(xiv) **Pharmacology** (Gr. pharmakon, drug;)**.** The study about action of drugs.

(xv) **Molecular biology:** The study of organic molecules which constitute cell and its organelles.

1.1.1 Relationship of biology with other sciences:

Biology is a multidimensional subject and linked with other sciences. For example, the movement of animals follows the laws of motion in physics. Biology is considered as interdisciplinary science, which is related with other sciences. Some of these are mentioned below:

Biophysics:

It is a branch of physics, in which laws and techniques of physics are applied to explain the processes of life. The radiophysics branch where radioactive isotopes are used to trace the translocation of different materials within the organisms. Radio-labeling and carbon-dating also show some uses of radioactive isotopes in determining the age of fossils, uses of sound waves as ultrasound and laser technology show relation of physics with biology.

Biomathematics/Biometry:

The branch of mathematics which collects data of living organisms. It plays very important role in research.

Biochemistry:

It is branch of biology which deals with the study of molecules which form living organisms or cell and requires authentic knowledge about biology and chemistry to explain the synthesis of biomolecules and function of different molecules in the body of an organism.

Biogeography:

It deals with the distribution of different living organisms in different geographical regions of the world. Many living organisms are restricted to particular geographical regions due to environmental conditions.

Bio-economics:

This deals with the economically important organisms involved in production, e.g meat production, etc. are calculated for cost value and profit value.

1.1.2 Careers in biology:

The career of student is subject to obtain a degree. The students, who have chosen the biology, they can plan to adopt some as a career in following fields:

Medicine and Surgery:

Medicine deals with diagnosis and treatment of diseases and surgery deals with repair, replacement or removal the affected organ.

Agriculture:

This deals with production of varieties of crops, fruit, vegetables, dairy products, etc. Pakistan being an agricultural country, it can play very important role.

Horticulture:

This is also part of agriculture, in which work is carried out for the development of new varieties of plants and their products.

Forestry:

Forests are the source of biodiversity of plants and animals of many kinds which live there. It is important in development of new forests as well as preservation of existing ones.

Farming:

In this profession, the development of different kinds of farms takes place, such as fish farm, cattle farm, poultry farm, etc. New technologies are used for the production of animals as source of meat and milk, leather, wool, etc.

Animal husbandry:

This profession is part of agriculture science. It deals with the care and breeding of animals which are beneficial for man.

Fisheries:

This profession deals with the increased quantity and quality of fish production. Fish is one of the best source of protein.

Biotechnology:

This is very important and sensitive profession. It deals with manipulation of gene to produce valuable chemical products, such as insulin, growth hormones, interferon, etc from bacteria as well as others.

1.1.3 Quran and Biology:

The Almighty Allah has conveyed a great knowledge about the origin and characteristics of animals and plants through our Holy Book, the Quran. A few of Ayah are quoted as under:

Allay Says;

وَجَعَلْنَا مِنَ الْمَآءِ كُلَّ شَيْءٍ حَيٍّ ط

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

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

"And Allah has created every animal from water of them there are some that creep on their bellies, some that walk on two legs; and some that walk on four. Allah creates what He will Lo! Allah is able to do all things."
(Surah Al-Nur, Ayah-45)

Here water is symbolized with the protoplasm as the basis of life and the vital power of protoplasm seems to depend on the constant presence of water.

وَفِي الْأَرْضِ قِطَعٌ مُّتَجٰوِرٰتٌ وَّجَنّٰتٌ مِّنْ اَعْنَابٍ وَّزَرْعٌ وَّنَخِيْلٌ
صِنْوَانٌ وَّغَيْرُ صِنْوَانٍ يُّسْقٰى بِمَآءٍ وَّاحِدٍ ۚ وَنُفَضِّلُ بَعْضَهَا
عَلٰى بَعْضٍ فِي الْاُكُلِ ۭ اِنَّ فِيْ ذٰلِكَ لَاٰيٰتٍ لِّقَوْمٍ يَّعْقِلُوْنَ ۝

"And in the earth are neighboring tracks, vineyards and ploughed lands, and date-palms, like and unlike which are watered with one water. And we have made some of them to excel others in fruit. Lo! Here in verily are portents for people who have sense."

(Surah: Al-Ra'd, Ayah: 4)

Here Allah has revealed some facts about plant growth and development.

1.1.4 Contribution of Muslim Scientists:

The Muslim scientists have played great role in the development of biological science. They began experiments and observations from the first Century of Hijra. Following are some details about the important Muslim scientists, who made significant contribution towards the development of biology.

1. Jabir Bin Hayan (722-817 A.D):

He was born in Iran. He worked in the field of chemistry but he also wrote a number of books on plants and animals. "Al-Nabatiat" and "Al-Haywan" are his two famous books on plants and animals, respectively.

2. Abdul Malik Asmai (741-828 A.D):

He was great zoologist and wrote many books on animals like "Al-Kheil" on horse, "Al-Ibil" on camels, "Al-Shat" on sheep, "Al-Wahoosh" on wild animals and "Khalqul Insan" on the different parts of human body and their functions.

3. Bu Ali Sina (980-1037 A.D):

He was greatest of all the Muslim scientists and considered as the founder of medicine. He is called as Avicenna in the west. He identified many diseases like tuberculosis, meningitis and other such inflammations. He also worked in the field of mathematics, astronomy, physics, paleontology and music. He wrote book like "Al-Qanoon" and "Fil Tib Al-Shafa".

1.2 THE LEVEL OF ORGANIZATION

The levels of organization in living world are based on chemical foundation. All the living organisms are made up of cells and the protoplasm of cell is the physical as well as chemical basis of life. These levels are as follows:

1. Atomic level of organization:

All the matter is made up of elements, which is composed of atom (a: not, form: cut). Each atom is made up of sub-atomic particles, such as electrons, protons and neutrons.

In nature, there are more than 100 kinds of elements and among these 16 elements are called as bio-elements, which are vital for life. Only six elements such as C, H, O, N, S and P are called basic elements of life.

2. Molecular level of organization:

Molecules are formed by the binding of atoms. These organic molecules of cells are called as bio-molecules. These are constructed in great variety and complexity. They are classified as micro-molecules and macro-molecules.

Glucose, amino acid and fatty acids are micro-molecules, where as carbohydrates, proteins and lipids are macro-molecules. The units of micro-molecules combine together to form macro-molecules.

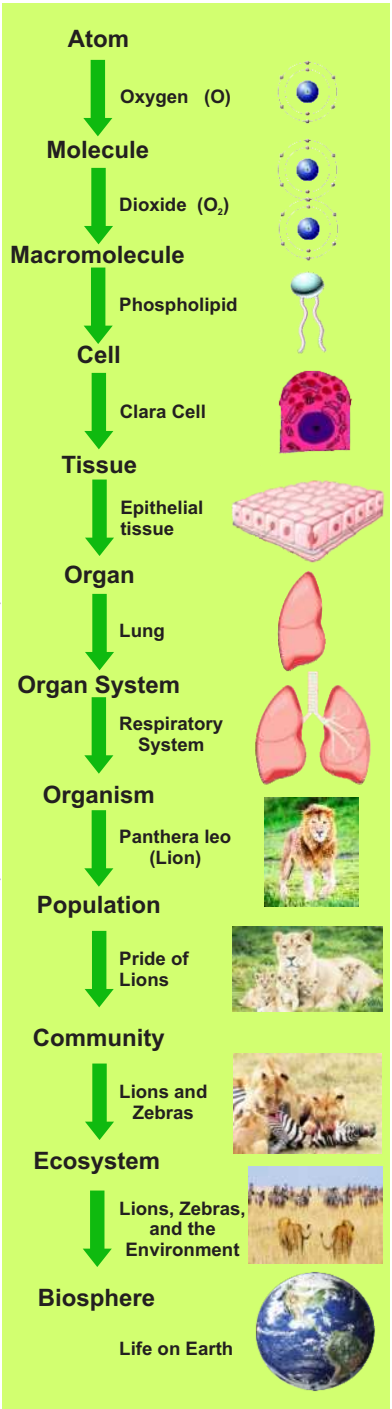


Fig: 1.1 Levels of organization

3. Cellular level of organization:

The biomolecules when work together in the form of suspension, It is called **Protoplasm**. Protoplasm is the combination of organic and specific inorganic substances. When protoplasm work in the form of a unit, this is called **Cell**. Cell is the basic unit of living organisms. When similar type of cells organize together in a group, called tissues. The different types of tissues arranged in a particular manner to work together are called **Organs**.

Organs of different types work in a co-ordinated manner to perform a function is called **Organ-system**. When different organ-system function in co-ordination in as a unit, they form a body or **Multicellular Organism**.

4. Taxonomic level:

There is another level of organization which is related with living organisms. The **Species** is the smallest unit of taxonomic level of organization, which includes morphologically similar living organisms which inter-breed and produce fertile offspring.

5. Population level:

All the members of a species, living in specific habitat are called **Population**. A group of parrots living on tree, is called parrot population.

6. Community level:

The members of different species living in specific habitat are called as **Community**. A group of different kind of birds, living on tree, is called as bird community.

7. Ecological system:

Communities always depends upon their non-living environment in a reciprocal interaction for their survival. For example oxygen for respiration is obtained from environment and in turn given out CO_2. This interaction is called Ecosystem or Ecological system.

8. Biosphere level:

The part of earth where life exists is called biosphere. It consists of different kinds of eco systems.

1.2.1 Unicellular Organizations:

All single cell organisms carry out all activities of life. They digest the food, respire, excrete, move etc on the cellular base by simple methods. Bacteria, Amoeba, Paramecium and Euglena are common examples of unicellular organisms.

1.2.2 Colonial Organization:

Many unicellular organisms live together by forming colonies but do not have any division of labor among them. In colonial type of cellular organization, each unicellular organism lives its own life, they are not dependent on each other and never form any multicellular structure. *Volvox* is a green alga (as shown in figure 1.4), is an example of colonial form of organization.

1.2.3 Multicellular Organization:

The organism formed by many cells is called as multicellular organism. Frog and mustard plant are examples of multicellular organization.

Mustard plant:

Brassica campestris is commonly known as mustard plant and locally it is called "**Sarsoon**". It is multicellular and cultivated in winter season. The leaves of this plant are used as vegetable while seeds are used for oil extraction. The length of this plant is 1 to 1.5 meter. This plant has two parts, the vegetative part, which consists of root, stem and leaves and reproductive part which consists of flowers. Each flower is yellowish in color and produce seeds.

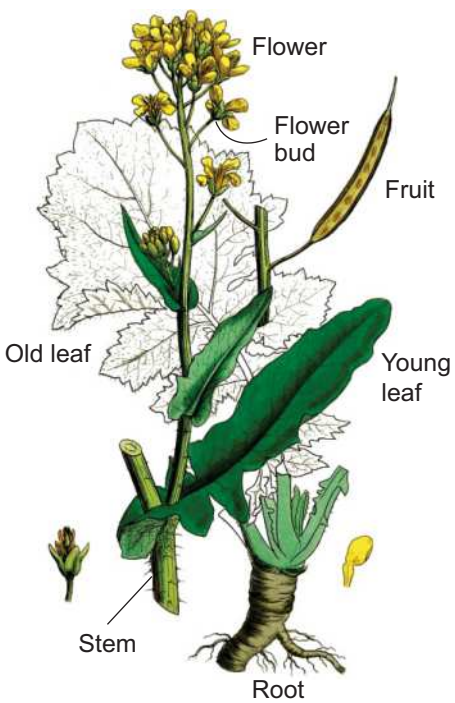


Fig: 1.2 Brassica campestris

Frog:

Rana tigrina is the scientific name of spotted frog found commonly in our region. It is multicellular animal. It lives in both water as well as on land. Its body is divided into head and trunk. There is no neck. Its body is made of organ system with different organs.

Fig: 1.3 Frog

All organs are made of different tissues such as epithelial, glandular, muscular, nervous etc. Frog lives near ditches, pools, ponds, stagnant stream and slow moving rivers. It feeds on small insects.

Activity: Identification of organs and organ-system in dissected frog:

Material Required:

- Preserved frog
- dissection box
- dissecting tray
- pins

Procedure:

Place the preserved frog on a dissecting tray on its back, as all vertebrates are dissected ventrally, pin down the fore limbs and hind limbs. Take scissor to cut the abdomen ventrally, from cloaca to the mouth. Again cut down the skin of limbs from each side and pin down. Expose the visceral organs clearly and make observation with the help of diagram. Locate the organs and identify them as below:

Table showing different organs with the relative organ system.

Organs	Organ System
Mouth, buccal cavity, Pharynx, Esophagus, stomach, small intestine, large intestine, cloaca, liver, gall bladder,pancreas.	Digestive system
Heart, atria ventricle, Aortae, Vena cavae	Circulatory system
Lungs, trachea, nostrils	Respiratory system
Kidneys, Ureter, Urinary Bladder	Excretory system
Testes, vasa efferentia, Ovaries, Oviduct, Ovisac	Reproductive system
Brain, Spinal Cord, Nerves	Nervous system

Draw the labelled diagram of dissected frog.

Fig: 1.4 Dissected frog

Amoeba:

Amoeba is a unicellular organism found in the mud of shallow pond, pools and at any stagnant water. Its size is about 0.25mm. Amoeba has a irregular shape. It has a cell membrane which helps in movement of molecules and protects cytoplasm. The outer part of cytoplasm is clear and transparent, called ectoplasm (gel) and inner part is called endoplasm (sol). The cytoplasm contains nucleus, food vacuoles, mitochondria etc. Amoeba moves by false foot, called pseudopodia.

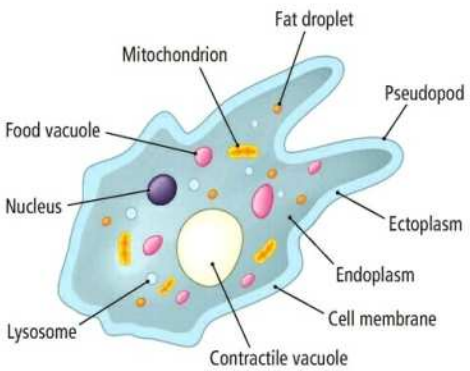


Fig: 1.5 Amoeba

Volvox:

Volvox is a polyphyletic (many ancestors) genus of chlorophyte green algae in the family Volvocaceae. It forms spherical colonies of upto 50,000 cells. They live in a variety of fresh water habitats and were first reported by ***Antonie Van Leeuwen Hoek*** in 1700.

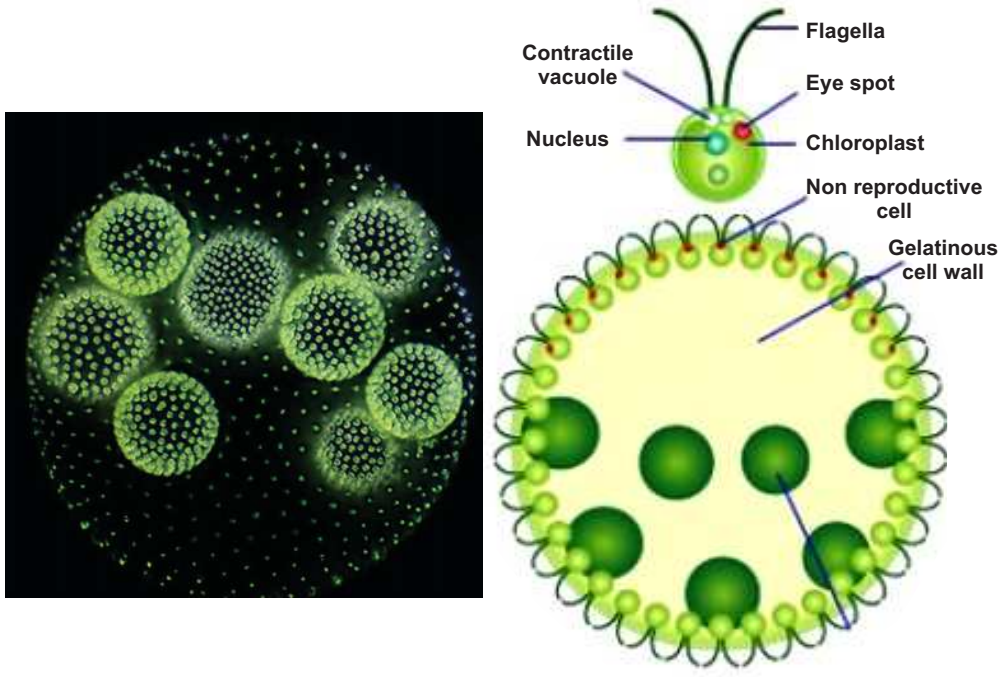


Fig: 1.6 Volvox colony

Volvox once called algae that live together in a colony. Each Volvox cell has two flagella. The flagella beat together to roll the body in water. Volvox cells have chlorophyll and make their own food by photosynthesis. These photosynthesis organisms are an important part of many aquatic eco system. Volvox are not harmful to humans because they do not produce any toxic substance.

Summary

- Biology deals with the study of living beings.
- Life can be identified on the basis of certain processes.
- Biology can be divided in three major divisions.
- Biology is linked with other sciences such as Physics, Chemistry, Mathematics, etc.
- Economically, Biology is very important for food, medicines, forestry and farming etc.
- The Almighty Allah has conveyed a great knowledge about origin and characteristics of living beings in the Holy Quran.
- Muslim Scientists have played great role in the development of biological science.
- Various levels of organization have been identified in the living world.
- Protoplasm is the chemical basis of life.
- Smallest unit of protoplasm is cell.
- Organisms could be unicellular or multicellular.
- Brassica campastris is commonly known as Mustard (Sarsoon) plant.
- Rana tigrina is biological name of frog.
- Amoeba is unicellular organism.
- Volox belong polyphylectic group of algae. It lives in colonial form.

Review Questions

1. Encircle the correct answer:

(i) A localized group of organisms that belong to the same species is called a:

(a) Biosphere (b) Community

(c) Ecosystem (d) Population

(ii) Increased quantity and quality of fish production:

(a) Fisheries (b) Farming

(c) Animal husbandry (d) Forestry

(iii) Study of remote past organic life, with the help of fossils.

(a) Entomology (b) Paleontology

(c) Taxonomy (d) Histology

(iv) Laws and techniques of physics are applied to explain the living processes of life.

(a) Biometry (b) Biostatistics

(c) Biophysics (d) Bio-economics

(v) Choose the incorrect statement:

(a) Six elements such as C, H, O, N, S and P are called basic elements of life.

(b) Foundation of life based on chemicals.

(c) Members of different species form population.

(d) Part of earth where life exists is called biosphere

(vi) Science of diagnosis and treatment of diseases.

(a) Agriculture (b) Medicine

(c) Surgery (d) Both B and C

(vii) Similar cells combine together to form:

a) Organs (b) System

(c) Tissue (d) Body

(viii) Scientific name of frog is:

(a) Palaeon (b) Rana tigrina

(c) Periplaneta (d) Pheretima

(ix) Select the correct sequence of biological organization

(a) Atom → Cell → Tissue → Molecule → Organ

(b) Atom → Tissue → Cell → Molecule → Organ

(c) Atom → Molecule → Cell → Tissue → Organ

(d) Atom → Cell → Molecule →Tissue → Organ

(x) *Volvox* is a polyphyletic genus of

(a) Green algae (b) Red algae

(c) Brown algae (d) None of these

2. Fill in the blanks

(i) Techniques for manipulation of gene to achieve desirable characters are called_____.

(ii) Distribution of different living organisms in different regions of the world_____.

(iii) Part of agriculture for the development of new varieties of plant, and their fruit is _____.

(iv) Bio elements considered as vital for life are _____ in members.

(v) Members of different species living in specific habitat are called _____.

(vi) The Muslim scientists who identified many diseases like tuberculosis, meningitis and other such inflammations was _____.

(vii) Part of earth where life exists is called_____.

(viii) Foundation of life based on _____.

(ix) Fish is one of the best source of_____.

(x) Radio labeling and carbon dating also show some uses of radioactive isotopes in determining the _____ of fossils.

3. Define the following terms

(i) Anatomy (ii) Histology (iii) Immunology

(iv) Pharmacology (v) Entomology (vi) Biometry

(vii) Biogeography (viii) Surgery (ix) Animal husbandry

(x) Bioelements

4. Distinguish between the following in tabulated form

(i) Colonial organization and multicellular organization

(ii) Agriculture and horticulture

5. Write short answers of following questions.

(i) Why subject biology is named as multidimensional subject?

(ii) How farming profession helps mankind?

(iii) Why species is called as smallest taxonomic level?

(iv) How population is different from community?

(v) How new varieties of plant are produced?

(vi) Draw a labeled diagram of frog's digestive system.

6. Write detailed answers of the following questions.

(i) Describe the role of Muslim scientists in the field of biology.

(ii) Describe the relationships of biology to other sciences.

(iii) Describe the level of organization.

SOLVING A BIOLOGICAL PROBLEM

Chapter 2

Major Concept

In this Unit you will learn:

- Biological Method
  - Scientific problem, Hypotheses, Deductions and Experiments
  - Theory, Law and Principle
  - Data organization and Data analysis
  - Mathematics as an integral part of the Scientific Process

Science is the systematic study of nature and how it affects us and the environment. It is a body of knowledge that is constantly changing through the use of better and more accurate tools for investigation. At the core of biology and other sciences lies a problem-solving approach called the scientific method.

The scientific method is a series of steps followed by scientific investigators to answer specific questions about the natural world.

2.1 BIOLOGICAL METHOD

As you know that biology is the branch of science concerned with the study of living things, or organisms. The system of advancing knowledge by formulating a question, collecting data about it through observation and experiment, and testing a hypothetical answer about living things is called biological method.

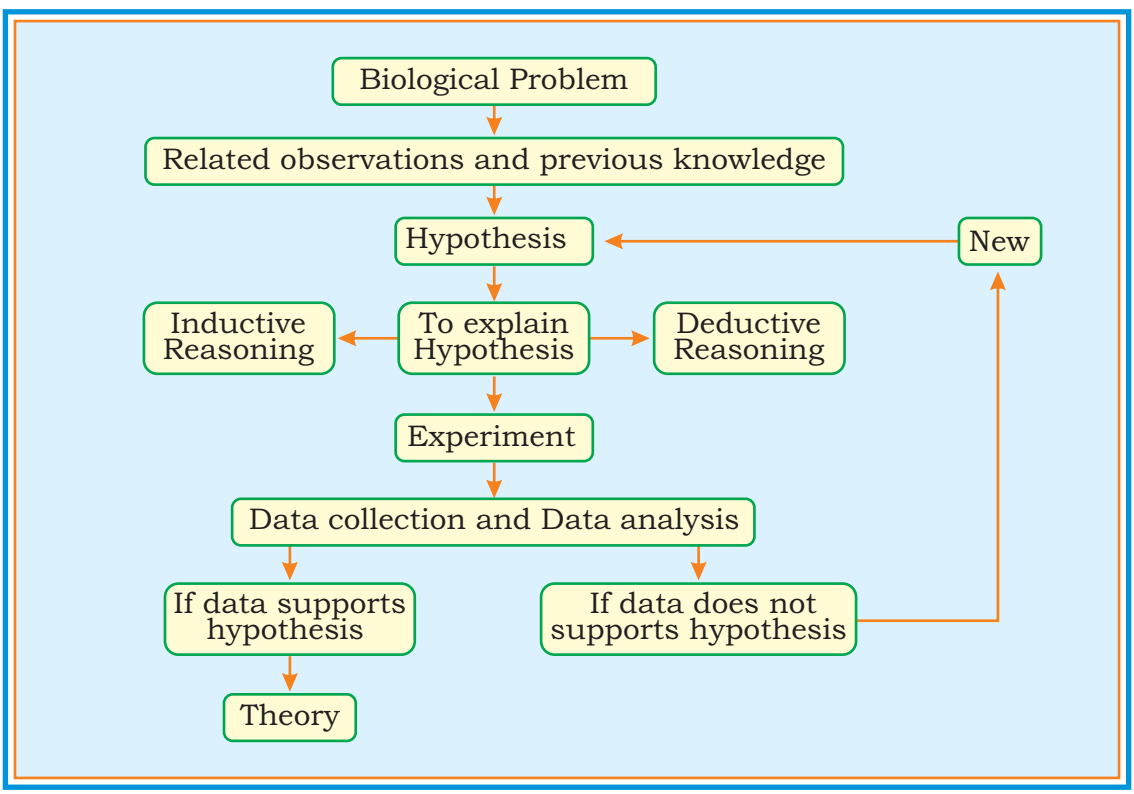


Figure 2.1 The steps involved in a biological method

2.1.1 Biological problem, Hypothesis, Deduction and Experiments:

Biological problem is a set of questions to be solved, about the natural world. These problems can be environmental, ecological, health related, etc. No matter what types of problems are being studied, scientists use the same problem-solving method to find answers that are logical and supported by evidence. Here we take an example of malaria (the greatest killer disease of man for centuries). You are familiar with the disease of malaria which spread through a female Anopheles mosquito. Previously the cause of malaria was unknown. It was thought that the malaria is caused by "bad air" (Latin word: 'mala' means bad, and 'aria' means air). This problem is solved when a Scientist identified the reason of malaria.

