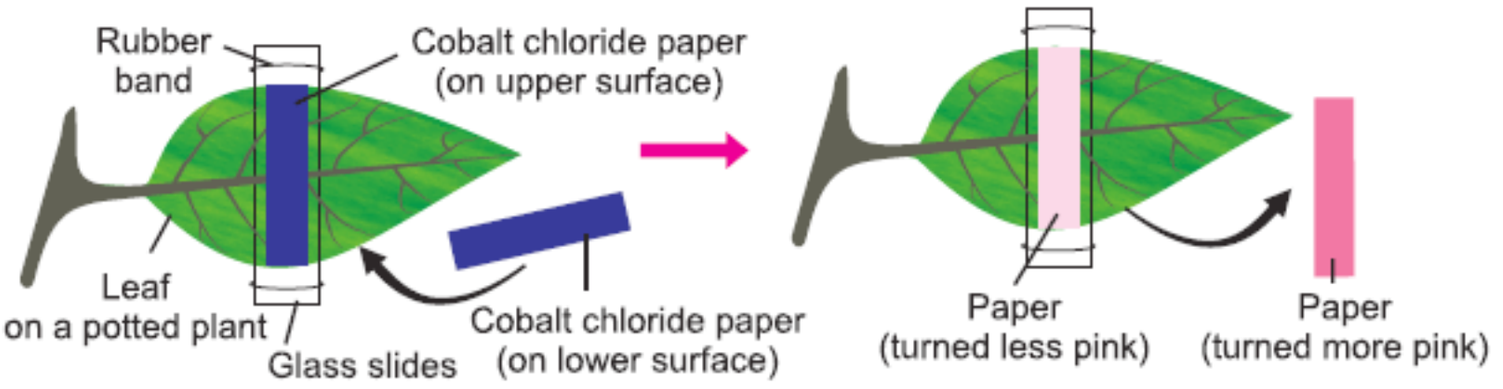


Figure 9.8: Experiment to explore the rate of transpiration on the two surfaces of a leaf

9.1.3 TRANSPORT OF WATER

The process by which water is raised to considerable heights in plants has been studied for years in botany. The result of this research is **"cohesion-tension theory"**.
According to this theory, the force which carries water (and dissolved materials) upward through the xylem is transpirational pull. Transpiration creates a pressure difference that pulls water and salts up from roots.
When a leaf transpires (loses water), the water concentration of its mesophyll cells drops. This drop causes water to move by osmosis from the xylem of leaf into mesophyll cells. When one water molecule moves up in the xylem of the leaf, it creates a pulling force that continues all the way to root.

This pulling force created by the transpiration of water is called **transpirational pull.** It also causes water to move transversely (from root epidermis to cortex and pericycle). Following are the reasons for the creation of transpirational pull.

- Water is held in a tube (xylem) that has small diameter.
- Water molecules adhere to the walls of xylem tube (adhesion).
- Water molecules cohere to each other (cohesion).

Animation 9.2 : Translocation Of Water And Nutrients
Source & Credit: Plantcellbiology

These attractions make an overall tension among water molecules. This tension forms 'columns' of water. The columns of water move from root to shoot and the water content of the soil enters in these 'columns'.

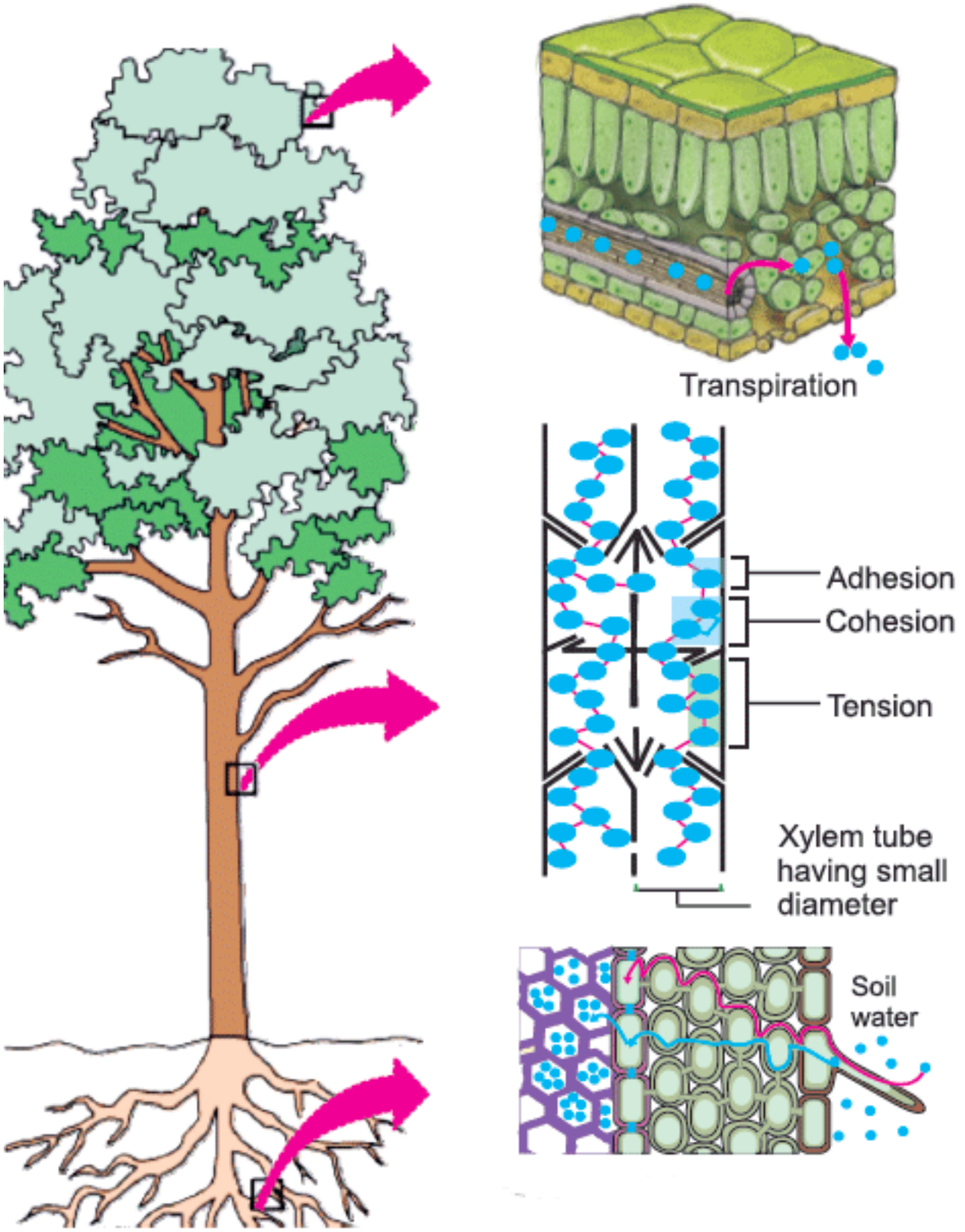


Figure 9.9: Transport of water

9.1.4 TRANSPORT OF FOOD

Phloem is responsible for transporting food substance throughout plant body. The glucose formed during photosynthesis in mesophyll cells, is used in respiration and the excess of it is converted into sucrose. In most plants, food is transported in the form of sucrose. Like the concept of "water movement in plants", movement of food in plants has been studied for years. The currently accepted hypothesis states that transport of food is through **pressure-flow mechanism**. In pressure-flow mechanism, food is moved from sources to sinks.

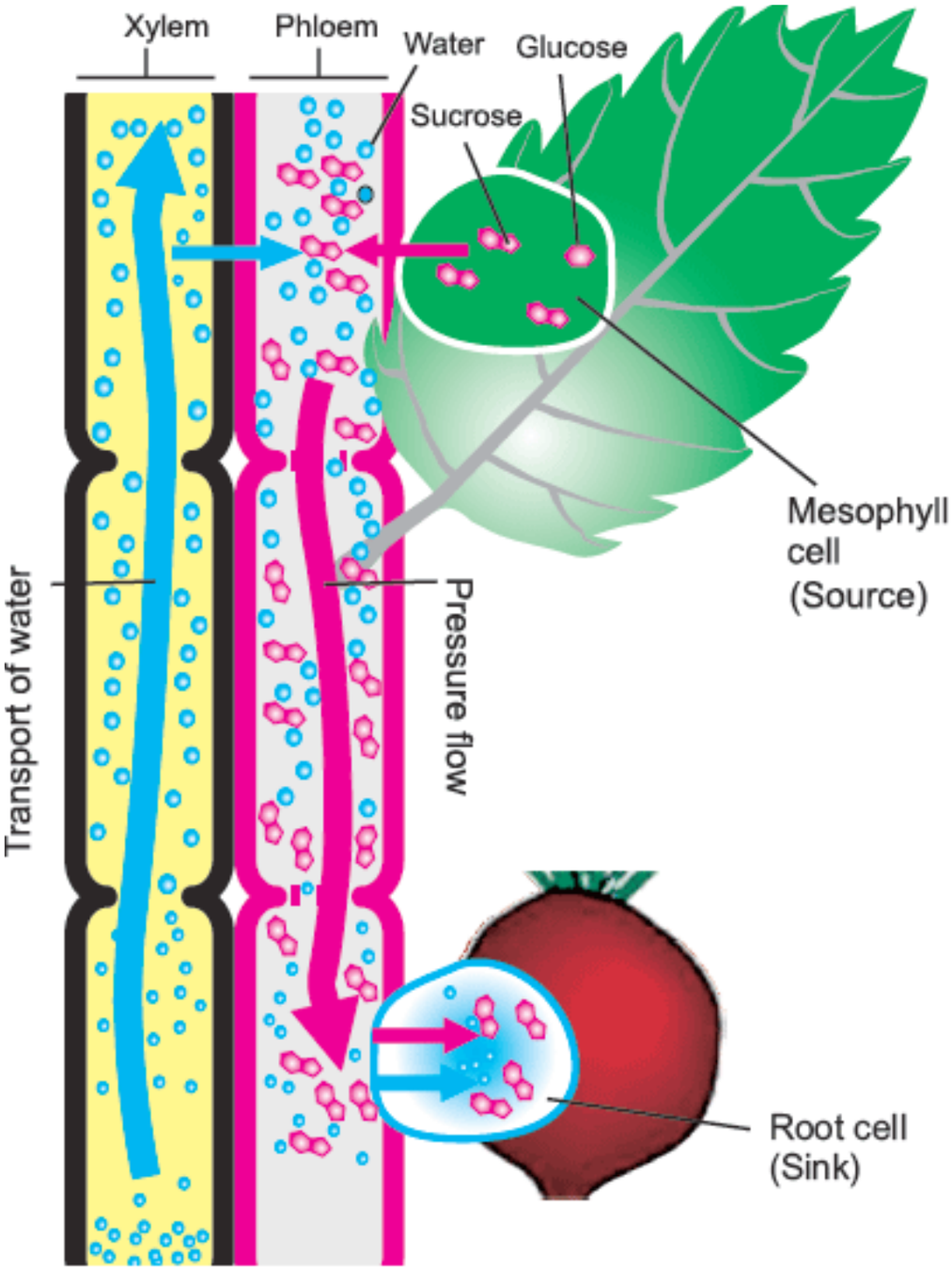


Figure 9.10: Transport of food

Sources include the exporting organs, typically a mature leaf or storage organ. **Sinks** are the areas of active metabolism or storage e.g. roots, tubers, developing fruits and leaves, and growing regions. A storage organ is capable of storing food and exporting the stored materials.

