INTEGRATED SCIENCE

FOR TTCs

YEAR I

STUDENT'S BOOK

OPTION: ECLPE

FOREWORD

Dear Student- teacher,

Rwanda Basic Education Board is honoured to present to you this Integrated Science book for Year One of TTC which serves as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of Integrated Science subject. The Rwandan educational philosophy is to ensure that you achieve full potential at every level of education which will prepare you to be well integrated in society and exploit employment opportunities.

The government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate your learning process. Many factors influence what you learn, how well you learn and the competences you acquire. Those factors include the instructional materials available among others. Special attention was paid to the activities that facilitate the learning process in which you can develop your ideas and make new discoveries during concrete activities carried out individually or with peers.

In competence-based curriculum, learning is considered as a process of active building and developing knowledge and meanings by the learner where concepts are mainly introduced by an activity, a situation or a scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values. For effective use of this textbook, your role is to:

- Work on given activities including laboratory experiments which lead to the development of skills;
- Share relevant information with other learners through presentations, discussions, group work and other active learning techniques such as role play, case studies, investigation and research in the library, from the internet or from your community;
- Participate and take responsibility for your own learning;
- Draw conclusions based on the findings from the learning activities.

I wish to sincerely extend my appreciation to the people who contributed towards the development of this book, particularly REB staff who organized the whole process from its inception. Special gratitude goes to teachers, illustrators and designers who diligently worked to successful completion of this book.

Dr. MBARUSHIMANA Nelson

Director General, REB

ACKNOWLEDGEMENT

I wish to express my appreciation to all the people who played a major role in development of this Integrated Science textbook for Year One of TTC. It would not have been successful without active participation of different education stakeholders.

I owe gratitude to different Universities and schools in Rwanda that allowed their staff to work with REB in the in-house textbooks production project. I wish to extend my sincere gratitude to lecturers, teachers, tutors, illustrators, designers and all other individuals whose efforts in one way or the other contributed to the success of writing of this textbook.

Finally, my word of gratitude goes to the Rwanda Basic Education Board staff particularly those from the Curriculum, Teaching and Learning Resources Department who were involved in the whole process of in-house textbook writing.

Joan MURUNGI,

Head of Curriculum, Teaching and Learning Resources Department

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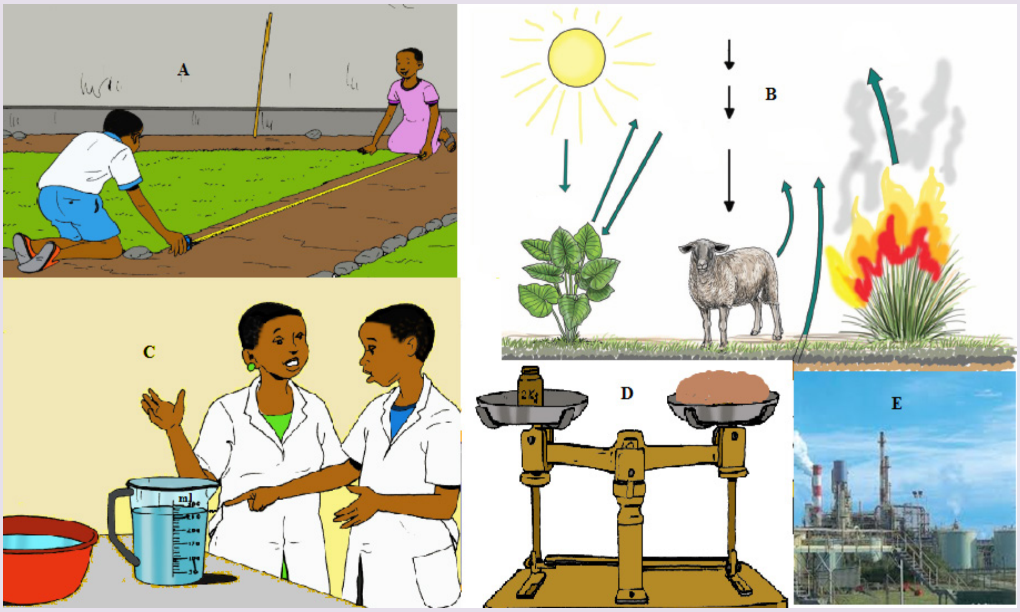
UNIT 1: THE CONCEPT OF INTEGRATED SCIENCE AND MEASUREMENTS OF PHYSICAL QUANTITIES

Key unit competence

Explain the concept of Integrated science and Use appropriate materials to measure different physical quantities.

Introductory Activity I

Look carefully at the following illustrations and answer the questions below:



Questions:

a) Describe the illustration A, B, C, D.

b) Based on your knowledge from O-level, what are scientific concepts can you associate to each of those illustrations? Group the noted concepts in their science subject areas.

c) Is there any one illustration in which you find application of many science subjects area? Justify your answer by providing other examples found in everyday life.

d) Can you explain how and why every person should have integrated understanding of those science subject areas?

e) What kind of physical quantities that can be measured in the illustration above? Suggest the names of the tools used in the illustration above?

f) Outline other examples of physical quantities and the corresponding measuring tools

g) What can be considered to select the best tool(s) to be used in measuring a given measurable quantity?

1.1 Introduction to integrated science

Activity 1.1

Task 1

It is known that an Integrated Science course serves the purpose of unifying sciences in a whole one subject covering both the physical and life sciences. These courses are integrated in that the fields of science are not segmented. For example, in describing the physics of light, we show how this applies to the inner workings of our eyes, which, in turn, are sensitive to visible light in great part because of the chemical composition of our atmosphere.

Use the paragraph above to answer the following questions:

a) What does the term Integrated Science mean?

b) Explain why Integrated Science is very important in finding appropriate solutions in various complex situations? Justify your answer based on the paragraph above and other examples observed in everyday life.

Task2

Suppose you visited two industries and took the photos below and saw that distinguished science subjects are involved in the process of production. Write a paragraph about your visit identifying how Physics, Biology and Chemistry are integrated in the process.

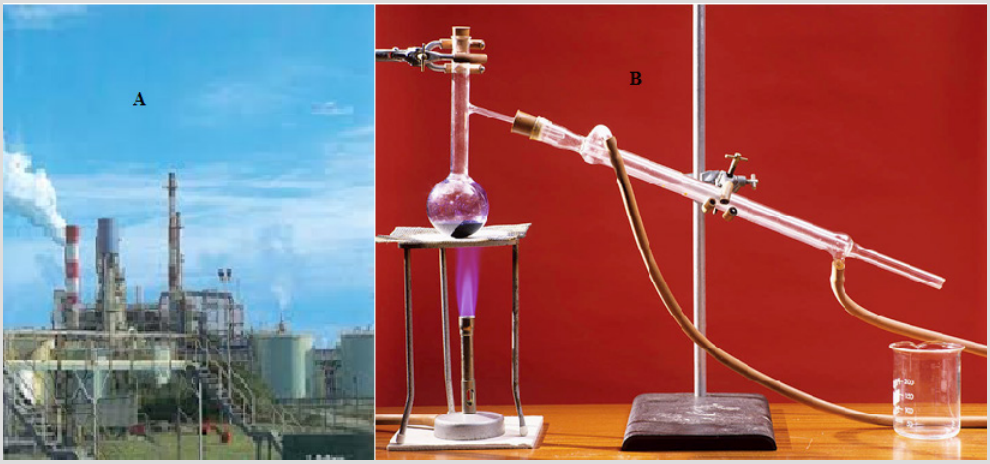


Fig 1.1: Photos took in field visit

1.1.1 Definition and rationale of integrated science

Human survival depends on knowledge through the exploration of the environment. Science provides knowledge while technology provides ways of using this knowledge. It is therefore very important to be aware of the global dimension of science needed in our lives in order to effectively deal with every day situation. The word "integrated" means "to restore the whole, to come together, to be a part of, to include." Integrated science is a subject which incorporates the knowledge base of all the science fields, both physical and life sciences and these science fields are included in one subject as a whole "integrated science" in that the fields of science are not segmented. It is a subject which offers experiences which help people to develop an operational understanding of the structure of science that should enrich their lives and make them more responsible citizens in the society.

Hence, integrated approach of learning science is appropriate as science knowledge is a tool to be used by every person to effectively deal with real world problems and life.

For examples, when you are studying digestion process of animals, you will need the knowledge of chemical processes. Another example, in describing the physics of light, we show how this applies to the inner workings of our eyes, which, in turn, are sensitive to visible light in great part because of the chemical composition of our atmosphere.