Observation:

The first step is to identify the reason of the problem followed by the formulation of a question about what has been observed. The solution of biological problem starts with observation. Your observation can be on anything from plant movement to animal behavior. An observation is a statement of knowledge gained through the senses (qualitative) or through the use of scientific equipment (quantitative).

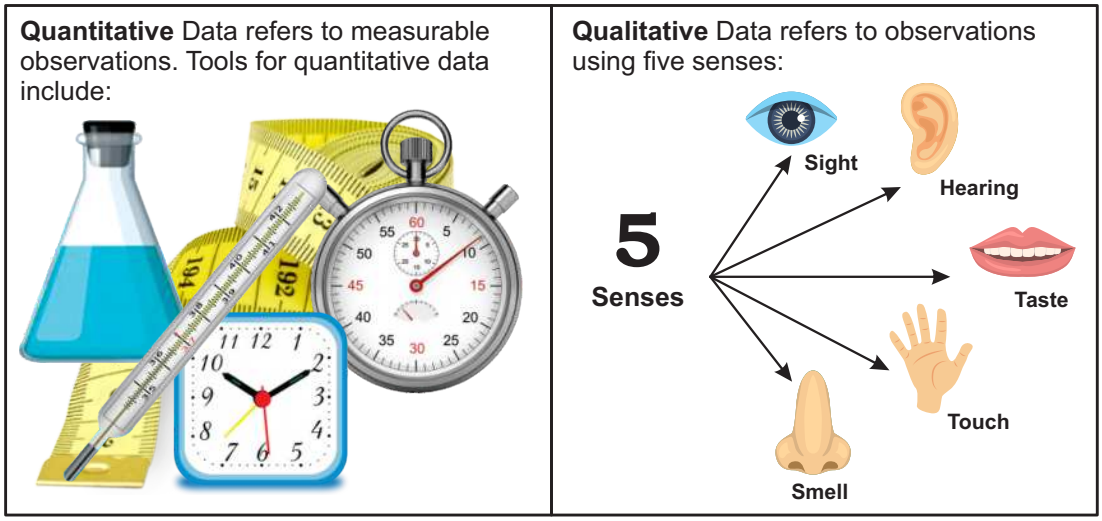


Figure 2.2 The qualitative and quantitative observation

About 280 million people suffer from malaria in over 100 countries, and more than 2 million die every year from the disease.

In 1880, a French physician, ***Laveran***, studied the blood sample of malaria patient under microscope and observed tiny creatures in it and named as ***Plasmodium***. So the observation was made that Plasmodium is present in the blood of malaria patients.

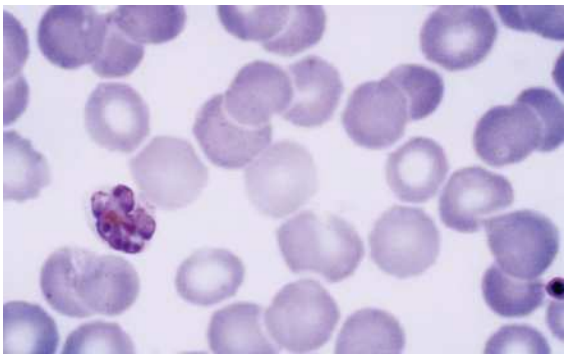


Figure 2.3 Plasmodium in blood sample

Hypothesis:

Hypothesis is a key component of the scientific process. It is defined as "the intelligent guess made by a scientist in the form of statement". It is important to note that a hypothesis must be testable. That means, you should be able to test your hypothesis through experimentation. Your hypothesis must either be supported or falsified by your experiment.

For Example: In malaria case, an intelligent guess is made after observation that **Plasmodium is the cause of malaria**. But it is only a guess which can be presented as a hypothesis.

Reasoning:

Biologists collect information about the problem and formulate the hypothesis by using a reasoning process i.e. 'inductive reasoning and deductive reasoning'.

Figure 2.4 A female Anopheles mosquito

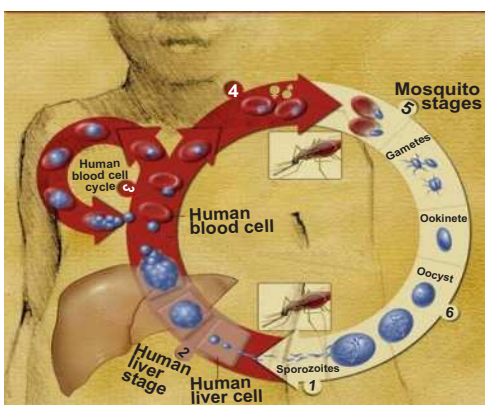


Figure 2.5 The Malarial Parasites (Plasmodium)

- **Inductive reasoning** moves from specific to general e.g. Shark is a fish. All fishes have scales therefore sharks also have scales.
- **Deductive reasoning** moves from general to specific. It is based on "if-then" statement. Deductive reasoning can be tested and verified by experiments. In malaria case, the following deduction is made:

"If *Plasmodium* is the cause of malaria, then all the malaria patient should have Plasmodium in their blood" as shown in figure 2.3.

Experiment:

Once a problem has been observed and a hypothesis is suggested, the next step in the scientific method is to design an experiment based on reasoning.

Experiment is a practical performance of a scientist to identify the real cause of a problem based on inductive and or deductive reasoning. A key assumption is that the experiment will be repeated many times by other scientists.

Scientist performs two types of test i.e. **control group** and **experimental group**. To find out the cause of malaria, blood samples of 100 malaria patients (experimental group) and the blood samples of 100 healthy persons (control group) were examined under microscope.

Figure 2.6 Hypothesis, an intelligent guess which leads the scientist to perform Experiment.

Result

The results are where you report what happened in the experiment. That includes detailing all observations and data made during your experiment. Result verifies the hypothesis. In the case of malaria, it was found that *all the malaria patients (experimental group) had Plasmodium in their blood whereas the blood samples of healthy persons (control group) were free from Plasmodium.*

Conclusion:

The final step of the scientific method is developing conclusion. This is where all the results from the experiment are analyzed and a determination is reached about the hypothesis. If your hypothesis was supported, its great. If not, repeat the experiment or think of other ways to improve your procedure.

Example: Conclusion is made that *"Plasmodium is the cause of malaria".*

2.1.2 Theory, Law and Principle:

Theory:

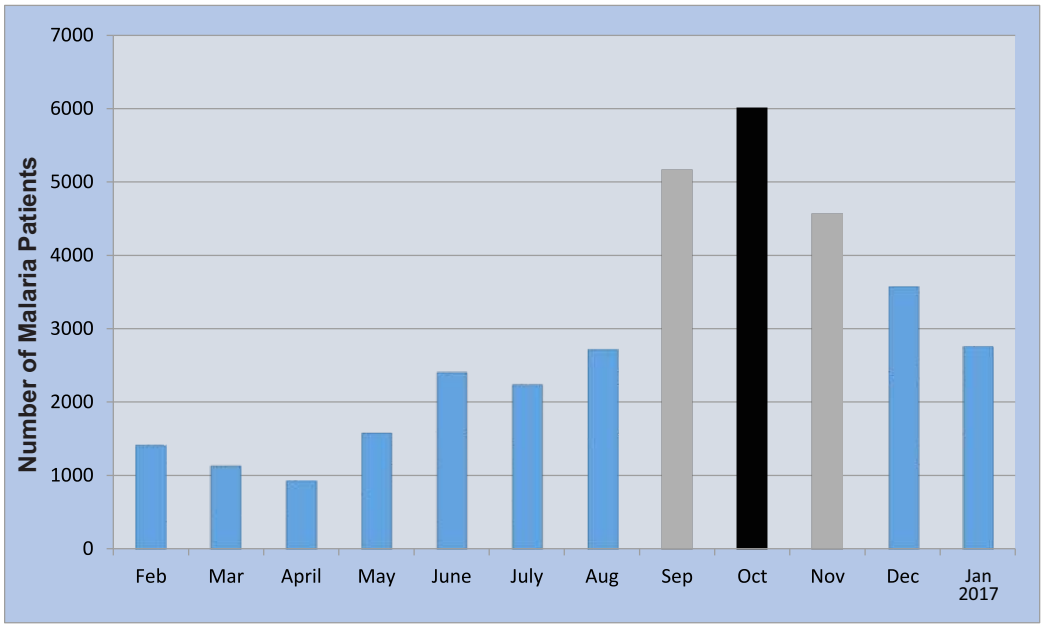
Scientists use the word "theory" in a very different way than non-scientists. When many people say "I have a theory", they really mean "I have a guess". Scientific theories, on the other hand, are well-tested and highly reliable scientific explanations of natural phenomena. They unify many repeated observations and data collected from lots of experiments. For example Theory of Evolution.

Law and principle:

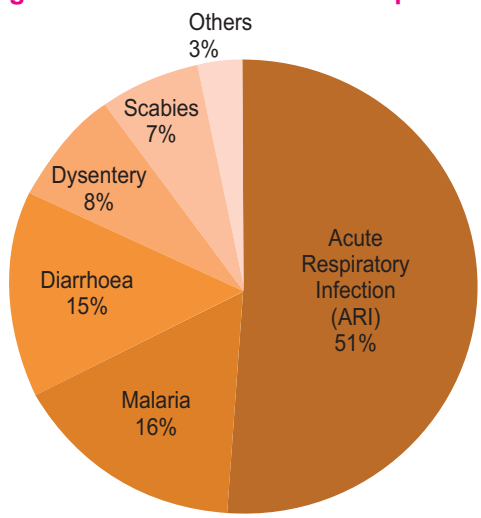
A scientific law is a uniform or constant fact of nature, it is virtually an irrefutable theory. Biology is short in laws due to puzzling nature of life.

2.1.3 Data organization and Data analysis:

For data organization you will prepare a table or graph of the data. Don't throw out data points you think are bad or that don't support your predictions. Some of the most incredible discoveries in science were made because the data looked wrong! Once you have recorded the data, you may need to perform a mathematical analysis to support or refuse your hypothesis.



A bar chart showing the trend of malaria cases reported in Sindh 2016-17



A Pie Chart showing Infectious diseases in Pakistan (2006)

In data analysis, the statistical methods (ratio and proportion) are applied. **Ratio** is a comparison of two values expressed as a quotient (1st/2nd). Example: A flower has 4 sepals and 12 petals. The ratio of sepals to petals is 4:12. This ratio can also be expressed as an equivalent fraction 1:3. A **Proportion** is an equation stating that two ratios are equal. Example: 4:12::1:3.

2.1.4 Mathematics as an integral part of the scientific process:

Imagine that you are a biologist studying the insect population. You go into the field and count the population sample in a specific region, then compare your sample with other regions to get population estimated. At every step of this process, you depend upon mathematics to measure, predict, and understand natural phenomena.

Mathematical biology is a field of research that examines mathematical representations of biological systems. One key role of mathematics in biology is the creation of **mathematical models**. There are equations or formulas that can predict or describe natural occurrences, such as organism behavior patterns, population changes over time, structure of protein, height of living organisms, population of an endangered species, bacterial growth and so on. Finally we can say that mathematics plays a critical role in better understanding the natural world.

Summary

- Science is the systematic study of nature and how it affects us and the environment.
- The biological method is the stepwise process in which a scientist finds out the reason of any biological problem about living things.
- An observation is a statement of knowledge gained through the senses (qualitative) or through the use of scientific equipment (quantitative).
- Your question should tell what it is that you are trying to discover or accomplish in your experiment.
- A hypothesis is an idea that is suggested as an explanation for a natural event, particular experience, or specific condition that can be tested through definable experimentation.
- The deductive reasoning involves the use of “if-then” logic. It moves from general to specific.
- Result includes detailing all observations and data made during your experiment.

- Conclusion is where all the results from the experiment are analyzed and a determination is reached about the hypothesis.
- Theories are the well-tested and highly reliable scientific explanations of natural phenomena.
- A scientific law is a uniform or constant fact of nature.
- Mathematical biology is a field of research that examines mathematical representations of biological systems.

Review Questions

1. Encircle the correct answer:

(i) Select the correct sequence of biological method.

(a) Law → Theory → Reasoning → Hypothesis

(b) Hypothesis → Theory → Law → Reasoning

(c) Hypothesis → Reasoning → Theory → Law

(d) Law → Hypothesis → Reasoning → Theory

(ii) Select the odd one

(a) Theory (b) Law

(c) Hypothesis (d) Ratio

(iii) Field of research that examines mathematical representations of biological system called.

(a) Ratio (b) Mathematical biology

(c) Proportion (d) Law

(iv) Biological method involves all of the following except.

(a) Data collection (b) Observation

(c) Experiment (d) Proportion

(v) Scientific reasoning moves from specific to general.

(a) Inductive (b) Deductive

(c) Observation (d) Both a and b

(vi) Quantitative observation is the use of

(a) Senses (b) Equipment

(c) Guess (d) Ratio

(vii) Equation stating that two ratios are equal

(a) Ratio (b) Proportion

(c) Guess (d) Senses

(viii) The comparison of two values is called

(a) Ratio (b) Proportion

(c) Graph (d) Table

(ix) What is a hypothesis?

(a) The same thing as an unproven theory.

(b) A tentative explanation that can be tested and is falsified.

(c) A verifiable observation.

(d) A fact based on quantitative data that is falsified.

(x) In data organization, which method is mostly useful?

(a) Table (b) Graph

(c) Ratio (d) Both a and b

2. Fill in the blanks:

(i) Problem solving approach of biology and other sciences called_____.

(ii) Solution of biological problem starts with_____.

(iii) The key component of the scientific process is _____.

(iv) Scientific reasoning based on "if-then" statement called _____.

(v) Final step of the scientific method is developing _____.

(vi) The uniform or constant fact of nature, virtually an irrefutable theory is _____.

(vii) Once you have the data, you may need to perform _____ analysis.

(viii) The equation stating that two ratios are equal is called _____.

(ix) Ratio is comparison of _____ values.

(x) The cause of malaria is _____.

3. Define the following terms:

(i) Ratio (ii) Biological method (iii) Graph

(iv) Hypothesis (v) Law (vi) Inductive reasoning

(vii) Conclusion (viii) Proportion (ix) Observation

(x) Mathematical models

4. Distinguish between the following in tabulated form:

(i) Theory and Law

(ii) Inductive reasoning and deductive reasoning

5. Write short answers of following questions:

(i) Theory is highly reliable scientific explanations, why?

(ii) Why biological sciences need mathematical models?

(iii) Draw a chart showing steps involved in biological methods.

(iv) Why table or graph is necessary for data organization?

(v) Why experiment is necessary for theory?

BIODIVERSITY

Chapter 3

Major Concept

In this Unit you will learn:

- Definition and Introduction of Biodiversity
- Aims and Principles of Classification
- History of Classification Systems
  - Two-Kingdom Classification System
  - Three-Kingdom Classification System
  - Four-Kingdom Classification System
  - Five-Kingdom Classification System
- The Five Kingdoms
- Binomial Nomenclature
- Conservation of Biodiversity

Nature has made the man with intelligence and he is always concerned with his aims to be achieved. He designs the things for this purpose into sequence. Similarly biologists mapped the whole diversity of organisms exist on earth, into simple groups. To understand about the characteristics of specific organisms individually, is simply called classification.

Classification is actually based on the similar and dissimilar characteristics what organisms shared with each other and by this biologists can easily study and identify the organisms.

3.1 DEFINITION AND INTRODUCTION OF BIODIVERSITY

Biodiversity is the combination of two words; **Bio (life), diversity (variation)** thus it is defined as; "The biodiversity or biological diversity is the degree of variation within or among the species exist on different regions of the earth". It is comprised of different organisms such as bacteria, protozoans, algae , fungi , animals and plants.

3.1.1 Importance of Biodiversity:

Biodiversity provides many beneficial products which includes fiber, oil, dyes, rubber, water, timber, paper and food. It also stabilizes the ecosystem by recycling the nutrients, reduces the amount of pollution by means of forest. Biodiversity also plays an important role in drug discovery and medicinal resources. Medicines from nature account for usage by 80% of the world's population. It also beautifies the nature with lots of tress and animals found in different regions which enhances the tourism.

Pictorial view of major biodiversity on earth:

Angiosperm plant

Gymnosperm Plant

Hornworts Liverworts Mosses

Figure: 3.1(a) variety of plants on earth.

Polar bear

Desert hopping mouse

Blue Bird

Cobra

Figure 3.1.(b) variety of different animals on earth

Can you identify other life on earth?

3.2 AIMS AND PRINCIPLES OF CLASSIFICATION

A system of classification is necessary because of the abundance of the variety of life on earth. There are currently around 1.5 million species that have been described and have been given scientific names. In future, more can be identified if they are found.

To study such a diverse pack of organisms exist on earth, biologists classified the organisms into groups and sub groups. This grouping of organisms is called **biological classification**.

3.2.1 Principles of Classification:

Some organisms share similar fundamental characteristics or functions. It is further explained by means of **Morphology** (external features of an organism) in which we study the organisms on the basis of their **Homologous** (similar in structure and have different functions) and **Analogous** (different in structure and have same functions). As shown in fig 3.2 a and b.

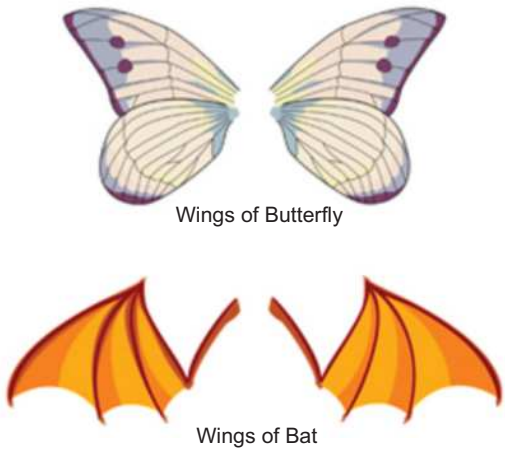


Figure 3.2 (a) Analogous structure

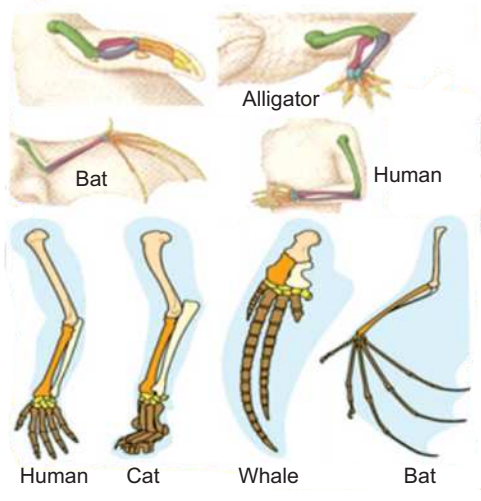


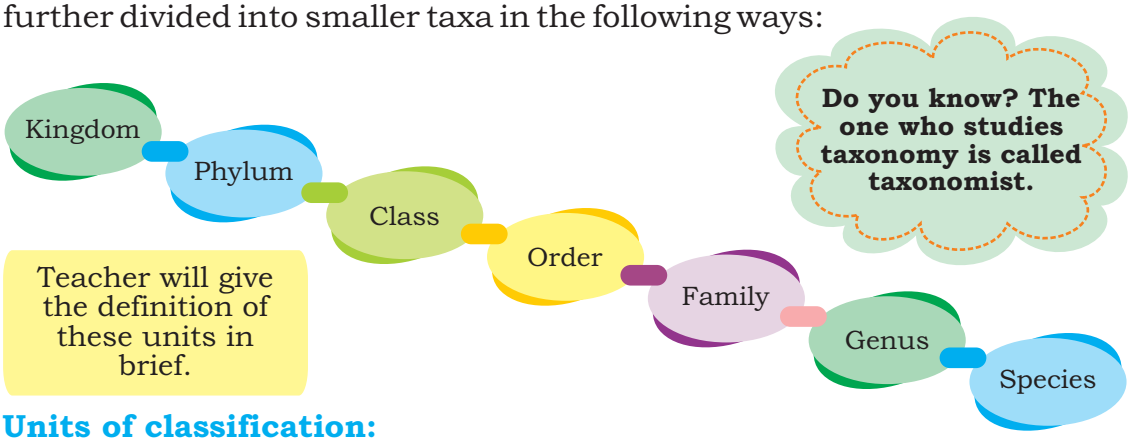
Figure 3.2 (b) Homologous structure

Have you seen the arm of a man and wing of a bird? Which type of structure is this?

Sometimes it is impossible to classify organisms using morphological characters, therefore scientists use other characteristics to classify organisms which include; Cytology and genetics in which organisms are classified on the basis of cellular study, genetic constitution and their development pattern. Biochemistry is also employed in which the chemical substances of the organisms are compared.

Taxonomic Hierarchy

The groups into which organisms are classified are known as taxonomic categories or taxa (singular taxon). The taxa are arranged in ascending order and form a ladder, called taxonomic hierarchy. All organisms are classified into five kingdoms, so the kingdom is the highest taxon of classification. On the basis of similarities, each kingdom is further divided into smaller taxa in the following ways:



Do you know? The one who studies taxonomy is called taxonomist.

Teacher will give the definition of these units in brief.

Units of classification:

The smallest and basic unit of classification is species. Taxonomic studies consider a group of individual organisms with the fundamental similarities as a species. Thus all the members of the particular species share the similar characteristics and can naturally interbreed to produce a fertile offspring. Closely related species are grouped together into genera (singular-genus). Similar genera are grouped together into families, families into orders, orders into classes, classes into phyla or division and phyla or division into kingdoms.

Simple Classification of two Organisms

Taxa	Human	Pea
Kingdom	Animalia	Plantae
Phylum	Chordate	Magnoliophyta
Class	Mammalia	Magnoliopside
Order	Primates	Fabales
Family	Moninidae	Fabaceae
Genus	Homo	Pisum
Species	Sapiens	Sativum
Scientific name	Homo sapiens	Pisum sativum

3.2.2 Aims of Classification:

Biologists classified the organisms in order to make them study easily, so the science of classification is called **Taxonomy**.

(Tazm=group, Nomy=naming)

The main aims of this branch are;

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

Use internet to search out THREE different species belongs to same Genus.

3.3 HISTORY OF CLASSIFICATION

The system that we still use today for giving scientific names to plants and animals has many founders, from the Greek philosopher **Aristotle** to the Swedish physician and botanist **Carolus Linnaeus**. Taxonomy's first father was the philosopher Aristotle (384-322 BC), sometimes called the "father of science." It was Aristotle who first introduced the two key concepts of taxonomy as we practice it today: classification of organisms by type and binomial definition.

Aristotle was the first to attempt to classify all the kinds of animals in his book on Animals (Historia Animalium in Latin). He grouped the types of creatures according to their similarities: animals with blood and animals without blood, animals that live on water and animals that live on land.