For example; root of beet is a sink in first growing season, but becomes source in next growing season, when sugars are utilized in the growth of new shoots.

At source, food (sugars) is moved by active transport into the sieve tubes of phloem. Due to the presence of sugar in sieve tubes, their solute concentration increases and water enters them from xylem (via osmosis). This results in higher pressure of water in these tubes, which drives the solution of food towards sink.

Xylem is a one way street from roots to leaves for water and salts. Phloem is a two way street for food. The direction of the movement of food is decided by supply and demand in sources and sinks.

At the sink end, food is unloaded by active transport. Water also exits from the sieve tubes. The exit of water decreases pressure in sieve tubes, which causes a mass flow from the higher pressure at the source to the now lowered pressure at the sink (Figure 9.10).

Plants need a lot of water. Young Brassica plants take up an amount of water equal to their shoot weight in about 5 hours - if that applied to us, we would have to drink 3 gallons of water an hour to stay alive!

9.2 TRANSPORT IN HUMAN

Like other higher animals, the task of the transport of different material in human body is performed by two systems i.e. blood circulatory system and lymphatic system. The two systems are well-coordinated and associated with each other. Here we will go into the details of human blood circulatory system (or cardiovascular system). Like other vertebrates, humans have a closed blood circulatory system (meaning that blood never leaves the network of arteries, veins and capillaries). The main components of the human blood circulatory system are blood, heart and blood vessels.

Recalling

Some invertebrates like arthropods have open circulatory system

According to the pressure flow mechanism what is the actual force behind the movement of food in phloem?

Drop in the pressure at the sink end.

How is plasma separated from blood?

Blood is taken from an artery and an anticoagulant (chemical that inhibits blood clotting) is mixed in it. After about 5 minutes, plasma separates from blood cells, which settle down.

9.2.1 BLOOD

Blood is a specialized body fluid (a connective tissue) that is composed of a liquid called blood plasma and blood cells. The weight of blood in our body is about 1/12th of our body. The average adult body has about 5 litres of blood.
In a healthy person, plasma constitutes about 55% by volume of blood, and cells or cell-like bodies are about 45% by volume of the blood (Figure 9.11).

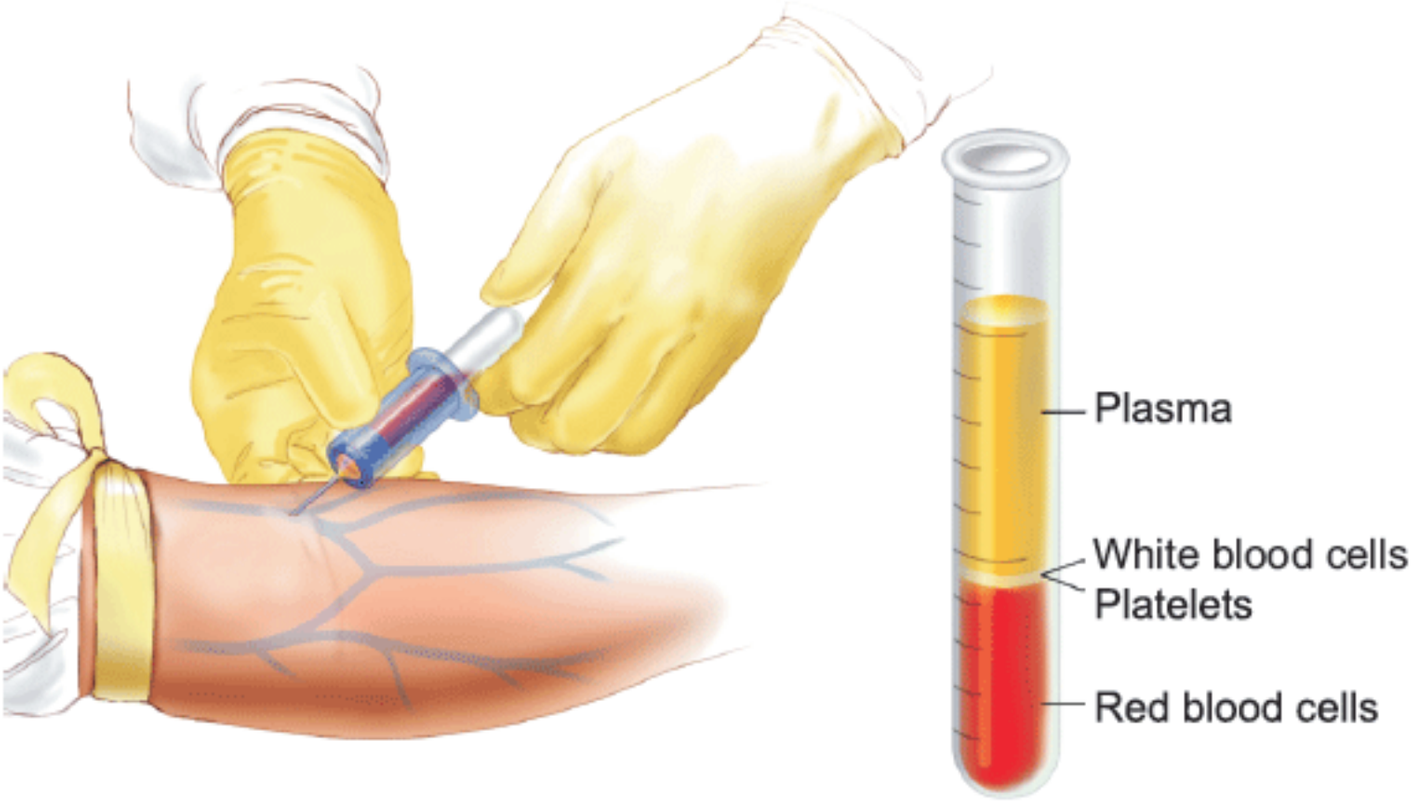


Figure 9.11: Percentage composition of human blood

BLOOD PLASMA

Plasma is primarily water in which proteins, salts, metabolites and wastes are dissolved.Water constitutes about 90-92% of plasma and 8-10% are dissolved substances.

Salts make up 0.9 % of plasma, by weight. Sodium chloride (the table salt) and salts of bicarbonate are present in considerable amounts. Ca, Mg, Cu, K and Zn are found in trace amounts. Changes in the concentration of any salt can change the pH of blood (normal is 7.4). **Proteins** make 7-9 % by weight of plasma. The important proteins present in plasma are antibodies, fibrinogen (blood clotting protein), albumin (maintains the water balance of blood) etc. Plasma also contains the digested food (absorbed from digestive system), nitrogenous wastes and hormones. Respiratory gases i.e. CO_2 and O_2 are present in the plasma.

BLOOD CELLS AND CELL-LIKE BODIES

These include red blood cells (erythrocytes), white blood cells (leukocytes) and platelets (thrombocytes).

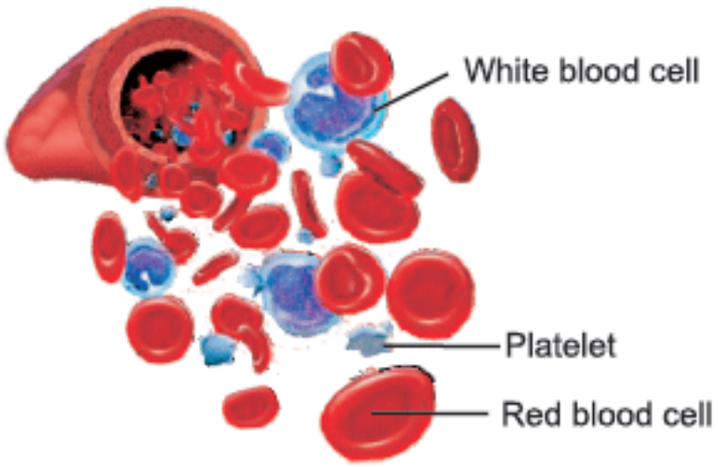
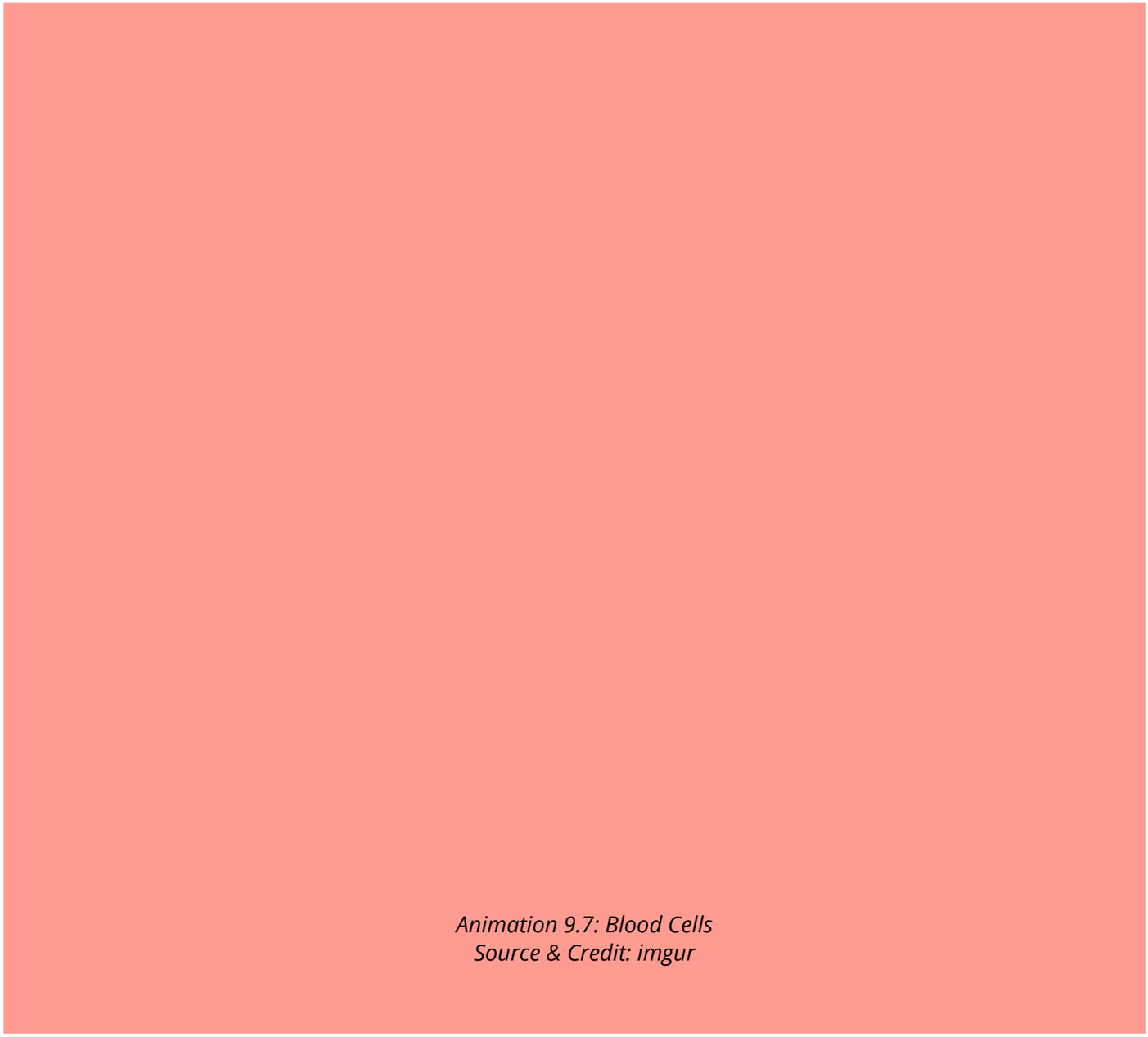


Figure 9.12: Different cells and cell-like bodies in blood plasma

Red Blood Cells (Erythrocytes)

These are the most numerous of blood cells. A cubic millimeter of blood contains 5 to 5.5 million of RBCs in males, and 4 to 4.5 million in females. When RBCs are formed, they have nucleus. In mammals, when a red blood cell matures, its nucleus is lost.