Aims and Objectives of Integrated Science subject

The overall aim of the integrated science subject is to enable students develop scientific literacy so that students can participate actively in the rapidly changing knowledge based society, prepare for further studies or careers in fields where the knowledge of science will be useful.

However, the broad aims of integrated science subject are to enable students to:

- Develop interest in and maintain a sense of wonder and curiosity about the natural and technological world;
- Acquire a broad and general understanding of key science ideas and explanatory framework of science and appreciate how the ideas were developed and why they are valued;
- Develop skills for making scientific inquiries;
- Develop the ability to think scientifically, critically and creatively and to solve problems individually or collaboratively in science related contexts;
- Use the language of science to communicate ideas and views on science – related issues;
- Make informed decisions and judgments about science related issues;
- Be aware of the social, ethnical, economic, environmental and technological implications of science and develop an attitude of responsible citizenship; and
- Develop conceptual tools for thinking and making sense of the world.

1.1.2. Interconnection between science subjects

The purpose of science is to produce useful models of reality which are used to advance the development of technology, leading to better quality of life for human being and the environment around him or her.

There are many branches of science and various ways of classifying them. One of the most common ways is to classify the branches into natural sciences, social sciences, and formal sciences.

Natural sciences: the study of natural phenomena (including cosmological, geological, physical, chemical, and biological factors of the universe). Natural science can be divided into two main branches: physical science and life science (or biological science). Social sciences: the study of human behavior and societies. The social sciences include, but are not limited to: anthropology, archaeology, communication studies, economics, history, musicology, human geography, jurisprudence, linguistics, political *science*, psychology, public health, and sociology. *Formal science* is a branch of *science* studying *formal* language disciplines concerned with *formal* systems, such as logic, mathematics, statistics, theoretical computer *science*, artificial intelligence, information theory, game theory, systems theory, decision theory, and theoretical linguistics.

Note:

- Chemistry mainly deals with the study of matter's properties and behaviors as well as reactions between them to produce new useful products. For a physicist to understand the working mechanism of chemical cells, help is sought from a chemist. On the other hand, the reasons behind the various colours observed in most of the chemical reactions are explained by a physicist. Petroleum products are dealt with by the chemist, but the transportation of such products make use of the principles of physics.
- In Biology, the study of living cells and small insects by a biologist requires magnification. The concept of magnification using simple or compound microscope is a brain child of a physicist. A good physicist needs to have good health.

1.1.3. Relationship between science with other subjects

The concepts of science and other subjects might be expanded or explainable in broader senses than you might have been exposed to, this should then predict not only the interconnection senses already known, but should also predict much broader interconnections. This might be useful to you and our future civilization.

Science is about observation and experimentation of things in the physical and natural world. If there no creative ideas, no destructive ideas, just more ideas of the same things that exist can this be healthy. There is such a thing as **inductive reasoning** not just **deductive reasoning.**

Now, science is the practical application of scientific knowledge. So we could have science as a conservative subject, or we could have science as a creative (conservative and destructive) subject, then leading to smaller or larger sets of science.

Note:

- In Geography, weather forecast, a geographer uses a barometer, wind gauge, etc. which are instruments developed by a physicist.
- In Agriculture, the water sprinkler, insecticide sprayer, etc. make use of the principles developed by physicists.
- In History, the determination of age fossils by historians and archaeologists use the principle developed by physicists.
- In games and sports, accurate measurement of time, distance, mass, and others uses instruments developed by physicists.

Application activity 1.1

1. Write a paragraph to convince someone that science is related to other subjects. Use clear examples to support your arguments and reasoning.
2. How can you describe the interconnections between science and technology, using at least three specific examples?

1.2 Measurements of physical quantities.

Activity 1.2

Task 1:

Look around the place and identify possiple physical quantities that can be measured? Explain the meaning of the physical quantities you have identified? Mention the SI units of the identified physical quantities?

Task 2:

It is possible to determine the nature and magnitude of the physical quantities that are measurable. Which of the following situations can be determined with the guidance of measurements? Support your answer with explanations and mention the physical quantity to be measured if possible.

a) Love between a boy and girl.

b) Size of the body.

c) Size of the garden?

d) Amount occupied by water in a tank.

1.2.1 Physical quantities and their measurements.

A quantity is any observable property or process in nature with which a number may be associated.

A physical quantity is defined as a property of a material that can be quantified by measurement.

Physical quantities are classified into fundamental and derived quantities.

FUNDAMENTAL PHYSICAL QUANTITIES

A quantity may be defined as any observable property or process in nature with which a number may be associated. This number is obtained by the operation of measurements. The number may be obtained directly by a single measurement or indirectly, say for example, by multiplying together two numbers obtained in separate operations of measurement. Fundamental quantities are those quantities that are not defined in terms of other quantities. In physics there are 7 fundamental quantities of measurements namely length, mass, time, temperature, electric current, amount of substance and luminous intensity.

- **DERIVED PHYSICAL QUANTITIES**

Quantities which are defined in terms of the fundamental quantities via a system of quantity equations are called derived quantities. Examples of derived quantities include area, volume, velocity, acceleration, density, weight and force.

The SI units of derived quantities are obtained from equations using mathematical expressions

Note that some derived units have been given names. For example, force is measured in kg m/s^2 and has been given a named unit called a newton (N).

1.2.2 International system of units

In order to measure any quantity, a standard unit (base unit) of reference is chosen. The standard unit chosen must be unchangeable, always reproducible and not subject to either the effect of aging and deterioration or possible destruction.

In 1960, an international system of units was established. This system is called the International System of Units (SI).

The ***International System of Units*** is an internationally agreed metric system of units of measurement. SI base quantities and units: The value of a physical quantity is usually expressed as the product of a *number* and a *unit*.

Quantity	symbol	SI unit	Unit symbol
length	l	metre	m
mass	m	kilogram	kg
time	t	second	s
Electric current	I	ampere	A
Thermodynamic temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I_v	candela	cd

Table 1: Common SI base units

Name, Symbol and factor of metric prefixes in everyday use at workplace.SI prefixes used to form decimal multiples and submultiples of S I units (table 2 below). Table 2: SI prefixes

Name	Symbol	Factor		Name	Symbol	Factor
deci	d	10^{-1}		deca	da	10^{1}
centi	c	10^{-2}		hecto	h	10^{2}
milli	m	10^{-3}		kilo	k	10^{3}
micro	μ	10^{-6}		mega	M	10^{6}
nano	n	10^{-9}		giga	G	10^{9}
pico	p	10^{-12}		tera	T	10^{12}
femto	f	10^{-15}		peta	P	10^{15}
anto	a	10^{-18}		exa	E	10^{18}

Table 2: SI prefixes

Example for length

- 10 mm= 1cm
- 1m= $10^{6}\mu$m
- 1m=10^{-9}Gm
- $1m^2=(10^{12}pm)^2=10^{24}pm^2$

Note: Numbers in the SI system are based on the number 10. Units in the SI system can therefore be multiplied or divided by 10 to form larger or smaller units.

1.2.3 Measuring fundamental physical quantities

- **MEASURING LENGTH AND DISTANCE**

We use different tools for measuring length: metre rule, ruler, tape measure, vernier caliper and the micrometer screw gauge based on the kind of length to measure. Straight distances that are less than one metre in length are generally measured using metre rules. Straight distances that are more than one metre in length are generally measured using tape measure.

A tape measure or measuring tape is a flexible ruler and used to measure distance. A tape measure is in form of a strip of metal, plastic or cloth that has numbers marked on it as shown in figure below and is used for measuring. The figure below represents examples of tape measures:

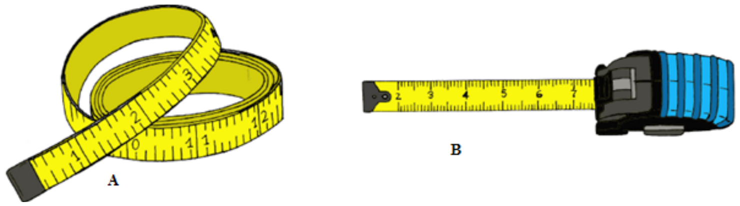


Fig 1.2: Tape measures used in measuring length or distance

It is a common measuring tool purposely designed to allow for a measure of great length to be easily carried out and permits one to measure around curves or corners. Surveyors use tape measures in lengths of over 100 m. Metre rules are graduated in millimetres *(*mm*)*. Each division on the scale represents 1 mm unit (Fig 1.3).