Aristotle

Abu usman Umer Aljahiz

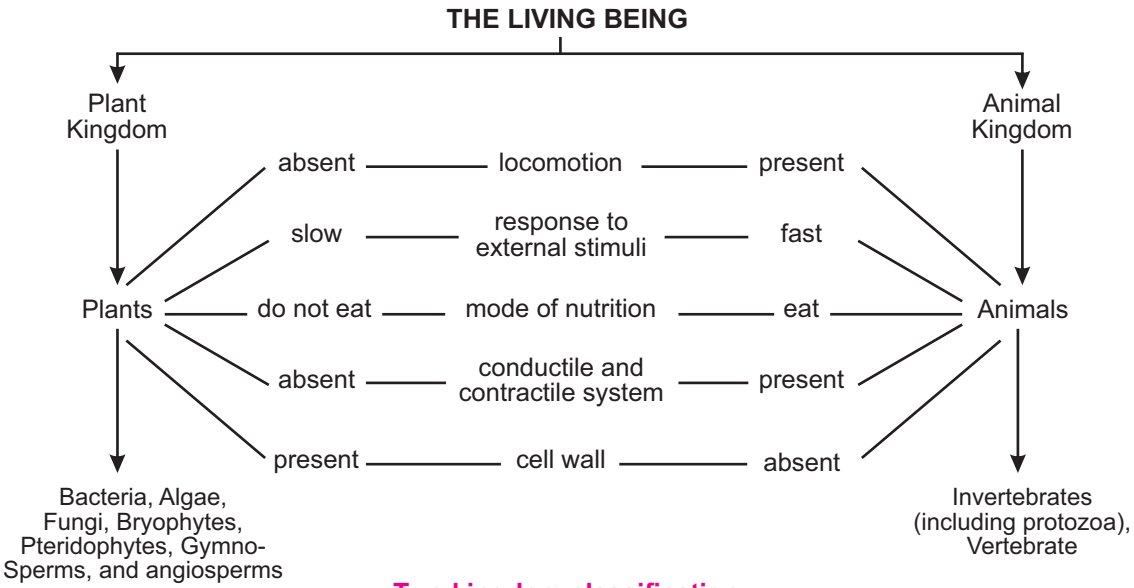
Abu Usman Umer Aljahiz was the first eminent Arab zoologist of the Muslim world.

He used to slaughter animals for studying the internal organs of their bodies. He also opened the abdomen of pregnant animals to find out the number of embryos and the location of each one of them in the body. His Encyclopedic work in seven big volumes **Kitab al-Haywan (Book of Animals)** is the most famous work on zoology, in which he has described in detail, the kinds of animals, their behavioral characteristics and their diseases and treatment.

Carolus Linnaeus is considered as the father of Taxonomy.

3.3.1 Two Kingdom classification:

Previously the organisms were classified into two groups; all the organisms possess cell wall were placed in plant kingdom and all the organisms do not possess cell wall were placed in animal kingdom.



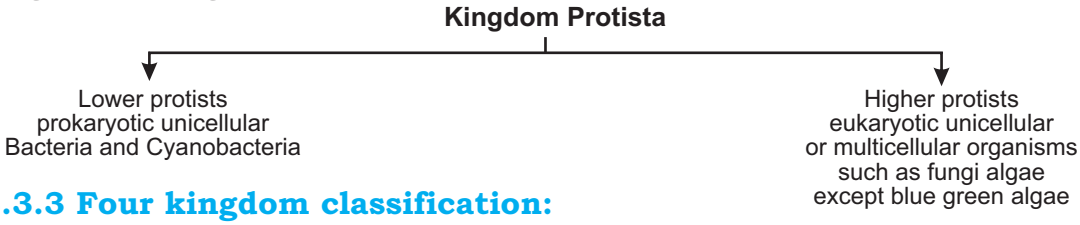
Two kingdom classification

3.3.2 Three Kingdom classification

Ernst Hackle in 1866, introduced a new Kingdom named as Protista to accommodate the organisms exhibiting characters either common to both plants and animals, or unique to their own such as Euglena, Bacteria were also placed under this kingdom.

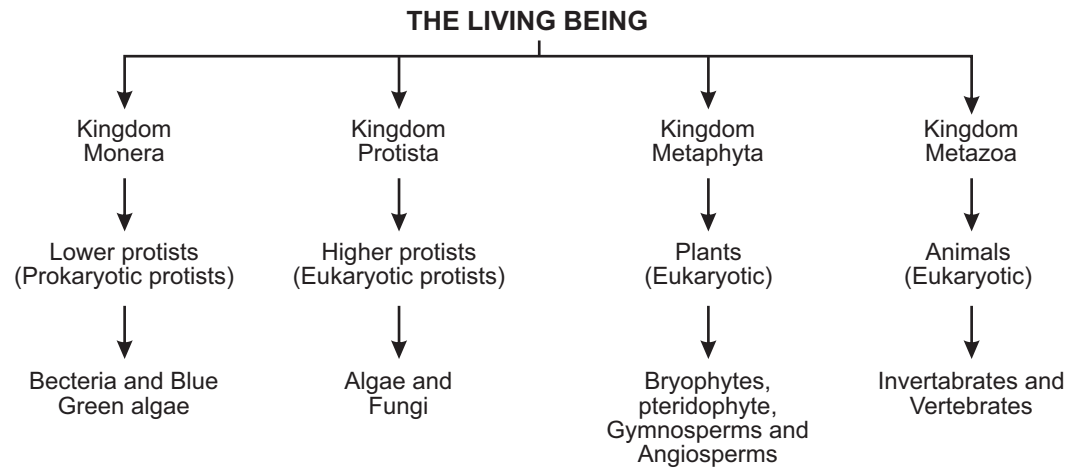
In 1937, ***Édouard Chatton*** clearified the concept of procariotique and Eucariotique to describe the cellular characteristics of organisms.

In 1930s, electron microscopy revealed, two distinct patterns among single celled organisms:



3.3.3 Four kingdom classification:

After the clear concept for kingdom Protista, Copeland (1959) came forward with a four kingdom system to classify the living beings. He designed a new kingdom named as Monera to place all the lower protists which include prokaryotic unicellular organisms and remaining single celled eukaryotic organisms were included in Protista.



Four Kingdom classification

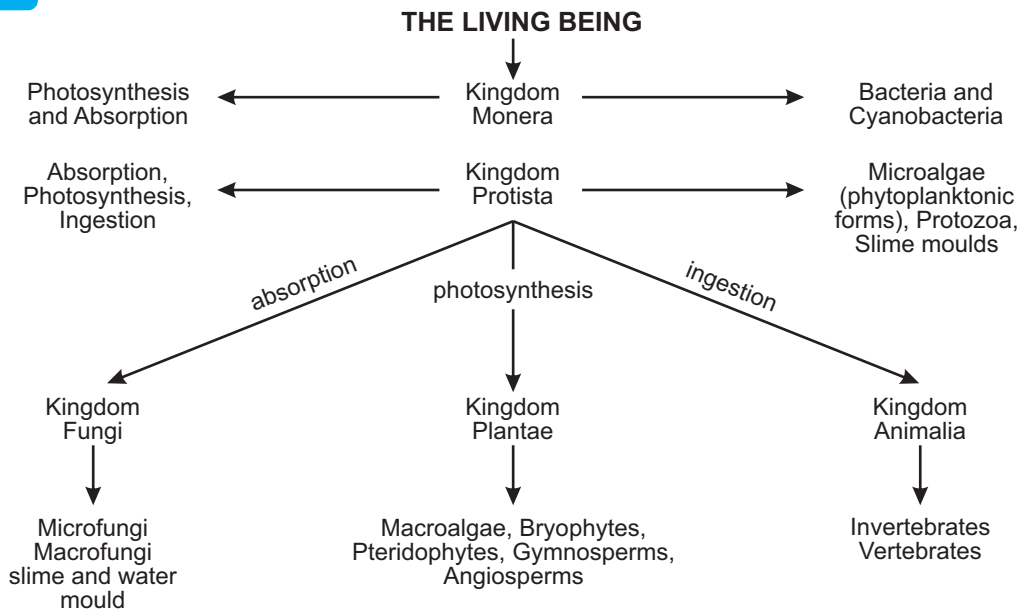
3.3.4 Five Kingdom Classification:

Robert Whittaker in 1969 classified the organisms into Five kingdoms which clearly categorized fungi into a separate kingdom.This system of classification was based on;

- Cellular structure and body organization; unicellular Prokaryote, Unicellular and multicellular eukaryotes.
- Mode of nutrition; autotrophs (plants), Ingestive heterotrophs (animals) and absorptive heterotrophs (fungi).

Draw a linkage chart to show the establishment of Five Kingdom System that includes Two to Five Kingdom classification.

3.4 THE FIVE KINGDOMS



Five Kingdom classification

(i) Kingdom Monera:

It includes all the prokaryotes i-e Bacteria and cyanobacteria.

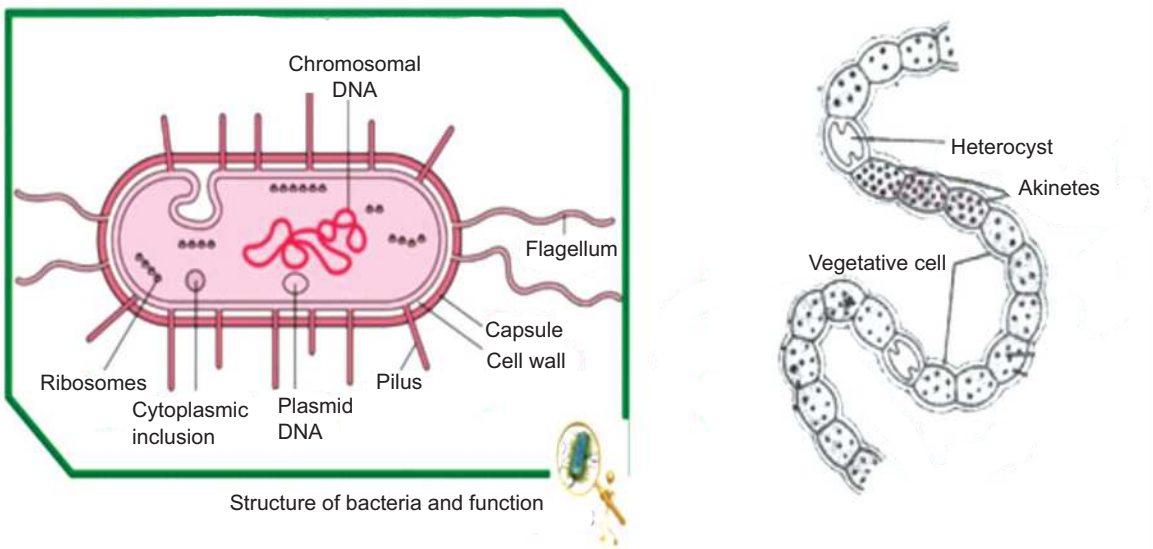
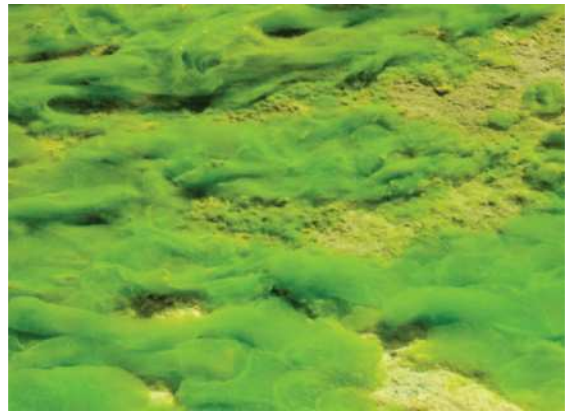


Figure 3.3 Bacteria and cyanobacteria

(ii) Kingdom Protista:

It is the place for all the eukaryotic unicellular organisms, except yeast which some of them have the features of both plant and animal like. Most protists are aquatic. It includes protozoa and unicellular algae.

Paramecium



Algae

Figure 3.4 protozoa and algae

(iii) Kingdom Fungi:

It includes all the multicellular eukaryotic fungi. They are Achlorophyllous, absorptive heterotrophs. They have cell wall made up of mainly chitin. They have a body called Mycelium which is made up of a thread like structure called hyphae.

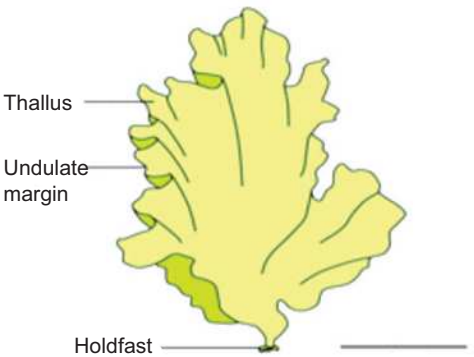
Mushroom

Mucor

Figure 3.5 Examples of fungi

(iv) Kingdom plantae:

It includes all the multicellular, eukaryotic, photosynthetic organisms. They have cell wall mainly made up of cellulose. It includes multicellular Algae, bryophytes, pteridophytes, gymnosperm and angiosperms.



Ulva lactuca

Bryophytes

Figure 3.6 Plants type

(v) Kingdom Animalia:

All animals are multicellular, eukaryotic which are ingestive heterotrophs without cell wall. It includes all vertebrates and invertebrates except protozoa.

Star fish

Kangaroo

Figure 3.7 Animals type

Table: Comparative characteristics of Five kingdom life.

Five Kingdoms					
Characters	**Monera**	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	(Polysaccharide + amino acid) or cellulose	Present in some	Present (without cellulose)	Present (cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular without bonded organelles	Cellular	Multicellular/ loose tissue	Tissue/ organ	Tissue/organ/ organ system
mode of nutrition	Autotrophic (chemosynthetic photosynthetic) and Hetero-trophic (sapro-phyte/parasite)	Autotrophic (Photosyn thetic) and Hetero-trophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosyn thetic)	Heterotrophic (Holozoic/ saprophytic etc.)

Structure of Virus:

Virus is non cellular obligate endoparasite (lives inside host cell). It does not have cellular organization but do have nuclear material either DNA or RNA. It has protein coat called capsid that encloses the nucleic acid. It reproduces only inside the host cell. Due to its non-cellular nature it cannot be placed in any of the five kingdoms. It causes number of diseases in plant like tobacco Mosaic Disease etc and animals like, cold, flue, dengue, polio, hepatitis, AIDS etc.

Prions and viroids are also non-cellular particles so cannot be placed in five kingdom classification system

3.5 BINOMIAL NOMENCLATURE

Carolus Linnaeus Swedish naturalist and explorer who was the first to frame principles for defining natural genera and species of organisms and to create a uniform system for naming them. The advantages of scientific over common names are that they are accepted by speakers of all languages, that each name applies only to one species, and that each species has only one name. As common names cause many problems to identify the organisms as different regions have different languages for the same thing for example; common name of onion in Urdu is 'Piyaz' but in other regions it is also known as 'ganda' or 'basal' etc but in scientific language it is known as **Allium cepa**.

This avoids the confusion that often arises from the use of a common name to designate different things in different places or from the existence of several common names for a single species.

Table: Biological name of some common plants and animals.

	COMMONE NAME	BIOLOGICAL NAME
	PLANTS	
1.	Onion plant	*Allium cepa*
2.	Mango plant	*Mangifera indica L.*
3.	Neem plant	*Azadirachta indica*
	ANIMALS	
1.	Frog	*Rana tigrina*
2.	Cat	*Felis catus*
3.	Housefly	*Musca domestica*

Through a system of nomenclature in which each species of animal, plant or others receives a name of two terms of which the first identifies the genus to which it belongs and the second the species itself or its specific names.

Principles for binomial nomenclature:

Some of the rules which are universally adopted for writing scientific name of a species are:

- Scientific name of any organisms should be italicized when printed, such as *Homo sapiens* and when handwritten these are underlined.
- The first word of the name is generic always started with capital letter, while second term is species which is never capitalized.
- When the scientific name is written first time, it is written full but when it is repeated several times, it is abbreviated. For example; The scientific name of the red rose is *Rosa indica*, it is abbreviated as *R.indica*.
- Sometimes the author name appears after species name which means the species was described by Him. For example; (mango plant) *Mangifera indica* L. It means *Mangifera indica* was first described by ***Linnaeus***.

Use internet to search a scientific name of potato, matar, china rose and Dog.

3.6 CONSERVATION OF BIODIVERSITY

Pakistan is one of few countries in the world to have every kind of geological structure. The geography of Pakistan is a blend of landscapes.

You'll find plains, deserts, forests, hills, and plateaus. There are coastal areas along the Arabian Sea and mountains of the Karakoram Range in the north part of Pakistan.

Figure 3.8 Beautiful views of Pakistan

This diversity contains diversified habitats and landscapes that support a rich biodiversity of both fauna and flora (animals and plants respectively). Arid and semi-arid regions covering almost 80% of the total land area of the country possess significant portion of country's biodiversity. During the last two-three decades, a number of animal and plant species have become threatened or endangered mainly due to over-exploitation and loss of natural habitat. Factors like deforestation, overgrazing, soil erosion, salinity and water logging are posing major threats to the remaining biodiversity of the country. The continuing loss of forest habitat, with its associated fauna and flora, will have serious implications for the nation's other natural and agricultural ecosystems. To overcome all these problems biodiversity should be paid attention in order to save the organisms from being endangered. **"Conservation simply is the way of caring, saving the species, inhabit on earth from dangers"**.

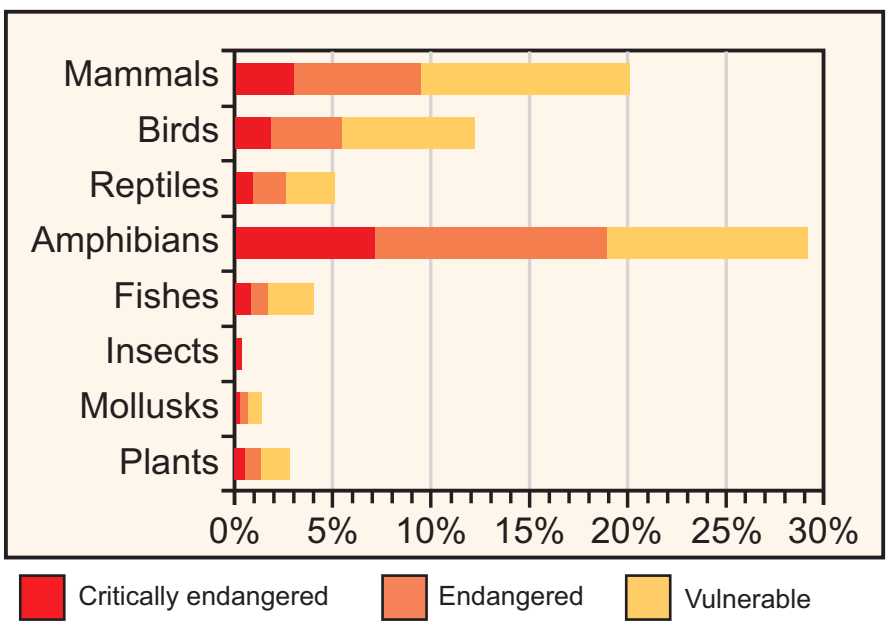
3.6.1 Reasons to conserve Biodiversity

Biologists warned that global ecosystem would be collapsed if biodiversity continues to be reduced at the same rate. Therefore, it is mandatory to conserve life on earth in order to make nature stable.

Some of the key points are highlighted below:

- Human should **conserve biodiversity** because of its benefit for example services and biological resources which are essential to live our life on earth.
- Biodiversity boosts ecosystem productivity where each species can easily survive in their habitat, if the one will not conserve biodiversity, so food chain and ecosystem will be imbalanced.
- With more plants, trees and animals, the soil improved and became stronger - less prone to erosion, drought and flooding.

Graph: Reporting the data to show the biodiversity at risk.



3.6.2 Problems associated to conserve biodiversity in Pakistan:

The article from 2009"Biodiversity in Pakistan Key issues", identified some of the primary challenges to implement Biodiversity Action Plan (BAP) are:

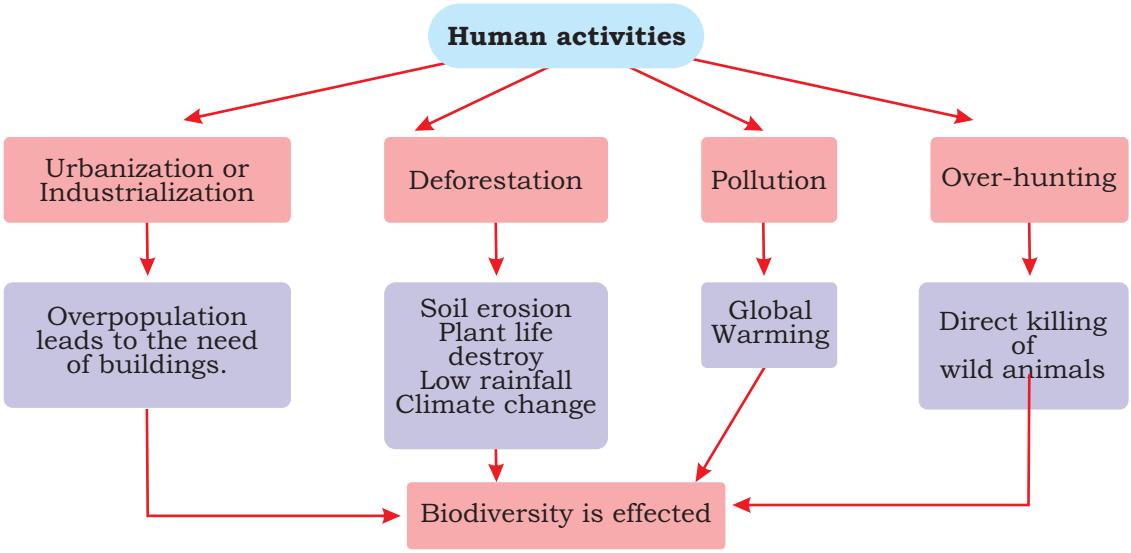
- Lack of awareness of environmental issues on the part of decision-makers and civil society.
- Weak governance (slow decision-making processes, inability to conceptualize policy, and lack of distinction between public and private interests).

- Weak capacity of government departments (lack of individual capacity and incentives for performance).
- Lack of funding.

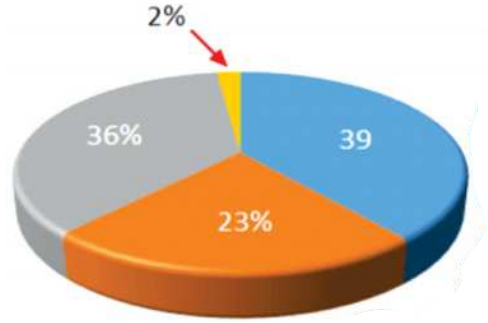
3.6.3 Problems associated to conserve biodiversity due to human intervention:

The International Union for Conservation of Nature (IUCN) reported that 75 percent of genetic diversity of agricultural crops has been lost, 75 percent of the world's fisheries are over exploited, and one-third of coral reefs are threatened with extinction. Man is the factor, which is directly involved in the destruction of biodiversity. The table below show some of the human intervention in the loss of biodiversity.

Table: Impact of human activities on Biodiversity.



Causes of Animal Extinction (Pie Chart)



Habitat Destruction

Hunting & Other Types of intentional Killing

Other Causes

Introduction to Invasive Species

Climate changes are not the only pressure on our environments. Habitat loss and degradation, pollution, overexploitation, and invasive species also play significant roles in biodiversity decline. These pressures are because of human invading activity.

3.6.4 Deforestation-causes and its effect on Biodiversity

Forests cover 31% of the land area on our planet. They produce vital oxygen and provide homes for people and wildlife. Many of the world's most threatened and endangered animals live in forests, and billions of people rely on its benefits. Forests offer food, fresh air, clothing, medicine and shelter. Forests play a critical role in reducing climate change because they act as a carbon sink soaking up carbon dioxide that would otherwise be free in the atmosphere and contribute to ongoing changes in climate patterns. But man is destroying this natural beauty by cutting them down for his sake and comfort. **"The cutting down of trees for the conversion of forest into non forest land is known as Deforestation"**.