Animation 9.7: Blood Cells
Source & Credit: imgur

After the loss of nucleus, RBC enters blood. About 95% of the cytoplasm of RBCs is filled with hemoglobin, which transports O_2 and small amounts of CO_2 .The remaining 5% consists of enzymes, salts and other proteins. RBCs are biconcave and have an elastic cell membrane. In the embryonic and foetal life, they are formed in liver and spleen. In adults, they are formed in the red bone marrow of short and flat bones, such as sternum, ribs and vertebrae. Average life span of RBC is about four months (120 days) after which it breaks down in liver and spleen by phagocytosis.

In a normal person about 2-10 million red blood cells are formed and destroyed every second.

White Blood Cells (Leukocytes)

These are colourless, because they do not contain pigments. They are not confined to blood vessels and also migrate out into tissue fluid. One cubic millimeter of blood contains 7000 to 8000 WBCs. Their life span ranges from months to even years, depending on body's needs. WBCs function as the main agents in body's defence system. There are two main types of WBCs.

Granulocytes have granular cytoplasm. These include **neutrophils** (destroy small particles by phagocytosis), **eosinophils** (break inflammatory substances and kill parasites) and **basophils** (prevent blood clotting).

Agranulocytes have clear cytoplasm and include **monocytes** (produce macrophages which engulf germs) and **B and T lymphocytes** (produce antibodies and kill germs).

Platelets (Thrombocytes)

They are not cells, but are fragments of large cells of bone marrow, called **megakaryocytes**. They do not have any nucleus and any pigment. One cubic millimeter of blood contains 250,000 platelets. The average life span of a blood platelet is about 7 to 8 days. Platelets help in blood clotting. The clot serves as a temporary seal at the damaged area.

WBCs die in the process of killing the germs. These dead cells accumulate and make the white substance called pus, seen at infection sites.	In dengue fever, there is a sharp decrease in the number of platelets in blood. Because of this, patients bleed from the nose, gums and under the skin.

Table 9.2: Composition of blood

	Description	Amount in %age	Functions
Plasma	Liquid portion of blood	55% by volume	Carries blood cells and important blood proteins, hormones, salts etc.
Cell Types	**Description**	**Average Number present**	**Functions**
Red Blood Cells (Erythrocytes)	Like a biconcave disc; without nucleus; contain haemoglobin	5,000,000 per mm^3	Transport Oxygen and a small amount of CO_2
White Blood Cells (Leukocytes)	Granular and agranular; contain nucleus; Larger in size than RBCs	7500 per mm^3	Play role in body's defense by different ways like: Engulf small particles Release anticoagulants Produce antibodies
Platelets (Thrombocytes)	Fragments of bone marrow cells (megakaryocytes)	250,000 per mm^3	Involved in blood clotting

Analyzing and Interpreting:
Identify red blood cells, white blood cells and platelets in specimens of prepared slides or diagrams (Figure 9.13)

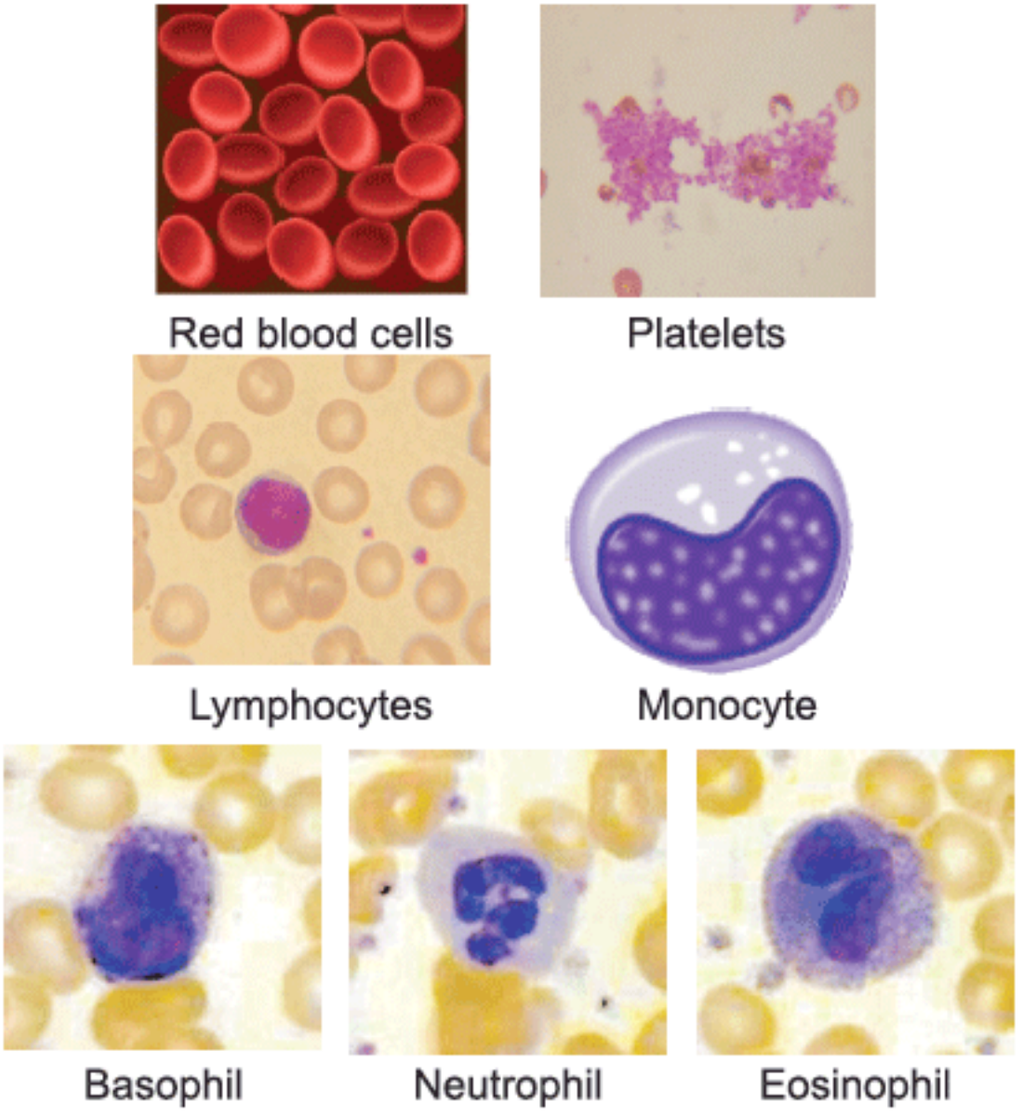


Figure 9.13: Blood cells as seen under microscope
(Courtesy: http://en.wikipedia.org/)

? Which blood cells are the most numerous in healthy human body?

Red blood cells

BLOOD DISORDERS

There are many types of blood disorders, including: bleeding disorders, leukaemia,thalassaemia etc. Here we will discuss leukaemia and thalassaemia.

The world celebrates the International Thalassaemia Day on 8th of May. This day is dedicated to raise public awareness about thalassaemia and to highlight the importance of the care for thalassaemia patients.

Leukaemia (blood cancer)

Leukaemia is the production of great number of immature and abnormal white blood cells. This is caused by a cancerous mutation (change in gene) in bone marrow or lymph tissue cells. The mutation results in uncontrolled production of defective white blood cells (leukocytes).
It is a very serious disorder and patient needs to change blood regularly with normal blood, got from donors. It can be cured by bone marrow transplant. It is effective in most cases , but very expensive treatment.

There are about 60-80 million people in the world who carry thalassaemia. India, Pakistan and Iran are seeing a large increase of thalassaemia patients. Pakistan alone has 250,000 such patients. The patients require blood transfusions for lifetime. (Source: The Thalassaemia International Foundation)

Thalassaemia (g. thalassa = sea; haem = blood)

It is also called Cooley's anaemia on the name of Thomas B. Cooley, an American physician. It is a genetic problem due to mutations in the gene of haemoglobin. The mutation results in the production of defective haemoglobin and the patient cannot transport oxygen properly. The blood of these patients is to be replaced regularly, with normal blood. It can be cured by bone marrow transplant but it does not give 100% cure rate.

BLOOD GROUP SYSTEMS

Blood group systems are a classification of blood based on the presence or absence of antigens on the surface of red blood cells. An antigen is a molecule that can stimulate an immune response (antibody production etc.).

ABO Blood Group System

It is the most important blood group system in humans. It was discovered by the Austrian scientist **Karl Landsteiner,** who found four different blood groups (blood types) in 1900. He was awarded the Nobel Prize in Medicine for his work.

In this system, there are four different blood groups which are distinct from each other on the basis of specific antigens (antigen A and B) present on the surface of RBCs. A person having antigen A has blood group A, a person having antigen B has blood group B, a person having both antigens has blood group AB, and a person having none of the A and B antigens has blood group O.

After birth, two types of antibodies i.e. anti-A & anti-B antibodies appear in the blood serum of individuals. These antibodies are present according to the absence of corresponding antigen. In persons with blood group A, antigen A is present and antigen B is absent. So their blood will contain anti-B antibodies. In persons with blood group B,antigen B is present and antigen A is absent. So their blood will contain anti-A antibody.

A total of 29 human blood group systems are now recognized by the International Society of Blood Transfusion (ISBT).

In persons with blood group AB, antigens A & B are present i.e. neither is absent. So their blood serum will contain no antibody. In persons with blood group O, neither antigen A nor antigen B is present i.e. both are absent. So their blood serum will contain both antibodies i.e. anti-A & anti-B.

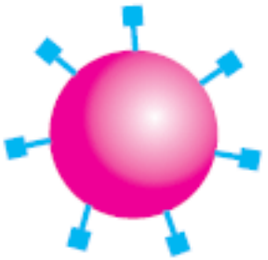
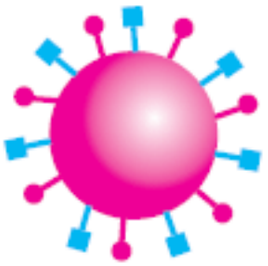
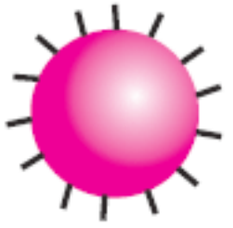
	Blood group A	Blood group B	Blood group AB	Blood group O
Red Blood Cells				
Antigens on RBCs	 antigen A	 antigen B	 Antigen A & B	None
Antibodies in serum	 Anti-B	 Anti-A	None	 Anti-A & Anti-B

Figure 9.14: Presence and absence of antigens and antibodies in ABO blood group system

Blood transfusions in ABO blood group system

Blood transfusion is the process of transferring blood or blood-based products from one person into the circulatory system of another. Blood transfusions can be life-saving in some situations, such as massive blood loss due to injury, or can be used to replace blood lost during surgery. People suffering from anaemia, haemophilia, thalassaemia or sickle-cell disease may require frequent blood transfusions.