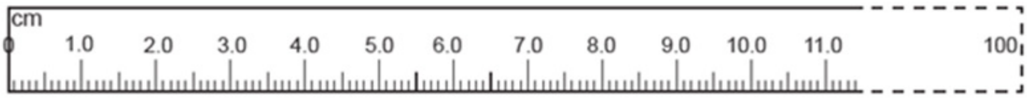


Fig 1.3: A metre rule

The direct way to measure length is by means of the straight edge of a ruler or metre ruler. The ruler is placed alongside the object to be measured, and the number of unit intervals of the ruler equal to the length of the object is then noted.

Metre rule is used to measure lengths up to about 100 cm and has a sensitivity of 0.5 mm.

Vernier caliper is an instrument used to measure outer dimensions of objects inside dimensions and depths. The figure below shows the vernier calipers:

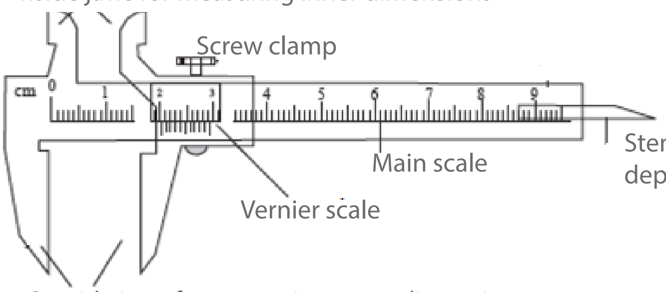


Fig 1.4: Vernier calliper

We can measure outer dimensions of objects (using the main jaws), inside dimensions (using the smaller jaws at the top), and depths (using the stem). The vernier calipers have a main scale and a sliding vernier scale that can allow readings to the nearest 0.02 mm. To measure outer dimensions of an object, the object is placed between the jaws, which are then moved together until they secure the object.

The screw clamp may then be tightened to ensure that the reading does not change while the scale is being read.The first significant figures are read immediately to the left of the zero of the vernier scale and the remaining digits are taken as the vernier scale division that lines up with any main scale division.

The internal diameter of the test tube is given by MSR + (VC × LC) Whereby the main scale reading (MSR), the vernier coincidence (VC).and The smallest reading called the *least count (LC)* that can be read from vernier callipers is 1 mm – 0.9 mm = 0.1 mm or 0.01 cm .

The main scale called the vernier coincidence *(VC)* and multiplying it with the least count i.e 0.01 cm.Therefore, the external diameter of the cylindrical object is MSR + (VC × LC)

A **micrometer screw gauge** is an instrument for measuring very short length such as the diameters of wires, thin rods, and thickness of a paper. Figure below shows a screw gauge:

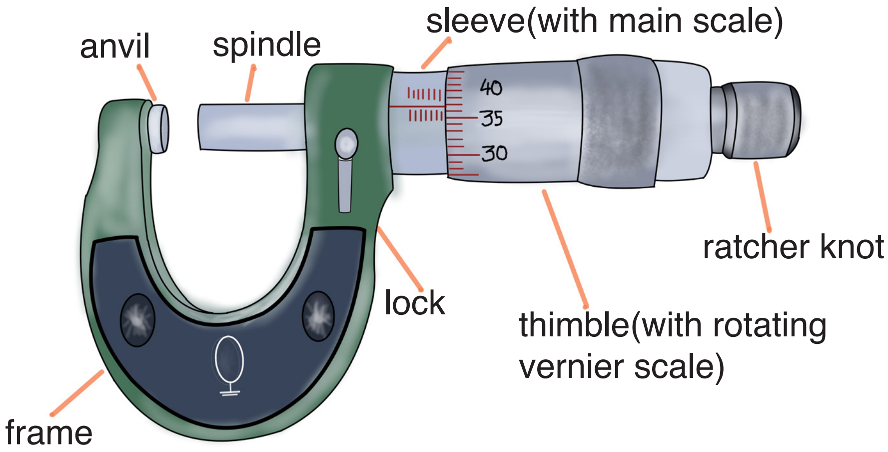


Fig 1.5: A micrometer screw gauge

The micrometers have a pitch of 0.50 mm (two full turns are required to close the jaws by 1.00 mm). The rotating thimble is subdivided into 50 equal divisions. The thimble passes through a frame that carries a millimetre scale graduated to 0.5 mm. Thimble, which has a circular rotating scale that is calibrated from 0 to either 50 or 100 divisions. This scale is called the head scale (thimble scale).

When the thimble is rotated, the spindle can move either forward or backwards. *Ratchet* which prevents the operator from exerting too much pressure on the object to be measured.The least count = 0.01 mm. The micrometer screw gauge reading = MSR + (HSC × LC).

When the pitch is 1 mm, the thimble has 100 divisions called head scale divisions. In this case each division represents 0.01 mm. This is the least count (LC) of this screw gauge.

The thimble reading called the head scale coincidence(HSC) is the value of the mark on the thimble that coincides with the horizontal line on the sleeve. Main scale reading is taken by considering the reading of a mark on the fixed scale that is immediately before the sleeve enters the rim of the head scale.

The jaws can be adjusted by rotating the thimble using the small ratchet knob. This includes a friction clutch which prevents too much tension being applied. The thimble must be rotated through two revolutions to open the jaws by 1 mm.

In order to measure an object, the object is placed between the jaws and the thimble is rotated using the ratchet until the object is secured. The ratchet knob must be used to secure the object firmly between the jaws, otherwise the instrument could be damaged or give an inconsistent reading.The lock may be used to ensure that the thimble does not rotate while you take the reading.

- **MEASURING MASS**

The mass of an object can be measured using a beam balance and a set of standard masses. It is noticed that the volume of the displaced water in measuring cylinder is equal to volume of an object lowered in the cylinder. There are many kinds of balances used for measuring mass illustrated below:

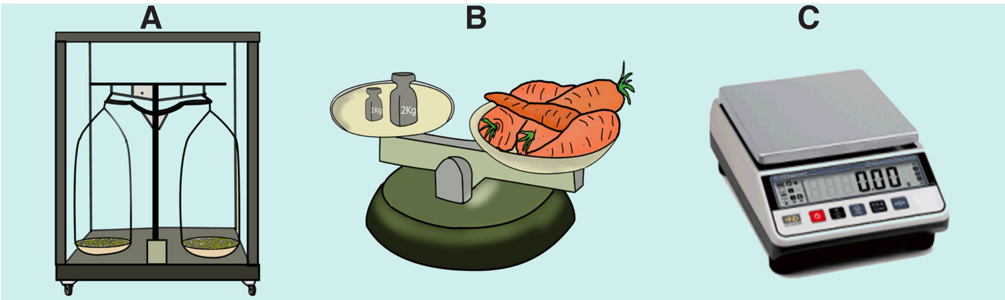


Fig 1.6: Different types of measuring instruments.

- **MEASURING TIME**

Time is measured using either analogue or digital watches and clocks and illustrated in figure below:

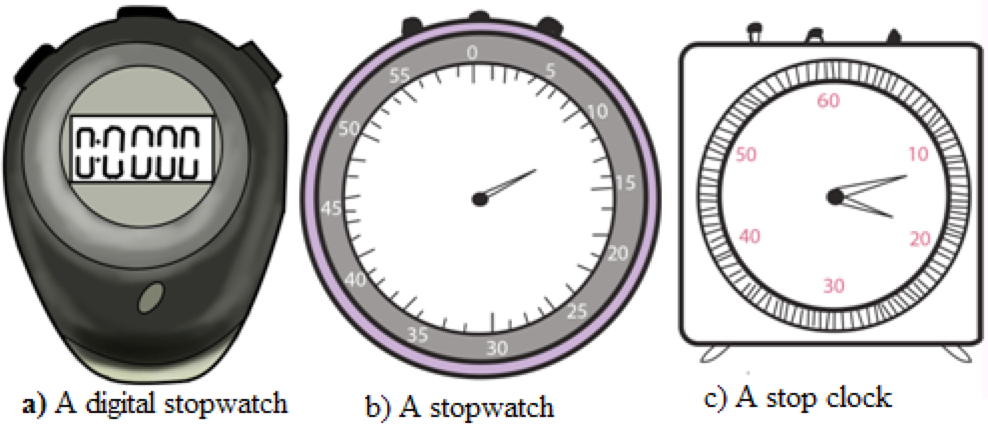


Fig 1.7: Stop watches and a stop clock

Application activity 1.2

1.Mention the appropriate instruments you would use to measure each of the following:

a) The The mass of an object.

b) The circumference of your waist.

c) The time someone uses to cover a certain length.

d) The diameter of a small ball.