Figure 3.9 Deforestation

Causes of Deforestation:

Deforestation is done deliberately due to the Mining, paper making, urbanization, timber, for making roads and Agriculture Expansion & Livestock breeding.

Effects of Deforestation:

Deforestation result with the great loss in Biodiversity such as; increase in the concentration of green house gases (carbon dioxide,

Methane, water vapopur, Nitrous oxide etc.) which leads to Global warming, temperature will be high that causes glaciers melting which is the reason of raising sea level and causes flood. It is also the reason of habitat loss of wild life. Soil erosion, low rainfall due to no transpiration are also the result of Deforestation.

3.6.5 Endangered and extinct species

Due to human activities such as entertainment or food, animals are becoming endangered (at risk of extinction in future) or some have gone extinct (surety of not finding the last individual of that species in ecosystem). Some of the endangered species are mentioned below:

Long Billed Vulture

Green Sea Turtle

Snow leopard

Marco polo sheep

European Otter

Baluchistan Forest Dormouse

Indus river dolphin

Asian black bear

Sindh Ibex (Markhor)

Figure 3.10 Endangered species of Pakistan

Summary

- Biodiversity or biological diversity is the degree of variation with or among species exist on different regions of the earth.
- Biodiversity provides many beneficial products including fibre, oil, dyes, ruber, water, timber, paper and food.
- Classification of organisms takes place on the basis of mological character or cytological character or genetical character.
- Morphological classification occur on homologous (Similar in structure) or an analogous characters (different in structure but similar in function).
- The groups of classified organism called taxon(Pl: taxa).
- The smallest and basic unit of classification is species. It is a group of organism which are similar in structure, can interbreed to provide fertile and visible off spring.
- The arrangement of taxa in ascending order to form a ladder called Taxanomic hierarchy.
- The science of classification is called Taxanomy.
- The father of Taxanomy is *Carolus Linnaeus.*
- *Carolus Linnaeus* gave the concept of binomial Nomenclature.
- In the beginning living organism were classified into two kingdom plant and animal kingdom.
- *Ernst Hackle* in 1866 introduced thee kingdom system.
- *Copeland* in 1959 classified living organism in four kingdoms.
- *Robert Whittaker* classified organism in 5 kingdoms, Monera, Protista, fungi, plantae and animalia.
- Lack of awareness of environmental issues, weak governance, etc are the main problems associate to conserve biodiversity.

Review Questions

1. Encircle the correct answer:

(i) Which of the following is the correct way of writing a scientific name of an organism?

(a) *Houbara bustard* (b) E.coli

(c) Alium Cepa (d) canis lupis

(ii) Select the mismatched

(a) Plantae → Pteridophyta (b) Fungi → Mucor

(c) Protista → Paramecium (d) Animalia → Amoeba

(iii) Identify the correct sequence of classifying an organism.

(a) Species → Genus → Kingdom → Phylum → Class → Order → Family

(b) Kingdom → Phylum → Class → Order → Family → Genus → Species

(c) Kingdom → Phylum → Class → Family → Order → Genus → Species

(d) Species → Genus → Class → Phylum → Order → Kingdom → Family

(iv) All are involve in classification except

(a) Analogous (b) Homologous (c) Cytology (d) Genetics

(v) In the taxonomic hierarchy choose the term which encompasses all other in the list

(I) Genus (II) Species (III) Order (IV) Class

(a) I and II (b) II (c) II and III (d) IV

(vi) In four kingdom classification, kingdom Metaphyta includes all of the following except.

(a) Algae (b) Angiosperm

(c) Gymnosperm (d) Bryophyta

(vii) In five kingdom system virus placed in

(a) Monera (b) Protista

(c) Plantae (d) None of these

(viii) Biological name of cat

(a) Felis catus (b) Azadirachta indica

(c) Alium Cepa (d) Canis lupis

(ix) Members of which kingdom have cell wall and are all heterotrophic

(a) Monera (b) Protista (c) Plantae (d) Fungi

(x) Biodiversity is effected with

(I) Pollution (II) Deforestation (III) Over hunting

(a) I only (b) II only (c) I and II (d) I, II and III

2. Fill in the blanks:

(i) Degree of variation within or among the species exists on different regions of the earth called _____.

(ii) _____ Species are given scientific names.

(iii) _____ Structures have different functions (physiology) but having similar internal architecture.

(iv) Science of classification is called _____.

(v) Most protists are _____.

(vi) _____ are achlorophyllous and absorptive living organism.

(vii) _____ is non-cellular obligate parasite.

(viii) Scientific name of any organism should be _____ when printed.

(ix) Cutting down of trees called _____.

(x) Animals which are at the risk of extinction in future called _____.

3. Define the following terms:

(i) Analogous (ii) Classification (iii) Species

(iv) Family (v) Metazoa (vi) Mycelium

(vii) Hyphae (viii) Genus (ix) Endangered species

(x) Kingdom

4. Distinguish between the following in tabulated form:

(i) Plant kingdom and Animal kingdom

(ii) Monera and protista (iii) Fungi and Plantae

5. Write short answers of following questions:

(i) Why scientific naming is necessary?

(ii) How living organisms are classified into two kingdom classification?

(iii) Why virus is not placed in any kingdom?

(iv) Draw chart showing three kingdom classification.

(v) Why amoeba is not placed in animal kingdom?

(vi) Why cyanobacteria are placed in monera?

6. Write detailed answers of the following questions:

(i) Describe in detail five kingdom classification.

(ii) What is taxonomic hierarchy? Explain aims of classification.

(iii) Describe effect of deforestation on biodiversity.

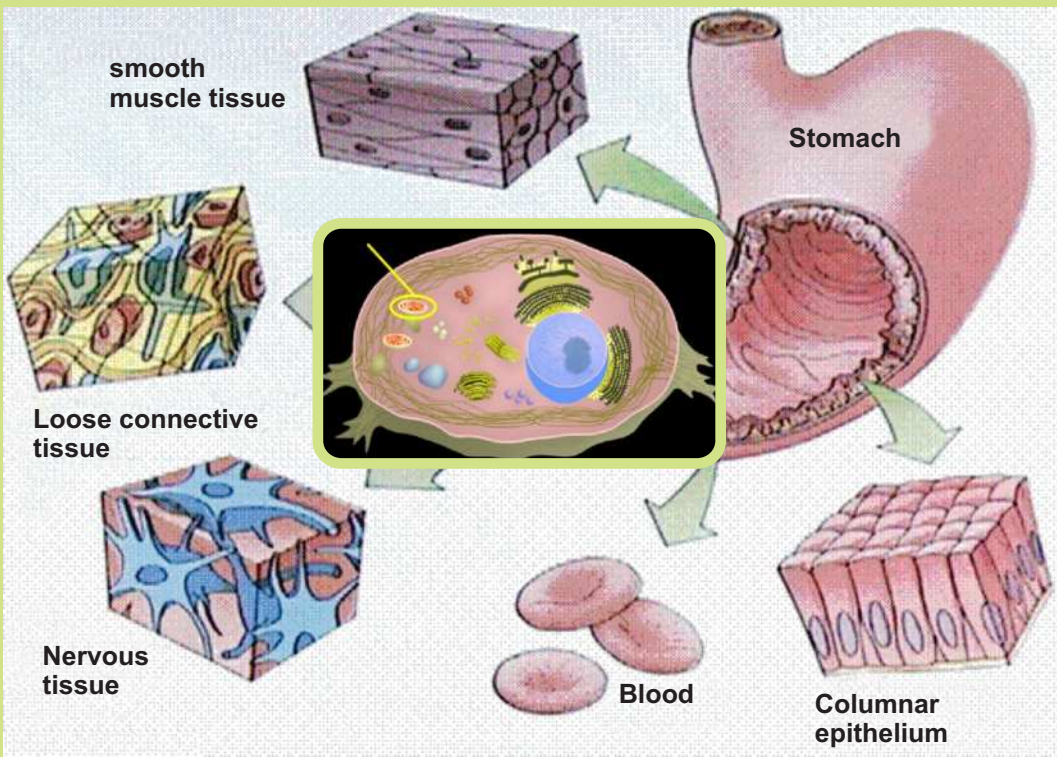
CELLS AND TISSUES

Chapter 4

Major Concept

In this Unit you will learn:

- Microscope and Emergence of Cell Theory
  - Light microscope and electron microscope
- Cellular Structures and Functions
  - Difference in prokaryotic and eukaryotic cells
  - Relationships between cells function and structure
- Cell size and shape as they relate to surface area to volume ratio
- Active and Passive Transport of Matter
  - Diffusion
  - Osmosis
  - Active transport
  - Exocytosis
  - Facilitated diffusion
  - Filtration
  - Endocytosis
- Tissues
  - Animal tissues
  - Plant tissues



You could find cells just as intricately patterned and beautifully formed in any plant you looked at-from the rose in your backyard, to the grass growing up through the sidewalk, to the carrots you ate for a snack. Let's not limit it to plants, either: exquisite layers of cells can be found in your skin, in an insect's wing, and in just about any other living tissue you choose to look at. We, and the world around us, are made of cells. We just need some microscopy to appreciate it.

4.1 MICROSCOPE AND EMERGENCE OF CELL THEORY

Zacharias Janssen is generally believed to be the first investigator to invent the compound microscope in the 1590. It was simply a tube with lenses at each end and its magnification ranged from 3X to 9X.

Zacharias Janssen
(1580-1638)

Van Leeuwenhoek's microscope

Robert Hooke had improved his version of the compound microscope to observe organisms.

Microscopes are instruments designed to produce magnified visual or photographic images of objects too small to be seen with the naked eye. There are two parameters especially important in microscopy; magnification and resolution.

Magnification: The enlargement of an image is called magnification. By combining a number of lenses in the correct manner, a microscope can be produced that will yield very high magnification values.

Resolution: The resolution of a microscope is defined as the smallest distance between two points on a specimen that can still be distinguished as two separate objects. It helps to measure clarity of object.

Both magnification and resolution are very important if you want a clear picture of something less than 0.1. For example, if a microscope has high magnification but low resolution, all you'll get is a bigger version of a blurry image.

4.1.1 Light microscope and electron microscope:

There are two microscopes are used in microscopy i.e. light microscope (LM) and electron microscope (EM).

(a) Light microscope:

In a light microscope, visible light passes through the specimen (the biological sample you are looking at). A photograph of an image taken through a microscope is called micrograph.

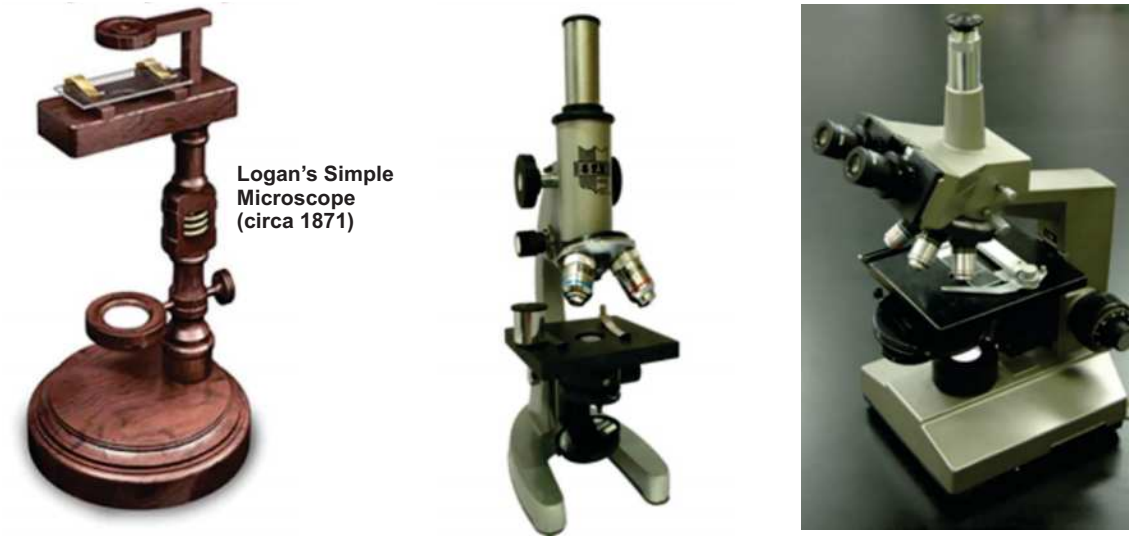


Figure 4.1 Light microscopes from simple to complex

The magnification of a light microscope is formed by using a mixture of the powers of the eye piece and the objective lens.

In order to ascertain the total magnification when viewing an image with a compound light micrscope, take the power of the objective lenses, which is at 4x, 10x, 40x and multiply it by the power of the eye piece which is typically 10x. Therefore, a 10x eyepiece used with a 10x objective lens will produce a magnification of 100x. This means that the object can be magnified, 40x, 100x or 400x.

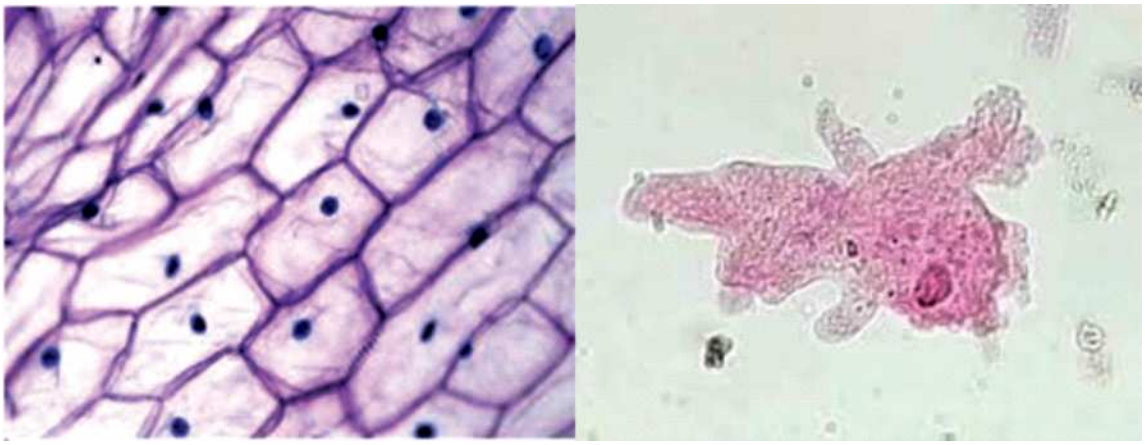


Figure 4.2 Light microscopic micrograph of onion cells and Amoebae

(b) Electron microscope:

Electron microscopes differ from light microscopes, that they produce an image of a specimen by using a beam of electrons rather than a beam of light. Electrons have a much shorter wavelength than visible light, and this allows electron microscopes to produce higher-resolution images than standard light microscopes. Electron microscopes can be used to examine not just whole cells, but also the subcellular structures and compartments within them. A live cell cannot be imaged by electron microscope.

Figure 4.3 Electronic microscope (TEM)

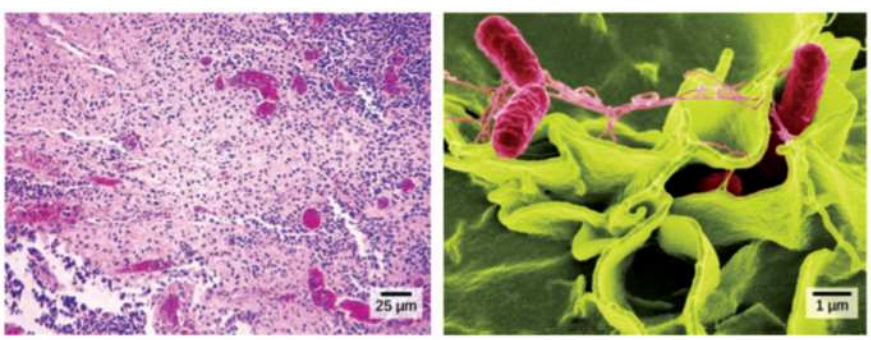


Figure 4.4 Salmonella bacteria under light micrograph (left) and through electron microscope (right).

Electron microscope has a resolution as small as 0.2 nanometer (nm) and magnification upto 250,000 times. There are two major types of electron microscopes.

1. Scanning electron microscopy (SEM)

2. Transmission electron microscopy (TEM)

In scanning electron microscopy, a beam of electrons moves back and forth across the surface of a cell or tissue, creating a detailed image of the 3D surface.

In transmission electron microscopy, in contrast, the sample is cut into extremely thin slices before imaging, and the electron beam passes through the slice rather than skimming over its surface. TEM is often used to obtain detailed images of the internal structures of cells.

Figure 4.5 SEM (left) and micrograph of Amphipod (right)

4.2 HISTORY OF THE DEVELOPMENT OF CELL THEORY

Ancient Greeks were the first to make comprehensive attempts to organize the data of the natural world. Aristotle presented an organized observation to support 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 microscope was first used in 17th century, no one knew that living organisms do share a fundamental unit i.e. cell.

1665	Cell was first observed by ***Robert Hooke***, an English scientist, discovered a honeycomb-like structure in a cork slice using a primitive compound microscope. He only saw cell walls as this was dead tissue. He coined the term "cell" for these individual compartments he saw.
1670	First living cells were seen by ***Anton van Leeuwenhoek***, a Dutch biologist, from pond water with a microscope.
1683	**Miniature animals:** ***Anton van Leeuwenhoek*** made several more discoveries on a microscopic level, eventually publishing a letter to the Royal Society in which he included detailed drawings of what he saw. Among these was the first protozoa and bacteria discovered.
1833	The center of the cell was seen by ***Robert Brown***, an English botanist, discovered the nucleus in plant cells.
1839	**Cell theory:** ***Theodor Schwann***, a German botanist reached the conclusion that not only plants, but animal tissue as well is composed of cells.
1839	This ended debates that plants and animals were fundamentally different in structure. He also pulled together and organized previous statement on cells into one theory, which states: 1- Cells are organisms and all organisms consist of one or more cells. 2 - The cell is the basic structure unit for all organisms.
1840	Where does life come from ***Albrecht von Roelliker*** discovered that sperm and eggs are also cells.
1845	***Carl Heinrich Braun*** reworked the cell theory, calling cells the basic unit of life.
1855	3rd part to the cell theory added by ***Rudolf Virchow***, a German physiologist/physician/pathologist. Added that cell is not Denovo structure. This translates mean that all cells develop only from existing cells.
1862	***Louis Pasteur*** was a French biologist; microbiologist and chemist provided the experimental proof of this idea.

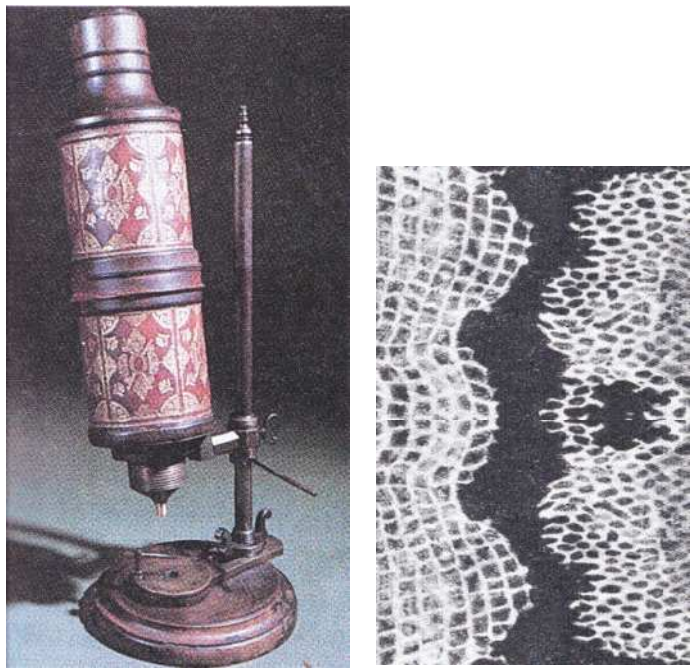


Figure 4.6 *Robert Hooke*, an English scientist, discovered a honeycomb-like structure in a cork slice using a primitive compound microscope.

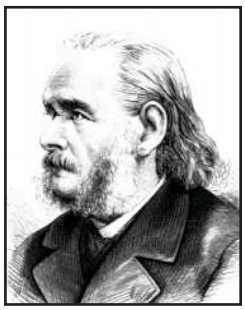
4.2.1 Cell theory:

One of the most important concepts in biology is that a cell is a basic structural and functional unit of living organism. This is known as a cell theory and was proposed jointly by two scientists in 1839. A Belgian Botanist called ***Schleiden*** and the German zoologist called ***Schwan***.

In 1855 ***Rudolf Virchow***, a German physicians proposed an important extension of cell theory-that all living cells arise from pre-existing.

The postulates of cell theory are:

1. All Living organisms are made of one or more cells.
2. The cell is the fundamental unit of structure and function in all living organisms.
3. The new cell is derived from pre-existing cells dividing into two by cell division.
4. The cell contains the hereditary material which is passed from generation to generation.



Mathias Jakob Schleiden

Theodor Schwann

Rudolf Virchow

Major contributors in the development of cell theory

Sub-cellular or Acellular Particles:

According to the first principle of the cell theory all organisms are composed of one or more cells.

Viruses, prions and viroids are not composed of cells rather they are sub-cellular or acellular particles but do not run any metabolic activity inside them. As they show some characteristics of living organisms i.e. they can increase in number and can transmit their characteristics to the next generations.

Cell:

Cells are the basic units of organisms and all tissues and organs are composed of cells. There are different types of cells. Cells can either be prokaryotic or eukaryotic. Eukaryotic cells have a proper nucleus and membrane bound organelles. Plant and animal cells are eukaryotes. Plant cells are generally a cubical shape while animal cells are usually spherical. Plant cells and animal cells have evolved different organelles to perform specific functions.

The activity of an organism depends on the total activity of independent cells. Energy flow occurs in cells through the breakdown of carbohydrates by respiration. Cells contain the information necessary for the creation of new cells. This information is known as 'hereditary information' and is contained within DNA. The contents of cells from similar species are basically the same.

DNA (the hereditary information of cells) is passed from 'parent' cells to 'daughter' cells during cell division.

Cells are the smallest form of life; the functional and structural units of all living things. Your body contains several billion cells, organized into over 200 major types, with hundreds of cell-specific functions.

Some functions performed by cells are so vital to the existence of life that all cells perform them (e.g. cellular respiration). Others are highly specialized (e.g. photosynthesis).

4.2.2 Comparison between Prokaryotes and Eukaryotes:

Organisms whose cells have a membrane bounded nucleus are called eukaryotes (from the Greek words **'Eu'** means well or truly and **'karyon'** means kernel or nucleus. Organisms whose cells do not have a membrane bounded nucleus are called prokaryotes (**'pro'** means before).