A number of infectious diseases (such as AIDS, hepatitis B and hepatitis C etc.) can pass from the affected blood donor to recipient. Before blood transfusion, the blood of donor is checked for the presence of germs etc.

Transfusion of blood is done after confirming that no **agglutination** (clumping of cells) results in the blood of recipient. If agglutination occurs, the clumped cells can not pass through capillaries. For the confirmation of no agglutination, blood samples of donor and recipient are cross-matched for compatibility. Antibodies of recipient's blood may destroy the corresponding antigen-containing RBCs of donor or antibodies of donor's blood may destroy antigen-containing RBCs of recipient.

O blood group individuals are called **universal donors**, because they can donate blood to the recipients of every other blood group. **AB blood group** individuals are called **universal recipients**, because they can receive transfusions from the donors of every other blood group.

Rh Blood Group System (+ ve & - ve blood group system)

In 1930's, Karl Landsteiner discovered the Rh-blood group system. In this system, there are two blood groups i.e. Rh-positive and Rh-negative. These blood groups are distinct from each other on the basis of antigens called **Rh factors** (first discovered in Rhesus monkey), present on the surface of RBCs. A person having Rh factors has blood group.

Rh-positive while a person not having Rh factors has blood group Rh-negative. Unlike the naturally occurring anti-A & anti-B antibodies of the ABO-system, an Rh-negative
person does not produce anti-Rh antibodies unless Rh-factor enters in his / her blood.

Blood transfusions in Rh blood group system

Rh-positive blood group can be transfused to Rh-positive recipient because recipient's blood already has Rh-antigens and it will not produce anti-Rh antibody. Rh-negative blood group can be transfused to Rh-negative because donor's blood does not have Rh-antigen and so recipient's blood will not produce anti-Rh antibody. If an Rh-negative person receives Rh-positive blood, he / she will produce anti-Rh antibodies against Rh-factors. Rh-negative blood can be transfused to Rh-positive recipient, only if donor's blood (Rh-negative) has never been exposed to Rh-antigens and does not contain any anti-Rh antibody.

Donor Blood Groups \ Recipient Blood Groups	A	B	AB	O
A	✓	x	✓	x
B	x	✓	✓	x
AB	x	x	✓	x
O	✓	✓	✓	✓

Blood Transfusion: Cross matching
✓: can be transfused
x : agglutination

? Persons with blood group O are called universal donors. What is the actual universal donor blood group? Blood group O-positive or O-negative!

O-negative blood group

9.2.2 HUMAN HEART

Heart is a muscular organ responsible for pumping blood through blood vessels by repeated contractions. The term "cardiac" means "related to the heart". The bulk of the walls of heart chambers is made of **cardiac muscles**.

In human body, heart is situated between lungs, in the middle of chest cavity (thorax) under breastbone.

Recalling

Cardiac muscles are involuntary in action and are composed of branched striated cells,each with a single nucleus.

Heart is enclosed in a sac known as **pericardium**. There is a fluid, known as **pericardial fluid,** between pericardium and heart walls. It reduces friction between pericardium and heart, during heart contractions.

Human heart consists of four chambers, like the heart of birds and other mammals. The upper thin-walled chambers are called left and right **atria** (singular 'atrium'), and the lower thick-walled chambers are called left and right **ventricles**. Left ventricle is the largest and strongest chamber in heart.

The heart is usually felt to be on the left side because the left chamber of the heart i.e. (left ventricle) is stronger (it pumps blood to all body parts).

Human heart works as a **double pump.** It receives deoxygenated (with less oxygen) blood from body and pumps it to lungs. At the same time, it receives oxygenated (with more oxygen) blood from lungs and pumps it to all body. Inside heart chambers, the deoxygenated and oxygenated bloods are kept separated. Here is a brief description of the circulation of blood inside heart to show its double-pump mechanism.

Right atrium receives deoxygenated blood from body via the main veins i.e. superior and inferior vena cavae. When right atrium contracts it passes the deoxygenated blood to **right ventricle**. The opening between right atrium and right ventricle is guarded by a valve known as **tricuspid valve** (because it has 3 flaps). When right ventricle contracts, the blood is passed to pulmonary trunk, which carries blood to lungs. Tricuspid valve prevents the backflow of blood from right ventricle to right atrium. At the base of pulmonary trunk, **pulmonary semilunar valve** is present which prevents the backflow of blood from pulmonary trunk to right ventricle.

The walls of left ventricle are the thickest one. These are about a half-inch thick. They have enough force to push blood into the body. This gives an evidence that the structures of the parts of heart are adaptive to their functions.

The oxygenated blood from lungs is brought by pulmonary veins to **left atrium.** Left atrium contracts and pumps this blood to **left ventricle**. The opening between left atrium and left ventricle is guarded by a valve known as **bicuspid valve** (because it has two flaps). When left ventricle contracts, it pumps the oxygenated blood in aorta, which carries blood to all parts of body (except lungs). Bicuspid valve prevents the backflow of blood from left ventricle to left atrium. At the base of aorta, **aortic semilunar** valve is present which prevents the backflow of blood from aorta to left ventricle (Figure 9.15).

Animation 9.8 : Blood flow
Source & Credit: thomascsherman

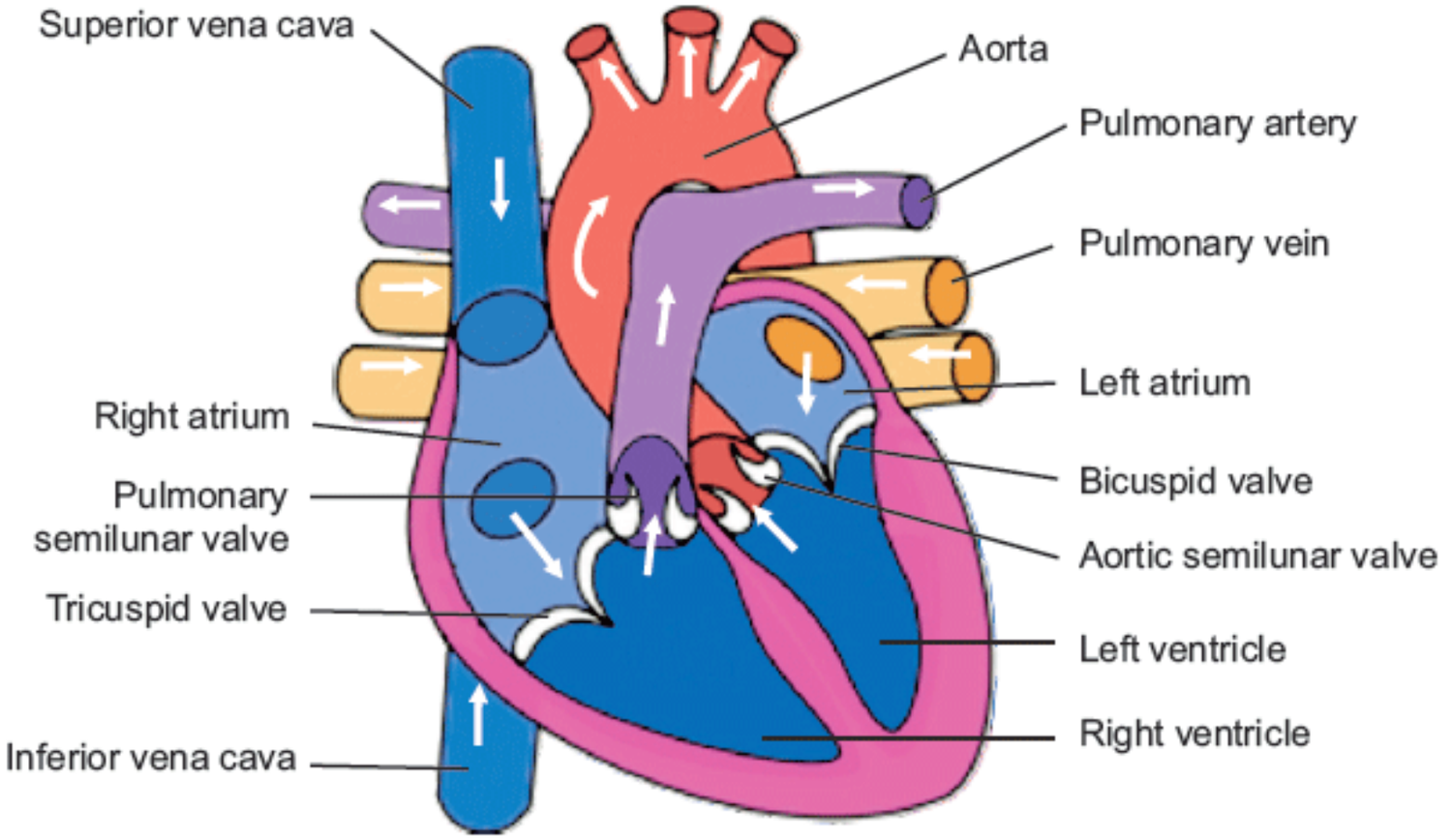


Figure 9.15: Human heart; structure and blood flow

Both atria are filled simultaneously. They contract together to pump the blood to both the ventricles. Similarly, both ventricles contract simultaneously to pump the blood out of heart

Pulmonary and systemic circulation

We see that right side of heart collects deoxygenated blood from body and distributes it to lungs while left side collects oxygenated blood from lungs and distributes it to body. The pathway on which deoxygenated blood is carried from heart to lungs and in return oxygenated blood is carried from lungs to heart is called **pulmonary circulation** or **circuit** (Figure 9.16). Similarly, the pathway on which oxygenated blood is carried from heart to body tissues and in return deoxygenated blood is carried from body tissues to heart is called **systemic circulation** or **circuit.**

The blood in pulmonary circulation is at lower pressure than the blood in systemic circulation. It gives sufficient time to blood for gaseous exchange in lungs.