2. It is possible to read and record the readings using a scale of a vernier caliper in order to measure the external diameter of the rod.

Steps followed in using vernier

a. Place the object to be measured between the outside jaws as shown in Figure below. Slide the jaw until they touch the rod.

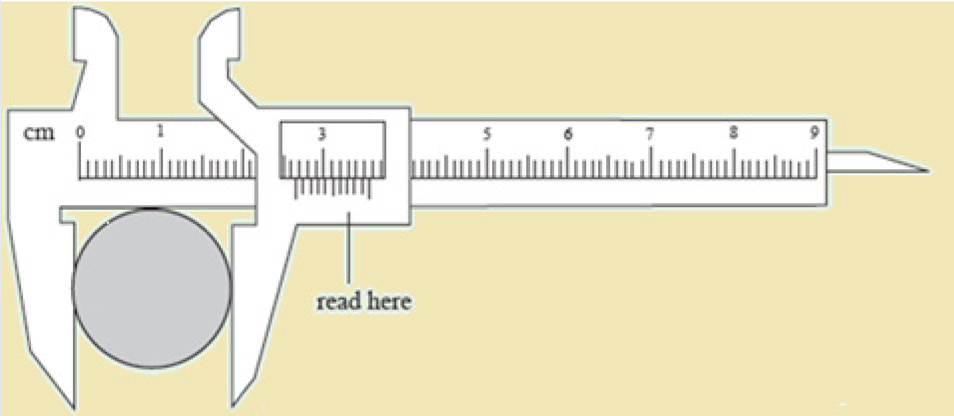


Fig 1.8: Measurement of external diameter using vernier caliper.

b. Record the readings on the main scale and the vernier scale. The main scale reading is the mark on the main scale that is immediately before the zero mark of the vernier scale.

c. Multiply the vernier scale reading by 0.01 cm.

d. Add the main scale reading (in cm) and the vernier scale reading (in cm) to get the diameter of the rod.

3. What is the diameter of the ball bearing shown in Figure below?

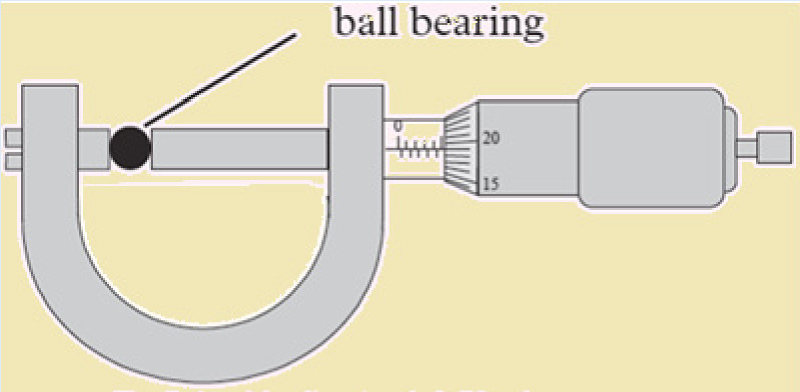


Fig 1.9: Determining diameter of a ball bearing.

4.

a) What does S I Units stands for?

b) Explain why it is correct to say that SI units are very important in measurements?

c) Suppose you wish to know the length of a big garden. How do you get the length of your garden?

d) Look at the following physical quantities: Mass, density, length, and time. Do all these quantities represent the fundamental quantities? Justify your decision by identifying the ones included in the category mentioned above.

5. Look at the table below and try to complete it based on the skills gained in the previous activities done;

Physical quantity	Name of the unit	Symbol of the S I units.
length		m
mass	kilogram	………..
………….	second	………..
volume	………………	m^3
	…………………	m^2
area		

6. Choose two physical quantities with which you are familiar. Imagine that you are skilled in physical quantities and its measurements. Explain briefly how the values of these quantities can be obtained?

7. Express the following the indicated units and fill in blank spaces:

a) 250 m in …..cm.

b) 320 mg in ……g.

c) 5μg in ………g.

d) 7200 cm in …..m.

e) 3 kg in ……… g.

1.3 Dimensions of physical quantities

Activity 1.3

Given the formulas for the following derived quantities, try go get the dimensions of each quantity.

a) velocity = displacement/time

b) acceleration = change of velocity/time

c) momentum = mass x velocity

d) force = mass x acceleration

e) work = force x displacement

1.3.1 Introduction to dimensions of physical quantities

The nature of physical quantity is described by nature of its dimensions. When we observe an object, the first thing we notice is the **dimensions**.

In fact, we are also defined or observed with respect to our dimensions that is, height, weight, the amount of flesh. The dimension of a body means how it is relatable in terms of **base quantities**. When we define the dimension of a quantity, we generally define its **identity and existence**. It becomes clear that everything in the universe has dimension, thereby it has presence.

Note: Dimensions are responsible in defining shape of an object.

1.3.2 Definition of dimensions of physical quantities

The dimension of a physical quantity is defined as the powers to which the fundamental quantities are raised in order to represent that quantity. The seven fundamental quantities are enclosed in square brackets [ ] to represent its dimensions.

- **EXAMPLES OF ASSIGNING DIMENSIONS TO PHYSICAL QUANTITIES**

Dimension of Length is described as [L], the dimension of time is described as [T], the dimension of mass is described as [M], the dimension of electric current is described as [A] and dimension of the amount of quantity can be described as [mol].Adding further dimension of temperature is [K] and that dimension of luminous intensity is [Cd]

Consider a physical quantity Q which depends on base quantities like length, mass, time, electric current, the amount of substance and temperature, when they are raised to powers a, b, c, d, e, and f. Then dimensions of physical quantity Q can be given as:

$[Q] = [L^a M^b T^c A^d mol^e K^f]$

It is mandatory for us to use [ ] in order to write dimension of a physical quantity. In real life, everything is written in terms of dimensions of **mass, length and time**. Look out few examples given below:

1. The volume of a solid is given is the product of length, breadth and its height. Its dimension is given as:

Volume = Length × Breadth × Height

Volume = [L] × [L] × [L] (as length, breadth and height are lengths)

Volume = $[L]^3$

As volume is dependent on mass and time, the powers of time and mass will be zero while expressing its dimensions i.e. $[M]^0$ and $[T]^0$

The final dimension of volume will be $[M]^0[L]^3[T]^0 = [M^0L^3T]$

2. In a similar manner, dimensions of area will be $[M]^0[L]^2[T]^0$
3. Speed of an object is distance covered by it in specific time and is given as:

Speed = Distance/Time

Dimension of Distance = [L]

Dimension of Time = [T]

Dimension of Speed = [L]/[T]

$[Speed] = [L][T]^{-1} = [LT^{-1}] = [M^0LT^-1]$

4. Acceleration of a body is defined as rate of change of velocity with respect to time, its dimensions are given as:

Acceleration = Velocity / Time

Dimension of velocity = $[LT^{-1}]$

Dimension of time = [T]

Dimension of acceleration will be = $[LT^{-1}]/[T]$

$[Acceleration] = [LT^{-2}] = [M^0LT^{-2}]$

Fundamental Quantity	Dimension
Length	[L]
Mass	[M]
Time	[T]
Temperature	[K]
Electric Current	[A]
Luminous Intensity	[Cd]
Amount of substance	[mol]

5. Density of a body is defined as mass per unit volume, and its dimension is given as:

Density = Mass / Volume

Dimension of mass = [M]

Dimension of volume = $[L^3]$

Dimension of density will be = $[M] / [L^3]$

$[\text{Density}] = [ML^{-3}]$ or $[ML^{-3}T^0]$

6. Force applied on a body is the product of acceleration and mass of the body

Force = Mass × Acceleration

Dimension of Mass = [M]

Dimension of Acceleration = $[LT^{-2}]$

Dimension of Force will be = $[M] \times [LT^{-2}]$

$[\text{Force}] = [MLT^{-2}]$

1.3.3 Rules for writing dimensions of a physical quantity

We follow certain rules while expression a physical quantity in terms of dimensions, they are as follows:

- Dimensions are always enclosed in [ ] brackets
- If the body is independent of any fundamental quantity, we take its power to be 0
- When the dimensions are simplified we put all the fundamental quantities with their respective power in single [ ] brackets, for example as in velocity we write $[L][T]^{-1}$ as $[LT^{-1}]$
- We always try to get derived quantities in terms of fundamental quantities while writing a dimension.
- Laws of exponents are used while writing dimension of physical quantity so basic requirement is a must thing.
- If the dimension is written as it is we take its power to be 1, which is an understood thing.
- Plane angle and solid angle are dimensionless quantity that is they are independent of fundamental quantities.
- Therefore, some of the examples of dimensions of physical quantities include the following:

Force, $[F] = [MLT^{-2}]$

Velocity, $[v] = [LT^{-1}]$

Charge, $(q) = [AT]$

Specific heat, $(s) = [L^2T^2K^{-1}]$

Gas constant, $[R] = [ML^2T^{-2}K^{-1}\ mol^{-1}]$

- **Benefits of Dimensions**

Before writing dimensions of a physical quantity, it is must know a thing to understand why do we need dimensions and what are benefits of writing a physical quantity. Benefits of describing a physical quantity are as follows:

- Describing dimensions help in understanding the relation between physical quantities and its dependence on base or fundamental quantities, that is, how dimensions of a body rely on mass, time, length, temperature and others.
- Dimensions are used in dimension analysis, where we use them to convert and interchange units.
- Dimensions are used in predicting unknown formulae by just studying

how a certain body depends on base quantities and up to which extent.