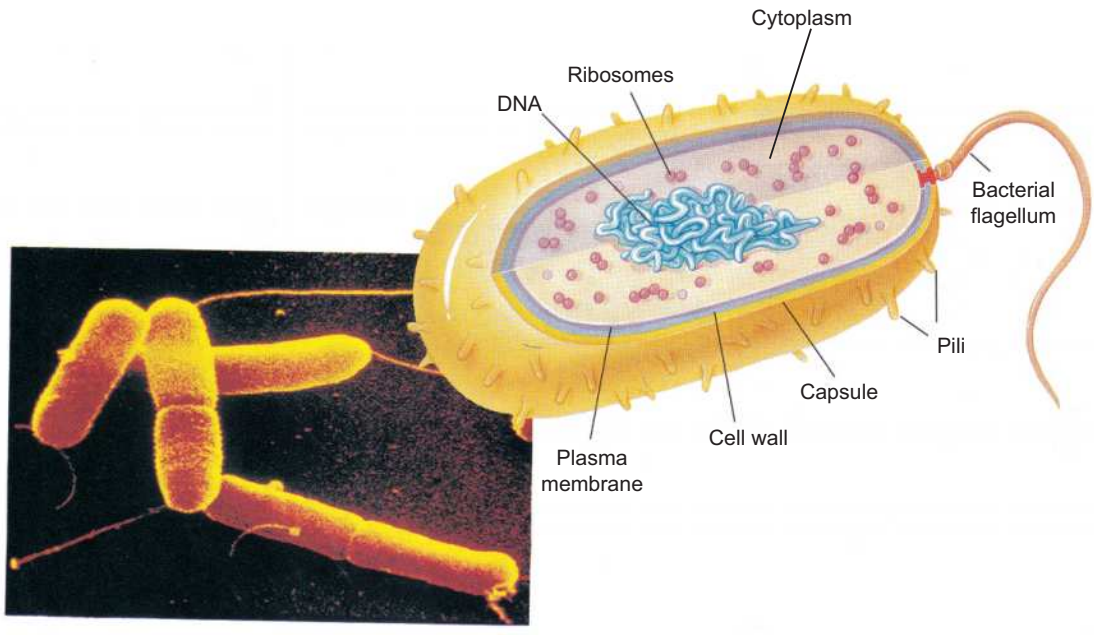


Figure 4.7 The structure of Bacterial Cell

Compare between prokaryotes and eukaryotes:

Cellular Structures	Prokaryotic cell	Eukaryotic cell
Example;	Bacteria and Cyanobacteria	Animals and plants
Nucleus	Without membrane	Membrane bounded
Number of chromosomes	One but not true chromosomes:	More than One
Number of cells	Unicellular	Unicellular and Multicellular
True membrane bound orgenelles	Absent	Present
Lysosomes and Peroxisome	Abscent	Present
Microtubules	Absent or rare	Present
Endoplasmic reticulum	Absent	Present
Mitochondria	Absent	Present
Ribosomes	Smaller 70S	Larger 80S
Vesicles	Present	Present
Golgi Apparatus	Absent	Present
Chloroplasts	Absent	Present (in plants)
Plasma membrane with steroid	Usually no	Yes
Permeability of nuclear membrane	Not present	Selective
Vacuoles	Absent	Present
Cell Size	1-10 µm	1-1000 µm
Flagella	Submicroscopic in size, composed of only one fiber	Microscopic in size; membrane bound

4.2.3 Cellular Structures and Functions:

We will now look at some of the basic cell structures and organelles in animal and plant cells. You will be noticed that there are key differences between plant and animal cells. The table below summarizes these differences.

Difference between animal and plant cell:

Animal Cells	Plants Cells
Do not contain plastids.	Almost all plants cells contain plastids such chloroplasts, chromoplasts and leucoplasts.
No cell wall.	Have a rigid cellulose cell wall in addition to the cell membrane.
Animals do not have plasmodesmata or pits.	Contain plasmodesmata and pits.
Few vacuoles (if any).	Large central vacuole filled with cell sap in mature cells.
Nucleus is generally found at the centre of the cytoplasm.	Nucleus is found near the edge or periphery of the mature cell.
Animal cells possess lysosomes which contain enzymes that digest cellular macromolecules.	Plant cells rarely contain lysosomes as the plant vacuole handles molecule degradation.
Animal cells contain these cylindrical structures that organize the assembly of microtubules during cell division.	Plant cells do not typically contain centrioles.

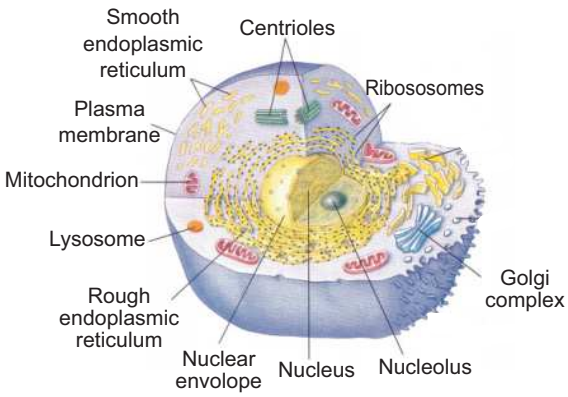


Figure 4.8 Animal cell

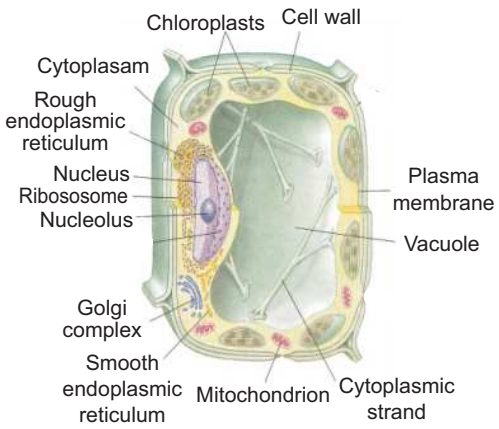


Figure 4.9 Plant cell

1. Cell wall:

A cell wall is a tough, rigid non-living and permeable protective layer in some cell types. This outer covering is positioned next to the cell membrane (plasma membrane) in plant cells, fungi, algae and bacteria. The cell wall has many important functions in a cell including protection, structure, and support.

Cell wall composition varies depending on the organism. In plants, the cell wall is composed mainly of strong fibers of cellulose. Bacterial cell walls are composed of a sugar and amino acid called peptidoglycan. The main components of fungal cell walls are chitin, glucans, and proteins.

In plants, the wall is composed of cellulose. It may consist up to three layers that help to support the plant. These layers include the middle lamella, the primary cell wall and the secondary cell wall.

Middle lamella: It separates one cell from another. It is a thin membranous layer on the outer side of the cell and is made of a sticky substance called pectin and cellulose.

Primary cell wall: It lies on the inside of the middle lamella and is mainly composed of cellulose.

Secondary cell wall: It lies along side the cell membrane. It is made up of a thick and tough material of cellulose which is held together by a hard, water proof substance called lignin. It is only found in cells which provide mechanical support in plants, i.e., Some cells of xylem like tracheid and vessels.

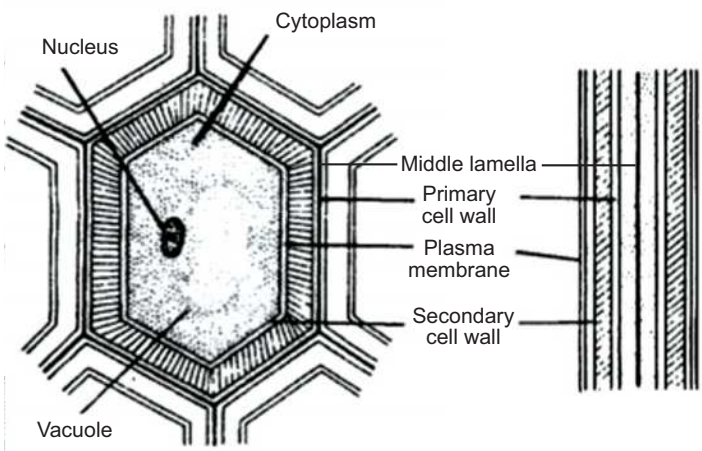


Figure 4.10 (a) Structure of cell wall

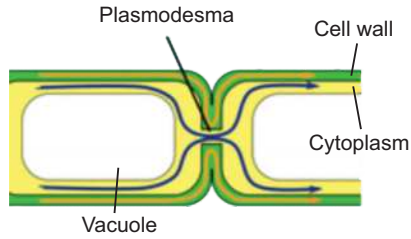


Figure 4.10 (b)
Cell wall showing plasmodesma

The openings in the cell wall are called **plasmodesmeta** which contain strands of cytoplasm that connect adjacent cells. This allows cells to interact with one another, allowing molecules to travel between plant cells.

The main function of the wall is to protect the inner parts of the plant cell, it gives plant cells a more uniform and regular shape and provides support for the plant body. The cell wall is completely permeable to water and mineral salts which allows distribution of nutrients throughout the plant.

2. Cell membrane:

The cell membrane is the outer most living boundary of all cells. The cell membrane, also called the plasma membrane, physically separates the intracellular space (inside the cell) from the extracellular environment (outside the cell). The cell membrane surrounds and protects the cytoplasm.

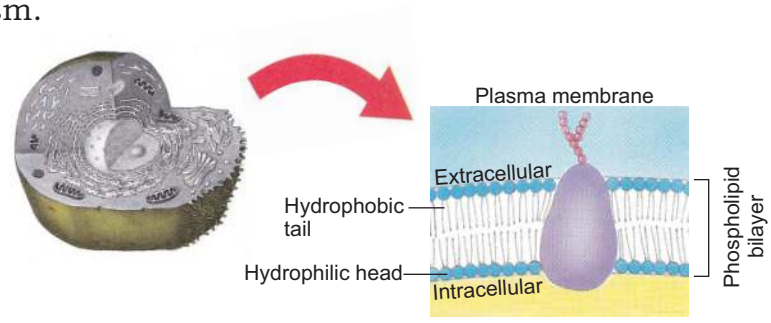


Figure 4.11 Cell membrane showing arrangment of phospholipid molecules in bilayers

The cell membrane is composed of a double layer (bilayer) of special lipids called phospholipids.

4.2.4 Structure of the cell membrane – the fluid mosaic model:

S.J. Singer and ***G.L. Nicolson*** proposed the Fluid Mosaic Model of the cell membrane in 1972. This model describes that phospholipid acting like matrix and conjugated glycoproteins (glucose and protein together) may float freely in this matrix.

This model describes the structure of the cell membrane as a fluid structure with various protein and carbohydrate components floating freely in the membrane. All the exchanges between the cell and its environment have to pass through the cell membrane. The cell membrane is selectively permeable to ions (e.g. hydrogen, sodium), small molecules (oxygen, carbon dioxide) and larger molecules (glucose and amino acids) and controls the movement of substances in and out of the cells. It performs many important functions within the cell such as osmosis, diffusion, transport of nutrients into the cell, processes of ingestion and secretion.

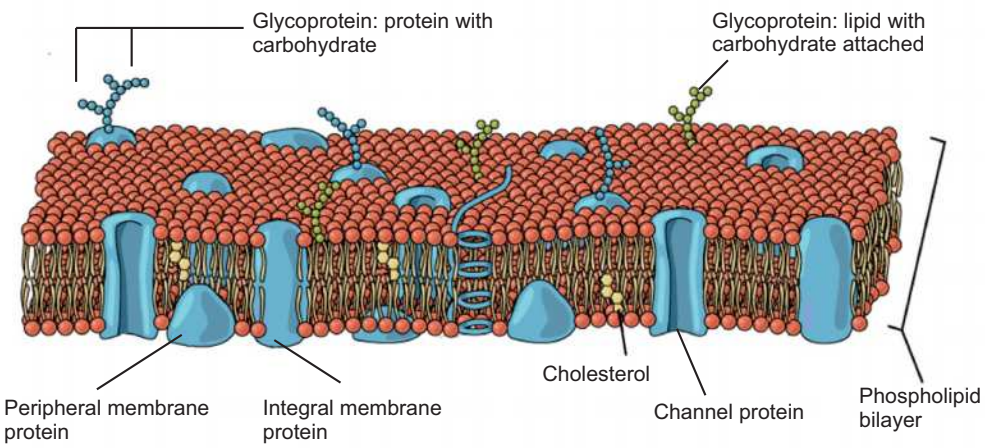


Figure 4.12 Section of cell-membrane

Movement across the membranes:

Movement of substances across cell membranes is necessary as it allows cells to acquire oxygen and nutrients, excrete waste products and control the concentration of required substances in the cell (e.g oxygen, water, hormones, ions, etc). This movement occurs by diffusion, osmosis, facilitated diffusion and active transport.

1. Diffusion:

Diffusion is the movement of substances from a region of high concentration to low concentration. It is therefore said to occur down a concentration gradient.

Diffusion is a passive process which means it does not require any energy input. It can occur across a living or non-living membrane and can occur in a liquid or gas medium. Examples diffusion of carbon dioxide, oxygen, water and other small molecules that are able to dissolve within the lipid bilayer.

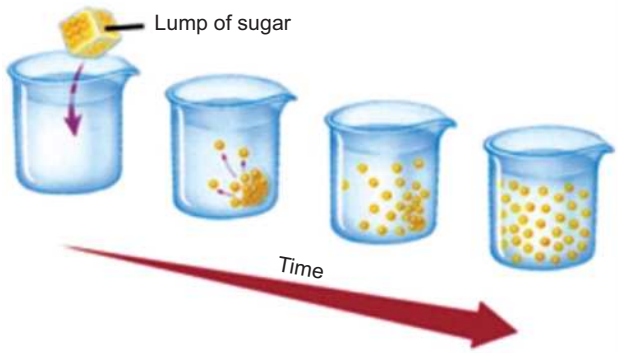


Fig 4.13 Diffusion:
The diagram shows the movement of dissolved particles within a liquid until eventually becoming randomly distributed.

2. Osmosis:

Movement of water always occurs down a concentration gradient, i.e., from dilute solution to concentrated solution. Osmosis is also a passive process and does not require any input of energy. Cell membranes allow molecules of water to pass through, but they do not allow molecules of most dissolved substances, e.g. salt and sugar, to pass through it.

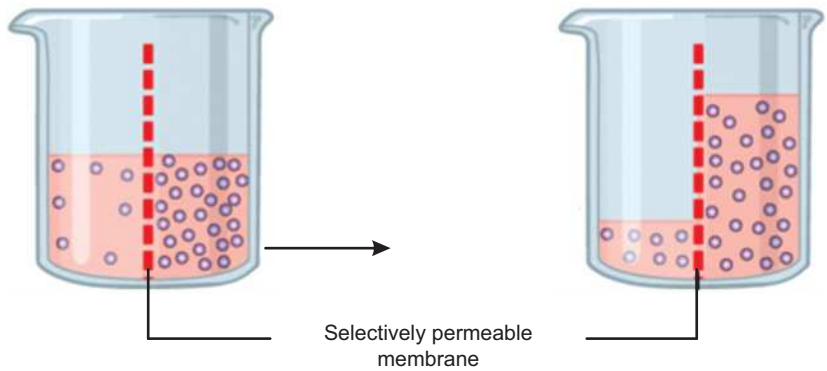


Fig 4.14 Osmosis

In biological systems, osmosis is vital to plant and animal cell survival. Figure 4.15 demonstrates how osmosis affects red blood cells and plant cell, when they are placed in three different solutions with different concentrations.

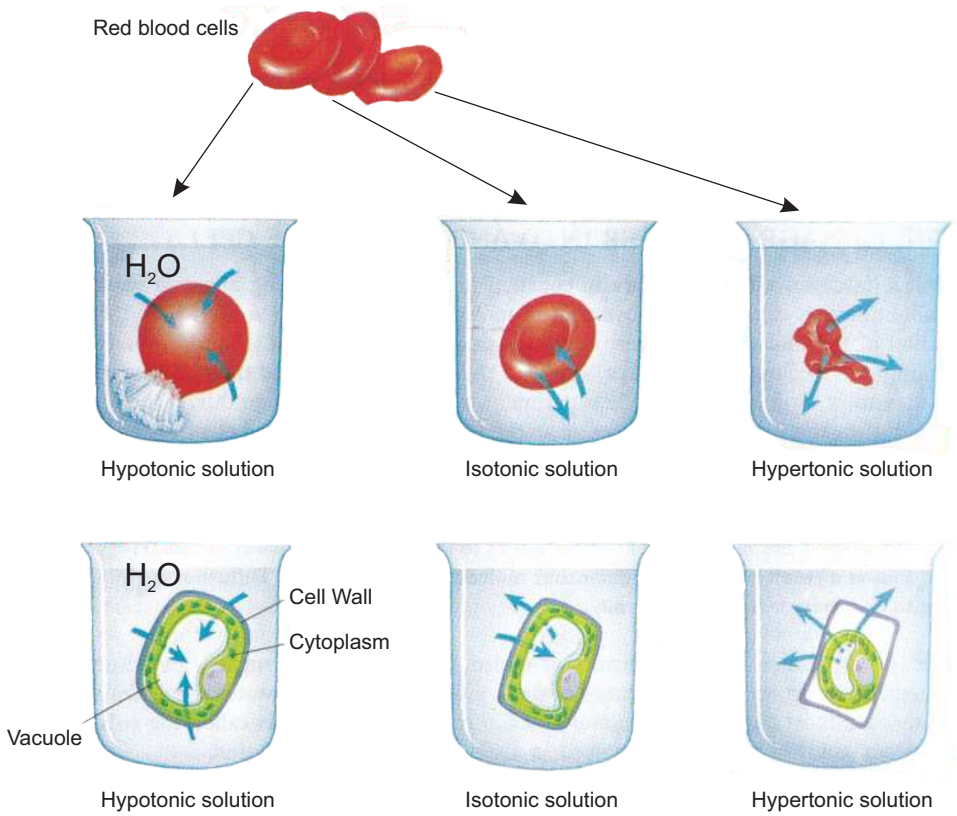


Figure 4.15 The effect of hypertonic, isotonic and hypotonic solutions on red blood cells and plant cell.

Plant cells use osmosis to absorb water from the soil and transport it to the leaves. In hypertonic conditions a plant cell loses water and cytoplasm shrinks and shrinkage of cytoplasm is called **plasmolysis**. Osmosis in the kidneys keeps the water and salt levels in the body and blood at the correct levels.

Activity: Predicting the direction of osmosis

Apparatus:

- Beaker
- Large potato
- Potato peeler/scalpel
- Pins
- Concentrated sucrose/sugar solution. To obtain this, add 100g of sugar to 200ml of water.

Procedure:

1. Peel off the skin of a large sized potato with a scalpel/potato peeler.
2. Cut its one end to make the base flat.
3. Make a hollow cavity in the potato almost to the bottom of the potato.
4. Add the concentrated sugar solution into the cavity of the potato, filling it about half way. Mark the level by inserting a pin at the level of the sugar solution (insert the pin at an angle into the cavity at the level) (A).
5. Carefully place the potato in the beaker containing water.
6. Observe what happens to the level of the sugar solution in the potato.
7. After 15 to 20 minutes, mark the level by inserting the second pin at the level of the sugar solution (insert as the first pin) (B).

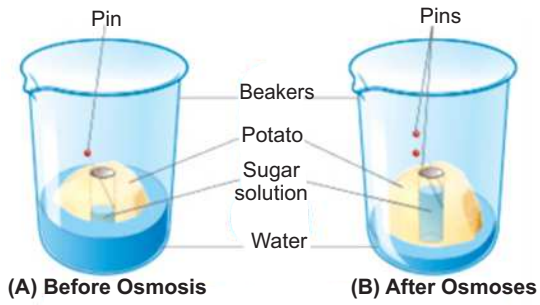


Figure 4.16 Potato Osmoscope

Questions

1. What do you observe happening to the level of the solution inside the potato?
2. What conclusion can you draw based on your observation?
3. What conditions were met in this experiment that makes this type of transport different to diffusion?

3. Facilitated diffusion:

Facilitated diffusion is a special form of diffusion which allows rapid exchange of specific substances. Particles are taken up by carrier proteins which change their shape as a result. The change in shape causes the particles to be released on the other side of the membrane.

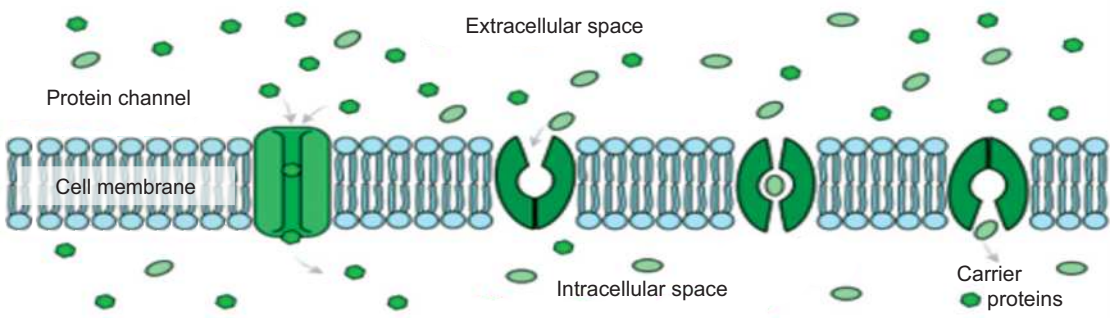


Figure 4.17 Facilitated diffusion in cell membrane, showing ion channels and carrier proteins

4. Active transport:

Active transport is the movement of substances against a concentration gradient, from a region of low concentration to high concentration using an input of energy. In biological systems, the form in which this energy occurs is adenosine triphosphate (ATP). Examples of substances moved include sodium and potassium ions as shown in Figure 4.18.

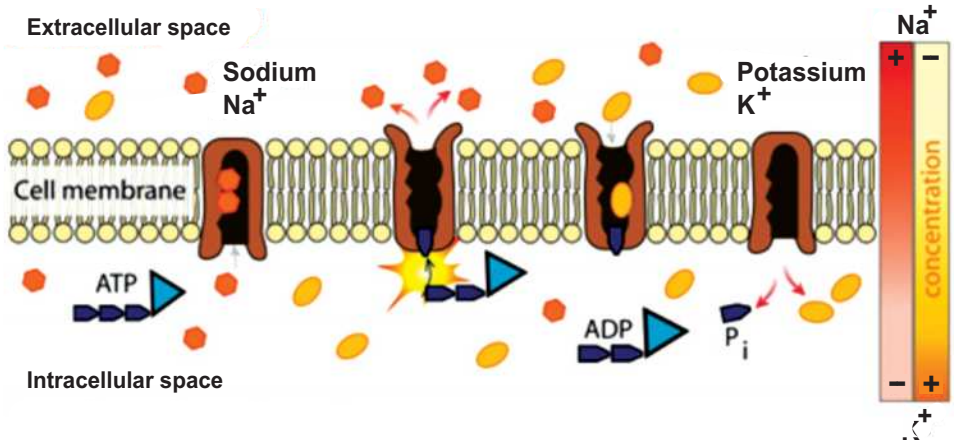


Figure 4.18 The sodium-potassium pump is an example of primary active transport.

ATP and ADP are molecules involved with moving energy within cells.

Cell organelles: We will now look at the key organelles that make up the cell. It is important to bear in mind that structure and function are closely related in all living systems. When studying each organelle, ensure that you observe the specific structures (from micrographs) that allow the organelle to perform its specific function.

Cytoplasm: The cytoplasm is the jelly-like substance that fills the cell. It consists of up to 90% water. It also contains dissolved nutrients and waste products. Its main function is to hold together the organelles which make up the cytoplasm. It also nourishes the cell by supplying it with salts and sugars and provides a medium for metabolic reactions to occur.

Cytoskeleton: A microscopic network of protein consists of microtubules and various filaments that spread out through the cytoplasm, providing both structural support and means of transport within the cell. Microtubules are made of tubulin while filaments made up of active protein.

Nucleus: The nucleus is the largest organelle in the cell and contains the entire cell's genetic information in the form of DNA. The presence of a nucleus is the primary factor that distinguishes eukaryotes from prokaryotes. Nucleus is covered by two phospholipids membranes known as nuclear envelope that separates the nucleus and its contents from the cytoplasm. Nuclear pores are found in the nuclear envelope and help to regulate the exchange of materials (such as RNA and proteins) between the nucleus and the cytoplasm. Inside nuclear envelope, a granular fluid is present called **nucleoplasm**. In nucleus an aggregation of RNA is also present called nucleolus. In non-dividing cell the genetic material is found in the form of net work in the nucleus called chromatin net work.

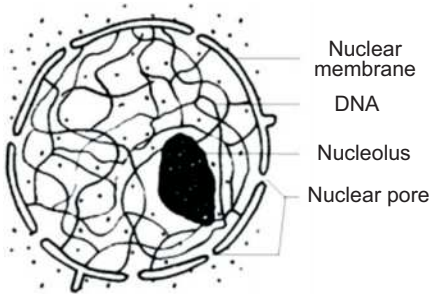


Figure 4.19 Schematic Diagram of nucleus

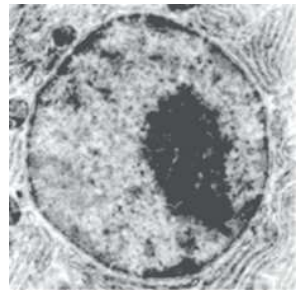


Figure 4.20 Micrograph of nucleus

Mitochondria (Singular; Mitochorion):

A mitochondrion is a membrane bound organelle found in eukaryotic cells. Mitochondria contain two phospholipid bilayers: there is an outer membrane, and an inner membrane. The inner membrane contains many folds called cristae which contain specialized membrane proteins that enable the mitochondria to synthesize ATP. Inside the inner membrane is a jelly-like matrix. The compartment, the compartments of the mitochondrion are shown in figure 4.21

Mitochondria is the site of aerobic respiration. During aerobic respiration energy is produced in the form of ATP. Therefore the Mitochondria is also called 'Power house' of cell.