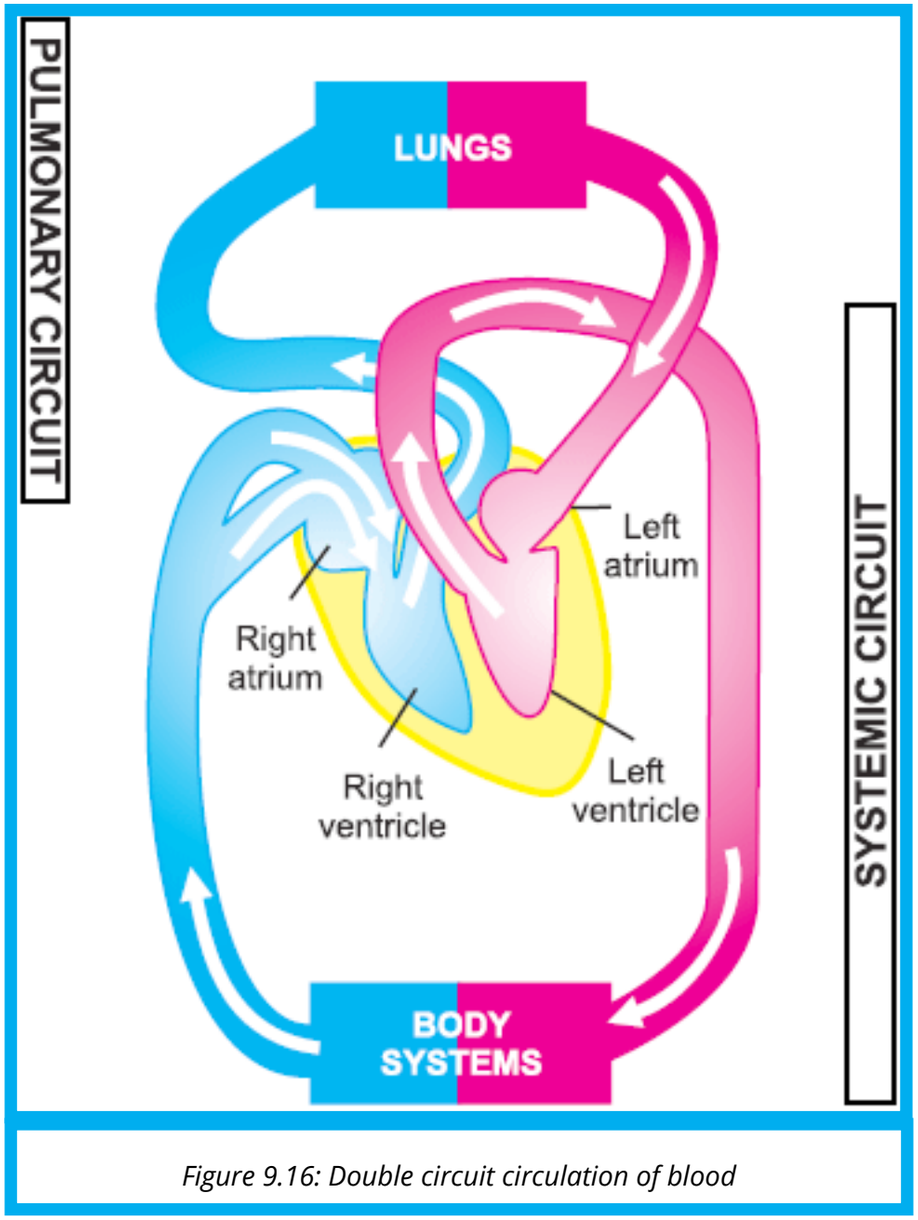


Figure 9.16: Double circuit circulation of blood

Analyzing and Interpreting:

In a given diagram of human heart, identify the components which you have studied in the current topic.

Heartbeat

The relaxation of heart chambers fills them with blood and contraction of chambers propels blood out of them. The alternating relaxations and contractions make up the cardiac cycle and one complete **cardiac cycle** makes one heartbeat. Complete cardiac cycle consists of the following steps. Atria and ventricles relax and blood is filled in atria. This period is called **cardiac diastole.** Immediately after their filling, both atria contract and pump blood towards ventricles. This period in cardiac cycle is called **atrial systole**. Now, both ventricles contract and pump blood towards body and lungs.

Animation 9.9 : How Blood Flows Through the Heart
Source & Credit : goldiesroom

Animation 9.10 : The Whole Heart
Source & Credit : Heart Point

The average human heart beats 70 times per minute. So, it would beat approximately 2.5 billion times during a lifetime of 66 years. In normal adults, the mass of heart is 250-350 g and the size is equal to a clenched fist.

The period of ventricular contraction is called **ventricular systole**. In one heartbeat, diastole lasts about 0.4 seconds, atrial systole takes about 0.1 seconds, and ventricular systole lasts about 0.3 seconds (Figure 9.17). When ventricles contract, tricuspid and bicuspid valves close and "lubb" sound is produced. Similarly when ventricles relax, the semilunar valves close and "dubb" sound is produced. "Lubb-dubb" can be heard with the help of a stethoscope.

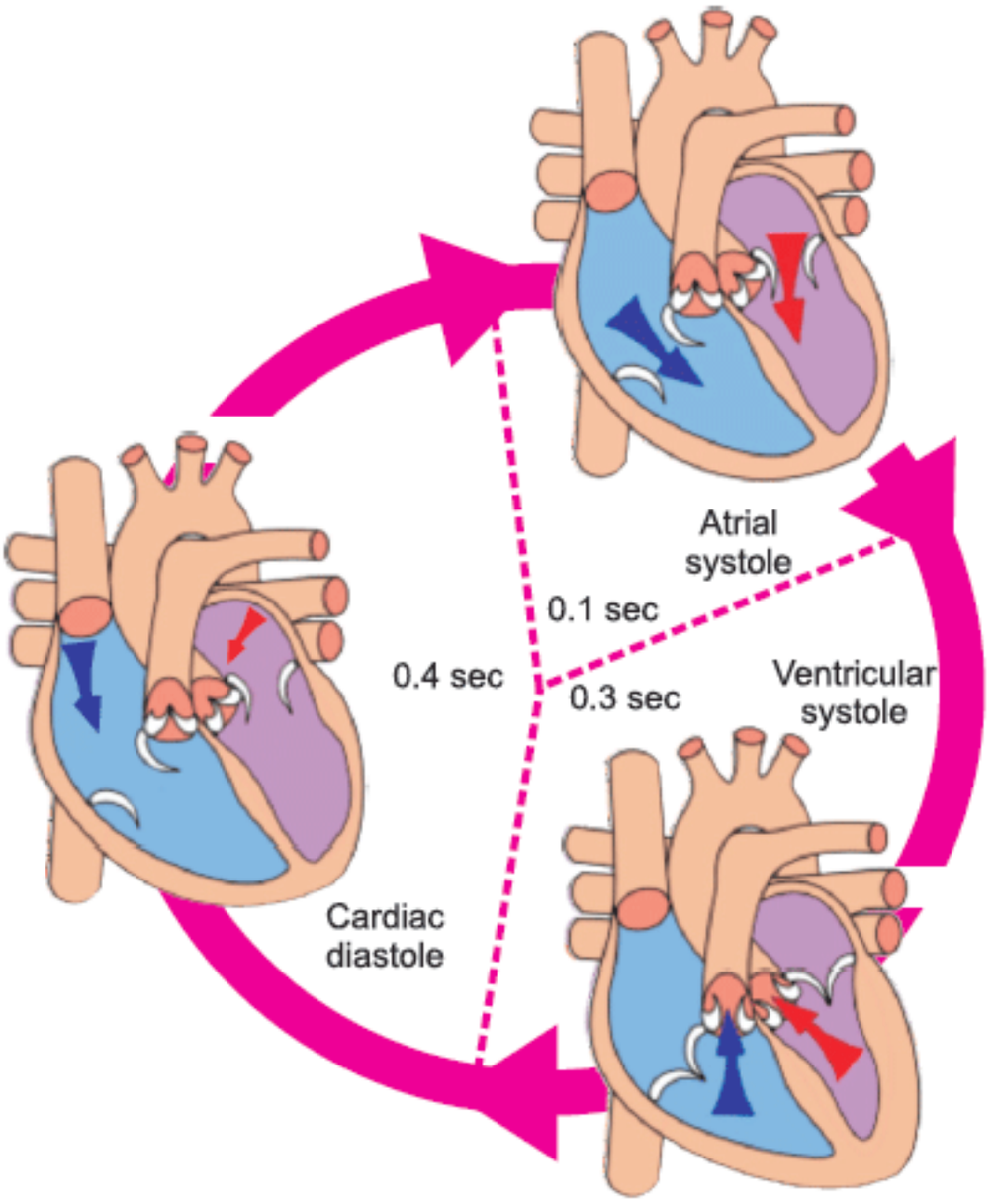


Figure 9.17: One cardiac cycle

Heart rate and Pulse rate

Heart rate is the number of times the heart beats per minute. At rest or during normal activities, the normal heart rate is 70 times per minute in men and 75 times per minute in women. The heart rate fluctuates a lot depending on factors such as activity level and stress level.

Heart rate can be measured by feeling the pulse. **Pulse** is the rhythmic expansion and contraction of an artery as blood is forced through it by the regular contractions of heart.Pulse can be felt at areas where artery is close to skin for example at wrist, neck, groin or top of foot. Most commonly, people measure their pulse in their wrist.

? When does our heart take rest? During sleep, during sitting, or never!

Never

Practical Work:

Investigation of the effect of physical activity on pulse rate

Pulse rate tells us the heart rate. As heart pumps blood through body, a pulsing can be felt in some of the blood vessels close to skin's surface. Pulse rate is measured to see how well heart is working.
Problem: How is pulse rate measured and how it is affected by various activities?

Background information:

- The pulse rate increases when involved in some physical exertion or exercise.
- Daily physical exercise increases the stamina and strength of the cardiovascular system.

Procedure:

1. Turn the palm side of your hand facing up.
2. Place your index and middle fingers of your opposite hand on your wrist, approximately 1 inch below the base of your hand (Figure 9.18).
3. Press your fingers down in the groove at this point. You should feel a throbbing -your pulse.

Animation 9.11 : Blood Pressure 2
Source & Credit : biology.clc.uc

4. Count the number of beats for 10 seconds, then multiply this number by 6. This will give you your pulse rate per minute at resting condition.
5. Do some physical exercise for example running in place, jumping jacks, or other exercise for one minute. After the exercise, measure your pulse rate by the same method (step 1 to 4).
6. Sit on a chair and take rest. After about five minutes, take your pulse again and write it down.
7. Record the differences in the table form and compare your calculations with the differences counted by your class fellows.

Observation:

Student pulse rate at rest will vary between 60 - 110 beats per minute. If pulse rate at rest is about 70 times per minute, it may increase up to 100 beats per minute during exercise.

Evaluation:

I. Are the heart rates of all students the same or different?
Ii. What is the average heart rate of all the students?

Figure 9.18: Method of taking pulse

Physical exertion and exercise should not be very strenuous that they increase your pulse rate beyond the limit.

9.2.3 BLOOD VESSELS

The third part of blood circulatory system are blood vessels, which function to transport blood throughout body. The most important vessels in blood circulatory system are arteries, veins, and capillaries. (Table 9.1)

Arteries: Arteries are the blood vessels that carry blood away from heart. In adults, all arteries with the exception of the pulmonary arteries, carry oxygenated blood.

The structure of arteries is well adapted to their function. The walls of an artery are composed of three layers. The outermost layer is made of connective tissue. The middle one is made up of smooth muscles and elastic tissue while the innermost layer is made up of endothelial cells. The hollow internal cavity in which blood flows is called lumen.

When arteries enter body organs, they divide into smaller vessels known as arterioles. Arterioles enter tissues and divide into capillaries.

Capillaries: Capillaries are the smallest blood vessels present in tissues. These are formed by the divisions of arterioles. The exchange of materials between blood and tissue fluid is carried out through capillaries.

The walls of capillaries are composed of only a single layer of cells i.e. endothelium. This layer is so thin that molecules of the digested food, oxygen and water etc. can pass through them and enter tissue fluid. Waste products such as carbon dioxide and urea can diffuse from tissue fluid into blood.

Capillaries are so small that the red blood cells need to partially fold into bullet-like shapes in order to pass through them in single file.

Veins: A vein is a blood vessel that carries blood towards heart. In adults, all veins with the exception of pulmonary veins, carry deoxygenated blood.

Veins are also well-adapted to their function. The walls of vein are composed of the same three layers as are present in artery wall, with the difference that the middle layer of vein has less smooth muscles and elastic tissue as compared to artery. So the middle layer of vein is comparatively thin. The lumen of the veins is broader than that of arteries.

In a tissue, capillaries join to form small venules, which join to form veins. Most veins have flaps called valves that prevent the backflow of blood.