- It makes measurement and study of physical quantities easier.
- We are able to identify or observe a quantity just because of its dimensions.
- Dimensions define objects and their existence.

Limitations of Dimensions

Besides being a useful quantity, there are many limitations of dimensions, which are as follows:

- Dimensions can't be used for trigonometric and exponential functions.
- Dimensions never define exact form of a relation.
- We can't find values of certain constants in physical relations with the help of dimensions.
- A dimensionally correct equation may not be the correct equation always.

- **Dimension Table**

It consumes a lot of time while deriving dimensions of quantities. So in order to save time, we learn some basic dimensions of certain quantities like velocity, acceleration, and other related derived quantities.

For Example, suppose you're asked to find dimensions of Force and you remember dimension of acceleration is $[LT^{-2}]$, you can easily state that the dimension of force as $[MLT^{-2}]$ as force is the product of mass and acceleration of a body.

The table below depicts dimensions of several derived quantities which one can use directly in problems of dimension analysis.

Quantity	**Formulae**	**Dimensions**
Velocity	Displacement/Time	$[LT^{-1}]$
Acceleration	Velocity/Time	$[LT^{-2}]$
Work done	Force × displacement	$[ML^{2}T^{-2}]$
Pressure	Force/ Area	$[ML^{-1}T^{-2}]$
Power	Work done/ Time	$[ML^{2}T^{-3}]$
Density	Mass / Volume	$[ML^{-3}T^{0}]$
Area	Length × Breadth	$[L^{2}]$

Application activity 1.3

1.

i. What are four uses of dimensional analysis? Explain with one example for each.

ii. What are three limitations of dimensional analysis in physics?

2. Show that $\frac{1}{2}gt^2$ has the same dimensions of distance.

3. What are the missing words in the following statements?

a) The dimensions of velocity are ………………………………… .

b) The dimensions of force are …………………………………… . .

4.

a) What does the term dimension mean in Physical quantities?

b) Given the formulas for the following derived quantities, calculate the dimensions of each quantity.

i. Velocity = $\frac{Displacement}{Time}$

ii. Acceleration = $\frac{\Delta Velocity}{\Delta Time}$

iii. Momentum = mass x velocity

iv. Force = mass x acceleration

v. Work = force x displacement

SKILLS LAB

Conduct a survey, collect and analyze data about when, where, and why people use different measuring instruments or devices and physical laws.

To complete this project you must

Develop a survey sheet about physical quantities, measuring instruments or devices, physical laws needed, appropriate SI units and metric prefixes used in everyday life.

Distribute your survey sheet to other student-teachers, family members and neighbors.

- Compile and analyze your data.
- Create a report to display your findings in your sheet.

Plan it! To get started, think about the format and content of your survey sheet. Brainstorm what kinds of questions you will ask. Develop a plan for involving student-teachers in your class or other classes to gather more data.

End unit assessment 1

1. Differentiate between a fundamental quantity and a derived quantity. Give one example of each and its corresponding SI units.
2. Express the following in millimetres:

   a) 2.7 m

   b) 26.9 cm

   c) 356 µm.
3. What is the length of the glass rod shown in Figure below?

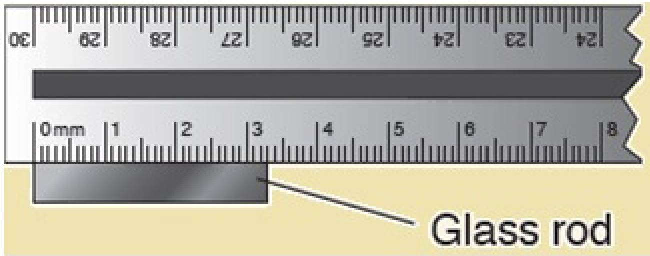


Fig1.21: Measuring length of a glass rod.

4. Use the knowledge and skills gained from the previous concepts to complete the following sentences:

   a) A quantity may be defined as any ……………………….. in nature with which a number may be associated.

   b) Physical quantities are classified into ……………. .and ………………… quantities.

   c) ……………………………are those quantities that are not defined in terms of other quantities.

   d) The value of a physical quantity is usually expressed as the product of a …………………and a ……………………

   e) The SI units stands for ………………………………………………..
5. Kaneza conducted an experiment on the growth of plants and recorded the results in a table. He used four plants of the same type and size and measured their growth after one month.

Fig: Table of results based on each plant type.

Plant	Amount of fertilizer/ml	Frequency of fertilizer	Fertilizer Brand	Growth after 1 month/cm
1	2	Once per week	Brand A	3
2	2	Three times per week	Brand A	4
3	2	Once per week	Brand B	2
4	2	Twice per week	Brand B	6

Questions on scientific report above:

a) Identify the possible data types that were considered in Kaneza's experiment?

b) Tell whether each data type was controlled effectively?

c) Explain what is wrong with Kaneza's experiment?

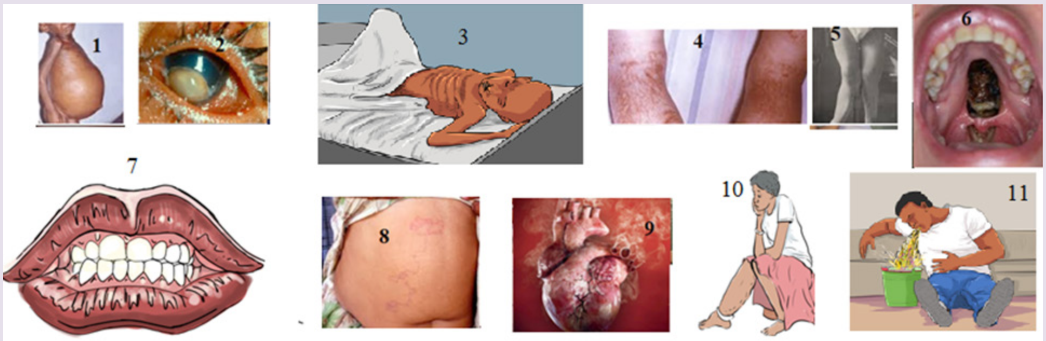
d) What could he change to allow better conclusions to be drawn in the scientific investigation above?

UNIT 2: COMMON DISEASES AND HYGIENE

Key unit competence

Implement ways of preventing and controlling common diseases and hygiene related issues.

Introductory Activity



The figure 1-11 indicates different situations.

a) According to what you always observe in community you live in, suggest what happened.

b) What do you think is a cause of each case in figure?

c) What can you do in community for limiting those situations?

2.1. Common diseases

Activity 2.1.a

1) The government of Rwanda encourages people to visit hospitals and test their blood. A person has done that test and he found having HIV positive.

a. Which opportunistic information can be associated with HIV?

b. What is its causative agent?

c. How is it transmitted from one people to another?

2) Basing on the ways of transmission, suggest other diseases that can be transmitted as the disease stated in a.1

3) How can you prevent those diseases?

Infectious diseases are caused by microorganisms known as pathogens which may include viruses, bacteria, fungi and protozoa. Those diseases are called communicable diseases as they can be transmitted from one person to another. They include cholera, malaria, typhoid, HIV and AIDS...Malaria is one of the most dangerous infectious diseases, endemic in Latin America, Africa and South-East Asia.

Some infectious diseases can also be from animals to humans.