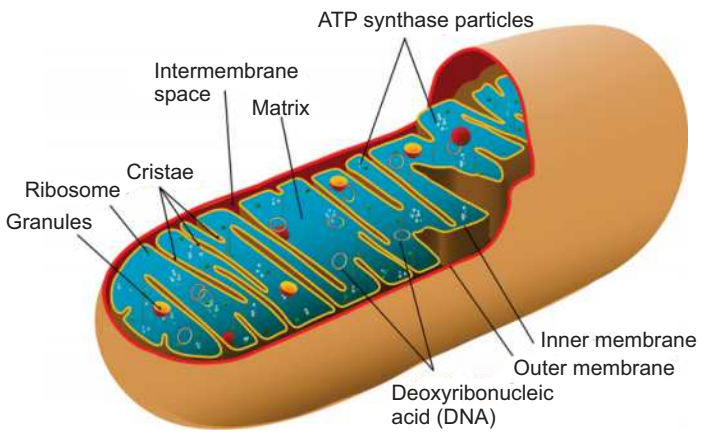


Figure 4.21 Mitochondria

Endoplasmic reticulum:

The endoplasmic reticulum (ER) is an organelle found in eukaryotic cells only. The ER has a double membrane consisting of a network of hollow tubes, flattened sheets, and round sacs. These flattened, hollow folds and sacs are called cisternae. The ER is located in the cytoplasm and is connected to the nuclear envelope. There are two types of endoplasmic reticulum: smooth and rough ER.

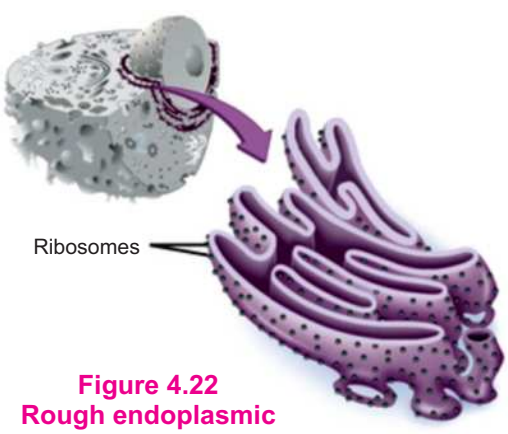


Figure 4.22
Rough endoplasmic reticulum

Smooth Endoplasmic Reticulum: does not have any ribosomes attached. It is involved in the synthesis of lipids, including oils, phospholipids and steroids. It is also responsible for metabolism of carbohydrates, regulation of calcium concentration and detoxification.

Rough Endoplasmic Reticulum: is covered with ribosomes giving the endoplasmic reticulum its rough appearance. It is responsible for protein synthesis and plays a role in membrane production. The folds present in the membrane increase the surface area allowing more ribosomes to be present on the ER, thereby allowing greater protein production.

Ribosomes:

Ribosomes are composed of RNA and protein. They occur in the cytoplasm and are the sites where protein synthesis occurs. Ribosomes may occur singly in the cytoplasm or in groups or may be attached to the endoplasmic reticulum thus forming the rough endoplasmic reticulum.

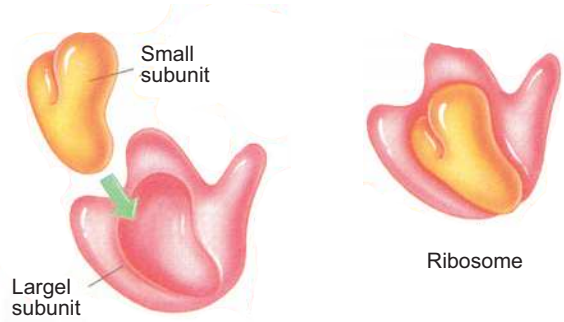


Figure 4.23
Structure of Ribosome

Golgi body:

The Golgi body was discovered by the Italian physician Camillo Golgi. It was one of the first organelles to be discovered and described in detail because its large size made it easier to observe. It is important for proteins to be transported through Golgi body from where they are synthesized to where they are required in the cell. The Golgi body is the sorting organelle of the cell.

The Golgi body consists of a stack of flat membrane-bound sacs called cisternae. The cisternae within the

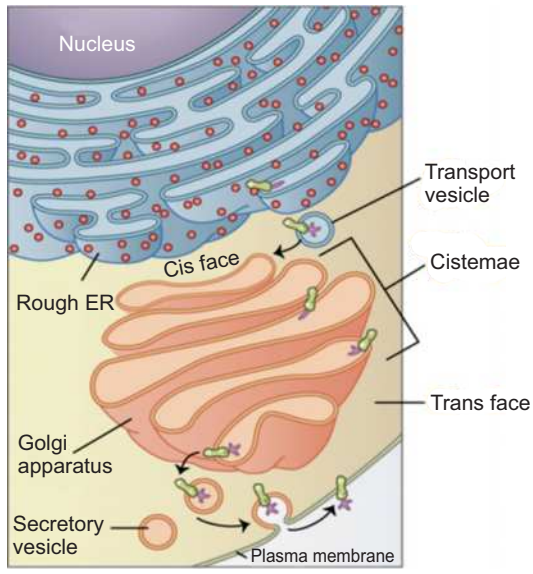


Figure 4.24 Golgi body

Golgi body consist of enzymes which modify the packaged products of the Golgi body.

Proteins are transported from the rough endoplasmic reticulum (RER) to the Golgi. In the Golgi, proteins are modified and packaged into vesicle. The Golgi body therefore receives proteins made in one location in the cell and transfers these to another location within the cell where they are required. For this reason the Golgi body can be considered to be the 'post office' of the cell.

Vesicles and lysosomes:

Vesicles are small, membrane-bound spherical sacs which facilitate the metabolism, transport and storage of molecules. Many vesicles are made in the Golgi body and the endoplasmic reticulum, or are made from parts of the cell membrane. Vesicles can be classified according to their contents and function. Transport vesicles transport molecules within the cell.

Lysosomes are formed by the Golgi body and contain powerful digestive enzymes that can potentially digest the cell. These powerful enzymes can digest cell structures and food molecules such as carbohydrates and proteins. Lysosomes are abundant in animal cells that ingest food through food vacuoles. When a cell dies, the lysosome releases its enzymes and digests the cell.

Vacuoles:

Vacuoles are fluid-filled spaces that occur in the cytoplasm of plant cells, but are very small or completely absent in animal cells. Plant cells generally have one large vacuole that takes up most of the cell's volume in mature cell. A selectively permeable boundary called the tonoplast, surround the vacuole. The vacuole contains cell sap which is a liquid consisting of water, mineral salts, sugars and amino acids. The vacuole plays an important role in hydrolysis, excretion of cellular waste, storage of water, organic and inorganic substances.

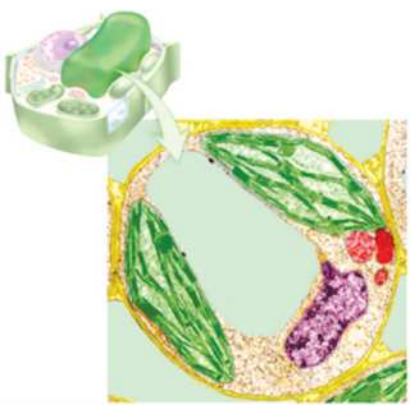


Figure 4.25 A vacuole

Centrioles:

Animal cells contain a special organelle called a centriole. The centriole is a cylindrical tube-like structure that is composed of 27 microtubules arranged in a very particular pattern of triplets in rows. The site where two centrioles arranged perpendicular to each other are referred to as a centrosome. The centrosome plays a very important role in cell division. The centrioles are responsible for organizing the microtubules that position the chromosomes in the correct location during cell division.

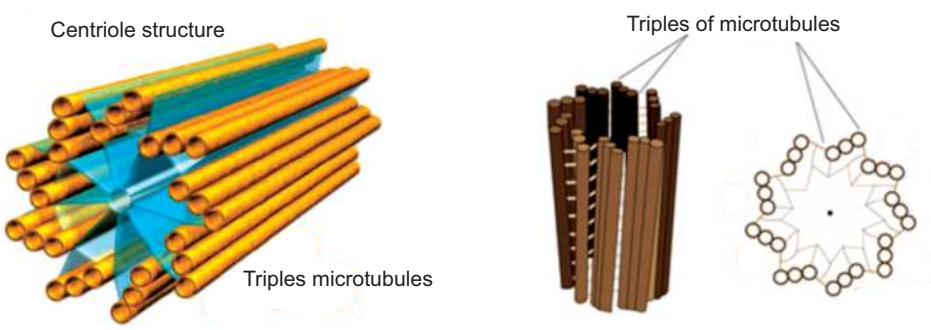


Figure 4.26 Centriole side view and pattern

Plastids

Plastids are large cytoplasmic and major organelles found in the cells of plants and algae. Plastids are the site of manufacture and storage of important chemical compounds used by the cell. Plastids often contain pigments used in photosynthesis, and the types of pigments present can change or determine the cell's colour. There are three different types of plastids:

Chloroplasts: Green-coloured plastids found in plants and algae.

Chromoplasts: Contain red, orange or yellow pigments and are common in ripening fruit, flowers or autumn leaves.

Leucoplasts: Colour less plastids.

The colour of plant flowers such as an orchid is controlled by a specialized organelle in a cell known as the chromoplast.

Chloroplast

The chloroplast is a double-membraned organelle. Within the double membrane is a gel-like substance called stroma. Stroma contains enzymes for photosynthesis. Suspended in the stroma are stack-like structures called grana (singular = granum). Each granum is a stack of thylakoid discs. The chlorophyll molecules (green pigments) are found on the surface of the thylakoid discs. Chlorophyll absorbs energy from the sun for photosynthesis.

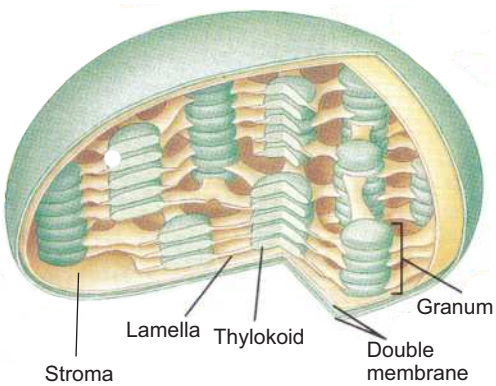


Figure 4.27 Structure of choloroplast

4.3 CELL SIZE AND SHAPE AS THEY RELATE TO SURFACE AREA TO VOLUME RATIO

Cells are microscopic mostly because of this constraint; there are some physiological limits to how big a cell can grow. The scale, or size of a cell compared to other objects, is incredibly small.

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 4.28 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

Surface area of 27 small cubes = 27 X 600 μm^2 = 16, 200 μm^2

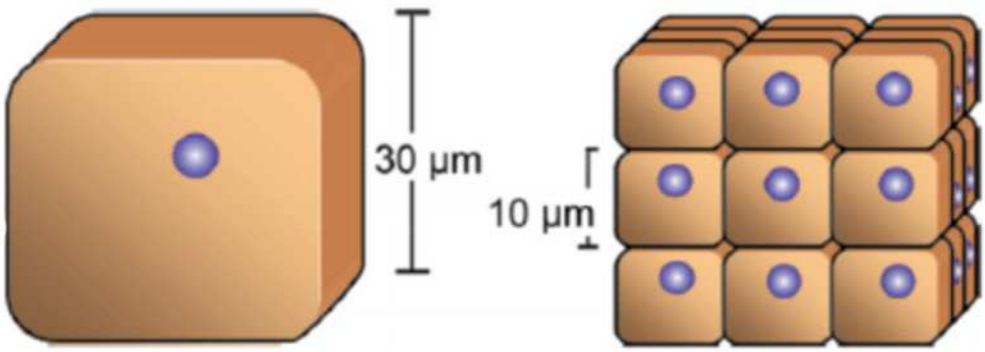


Figure 4.28 Surface-area to volume ratio too small = decreased rate of chemical exchange ⟶ cell dies

Cell size and volume ratio:

Waste production and demand of nutrients 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. Each internal region of the cell has to be served by part of the cell surface. As a cell grows bigger, its internal volume enlarges and the cell membrane expands. Unfortunately, the volume increases more rapidly than does the surface area, and so the relative amount of surface area available to pass materials to a unit volume of the cell steadily decreases. Hence we conclude that the membranes of small cells can serve their volumes more easily than the membrane of a large cell.

In Life Sciences it is important to note that whenever a structure has an increased surface area, there is an increase in the functioning of that structure.

Activity 1: Examining plant cells under the microscope

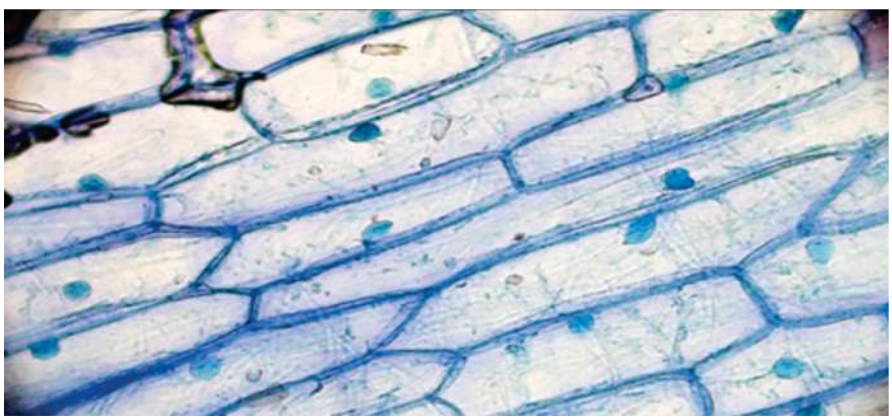
To study the microscopic structures of plant cells.

Apparatus:

- Onion
- Brushes
- Forceps
- Watch glass
- Blade
- Tissue paper
- Dropper
- Petri dish containing water
- Slides and coverslips
- Compound microscope
- Iodine solution

Procedure:

1. Peel off the outer most layer of an onion carefully, using a pair of forceps.
2. Place the peeled layer in a watch glass containing water. Make certain that the onion peel does not roll or fold.
3. Using a scalpel or a thin blade, cut a square piece of the onion peel (about $1cm^2$).
4. Remove the thin transparent skin from the inside curve of a small piece of raw onion and place it on a drop of iodine solution on a clean slide.
5. Cover the peel with a coverslip ensuring that no bubbles are formed.
6. Using a piece of tissue paper wipe off any excess iodine solution remaining on the slide.
7. Observe the onion skin under low power of the microscope and then under high power.
8. Draw a neat diagram of 5-10 cells of the typical cells you can see.



Onion cells stained with methylene blue.

Activity 2: Examining animal cells under the microscope

To study the microscopic structures of human cheek cells under a compound microscope.

Apparatus:

- Cotton bud
- Dropper
- Forceps
- Clean slide
- Water
- Microscope
- Methylene blue
- Tissue paper

Procedure:

1. Place a drop of water on a clean glass slide.
2. Using a clean ear bud, wipe the inside of your cheek. The ear bud will collect a moist film.
3. Spread the moist film on a drop of water on a clean glass slide, creating a small smear on the slide.
4. Use a coverslip to cover the slide gently.
5. Place one or two drops of stain on the side of the cover slip.
6. Use a piece of tissue to remove the excess dye.
7. Observe the cheek cells under low power magnification and then under high power magnification.

Cheek epithelial cells

Questions

1. What are the shapes of epidermal cells of the onion peel and the human cheek cells?
2. Why is iodine used to stain the onion peel?
3. What is the difference between the arrangement of cells in onion cells and in human cheek cells?
4. Why is a cell considered the structural and functional unit of living things?

4.4 ANIMAL AND PLANT TISSUES

We know the levels of organization where a group of similar cells that work together to perform a common function is known as a tissue. For instance, the cells in the small intestine that absorb nutrients look very different from the muscle cells needed for body movement.

(A) Animal tissues:

Humans and other large multicellular animals are made up of four basic types tissue: **epithelial** tissue, **connective** tissue, **muscular** tissue and **nervous** tissue.

1. Epithelial tissue:

Epithelial tissue covers the surface of the body, lines the spaces inside the body and forms glands. For instance, the outer layer of your skin is an epithelial tissue and the lining of small intestine are made up of epithelial tissues.

Epithelial cells are polarized, means that they have a top and a bottom side.

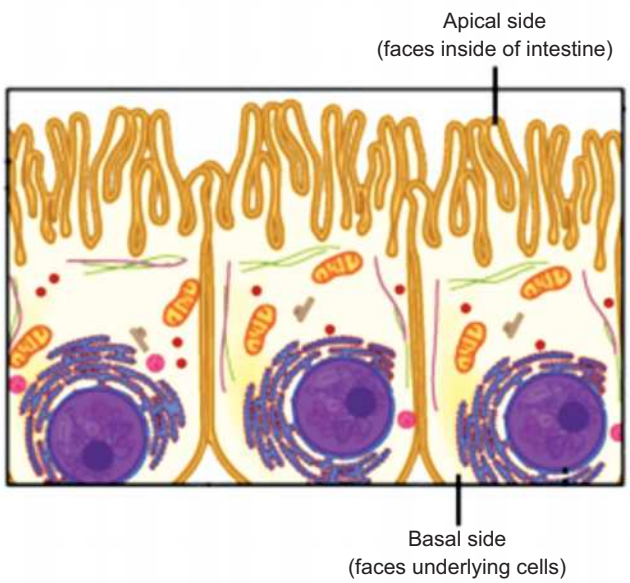
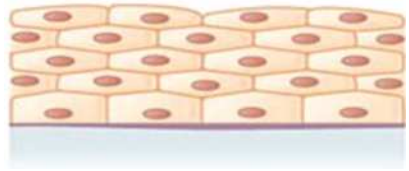
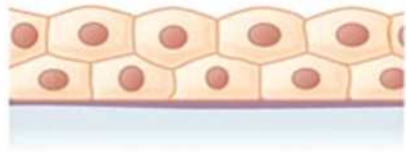
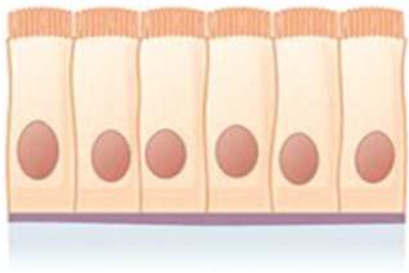
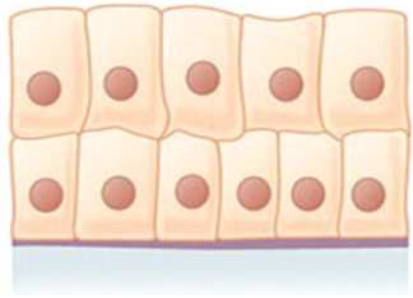


Figure 4.29 Epithelial tissue

There are different types of epithelial tissue depending on their function in a particular location. The simplest classification of these tissues is based on the number of cell layers.

When the epithelium is composed of a single layer of cells, it is called **simple epithelial tissue** and those containing two or more layers of cells are called **stratified epithelial tissues**.

	Simple	Stratified
Squamous	 Simple squamous spithelium	 Startified squamous epithelium
Cubical	 Simple cuboidal epithelium	 Stratified cuboidal epithelium
Columnar	 Simple columnar epithelium	 Stratified columnar epithelium

Simple squamous epithelium is found in the alveoli of lungs, and its structure is important for the exchange of gases between the blood and lungs. **Simple cuboidal epithelia** line the lumen of collecting ducts in the kidney and are present in the thyroid gland around the follicles that secrete thyroid hormones.

Simple columnar epithelia are found in the female reproductive system and in the digestive tract.

Stratified epithelia consist of more than one layer of cells and only one layer is in direct contact with the basement membrane.

Stratified squamous epithelia are found in skin, with many dead, keratinized cells providing protection against water and nutrient loss. **Stratified cuboidal epithelia** are found surrounding the ducts of many glands, including mammary glands in the breast and salivary glands in the mouth. **Stratified columnar epithelia** are rare, found predominantly in some organs of the reproductive system. **Transitional epithelia** are a special subset of stratified epithelia. They are exclusively found in the excretory system.

2. Connective tissue:

This tissue which connects or bind the different types of cells called connective tissues. They also bind other tissues of the body with each other. Connective tissue holds structures in the body together, such as tendons.

Cartilage is a type of supporting connective tissue. It is a dense connective tissue. Cartilage has limited ground substance and can range from semisolid to a flexible matrix.

Figure 4.30 Cartilage presant in pina of ear

Bone is another type of supporting connective tissue. Bone can either be compact (dense) or spongy (cancellous), and contains the osteoblasts or osteocytes cells.

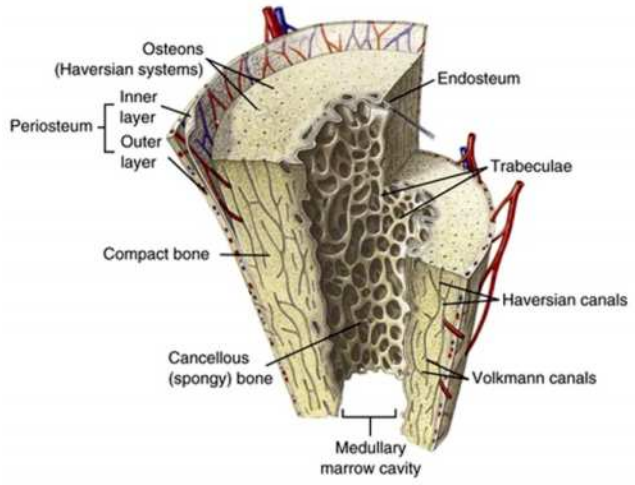


Figure 4.31 Longitudinal section of bone

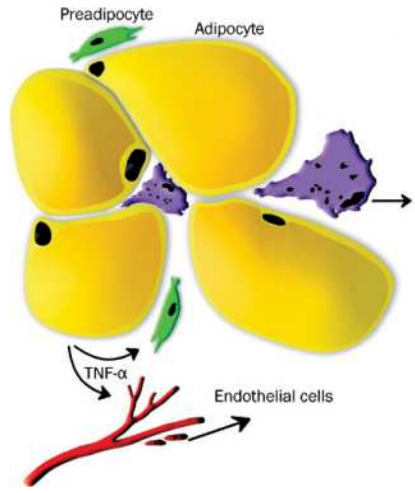


Figure 4.32 Adipose tissue

Adipose is another type of supporting connective tissue that provides cushions and stores excess energy and fat.

Blood referred to as connective tissue. It is a type of fluid connective tissue.

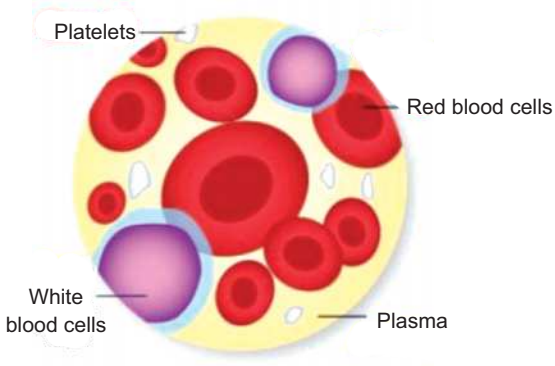


Figure 4.33 Blood cells

3. Muscle tissues:

Muscle tissue contains the cells that are responsible for the contraction of muscles. There are three types of muscular tissues i.e. cardiac, smooth, and skeletal.

Skeletal muscle, which is also called striated (striped) muscle, is what we refer to as muscle in everyday life. Skeletal muscle is attached to bones by tendons. For instance, the muscles in your legs and your arms are skeletal muscle.