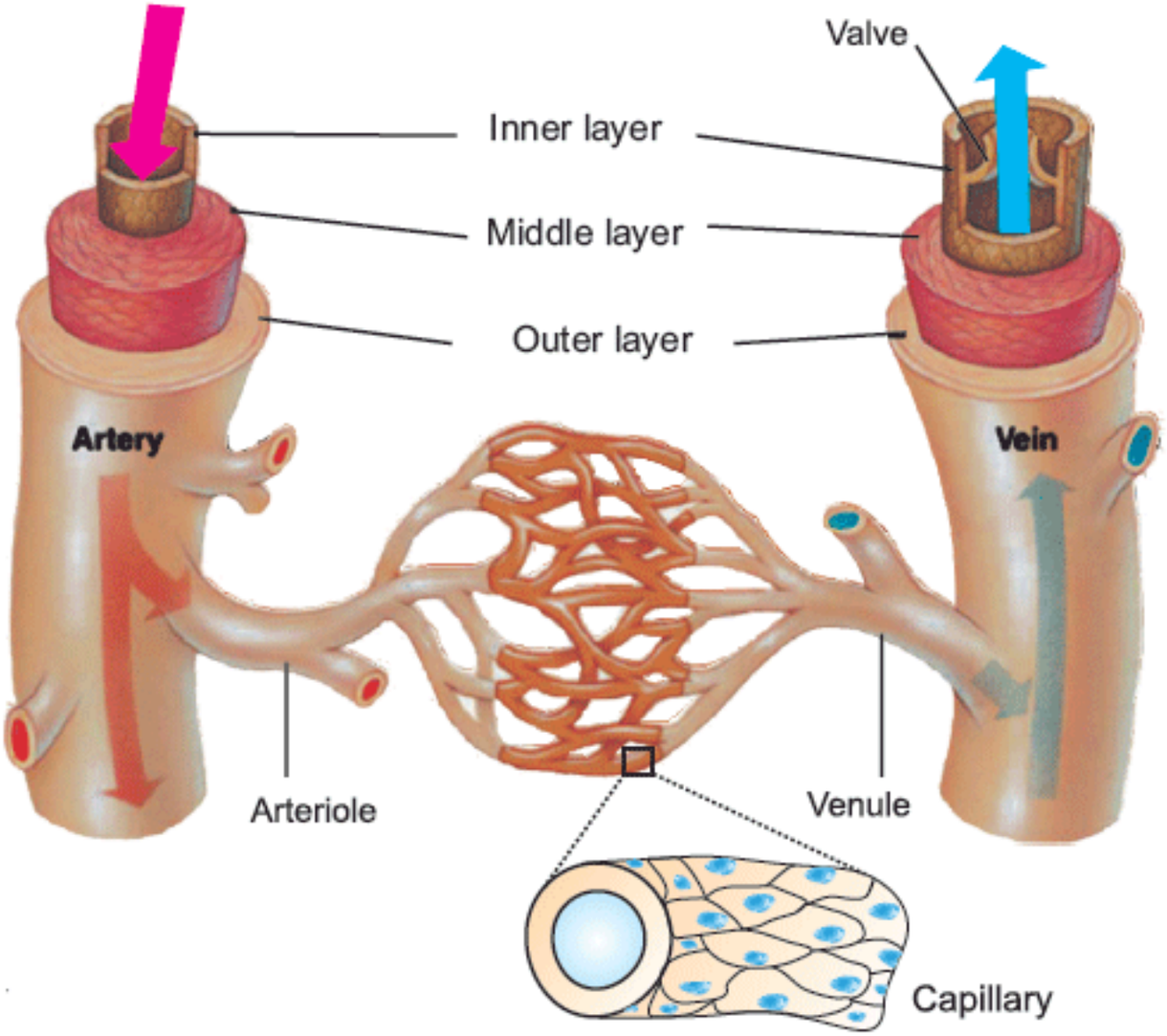


Figure 9.19: Blood vessels

Vascular surgery is a field in surgery in which diseases of arteries and veins (like thrombosis etc.) are managed by surgical methods. A vascular surgeon treats the diseases of all parts of blood circulatory system except that of heart and brain.

Table 9.1: Comparison of arteries, capillaries and veins

Characteristics	ARTERIES	CAPILLARIES	VEINS
Function	Carry blood away from heart	Allow the exchange of materials between blood and tissues	Carry blood towards heart
Thickness and Elasticity in walls	Thick and elastic	One-cell thick non-elastic walls	Thin and less elastic
Muscles in walls	Thick	No muscles	Thin
Blood pressure	High BP	Medium	Low BP
Valves	No valves	No valves	Valves present

Practical work:

Experiment to show capillary flow in the tail or fins of a fish

Capillaries are the smallest blood vessels, which are formed by the divisions of arterioles. Fishes possess a rich network of capillaries under their skin.

Procedure:

See the figure given (9.20) while setting up the experiment.

1. Place a thin wet wad of cotton on the bottom of a Petri dish towards one end.
2. Place a slide at the other end.
3. Remove a fish from the aquarium or jar of water and place it on the Petri dish such that its body lies over the wet cotton and its tail lies over the slide.
4. Place a thick wet wad of cotton over fish and place another slide over the tail. Keep both cotton wads moist by putting water drops over these.

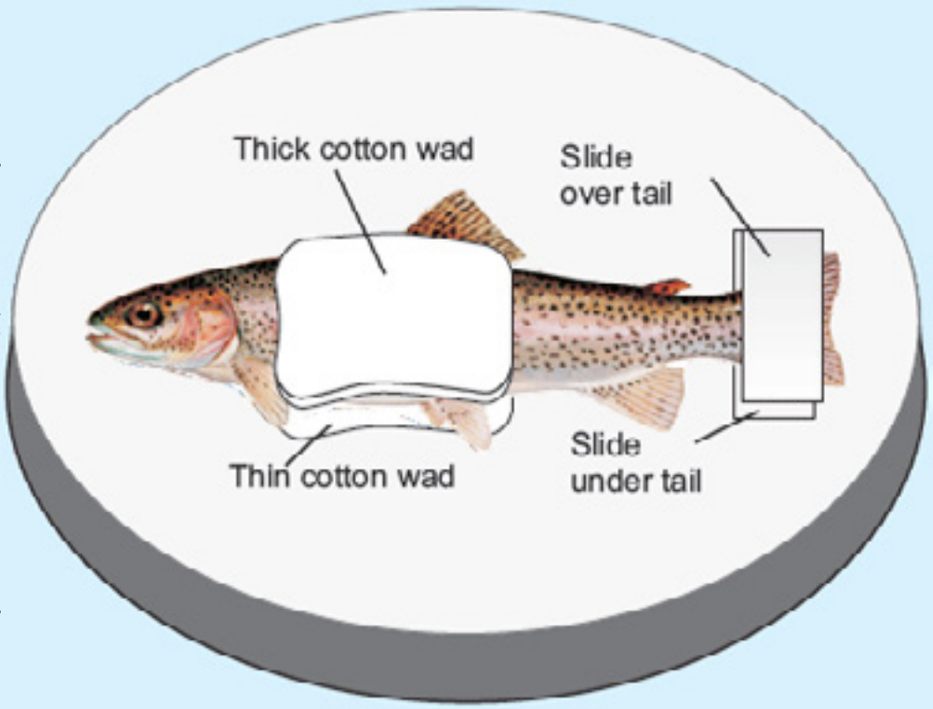


Figure 9.20: Experiment setup to show the capillary flow in fishtail

5. Remove the clips from the stage of microscope and place the Petri dish on the stage so that the tail of fish is over the opening of stage.
6. Focus the microscope on tail and adjust the part of tail where blood capillaries are seen. Draw the structure of capillary network seen in tail of fish.

?

Through which blood vessels the materials are exchanged between the blood and the surrounding tissues?

Capillaries

9.2.4 General Plan of Human Blood Circulatory System

Many scientists worked for discovering the facts about the circulation of blood in human body. Two important scientists who revealed much knowledge of blood circulatory system were **Ibn-e-Nafees** and **William Harvey**. Ibn-e-Nafees (1210-1286 AD) was a physician and he is honoured as the first scientist who described the pathway of blood circulation. William Harvey (1578-1657 AD) discovered the pumping action of heart and the pathway of blood in major arteries and veins.

Now we will see how do the major arteries and veins make arterial and venous systems respectively.

Arterial System

Large **pulmonary trunk** emerges from right ventricle and divides into right and left pulmonary arteries, which carry the deoxygenated blood to right and left lungs.

The oxygenated blood leaving the left ventricle of heart is carried in a large artery i.e. **aorta**. It ascends and forms an **aortic arch**. The arch curves left and descends inferiorly into body. From the upper surface of aortic arch, three arteries emerge, which supply blood to head, shoulders and arms. As aorta passes down through thorax, it becomes **dorsal aorta**. It gives off many branches and the important ones are listed here. Several **intercostal arteries** supply blood to ribs. **Caeliac artery** and **superior mesenteric artery** supply blood to digestive tract while hepatic artery supplies blood to liver.

Even though the heart chambers are continually bathed with blood, this does not nourish heart muscles. The blood supply to heart muscles is provided by coronary arteries, which emerge from the base of aorta. Heart muscles are drained by coronary veins, which empty into right atrium. Coronary arteries and veins are collectively called coronary circulation and it is a part of systemic circulation.

Inferior to these, there are a pair of **renal arteries** that supply blood to kidneys. **Gonadal arteries** supply blood to gonads. Just below the gonadal arteries, is **inferior mesenteric artery**, which supplies blood to a part of the large intestine and rectum.Then aorta divides into two **common iliac arteries**, each of which divides into an internal iliac artery and an external iliac artery. Each external iliac becomes **femoral artery** in upper thigh. It gives branches to thigh, knee, shank, ankle and foot.

Animation 9.12: Blood Circulatory system
Source & Credit: my-ecoach

Venous System

Veins from lungs, called **pulmonary veins** return the oxygenated blood to the left atrium of heart. Two major veins i.e. **superior vena cava** and **inferior vena cava** carry the deoxygenated blood from rest of the body and empty into right atrium.

Superior vena cava forms when different veins from head, shoulders and arms join together. From legs, the deoxygenated blood is returned to heart by many veins which empty into inferior vena cava. Veins carrying blood from calf, foot and knee join together to form **femoral vein**. It empties into **external iliac vein** which joins with the **internal iliac** and both empty into **common iliac vein**.

Right and left common iliac veins join to form inferior vena cava. Many short veins empty into inferior vena cava. Among these are **hepatic vein, renal veins,** and **gonadal veins**. All veins coming from stomach,spleen, pancreas and intestine drain into **hepatic portal vein**, which carries blood to liver. From liver, a hepatic vein carries blood and empties into inferior vena cava. Two renal veins carry blood from kidneys while two gonadal veins carry blood from gonads to inferior vena cava. In thoracic cavity, inferior vena cava also receives veins from thoracic walls and ribs.