Some technical terms used when discussing about infectious diseases are:

- **Aetiology**: The study of the cause of disease.
- **Epidemiology**: The study of all the factors that contribute to the appearance of a particular disease
- **Causative agent**: The organism which causes the disease
- **Vector**: An organism which carries the causative agent of the disease from one person to another or from infected animal to human.
- **Incubation period**: The period of time between the original infection and the appearance of signs and symptoms.
- **Infective period**: The time during which a person is capable of passing the disease on to another person.
- **Carrier:** The person who has been infected but develop no signs and symptom, the carrier can pass the disease on to another person**.**
- **Prevention:** Measures taken to prevent diseases.

– **Treatment:** Measures taken to cure diseases.

– **Antibody:** Is a protein produced by the body's immune system when it detects harmful substances called antigen.

– **Antigen:** Is any substance that causes your immune system to produce antibodies against it.

– **Host:** A host can be anything living organism ion which pathogens can survive

– **Hygiene**: Practices that help to maintain health and prevent the spread of diseases

– **Immunity:** Is the ability of the body to resist to infections.

Some groups of communicable diseases

- **Bacterial diseases:** these are diseases caused by bacteria. They include cholera, typhoid, tetanus, tuberculosis, etc.
- **Viral diseases:** these are diseases caused by viruses. They include AIDS, polio, measles, Ebola, etc.
- **Protozoan diseases:** these are diseases caused by protozoa. They include malaria, sleeping sickness, trichomoniasis, etc.
- **Fungal diseases:** these are diseases caused by fungi. They include candidiasis, athlete's foot, ring worms, etc.
- **Worm diseases:** these are diseases caused by worms. They include elephantiasis, bilharzias, etc.
- **Sexually transmitted diseases:** these are diseases transmitted through sexual contact. They include HIV-AIDS, syphilis, gonorrhea, etc. c.

Transmission of infectious diseases

Pathogens can spread when you have direct contact with an infected person. For example, if you have contact with the person's blood, body fluids or open wounds. Pathogens can also be spread through contaminated food, water or air. Infected animals can spread pathogens to people.

The following conditions lead to the spread of an infectious disease:

- A pathogen which causes the disease.
- A source which is an infected organism.

Mode of transmission: A pathogen must be able to enter the body of the new host to cause an infection. Infectious diseases follow a pattern of development from the time of infection.

2.1.1. Cholera

Cholera is a good example of a waterborne disease. It is endemic in parts of Asia, particularly India. The organism which causes cholera is a comma shaped motile bacterium called ***Vibrio cholerae***.

a) Transmission and symptoms of cholera

The main source of infection is water contaminated by feces with **Vibrios**. It is estimated that only about one infected person in 50 develops the disease, the rest being carriers. Drinking contaminated water, or washing food or utensils in it, is the most common means of transmission. Direct contamination of food with feces as a result of poor hygiene is also possible, house flies being the main vector in this last case.

Figure 2.1: People using and drinking contaminated water

b) Signs and symptoms of cholera

Vibrio cholerae multiply in the intestine, releasing a powerful toxin which results in violent inflammation of the intestine and production of the watery diarrhea.

The main sign of the disease is severe diarrhoea due to irritation of the bowel by toxins from the vibrios. The liquid of the feces is so profuse and cloudy like "rice water".

Abdominal pain and vomiting are also common. Dehydration is rapid and quickly results in death unless rehydration treatment is given.

Figure 2.2: Abdominal pain and vomiting signs cholera

Fever is absent; in fact, the skin feels deathly cold and often damp.

Table 2.1: The features of cholera.

Pathogen	*Vibrio cholerae*
Methods of transmission	food-borne, water-borne
Global distribution	Asia, Africa, Latin America
Incubation period	two hours to five days
Site of action of pathogen	wall of small intestine
Clinical features	severe diarrhoea (‘rice water’), loss of water and salts, dehydration, weakness
Method of diagnosis	microscopical analysis of faeces

c) Treatment of cholera

The prime cause of death from cholera is dehydration i.e. loss of water with its minerals salts. For that it is obligatory to rehydrate with oral serum which contain mineral salts and sugar,

The fluid lost may be replaced by administration of a drip food into a vein.

Various antibiotics, such as **tetracyclines** and **chloramphenical,** are used to treat cholera. **Chloramphenical** is effective against tetracycline-resistant vibrios.

d) Prevention of cholera

- Use clean drinking water,
- Proper treatment of sewage and sanitation
- High standards of public and personal hygiene, particularly in relation to food (such as washing hands after defecation)

Figure 2.3: Person washing hands with soap after living toilet

- Health education
- Vaccination is recommended for people visiting areas where cholera is endemic and for those living in such areas. But this vaccine lasts few months.
- Isolation of patients and hygienic disposal of feces and vomit from patients.

e) Failure to eradicate cholera

- Vaccination is not very effective
- It is a waterborne disease i.e. transmitted through contaminated water
- Poor sanitation condition in camps.

2.1.2. Tuberculosis

a) Causal agent of tuberculosis

Tuberculosis is caused by bacterium called *Mycobacterium tuberculosis*, first discovered by **Robert Koch** in 1882. It is sometimes referred to as the tubercle bacillus, bacilli being rod-shaped bacteria. The common form is pulmonary TB which infects the lungs, although other organs may be affected.

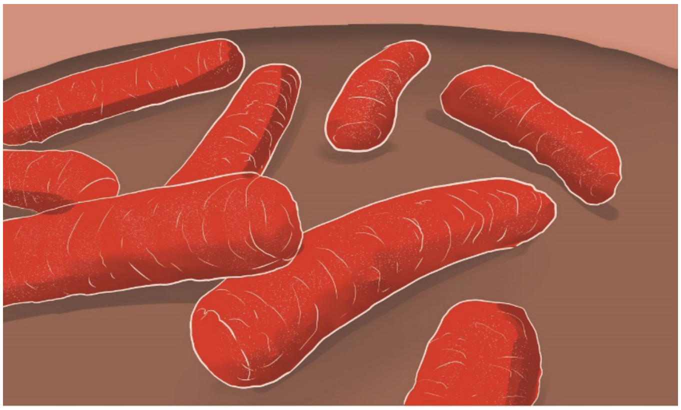


Figure 2.4: Mycobacterium tuberculosis

Two strains of the bacterium may cause the disease, the human and the bovine forms. The latter can be present in cattle and can enter the milk of cows. It is very resistant and can remain alive for long time in milk products as well as in durst.

Table 2.2: *Features of TB.*

Pathogen	*Mycobacterium tuberculosis*; *Mycobacterium bovis*
Methods of transmission	airborne droplets (*M. tuberculosis*); via undercooked meat and unpasteurised milk (*M.bovis*)
Global distribution	Worldwide
Incubation period	few weeks or up to several years
Site of action of pathogen	primary infection in lungs; secondary infections in lymph nodes, bones and gut
Clinical features	racking cough, coughing blood, chest pain, shortness of breath, fever, sweating, weight loss
Methods of diagnosis	microscopic examination of sputum for bacteria, chest X-ray

b) Transmission of tuberculosis

Tuberculosis is mainly airborne disease. The infection is done through the droplets from the patient.

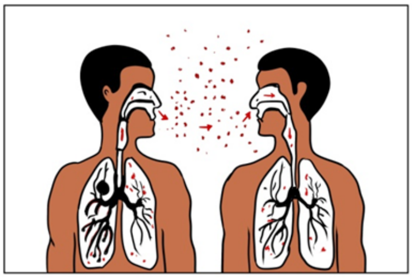


Figure 2.5: Patient transmitting TB germ to another through coughing

It is much less infectious than the common cold and requires prolonged contact between people, poor ventilation and overcrowded living conditions. Other factors include poverty, bad housing, malnutrition, age, smoking and AIDS. In addition, **TB** is an **opportunistic infection**, striking many people with a depressed immunity.

c) Signs and symptoms of tuberculosis

Figure 2.6: Patient on bed suffering from a TB

The disease frequently shows itself by vague symptoms such as: loss of appetite; loss of weight; excessive sweating; coughing, appearance of blood in the sputum, pains on the chest, shortness of breath (case of lung tuberculosis).

d) Treatment and prevention of tuberculosis

The development of an effective vaccine against the disease result of the work of Abert Calmette and Camile guérin (BCG). A cure for people already affected by T.B did not come until 1843 when the antibiotic **streptomycin** was discovered. The number of cases started to fall more rapidly after this and continued to decline aided by introduction of further antibiotics such as **rifampicin, isoniazid** and others.

e) Failure to eradicate tuberculosis

- Patients can carry pathogen and infection without showing symptoms. Therefore they are difficult to identify and isolate / long period of incubation
- Germs of tuberculosis can survive longer in the house dust
- The disease is related to poverty where many people share the same room and have malnutrition.
- The disease is associated with AIDS that reduced the body immunity
- Long period of medication (6-8 moths), hence patients give up when not yet fully healed. The pathogens then form endospores that resists to medicines.
- The disease is also spread through milk from infected animals. Hence it is difficult to vaccinate.
- Tuberculosis is an airborne disease i.e. spread in air.