Cardiac muscle is found only in the walls of the heart. Like skeletal muscle, cardiac muscle is striated, or striped. But it's not under voluntary control, so thankfully! you don't need to think about making your heart beat.

Smooth muscle is found in the walls of blood vessels, as well as in the walls of the digestive tract, the uterus, the urinary bladder, and various other internal structures. Smooth muscle is un-striped, (unstriated), it is involuntary, not under conscious control. That means you don't have to think about moving food through your digestive tract!

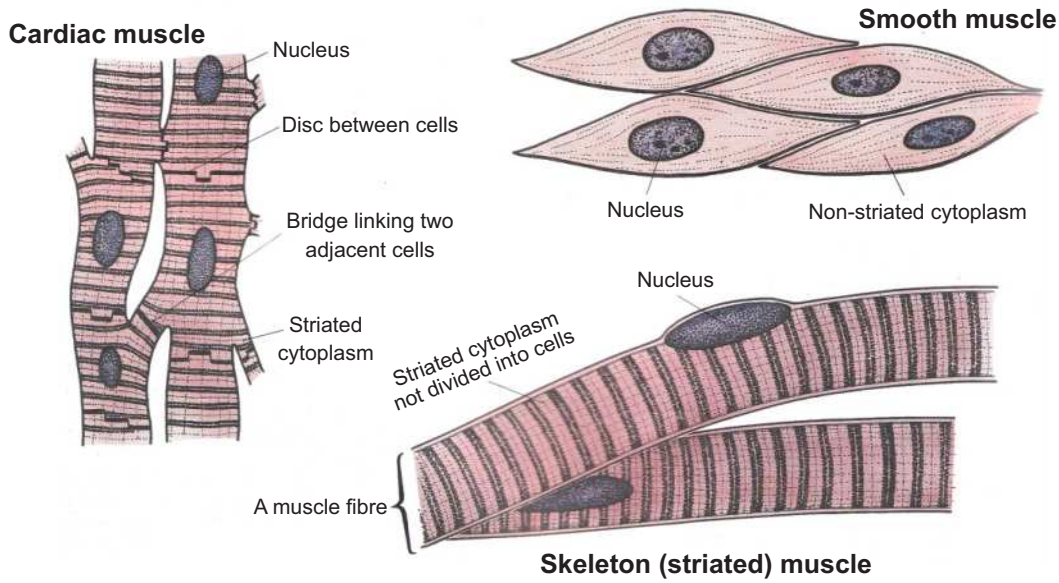


Figure 4.34 Types of msucles

4. Nervous tissues:

Nervous tissue is composed of neurons, which transmit information to other cells. Nervous tissue is found in the brain, spinal cord, and nerves. It is responsible for coordinating and controlling many body activities. It stimulates muscle contraction, creates an awareness of the environment, and plays a major role in emotions, memory, and reasoning. To do all these things, cells in nervous tissue need to be able to communicate with each other by way of electrical nerve impulses.

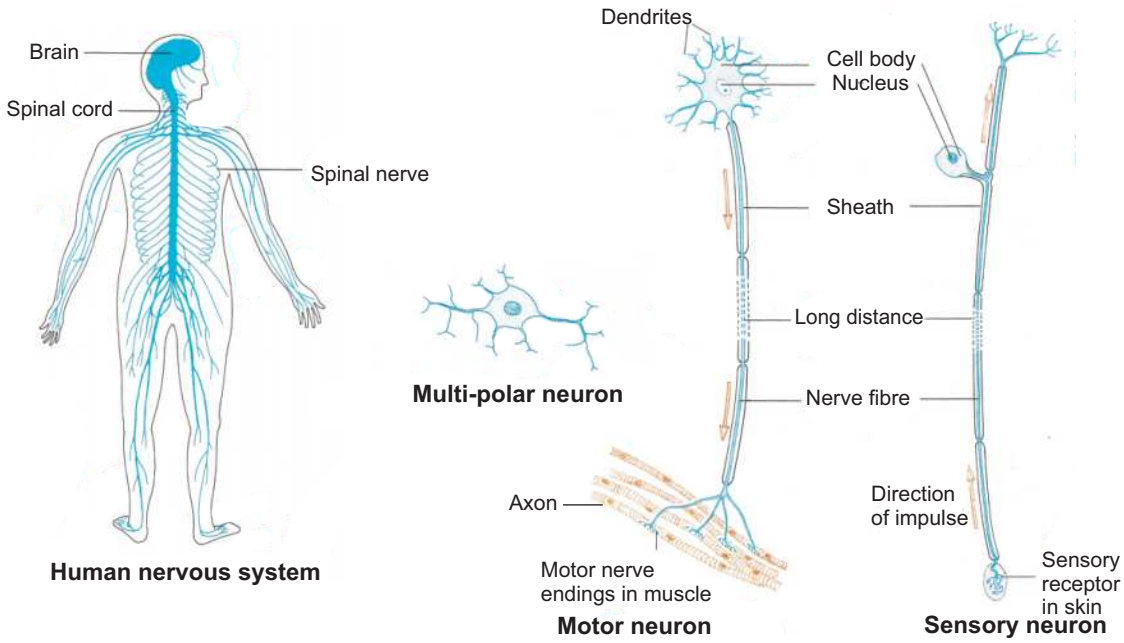
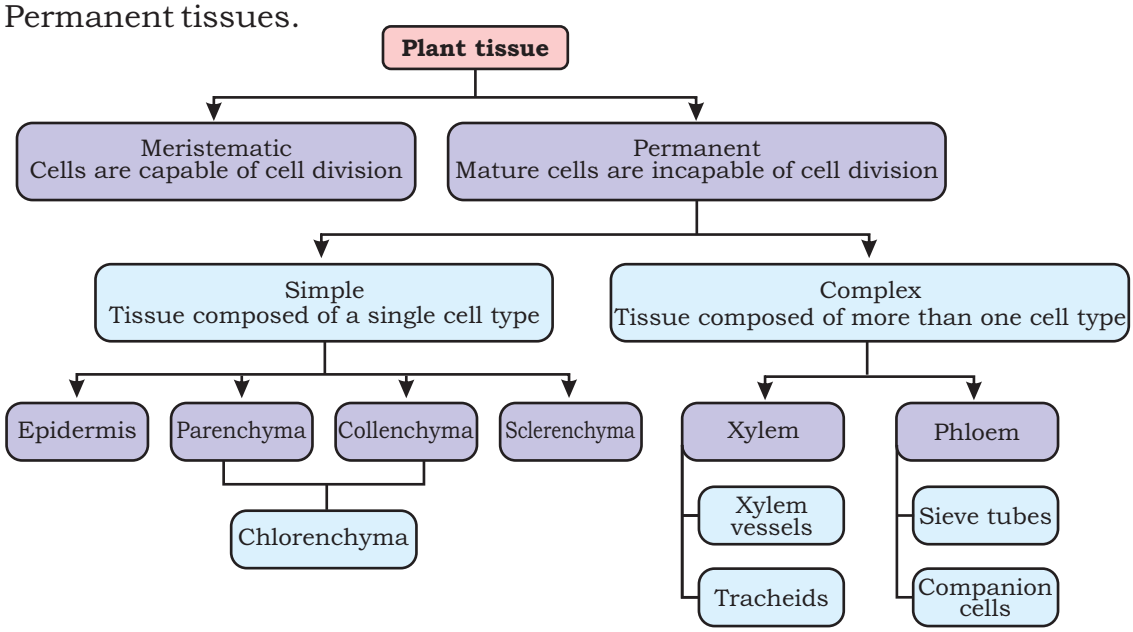


Figure 4.35 Human nervous system and various types of neuron cells

(B) Plant tissues

As same in animals, plant cells are grouped into tissues with characteristic functions such as photosynthesis, transport etc. There are two major categories of tissues in plants i.e. Meristematic tissues and Permanent tissues.



1. Meristematic Tissues:

These tissues are composed of cells, which have the ability to divide. The cells are thin walled, have large nucleus and number of small vacuoles. Usually they do not have inter-cellular spaces, so the cells are arranged compactly.

Two main types of meristematic tissues are recognized in plants.

(i) **Apical meristems** tissues are present at the apex of roots and stems. According to their position they are Apical meristems. Stem and root increase in length by the division of cells of these tissues. This type of 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 grith of plant parts. This growth is called secondary growth.

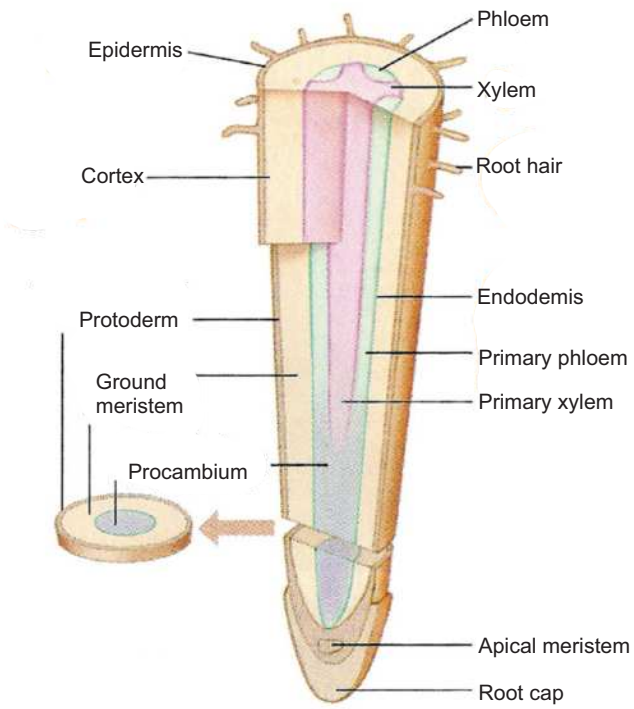


Figure 4.36 ***Apical meristem at root tip, Vascular and cork cambium***

2. Permanent Tissues :

Permanent tissues originate from meristematic tissue. The cells of these tissues do not have the ability to divide and may have intercellular spaces in between cells. They are further classified into following types: either on the basis of position or composition. There are two types of permanent tissues i.e. (a) Simple permanent tissue (b) Compound or complex tissue.

(A) Simple permanent tissue:

Simple permanent tissues are made up of only one type of cell.

(i) 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**.

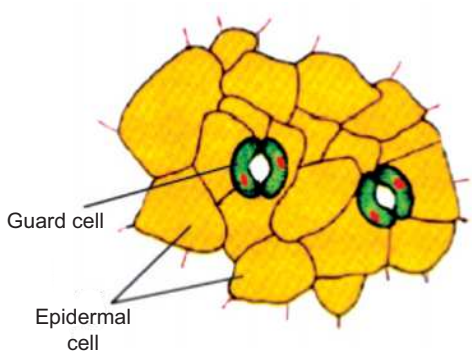


Figure 4.37 Epidermal tissue

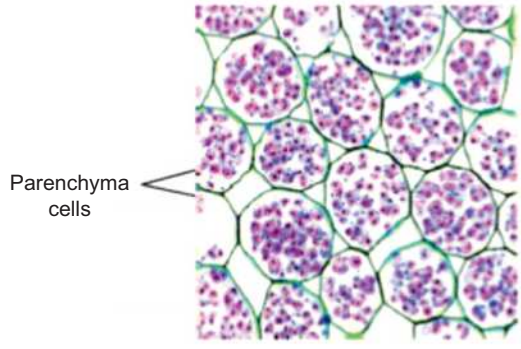


Figure 4.38 Ground tissue

(ii) 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.

(iii) Supporting Tissues:

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

(a) Collenchyma Tissues:

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.

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.

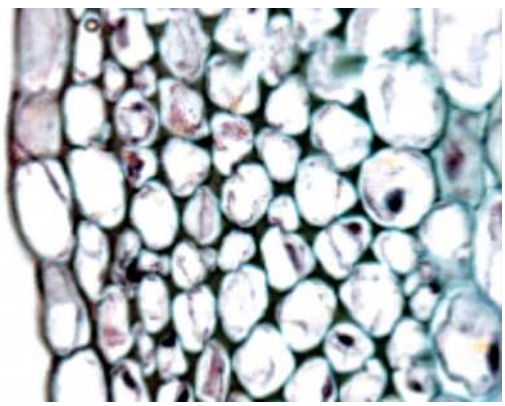


Figure 4.39 Collenchyma tissue

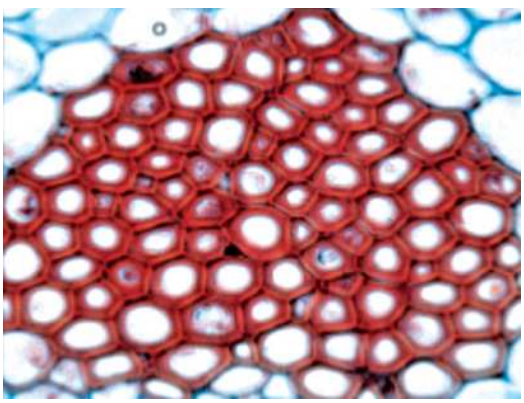


Figure 4.40 Schlerenchyma tissue

(b) Sclerenchyma Tissues :

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.

(B) 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.

(i) 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 main types of cell are found in xylem tissue i.e. vessel and tracheids. **Vessels** have thick secondary cell walls. Their cells lack end walls and join together to form long tubes. **Tracheids** are made up of slender cells with overlapping ends.

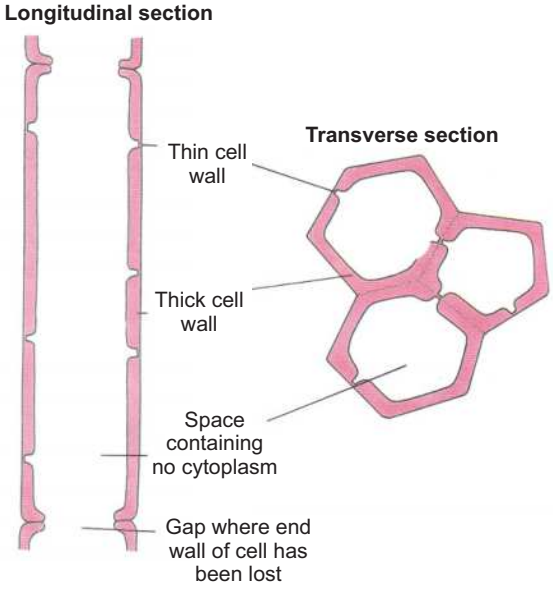


Figure 4.41 Xylem tissue

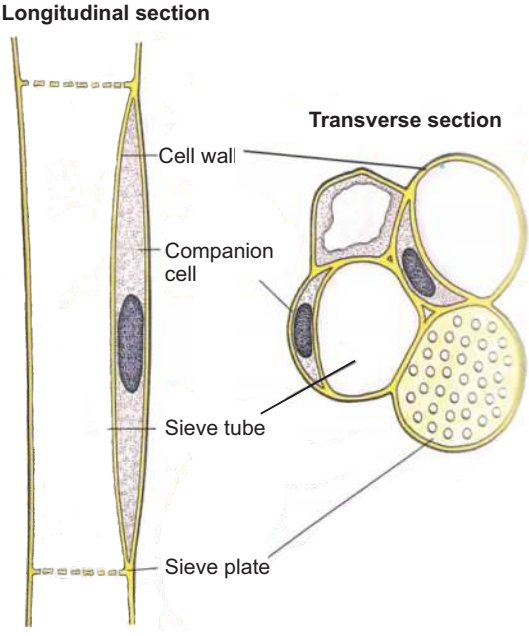


Figure 4.42 Phloem tissue

(ii) Phloem Tissue:

Phloem tissue is responsible for the conduction of dissolved organic matter (food) between different parts of plant body. Phloem tissue mainly contains sieve tube cells and 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** are parenchymatous, narrow, elongated cells, and are closely associated with the sieve tube. Conduction with the sieve tube is done through the pores present on the walls of these cells. They help the sieve tubes in conduction of food materials and make proteins for sieve tube cells.

Summary

- *Zachanan Janson* is believed to be the first investigation to invent compound microscope and *Robert Hooke* improved it.
- Two parameters are important in microscopy i.e magnification and resolution.
- Another microscope is electron microscope this microscope produce higher resolution. It can be used to examine sub-cellular structures.
- A cell is the basic structural and functional unit of organisms explained by cell theory important generalization of Biology.
- There are 2 types of cells on the bases of their sub-cellular structure i.e prokaryotic and eukaryotic cell.
- The prokaryotic cell has improper nucleus i.e with out nucleus membrane while eukaryotic cell has proper nucleus surrounded by nuclear membrane.
- Cell wall is a tough, rigid, non-living, permeable outer protective layer of some cells.
- Cell- membrane is the outer most living, differentially permeable boundary of all cells.
- *S.J singer* and *G.L. Nicholson* proposed fluid mosaic model to explain the structure of cell membrane.
- Movement across cell-membrane then place through osmosis, diffusion, active transport facilitated diffusion.
- The structure present in cell called cell organelle like, Mitochondria, Golgi bodies, Endoplasmic reticulum, ribosome, lysosome, vacuoles, centrioles, plastids and nucleus.
- Cells are of variable size like bacterial cells of smallest size and egg cells of largest size.
- waste production and demand of nutrients are directly proportional to cell volume.
- Tissues are the group of similar cells may be on the basis of structure.
- In plants there are two major types of tissues i.e meristematic and permanent tissues.

Review Questions

1. Encircle the correct answer:

(i) What is responsible for the high resolution of the electron microscope?

(a) High magnification

(b) Short wavelength of the electron beam

(c) Use of heavy metals strains

(d) Very thin section

(ii) What is a function of the rough endoplasmic reticulum?

(a) Aerobic respiration (b) Intracellular digestion

(c) Synthesis of steroids (d) Synthesis of protein

(iii) Which statement about the fluid mosaic model of membrane structure is correct?

(a) The less unsaturated the fatty acid, the more fluid nature.

(b) The more unsaturated the fatty acid, the more fluid nature.

(c) Higher the temperature, less fluid nature.

(d) The lower the temperature, more fluid nature

(iv) Which process allow movement in and out of cell

I. Osmosis

II. Diffusion

III. Active transport

(a) I only (b) I and II only

(c) II and III only (d) I, II and III

(v) All are postulates of cell theory except

(a) New cell is derived from pre-existing cells.

(b) Cell does not contain the hereditary material.

(c) All living organisms are made up of one or more cells.

(d) Cell is the fundamental unit of life

(vi) Secondary wall is made up of

(a) Pectin and cellulose (b) Cellulose and protein

(c) Cellulose and lignin (d) Lignin and pectin

(vii) Select the odd one

(a) Active transport (b) Diffusion

(c) Facilitated diffusion (d) Osmosis

(viii) Trace the correct pathway of protein produce from protein factories

(a) RER → Ribosome → Golgi body → Lysosome

(b) Ribosomes → RER → Golgi body → Lysosome

(c) Golgi body → RER → Ribosome → Lysosome

(d) RER → Ribosome → Lysosome → Golgi body

(ix) Cell organelle found in animal cell and help intracellular digestion

(a) Lysosome (b) Ribosomes

(c) Mitochondria (d) Golgi apparatus

(x) Select the mismatched

(a) Plastids → Storage of chemicals

(b) Centriole → Help in cell division

(c) Ribosomes → Synthesis of steroids

(d) Mitochondria → Synthesis of ATP

2. Fill in the blanks:

(i) Microscopes are instrument designed to produce _____ visual image.

(ii) Resolution of a microscope is defined as the smallest distance between_____ points.

(iii) Magnification of a light microscope is formed by using mixture of the power of the eyepiece and the _____ lens.

(iv) Electron has a much shorter wavelength than visible light, and this allows electron microscopes to produce _____ images.

(v) In plants, the cell wall is composed mainly of strong fibers of _____.

(vi) Cell membrane is composed of _____layer.

(vii) Diffusion is a _____ process, which does not require energy input.

(viii) Plant cell loses water and cytoplasm shrinks in a process called _____.

(ix) Special type of movement of specific substances through carrier protein is _____.

(x) The microtubules arranged in a very particular pattern to form centriole are _____ in number.

3. Define the following terms:

(i) Exocytosis (ii) Vesicles (iii) Cartilage

(iv) Nucleoplasm (v) Cyclosis (vi) Plasmolysis

(vii) Resolution (viii) Tissue (ix) Magnification

(x) Cisternae

4. Distinguish between the following in tabulated form:

(i) Prokaryotic cell and eukaryotic cell

(ii) Mitochondria and Chloroplast

(iii) Lysosome and Ribosomes

5. Write short answers of following questions:

(i) Why mitochondria is also called power house of cell?

(ii) Why iodine used to stain the onion peel?

(iii) How electron microscope is different from simple compound microscope?

(iv) Why cell membrane is semipermeable in nature?

(v) How facilitated diffusion is different from active transport?

(vi) Why cell is considered as the structural and functional unit of living things?

6. Write detailed answers of the following questions:

(i) Describe structure and function of nucleus with the help of diagram.

(ii) What is microscope? Describe types of microscopes.

(iii) Describe fluid mosaic model of cell membrane also draw the diagram.

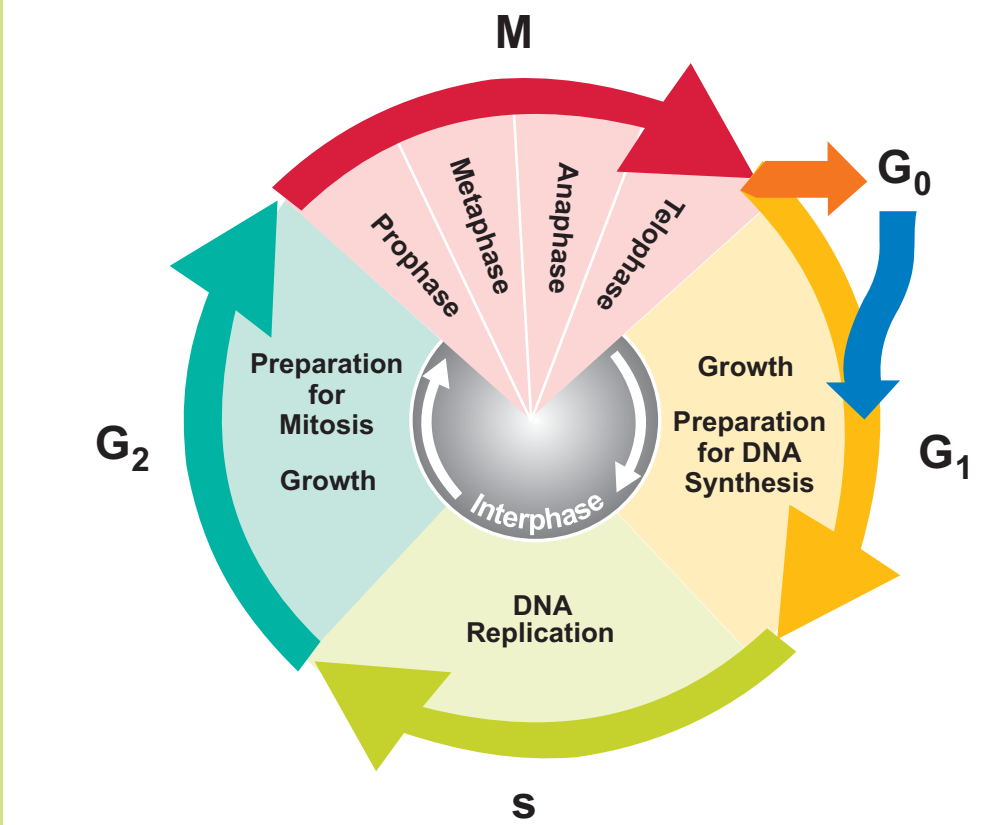
CELL CYCLE

Chapter 5

Major Concept

In this Unit you will learn:

- Chromosomes Structure and Functions
- Cell Cycle (Interphase and Division)
- Mitosis
  - Phases of Mitosis
  - Significance of Mitosis
- Necrosis and Apoptosis
- Meiosis
  - Phases of Meiosis



5.1 CHROMOSOMES

The term Chromosomes is given by German embryologist *Walter Fleming* in 1882 when he was examining the rapidly dividing cells of salamander larvae after treating with Perkin's Aniline. He observed that chromosomes colour is much darker than the rest of organelles. The term chromosomes is misnomer because its means coloured body later it was found that chromosomes are colourless bodies

Fig: 5.1 structure of chromosome

Chromosomes are thread like structure appear at the time of cell division includes found in specific numbers, made up of chromatin material in eukaryotic cell. They contain heredity units called **Genes**.