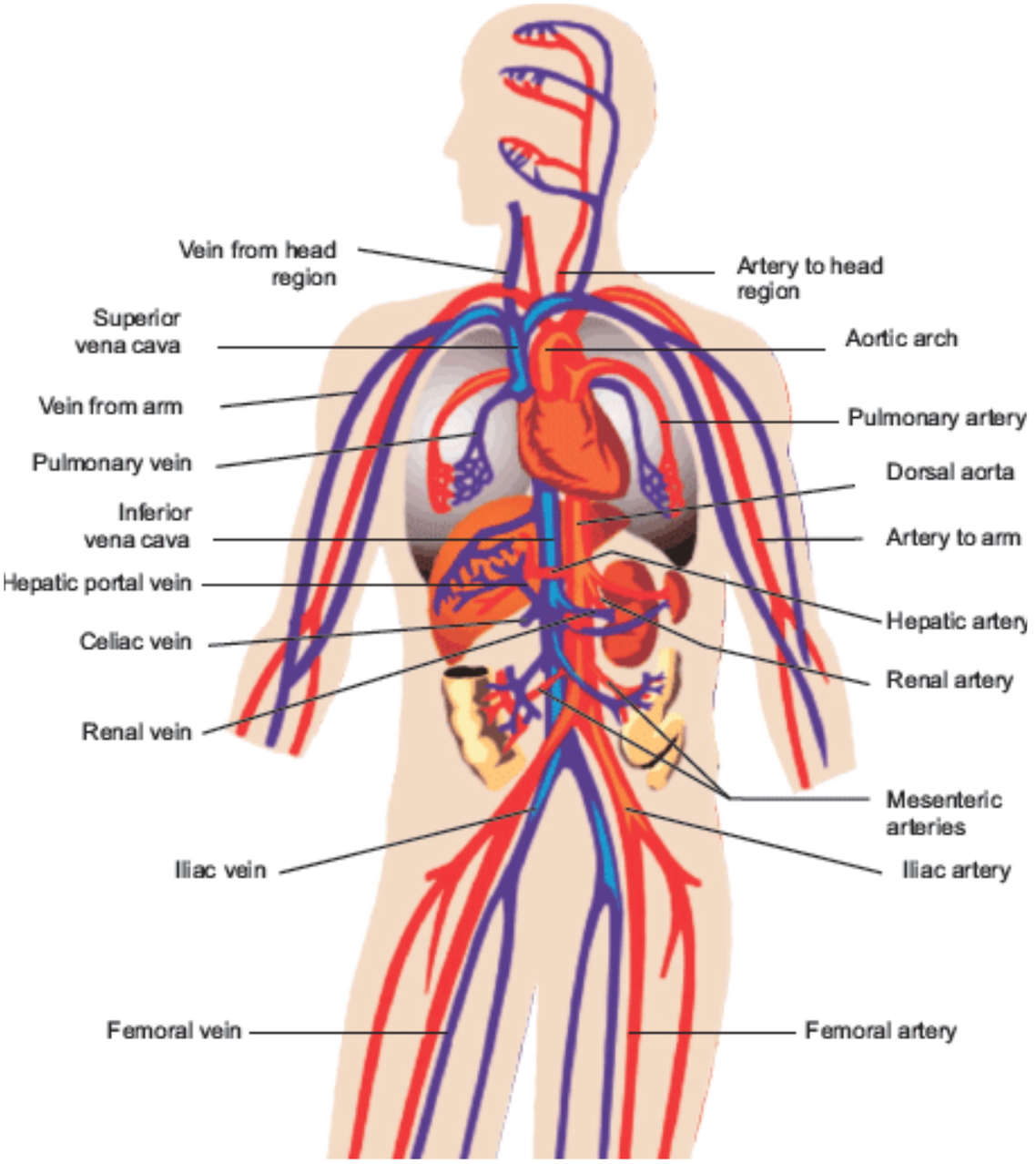


Figure 9.21: Major arteries and veins in human body

? Through which blood vessel the oxygenated blood leaves the human heart?

Aorta

9.3 CARDIOVASCULAR DISORDERS

The diseases that involve the heart or blood vessels are collectively called cardiovascular disorders. These diseases have similar causes, mechanisms, and treatments.
The risk factors that lead to cardiovascular disorders include advanced age, diabetes, high blood concentration of low density lipids (e.g. cholesterol) and triglycerides, tobacco smoking, high blood pressure (hypertension), obesity, and sedentary lifestyle.

9.3.1 ATHEROSCLEROSIS AND ARTERIOSCLEROSIS

Atherosclerosis and arteriosclerosis are the diseases of arteries. These diseases also lead to heart diseases. Atherosclerosis is commonly referred to as a “narrowing” of arteries. It is a chronic disease in which there is accumulation of fatty materials,cholesterol, or fibrin in arteries. When this condition is severe, arteries can no longer expand and contract properly, and blood moves through them with difficulty.

Accumulation of cholesterol is the prime contributor to atherosclerosis. It results in the formation of multiple deposits called **plaques** within arteries. Plaques can form blood clots called thrombus within arteries. If a **thrombus** dislodges and becomes free floating,it is called an **embolus.**

It has been estimated that cardiovascular disorders are the major cause of sudden non-accidental deaths in developed as well as developing countries.

9.3.2 MYOCARDIAL INFARCTION

The term myocardial infarction is derived from myocardium (the heart muscle) and infarction (tissue death). It is more commonly known as a heart attack. It occurs when blood supply to a part of heart is interrupted and leads the death of heart muscles. Heart attack may be caused by blood clot in

coronary arteries. It is a medical emergency, and the leading cause of death for both men and women all over the world. Severe chest pain is the most common symptom of myocardial infarction and may be in the form of sensation of tightness, pressure, or squeezing. Pain radiates most often to left arm, but may also radiate to lower jaw, neck, right arm and back. Loss of consciousness and even sudden death can occur in myocardial infarction.

Approximately one fourth of all myocardial infarctions are silent i.e. without chest pain or other symptoms. A silent heart attack is more common in the elderly, in patients with diabetes mellitus and after heart transplantation.

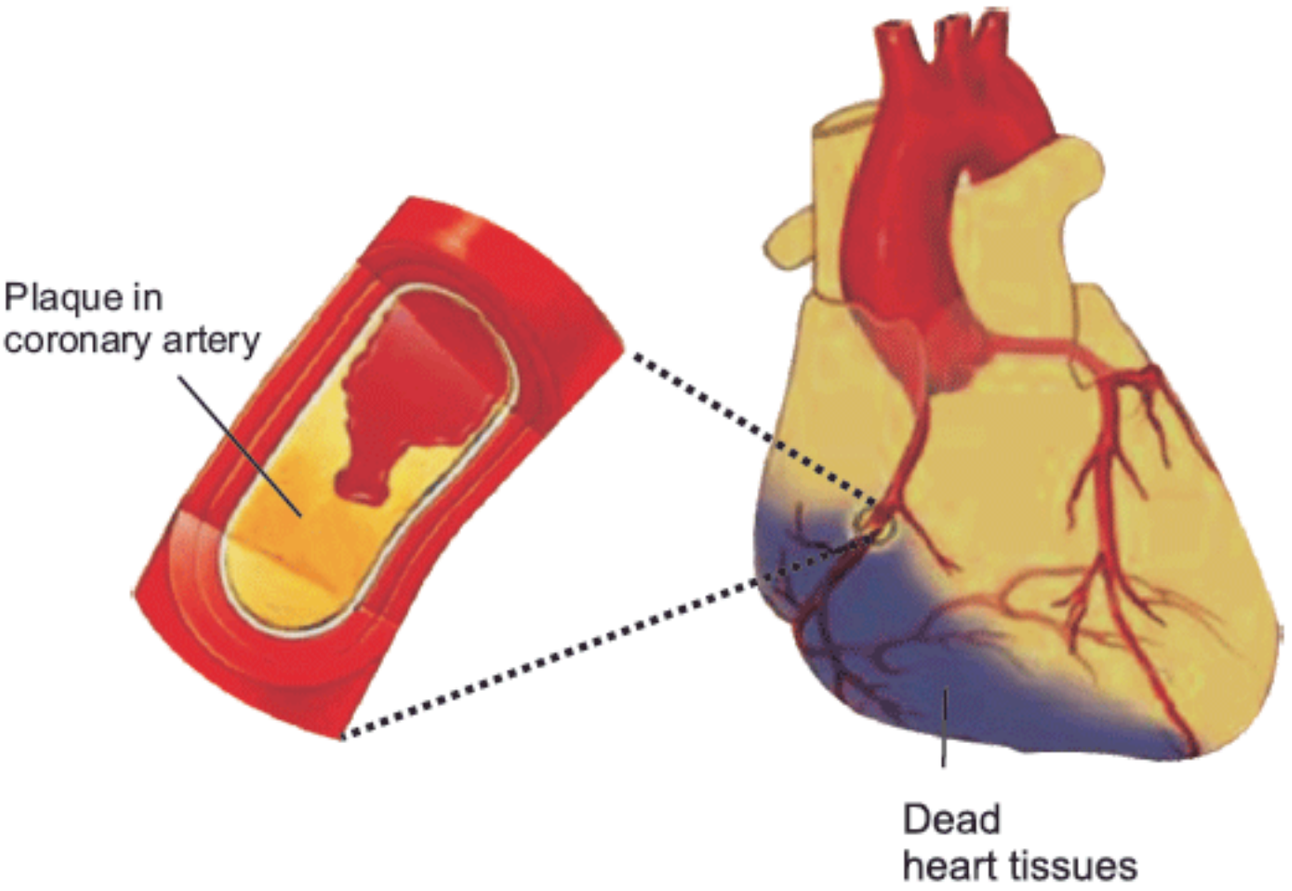
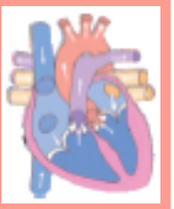


Figure 9.22: Atherosclerosis and resulting Myocardial infarction

Immediate treatment for suspected acute myocardial infarction includes oxygen supply,aspirin, and sublingual tablet of glyceryl trinitrate. Most cases of myocardial infarction are treated with **angioplasty** (mechanical widening of a narrowed or totally obstructed blood vessel) or **bypass surgery** (surgery in which arteries or veins from elsewhere in the patient's body are grafted to the coronary arteries to improve blood supply to heart muscles).

Angina pectoris means "chest pain". It is not as severe as heart attack. The pain may occur in heart and often in left arm and shoulder. It is a warning sign that blood supply to heart muscles is not sufficient but shortage is not enough to cause tissue death.

World Heart Day is held on 28th September every year throughout the world. Its objective is to help people better understand their personal risks of cardiovascular disorders.



Cardiovascular disorders are the cause of 12% of adult deaths in Pakistan (Source: Federal Bureau of Statistics of Pakistan). Hypertension (blood pressure higher than normal) is the most common cause of cardiovascular disorders in Pakistan.

- There are over 12 million hypertension patients in Pakistan.
- About 10% of our population is diabetic.
- According to the World Health Organization,in Pakistan 1 in 7 urban adults is obese.

Animation 9.13 : Heart
Source & Credit: photobucket

UNDERSTANDING THE CONCEPTS

1. How would you relate the internal structure of root with the uptake of water and salts?
2. Define transpiration and relate it with cell surface and with stomatal opening and closing.
3. How do different factors affect the rate of transpiration?
4. Transpiration is a necessary evil. Give comments.
5. Explain the movement of water in terms of transpirational pull.
6. Describe the theory of pressure flow mechanism to explain the translocation of food in plants.
7. List the functions of the components of blood.
8. How do we classify blood groups in terms of the ABO and the Rh blood group systems?
9. State the signs and symptoms, causes and treatments of leukemia and thallassemia.
10 What four chambers make the human heart and how blood flows through these chambers?
11 Compare the structure and function of an artery, a vein and a capillary.
12. Draw diagrams which can illustrate the origins, locations and target areas of the main arteries in human blood circulatory system.
13. Draw diagrams which can illustrate the areas and locations of the main veins in human blood circulatory system.
14. How would you differentiate between atherosclerosis and arteriosclerosis?
15. State the causes, treatments and prevention of myocardial infarction.