2.1.3. Malaria

a) Causal agent of Malaria

Human malaria is caused by infections from four species of plasmodium: *Plasmodium falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*, each responsible for a different form of the disease.

Malaria is characterized by chills, fever, and, in the most severe cases, coma leading to death.

The *parasite*, Plasmodium is transmitted by the bite of female mosquitoes (the *vector*) belonging to the genus *Anopheles.*

The life cycle of Plasmodium involves both sexual reproduction within the host mosquito, and asexual reproduction within the human being.

It is the reproductive activity of the parasite within the human bloodstream that produces the characteristic recurrent attacks of the disease.

The infection begins when a mosquito vector injects parasite particles (infectious stages) called **sporozoites**, present in the mosquito's saliva, into the bloodstream when it feeds on a human blood.

b) Symptoms

Malaria is a very serious disease characterized by severe chills, fever, sweating, fatigue and great thirst. Malaria is caused by a protozoan of the genus Plasmodium.

Victims die of anemia, kidney failure or brain damage. The genus Plasmodium infects humans, and all have life cycles that involve the female anopheles mosquito.

c) Life cycle of *Plasmodium*

It is the reproductive activity of the parasite within the human bloodstream that produces the characteristic recurrent attacks of the disease.

The infection begins when a mosquito vector injects parasite particles (infectious stages) called sporozoites, present in the mosquito's saliva, into the bloodstream when it feeds on a human blood.

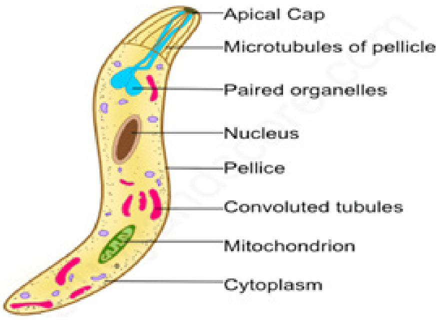


Figure 2.7: Structure of Sporozoite

These enter liver cells where they multiply by asexual reproduction for about 7 to 14 days (the incubation period of the disease) before producing daughter cells called **merozoite**, which invade red blood cells. The parasites multiply in the red cells, again by asexual reproduction, to produce between 8 and 16 **merozoites** every 48 or 72 hours, depending on the species of **Plasmodium.** These **merozoites** are released by the bursting of the infected red blood cells and the cycle is repeated.

The bursting of the red blood cells and the release of toxic substances cause the characteristic fever of malaria. After a number of such cycles, sexual stages, male and female gametocytes, are produced, and these are taken up by a feeding mosquito, in which the *Plasmodium* life cycle is completed by sexual reproduction, resulting in new **sporozoites**.

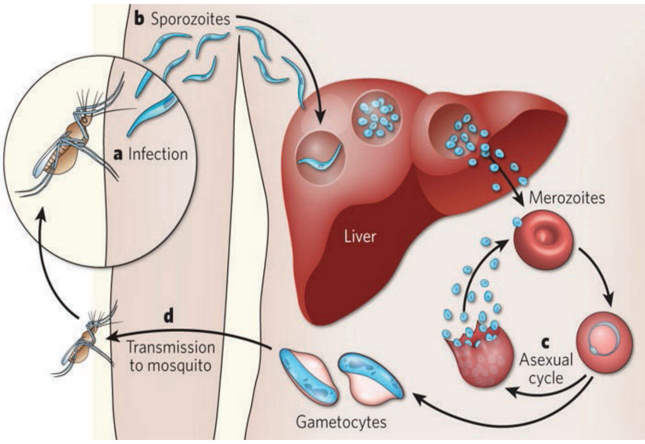


Figure 2.8: Life cycle of Plasmodium

d) Prevention of malaria

- **Drainage of stagnant water:** The larval stages of the mosquito live in stagnant water, so drainage removes breeding sites. This has had some success.

- **Destruction of the breeding sites of the mosquito:** The larvae and pupae of mosquitoes obtain their oxygen by means of small tubes which are pushed through the water surface film. Thus any method of blocking these tubes will result in the death of the intermediate life stages of the mosquito (petrol, oil….)

- **Destruction of the adult mosquitoes:** This is aimed at killing the mosquitoes that enter houses. Thus, the indoor surfaces are sprayed with a persistent insecticide.

Use of mosquito nets.

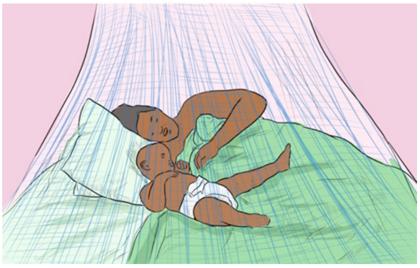


Figure 2.9: Sleeping under mosquito nets.

e) Occurrence of malaria

The disease now occurs in tropical and subtropical regions of the world, and its distribution is limited by conditions that are inimical to the development of the mosquito vector, such as temperature and altitude.

Malaria is endemic in tropics because:

- Tropical climate provides the best breeding and living conditions for the Anopheles mosquito which transmits malaria
- The Anopheles cycle requires areas of stagnant water and these are common within tropics
- In the tropical areas there is presence of bushes or abundant vegetation which makes suitable habitat for mosquitoes

Plasmodium needs temperature in excess of 20°C for it to complete its cycle within the mosquito.

Table 2.3: The features of malaria

Pathogen	*Plasmodium falciparum, P. vivax, P. malariae*
Methods of transmission	Insect vector: female anopheles mosquito
Global distribution	Throughout the tropics and subtropics (endemic in 106 countries)
Incubation period	From a week to a year
Site of action of pathogen	Liver, red blood cells, brain
Clinical features	Fever, anemia, nausea, headache, muscle pain, shivering, sweating, enlarged spleen.
Method of diagnosis	Microscopic examination of blood; dip stick test for malaria antigens in blood.

Treatment of malaria

The common drugs used in treatment of malaria include the following: Chloroquine, Atovaquone-proguanil (Malarone), Artemether-lumefantrine (Coartem), Mefloquine, Quinine, Doxycycline (used in combination with quinine)

f) Failure to eradicate malaria

- There is no effective vaccine against malaria
- The pathogens are transmitted by mosquitoes which are not eradicated.
- The plasmodium have become resistant to different anti-malarial drugs
- Ignorance of some people toward the disease and how it is spread.

2.1.4. HIV/AIDS and other Sexual Transmission Diseases (STD)

AIDS (**Acquired Immune Deficiency Syndrome)** is a disorder which damages the human body's immune system. It is caused by the HIV virus (Human Immunodeficiency Virus).

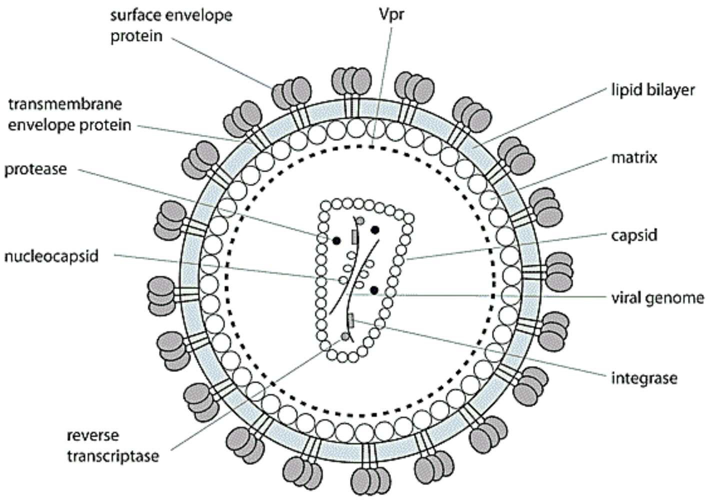


Figure 2.10: Structure of HIV

This is an RNA virus. The virus replicates inside **the T4 lymphocytes** or **helper T cells**. Thus these cells can no longer help or induce other T cells, called killer cells, to fight invaders. The body's immune system breaks down leaving the patient exposed to a variety of diseases called **opportunistic infections**. AIDS is not a disease; it is a collection of these opportunistic diseases associated with immunodeficiency caused by HIV infection. It is important to realize, however, that the infection with the HIV virus does not necessarily result in AIDS. As with other diseases, some people remain symptomless and are therefore called carriers.