Chromosomes are made up of DNA and basic protein, Histones, appear during the cell division in the shape of rod. It has two parts arms and centromere.

The chromosomes are of different types, depending upon position of centromere. These types are:

(i) **Metacentric:** Chromosomes with equal arms.

(ii) **Sub-meta centric:** Chromosomes with un equal arms

(iii) **Acrocentric or sub-telocentric:** Rod like chromosomes with one arm very small and other very long. The centromere is subterminal.

(iv) **Telocentric:** Location of centromere at the end of chromosomes.

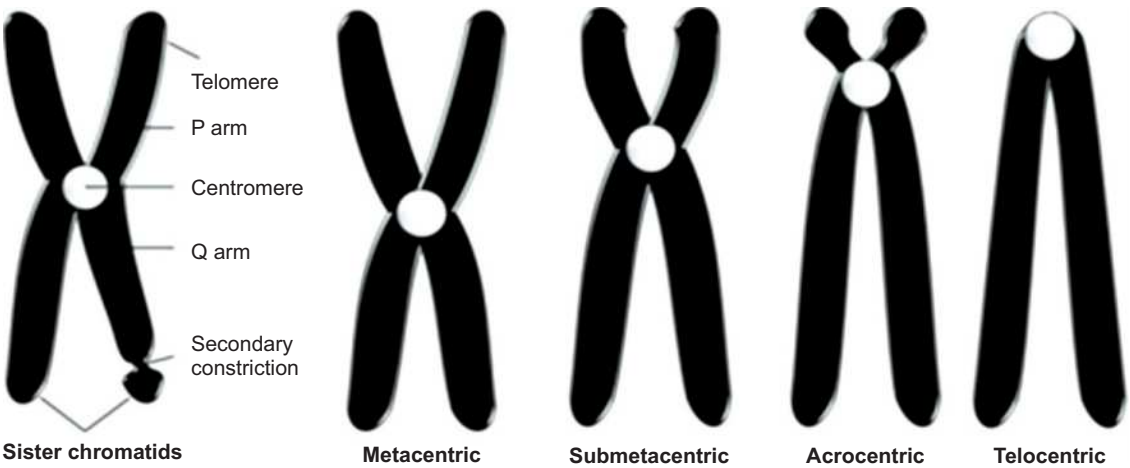


Fig: 5.2 Types of chromosomes

In the beginning of cell-division each chromosome is consist of two genetically identical copies of thread attach with each other called chromatids or sister chromatids.

Formation of chromosome:

Each chromosomes in eukaryotes are composed of chromatin fiber, which is made of nucleosomes. Chromatin fibers are packaged by proteins into a condensed structure called chromatin.

Chromatin allows the very long DNA molecules to fit into the cell nucleus. During cell division chromatin condenses further to form microscopically visible chromosomes. The structure of chromosomes varies through the cell cycle.

During cell cycle chromatin material replicate, divide and passed successfully to their daughter cells for survival of their progeny. Some time cell-division is also responsible for genetic diversity.

5.2 CELL CYCLE

The sequence of changes which occurs between one cell division and the next is called Cell Cycle." It has two phases, **Interphase**, which is the period of non-division and **M-phase**, which is a period of cell division.

The cell cycle undergoes a sequence of changes, which involve period of growth, replication of DNA followed by cell division. This sequence of changes is called **cell cycle**.

Interphase:

The period of cell cycle between two consecutive divisions is called Interphase. It is a period of growth and synthesis of DNA. During this period the cell prepares itself for the M- phase.

The Interphase is divided further into three sub-phase, G_1- phase, S-phase and G_2-phase.

G_1-(Gap one) phase: It is the period of extensive metabolic activity, in which:

Cell grows in size, specific enzymes are synthesized and DNA base units are accumulated for the DNA synthesis.

At a point in G_1, the cell may enter into a phase called G_0 (G-knot) where cell cycle stop. It remains for days, weeks or in some cases even for the life time of the organism.

S-(Synthesis) phase: During this phase, replication of DNA occurs. As a result of it chromatin material is duplicated.

G_2– (Gap two) phase: (Pre-Mitotic Phase): The following changes occur during this phase: Cell grows in size, cell organelles are replicate in numbers as well as enzyme require for cell-division also synthesized during this phase.

5.3 MITOSIS

In this type of cell division a parent cell divides into two daughter cells in a way that the number of chromosomes in the daughter cells remains the same as in the parent cell.

Although mitosis is a continuous process, but for the study point of view we can divide it into two phases; (a) Karyokinesis - nuclear division (b) Cytokinesis - cytoplasmic division.

(a) The karyokinesis can be divided further for convenience into four phases which are **Prophase**, **Metaphase**, **Anaphase** and **Telophase**. Let us study mitosis in an animal cell.

(i) Prophase:

During early prophase chromatin material condenses and become visible as thick coiled, thread like structures called **chromosomes**. Each chromosome at this stage is already double, consists of two **chromatids**. The chromatids are attached to each other at **centromere**. The nuclear membrane gradually disappears and at the same time centrosome divides to form two centrioles, each moves towards the opposite pole of the animal cell and forms the spindle fibres. The centrioles are absent in plant cells.

(ii) Metaphase:

During this phase each chromosome arranges itself on the equator of the spindle. Each chromosome is attached to separate spindle fibre by its centromere.

(iii) Anaphase:

In this phase the spindle fibre contract, centromere of a chromosome divides and the chromatides of each chromosome separates from each other and begin to move towards the other poles. In this way one set of the chromatids (each chromatid is now an independent chromosome) move towards one pole while the other set towards the other pole.

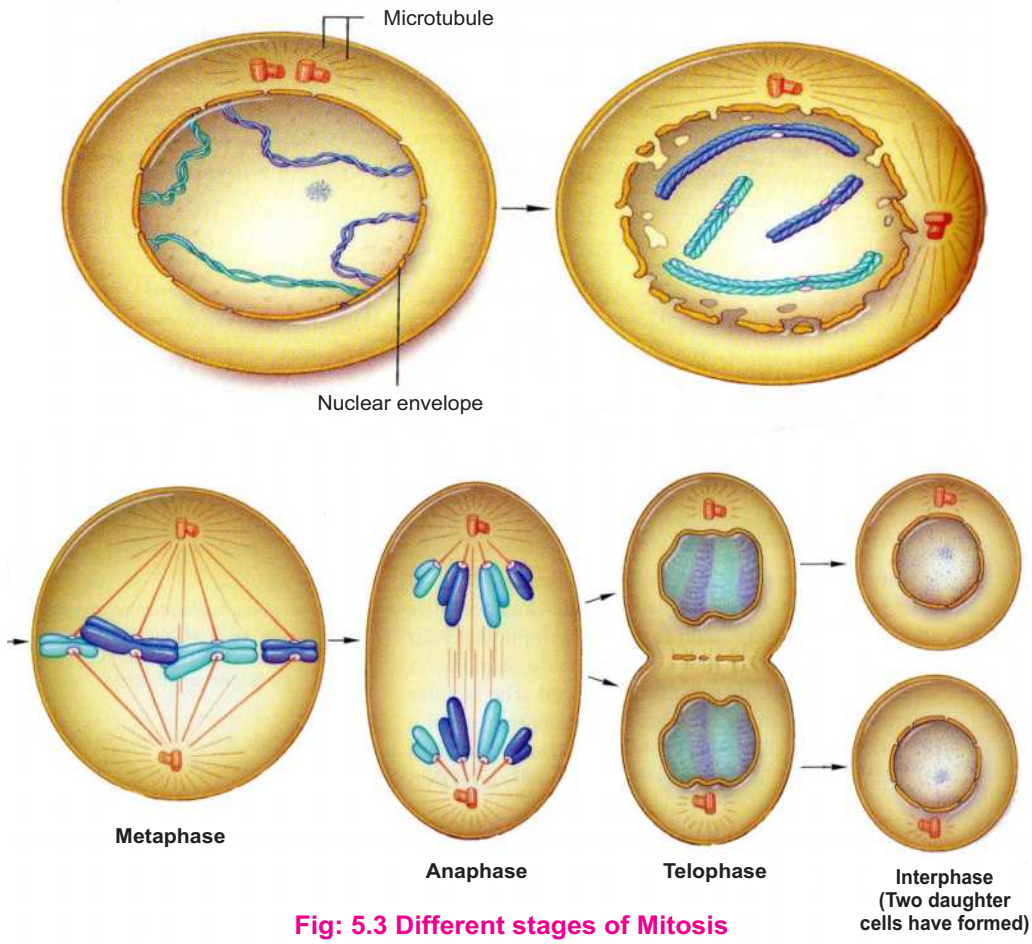


Fig: 5.3 Different stages of Mitosis

(iv) Telophase:

This is a stage when the chromatids (now called chromosomes) reach at the respective poles and their movement ceases. Each pole receives the same number of chromosomes as were present in the parent cell. The nuclear membrane is reformed around each set of chromosomes. In this way two daughter nuclei formed in each cell.

(b) Cytokinesis; soon the cytoplasm of the cell also divides and two daughter cells are formed. In animal cell cytokinesis takes place by developing a constriction. This constriction become deep to divide cytoplasm in two equal halves and two daughter cells are formed. In plant cells it occurs by developing cell plate. In this way the daughter cells become the exact copies of their parent cell.

Significance of mitosis:

Mitosis plays an important role in the life of an organism. It is responsible for development and growth of organisms by increasing exact copies of cells. With few exception all kinds of asexual reproduction and vegetative propagation take place by mitosis. The production of new somatic cells, such as blood cells depends on mitosis. The healing of wounds, repair of wear and tear within organism is also dependent upon the mitotic division.

5.4 APOPTOSIS AND NECROSIS (two ways of cell death)

Cell in an organism depends upon various extra cellular signals for its regulated and controlled activities. It means all the activities even the death of cells is programmed.

Is cell death beneficial?

Programmed cell death helps in proper control of multicellular development, which may lead to deletion of entire structure, e.g. the tail of developing human embryo, or some part an organ which is more required like tissue between developing digits.

Two ways of cell death in Multicellular organisms:

Apoptosis or Self - Destruction (Autophagy): "Programed change which lead to sequence of physiological changes in cell by which cells commit suicide collectively called **Apoptosis**".

Necrosis:

This type of cell death which is caused by external factors i.e infection, toxin and tumor i.e accidental cell death.

5.5 MEIOSIS (Reduction Division)

Meiosis is a type of cell division in which single cell divides into four daughter cells and number of chromosomes becomes half in each daughter cell.

In animal meiosis takes place in germ cell to produce gametes i.e. Sperms and Eggs whereas in plants it takes place in spore mother cells (S.M.C) to produce spores.

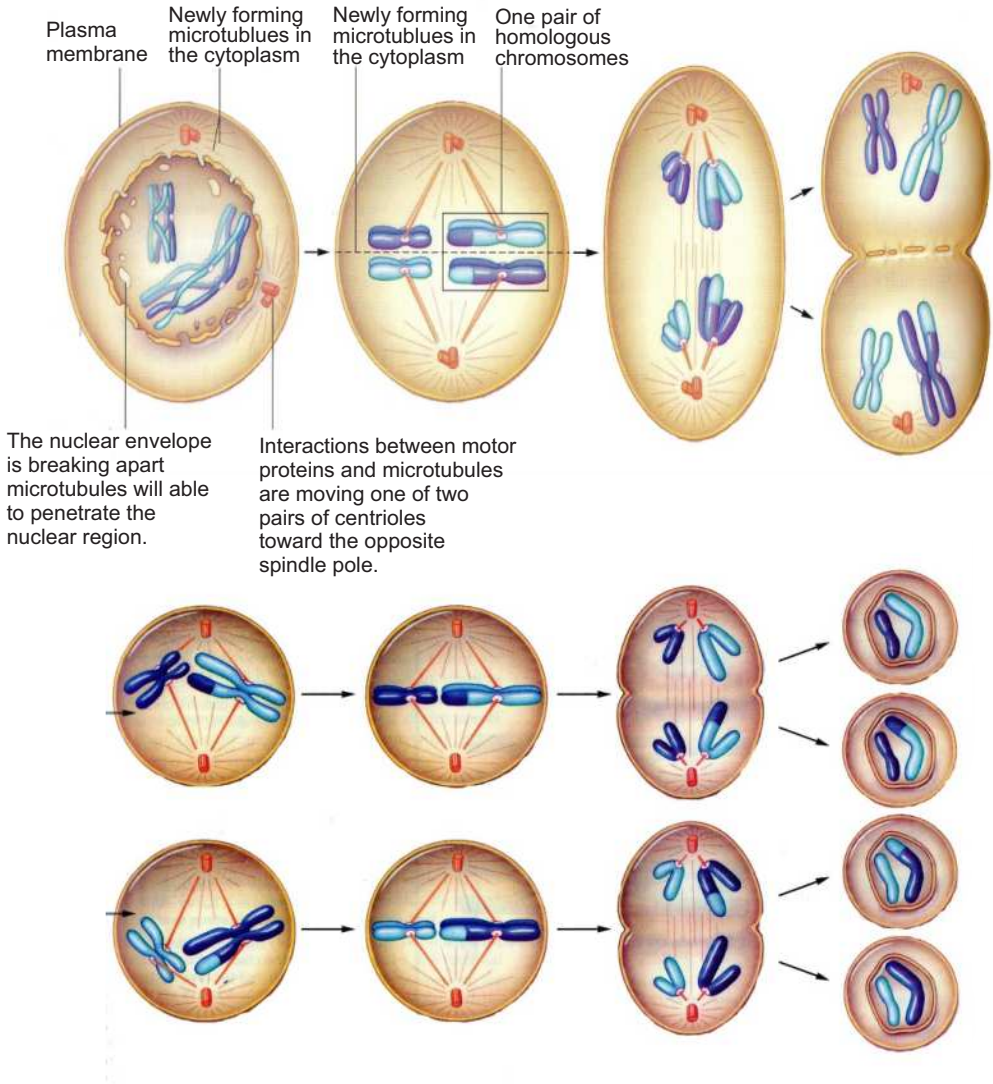


Fig: 5.4 Different stages of Meiosis

Events of Meiosis:

Meiosis is a series of two divisions, MEIOSIS I and MEIOSIS II which result in the formation of four haploid cells.

Meiosis I (First Meiotic Division)

First meiotic division is the reduction division during which the chromosomes number is reduced to half. Meiosis I consists of Prophase I, Metaphase I, Anaphase I and Telophase I.

Prophase I:

It consists of the longest phase of meiosis. It can be subdivided into following sub stages:

(1) Leptotene (2) Zygotene (3) Pachytene
(4) Diplotene (5) Diakinesis

(1) Leptotene:

During this sub stage following changes occur; The chromatin network break into specific number of long thin beaded thread called leptotene. Each thread has two morphologically similar leptene in each cell called homologous structure.

(2) Zygotene:

During this sub stage the Homologous (Similar structure) chromosomes, which comes from the mother (by ovum) and father (by sperm) are attracted towards each other and their lengthwise pairing takes place. The pairing of homologous chromosomes is known as **synapsis**, while the paired homologous chromosomes are known as **bivalent**.

(3) Pachytene:

The synaptic forces of attraction between each bivalent decrease and the chromosomes uncoil and separate. The separation is however incomplete and paired chromosomes are in contact with each other at one or more points, called Chiasmata. Each homologous chromosome split longitudinally except in the centromere region. Now each bivalent is composed of four chromatids and therefore is known as **bivalent tetrad**.

(4) Diplotene:

The homologous chromosomes exchange their parts of chromatid at Chiasmata. This exchange of segments of chromatids at chiasmata between the homologous chromosomes is called Crossing Over.

(5) Diakinesis:

During this sub stage; nucleoli and nuclear membrane are disappeared, whereas Mitotic Apparatus (spindle) is completed. Chiasmata moves from the centromere towards the ends of the chromosomes like a zipper.

This type of movement of chiasmata is known as Terminalization. At the end of Diakinesis chromatids still remain compacted at their ends.

Metaphase I:

Following changes occur in this phase:

The bivalent line up at the equatorial plane. The centromere of each chromosome attaches with same fibres of spindle.

Anaphase I:

At this stage one chromosome from each member of homologous pair (bivalent) begins to separate and move towards its respective pole by the contraction of spindle fibers.

The actual reduction occurs at this stage because half the number of chromosomes moves to each pole. Moreover as a result of crossing over the two chromatids of a chromosome do not resemble with each other in the genetic terms.

Telophase I:

The nuclear membrane form around the chromosomes at each pole and chromosomes become uncoil. The nucleolus reappears and thus two daughter nuclei formed.

Cytokinesis: Telophase may or may not be accompanied by cytokinesis and daughter cells formation.

Interphase: Following Telophase I (If this stage occurs), there is a short period called **Interphase** before meiosis II. It is similar to Interphase between Mitotic divisions except that DNA replication does not occur. Replication of DNA is unnecessary because each chromosome already has two chromatids.

Second Meiotic Division (Meiosis II):

The second meiotic division is actually the mitotic division which divides each haploid cell formed during meiosis I into two daughter haploid cells. The second meiotic division includes:

(1) Prophase II (2) Metaphase II (3) Anaphase II (4) Telophase II

(1) Prophase II:

The spindle fibres are formed. The nuclear membrane and the nucleolus disappear.

(2) Metaphase II:

The chromosomes are attached to half spindle fibers by their centromere and get arranged at equatorial plane. Each chromosome attach with separate fiber of spindel.

(3) Anaphase II:

The spindle fibers attached to the centromeres shorten and the chromatids of chromosomes are pulled away from one another. This movement continues until one complete set of chromosomes is positioned at each pole of the cell.

(4) Telophase II:

The spindle fibers disappear completely and chromosomes begin to uncoil. They become longer and indistinct and form group at each pole. Around each group nuclear envelope is formed.

After the kayrokinesis in each haploid meiotic cell the cytokinesis i.e. division of cytoplasm occurs and thus four haploid cells are formed.

What happens in absence of meiosis?
In the absence of meiosis number of chromosomes would have been doubled giving rise to abnormal growth, changes in species characteristics and or may prove fatal.

Significance of Meiosis:

(1) Constant number of chromosomes:

Meiosis maintains chromosome number constant from generation to generation. It is due to the fact that meiosis reduces the diploid number of chromosomes to half i.e. haploid in the gametes.

During fertilization the diploid number of the chromosomes is restored.

(2) Responsible for genetic variation among species:

By crossing over, the meiosis provides an opportunity for the exchange of the genes between homologous chromosome and thus cause the genetic variations among the species. The variations are the raw material of the evolutionary process.

Meiotic errors:

In normal course of meiosis, the two chromosomes of each homologous pair separates and enter into two gametes, but sometimes a pair of homologous chromosomes fails to separate from one another, during meiosis I. this phenomenon is called Non-disjunction.

Non-disjunction produce gametes with abnormal number of chromosome i.e either with less or extra chromosome. If such abnormal gametes fuse with normal gametes, the resulting zygote will also have abnormal number of chromosome.

Summary

- Term chromosome is given by *Fleming* in 1882. These are thread like structures appear at the time of cell- division made up of chromatin material in specific number in Eukaryotic cell.
- Chromosomes are made up of DNA and histone protein.
- There are four types of Chromosome i.e Metacentric, Sub-metacentric Aerocentric and Telocentric.
- Sequences of change occur between two successive Cell division called cell-cycle.
- Cell-cycle is mainly consist of two phases i.e cell-division and inter phase.
- Inter phase is divided further into three sub phases G1, S and G2 phases.
- Mitosis is the type of cell division, where a parent cell divides into two daughter cells, with same number of chromosomes as the parent cell contain.
- Meiosis is the type of cell division in which a single cell divides into four daughter cells and number of chromosomes become half of the parent cell.
- In animal meiosis takes place in the Germ cells while in plant it takes spore mother cells to produce gametes and spores respectively.
- Meiotic error, where a pair of homologous Chromosomes fails to separate form one another called non disjunction. This non disjunction produce gametes with abnormal number of chromosomes with less or extra chromosomes.

- Cell-death occur in two ways:
  (i) Apoptosis; programmed cell death, which help in proper control of development.
  (ii) Necrosis; cell death occur by external factor or accidental cell-death.

Review Questions

1. Encircle the correct answer:

(i) Which processes involve mitosis?
(a) Growth, reduction division and asexual reproduction.
(b) Growth, repair and asexual reproduction.
(c) Growth, repair and semiconservative replication.
(d) Growth, reduction division and repair

(ii) What occurs in metaphase of mitosis?
(a) Chromosome line up on the equator of the cell.
(b) Chromatids reach the poles of the spindle.
(c) Chromatids separate and move to opposite poles
(d) Chromosomes start to coil up and become visible.

(iii) Select the mismatched
(a) Anaphase → Chromatids move
(b) Prophase → Centriole move
(c) Telophase → Nuclear membrane disappear
(d) Metaphase → Chromosome line up.

(iv) Which process occurs during prophase of mitosis in an animal cell?
(a) Division of centromeres (b) Formation of chromosomes
(c) Replication of DNA (d) Separation of centrioles

(v) Sequence of physiological changes by which cell commit suicide.
(a) Apoptosis (b) Necrosis
(c) Autophagy (d) Both “a” and “b”

(vi) Choose the incorrect statement regarding meiosis.

(a) Maintain chromosome number from generation to generation.

(b) Reduces the diploid number of chromosomes to half

(c) Takes place in germ cell to produce gametes

(d) Production of new somatic cells from germ cells.

(vii) A type of cell division in which spore mother cell produce spores.

(a) Amitosis (b) Mitosis

(c) Meiosis (d) Both "a" and "c"

(viii) Stage of mitosis in which chromatids reach the poles and their movement ceases.

(a) Prophase (b) Metaphase

(c) Anaphase (d) Telophase

(ix) Stage of meiosis in which centromeres shorten and the paired chromatids are pulled away from one another.

(a) Anaphase-II (b) Metaphase-II

(c) Telophase-II (d) Prophase-II

(x) Phenomenon in which pair of homologous chromosome fails to separate called.

(a) Non-disjunction (b) Terminalization

(c) Synapsis (d) Linkage

2. Fill in the blanks:

(i) Chromosomes are thread like structures appear at the time of _____.

(ii) Sequence of changes which occurs between one cell division and the next is called_____.

(iii) The two chromatids are attached to each other at_____.

(iv) Chromosomes in the cell which are similar to each other in shape and size are called_____.

(v) Chromosomes with one arm very small and other very long called_____.

(vi) Chromosomes consist of two genetically identical copies of thread called_____.

(vii) Period of extensive metabolic activity, in which cell grow, enzymes are synthesizes_____.

(viii) In animal meiosis produces_____.

(ix) During metaphase homologous chromosomes arrange themselves on the _____.

(x) Cell death which is caused by external factor called_____.

3. Define the following terms:

(i) Pachytene (ii) Cytokinesis (iii) Bivalent

(iv) Chaismata (v) Chromatids (vi) Diakinesis

(vii) Terminalization (viii) Necrosis (ix) Crossing over

(x) Centromere

4. Distinguish between the following in tabulated form:

(i) Prophase and Prophase-I (ii) Prophase and Telophase

(iii) Apoptosis and Necrosis

5. Write short answers of following questions:

(i) Why meiosis-I is called reduction division?

(ii) Why mitosis is necessary for growth?

(iii) How number of chromosomes remains constant from generation to generation?

(iv) Why interphase is called as phase of high metabolic activities?

(v) Why interphase between meiosis-I and meiosis-II is short?

6. Write detailed answers of the following questions:

(i) Describe various stages of mitosis with suitable diagrams.

(ii) Describe stages of meiosis-I with suitable diagrams.