SHORT QUESTIONS

1. What are lenticels and where are they found in plant body?

2. What is the role of potassium ions in the opening of stomata?
3. Define the cohesion-tension theory?
4. What do you mean by sources and sinks according to the pressure flow mechanism?
5. What are the two main types of white blood cell? How do they differ?
6. You see pus at the site of infection on your skin. How is it formed?
7. What role does the pericardial fluid play?
8. Define the terms systole and diastole.

THE TERMS TO KNOW

ABO system
Agglutination
Agranulocytes
Albumin
Angina pectoris
Anti-A antibody
Anti-B antibody
Antigen
Antigen A
Antigen B
Anti-Rh antibody
Aorta
Aortic arch
Arteriole
Arteriosclerosis
Lymphocytes
Lymphogenous cells
Megakaryocytes
Monocytes
Myocardial Infarction
Neutrophils
Pericardial fluid
Pericardium
Pericycle
Phloem
Plasma
Platelets
Pulse
Artery
Atherosclerosis
Atrial systole
Atrium
B lymphocytes
Basophils
Bicuspid valve
Bloodgroup system
Capillary
Cardiac cycle
Cardiovascular system
Cohesion-tension theory
Coronary artery
Cortex
Red Blood Cells
Rh factors
Rh-blood group system
Root hair
Semilunar valve
Stoma
Systemic circulation
T lymphocytes
Thalassaemia
Thrombocytes
Thrombus
Transpiration
Transpirational pull
Diastole
Dorsal aorta
Embolus
Endodermis
Eosinophil
Erythrocyte
Fibrin
Fibrinogen
Granulocytes
Guard cell
Haemoglobin
Heart rate
Lenticels
Leucocytes
Leukaemia
Ventricle
Ventricular systole
Venule
White Blood Cells
Wilting
Xylem
Pulmonary artery
Pulmonary circulation
Pulmonary vein
Tricuspid valve
Vein
Vena cava

ACTIVITIES

1. Observe root hairs on a growing root of onion, carrot etc.
2. Describe the structure and number of stomata after microscopic observation of an epidermal peel of a leaf.
3. Investigate the rate of water loss at the two surfaces of a leaf by a simple experiment using cobalt chloride paper.
4. Investigate transpiration in potted plant under a bell jar.
5. Identify xylem and phloem tissues in the prepared slides of stem, root and leaf.
6. Investigate the pathway of water in a cut stem, using a suitable stain.
7. Identify red and white blood cells under the light microscope on prepared slides and in diagrams and photomicrographs.
8. Investigate the effect of physical activity on pulse rate.
9. Show the capillary flow in a fishtail or fin or frog's web.

SCIENCE, TECHNOLOGY AND SOCIETY

1. State vascular surgery as one of the major fields in the careers.
2. Identify that cardiovascular disorders are the major cause of sudden non-accidental deaths.
3. Explain the social as well as personal factors that contribute to cardiovascular disorders in Pakistan.

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GLOSSARY

Active transport: The movement of molecules across a cell membrane from the area of lower to the area of higher concentration.
Aerobic respiration: A type of cellular respiration in which oxygen is utilized and glucose is completely oxidized into carbon dioxide and water.
Agriculture: The profession that deals with the food crops and animals which are the source of food.
Amino acids: The organic molecules which are the units of proteins.
Anaerobic respiration: A type of cellular respiration in which oxygen is not utilized and glucose is incompletely oxidized.
Anatomy: The study of the structure of internal organs.
Antibodies: Proteins produced by lymphocytes that attack antigens.
Antigens: Foreign invaders in the body that trigger an immune response.
Arteries: The thick-walled blood vessels which carry blood away from the heart.
Asexual reproduction: Reproduction which does not involve the fusing of gametes.
Assimilation: The incorporation of the products of digestion into the body, where they are used to provide energy or for growth and repair of tissues.
ATP: A high-energy chemical used in cells as an energy store.

B

Bile: A secretion produced in the liver which emulsifies fats to prepare them for digestion.
Biodiversity: Variety in and between organisms, species and ecosystems.
Bioelement: Elements that make the body of living organisms.
Biogeography: The study of the occurrence and distribution of species in different geographical regions of the world.
Biophysics: The interdisciplinary science that deals with the study of the principles of physics which are applicable to biological phenomena.
Biosphere: The earth's landmasses, oceans and atmosphere, and all the organisms living in them.
Bivalent: Having two chromosomes - one from the male gamete and one from the female gamete.

C

Capillaries: Extremely narrow tubes which carry blood around our tissues.
Carbohydrate: Food belonging to the group consisting of sugars, starch and cellulose. They are vital for energy in humans.

Carnivore: An animal which feeds only on other animals.
Cellulose: A carbohydrate which forms the cell wall in plant cells.
Chlorophyll: The green pigment inside the chloroplasts of plant cells. It enables photosynthesis to take place.
Chloroplasts: Cell organelles containing chlorophyll; found in green plant cells where photosynthesis takes place.
Chromatids: One of two daughter strands of a replicated chromosome.
Chromosomes: One of the rod shaped bodies found in the nucleus of cells that contain genetic information (DNA).
Cloning: Producing organisms which are genetically identical to one another.
Community: Populations of different organisms living together in a habitat.
Cytokinesis: The division of the cytoplasm, after nuclear division (karyokinesis).

D

Decomposer: An organism which eats dead materials and breaks them down into simple materials.
Defecation: Getting rid of undigested material from the body.
Deforestation: The process of cutting down a large number of trees in a forest and not replacing them.
Diaphragm: A large sheet of muscle that separates the lungs from the abdominal cavity.
Dietary fiber: Non-digestible carbohydrates.
Diffusion: The movement of molecules or ions from an area of higher concentration to an area of lower concentration.
Digestive system: System of organs are involved with the ingestion, digestion, absorption of food
DNA: Deoxyribonucleic Acid: The material inside the nucleus of cells which carries genetic information.
Duodenum: The first part of the small intestine where most of the digestion takes place.

E

Ecology: The study of living things within their environment.
Embryo: The developing human offspring inside the womb.
Enzyme: Proteins which speed up chemical reactions inside living organisms, by minimizing the activation energy.
Epiglottis: Small flap at the back of the tongue; it closes the glottis when we swallow so that food does not go down into trachea.
Extinct: Species of organism that is no longer living.

F

Fatty acids: Important components of lipids. Long-chain molecules made up of hydrogen and carbon atoms.

Fertilizers: Nutrients applied to crops to speed up growth.

Flaccid: Lacking turgor; lacking in stiffness.

Fossil: Remains or impression of an organism that existed in the geological past.

G

Genetics: The study of inheritance. Inheritance means the transmission of characters from one generation to the other.

Guard cells: Bean-shaped cells which control the opening and closing of stomata in a green plant's leaves.

H

Habitat: A place where plants, animals and micro-organisms live.

Haemoglobin: The red protein found in red blood cells that transports oxygen.

Herbivore: An animal which feeds only on plants.

Horticulture: The growing of garden plants;the cultivation of fruit and vegetables.

I

Ileum: The longest part of the small intestine, where food is completely digested and absorbed.

Immune system: The body's defence system against diseases and infections.

L

Limiting factors: Something which, when not sufficient, prevents or slows down a process.

Lymphocytes: A type of white blood cells which attack pathogens.

M

Meiosis: Type of cell division which forms gametes in animals and spores in higher plants, each with half the usual number of chromosomes.

Mesophyll: The inner tissue of a leaf, whose cells are green because they contain chloroplasts.

Metabolism: The sum of all chemical processes taking place in our cells, and the rate at which these proceed.

Microbiology: The division of biology that studies the life of microorganisms.

Mitochondria: Structures in the cytoplasm of all cells where respiration takes place. Singular is mitochondrion.

Mitosis: A type of cell division which produces daughter cells identical to the parent.

Morphology: The study of the structures of living organisms.

Mutation: A change in DNA which results in a change in an organism's genome.

N

Nucleus: The organelle of eukaryotic cells where genetic information is stored.

O

Omnivore: An animal which feeds on both plants and animals.

Organ: Group of tissues doing a particular job e.g. the heart.

Organ system: Group of organs doing a particular job, e.g. the circulatory system.

Organelle: Microscopic structure which does a particular job in a cell, e.g. the nucleus.

Osmosis: The movement of water molecules across a semi permeable membrane, from a solution of lower solute concentration to a solution of higher solute concentration.

Oxygenated blood: The blood containing more oxygen.

P

Palisade mesophyll: The upper layer of mesophyll where photosynthesis mostly takes place.

Pancreas: Large gland located in the abdomen near the stomach which produces Pancreatic juice for digestion and the hormone insulin.

Parasite: An organism that lives in or on another organism and causes harm to it.

Partially permeable or semi-permeable: Allowing some particles to pass through but not others.

Peristalsis: Wave-like muscular contractions in the walls of the gut which move food through the alimentary canal.

Phloem: Compound tissue through which food is transported in a plant.

Photosynthesis: The chemical change in autotrophs that uses light energy to convert carbon dioxide and water into glucose.

Physiology: The study of the functions of living organisms and their parts.

Plasma: Liquid, non-cellular part of the blood.

Platelets: White blood cell fragments which circulate in the blood and assist in clotting.

Population: Members of a single species living in a habitat.

Predator: Animal that hunts, kills and eats other animals for food.

Producer: An organism which can make its own food - i.e. a green plant.

Proteins: Organic compounds made up of amino acid molecules, one of the three main food groups.

R

Red Blood Cells: Cells which contain haemoglobin and carry oxygen.

Renal artery: Related to kidneys e.g. renal artery, renal vein.

RNA: (Ribonucleic acid) - it converts the genetic information stored in DNA into proteins.

Root hairs: Tiny hairs covering the ends of the smallest roots. They give the root a very large surface area to absorb water and mineral salts from the soil.

S

Saliva: Fluid secreted by glands in the mouth which moistens, softens and semi-digests food.
Sexual reproduction: Reproduction which involves the fusing of male and female gametes.
Spindle fibres: Fibres produced during cell division. They contract to drag chromatids to the poles of the cell.
Spongy mesophyll: The lower layer of mesophyll which contains numerous air spaces where gas exchange takes place.
Starch: A type of carbohydrate. Plants can turn the glucose into starch for storage.
Stomata (singular 'stoma'): Tiny pores in the epidermis of a leaf. They control water loss and gas exchange by opening and closing.

T

Thorax: The chest, containing the heart and lungs and encased by the ribs.
Tissue: Group of cells of the same type doing a particular job, e.g. the glandular tissue, muscular tissue, nervous tissue etc.
Trachea: The windpipe or tube from the back of the mouth to the top of the lungs.
Transpiration: The loss of water from plant surface by evaporation.
Turgor: Swelling and stiffness in plant cell due to endosmosis of water.

V

Vaccines: Substances containing disabled antigens of a particular disease; Vaccines stimulate the body to produce antibodies to provide immunity against that disease.
Valves: Structures containing a flap or flaps to ensure one-way flow of liquid.
Variegated leaf: Leaf with alternating green and white patches.
Veins: Thin-walled, valved tubes which carry blood back to the heart.
Villi: Minute hair-like projections which cover the lining of the small intestine; provide surface area for absorption.
Virus: Ultramicroscopic non-cellular organism that replicates itself inside the cells of living hosts.
Vitamins: Organic substances which are essential in small amounts to regulate the metabolism and maintain the immune system.

X

Xylem: Compound tissue which transports water and minerals up a plant.