TRANSMISSION, SIGNS AND SYMPTOMS

The HIV virus can only survive in body fluids and is transmitted by blood or semen. In 90% of cases the transmission is achieved by sexual contact.

People can contract the disease as follows:

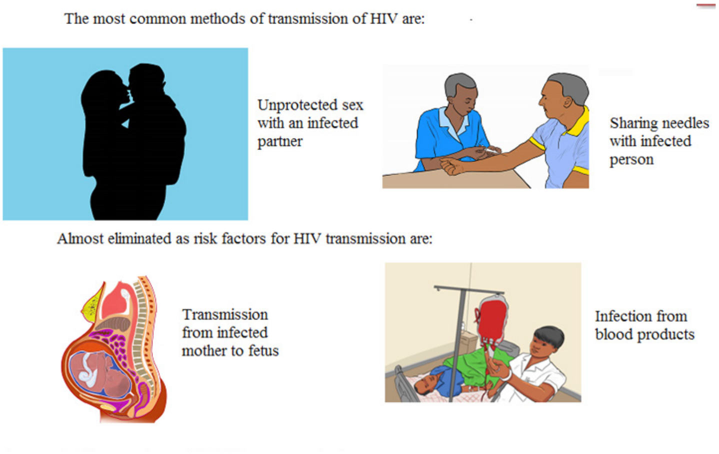


Figure 2.11: modes of AIDS transmission

- **Intimate sexual contact.** The most frequent mode of transmission of HIV is through sexual contact with an infected person.
- **Infected blood entering bloodstream:** by means of unsterilized needles and syringes. Unfortunately the disease can be contracted after being given blood or blood products already infected with HIV. Close contact between infected and non infected people through cuts and open wounds has also been known to pass on the virus.
- **From mother to baby:** An infected pregnant woman can pass on the virus to her baby through the placenta, at birth or through breast milk during suckling. The chances of infection being transmitted from the mother to her baby are currently estimated to be 25-50%.

TEST FOR THE DISEASE

A blood test is used to tell whether or not a person has been infected by the HIV virus. Under normal circumstances the immune system reacts to infection by producing antibodies and when the HIV virus enters the body, anti-HIV antibodies are produced. The blood of the person being tested is added to HIV proteins which have been commercially prepared. If there are anti-HIV antibodies in the blood sample they will bind to the viral proteins and the person is described as HIV positive. However, if the test proves negative that person may still be infected. This is because it takes up to three months or longer for HIV antibodies to be produced after infection.

PREVENTION OF THE DISEASE

There are many precautions which can be followed in trying to prevent the disease:

***Figure 2.12: illustrating a girl saying no to sex**,*

The use of a barrier during intercourse can prevent the virus from infecting through blood or semen. Thus the use of a sheath or condom is recommended. This practice has been encouraged through many advertising campaigns throughout the world.

- Restriction to one sex partner and the absence of promiscuity will also clearly reduce the risk of infection.
- A reduction in the spread of HIV can be brought about by the use of clean needles and syringes by drugs addicts.
- The blood donated should be tested for the presence of antibodies to HIV which indicates whether or not the donor is infected. Blood containing these antibodies is not used.
- Educating the people about the disease.
- Taking antiretroviral during pregnancy and delivery.
- To avoid breastfeeding and to administer antiretroviral drugs to the newborn.

Table 2.4: The features of HIV/AIDS

Pathogen	*Human immune deficiency virus*
Methods of transmission	In semen and vaginal fluids during sexual intercourse, infected blood or blood products, contaminated hypodermic syringes, mother to fetus across the placenta, at birth, mother to infant in breast milk
Incubation period	Initial incubation a few weeks, but up to ten years or more before symptoms of AIDS may develop

Site of action of pathogen	T helper lymphocytes, macrophages, brain cells
Clinical features	HIV infection-flu-like symptoms and then symptomless AIDS-opportunistic infections including pneumonia, TB and cancers; weight loss, diarrhoea, fever, sweating, dementia.
Method of diagnosis	Testing blood, saliva or urine for the presence of antibodies produced against HIV.

Other sexual transmission diseases (STD)

Sexually transmitted diseases (STDs) are transmitted by infected persons to healthy persons during sexual intercourse.

Sexually transmitted diseases (STD), also referred to as sexually transmitted infections (STI) and venereal diseases (VD), are illnesses that have a significant probability of transmission between humans by means of sexual behavior, including vaginal intercourse, anal sex and oral sex. Some STIs can also be contracted by using drug needles after their use by an infected person, as well as through any incident involving the contact of a wound with contaminated blood or through childbirth or breastfeeding.

Sexually transmitted infections have been well known for hundreds of years, and venereology is the branch of medicine that studies these diseases. While in the past, these illnesses have mostly been referred to as STDs or VD, the term *sexually transmitted infections* (*STIs*) has been preferred by many up-to-date medical sources, as it has a broader range of meaning; a person may be *infected*, and may potentially infect others, without having a *disease*.

There are 19 million new cases of sexually transmitted infections every year in the United States, and, in 2005, the World Health Organization estimated that 448 million people aged 15–49 were being infected a year with curable STIs (such as syphilis, gonorrhea and chlamydia).

Until the 1990s, STIs were commonly known as *venereal diseases*, the word venereal being derived from the Latin word venereus, and meaning relating to sexual intercourse or desire, ultimately derived from Venus, the Roman goddess of love. *Social disease* was a phrase used as a euphemism.

While many people with STDs show no signs or symptoms of their infection, when there are signs of STDs they are most likely to be in the genital area. The genital area in women includes the vulva (the area around the vagina including the lips), vagina (the opening where menstrual blood comes out), buttocks, urethra (the opening above the vagina where urine comes out) and anus (the opening where a bowel movement comes out). The genital area in men includes the penis, scrotum ("balls"), urethra, and anus.

What Are the Symptoms of STDs?

Sometimes, there are no symptoms of STDs. If symptoms are present, they may include one or more of the following:

- Bumps, sores, or warts near the mouth, anus, penis, or vagina.
- Swelling or redness near the penis or vagina.
- Skin rash.
- Painful urination.
- Weight loss, loose stools, night sweats.
- Aches, pains, fever, and chills.
- Yellowing of the skin (jaundice).
- Discharge from the penis or vagina. (Vaginal discharge may have an odor.)
- Bleeding from the vagina other than during a monthly period.
- Painful sex.
- Severe itching near the penis or vagina.

Examples of these diseases are **chlamdia, gonorrhoea, syphillis and, HIV and AIDS.**

1. Chlamydia

Chlamydia is caused by the bacterium ***Chlamydia trachomatis***.

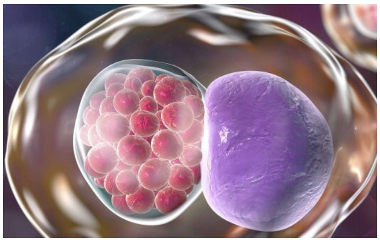


Figure 2.13:Chlamydia trachomatis.

The disease is spread by **oral, vaginal** or **anal sex,** and also **through touch**, for example, touching the eyes with a contaminated hand, may lead to conjunctivitis. Chlamydia can also be passed to the **infant during birth**.

It causes inflammation of the cervix in women, urethra and rectum in both men and women. Occasionally, other parts of the body like eyelids and throat may be affected. Any sexually active person is at risk of contracting the disease. However, it is more common in young people.

The disease is known as a 'silent' infection because it is mainly asymptomatic, thus the symptoms can be mild or be confused with gonorrhea.

Signs and symptoms of chlamydia

In males

- Pain when passing out urine.
- White discharge from the penis.
- The testicles may be painful or swollen.
- Swelling of skin around the anus.

In females

- Painful and frequent urination.
- Smelly yellowish and abnormal vaginal discharge.
- Pain in the lower abdomen.
- Swollen skin in the vagina or around the anus.

Treatment

Chlamydia is easily treated using antibiotics usually **Azithromycin** or **doxyclyne**.

2. Gonorrhoea

Gonorrhoea is transmitted through sexual contact with the penis, vagina, mouth or anus of an infected partner. Gonorrhoea can also be spread from mother to baby during childbirth. Gonorrhoea is caused by a bacterium called ***Neisseria gonorrhoeae***.

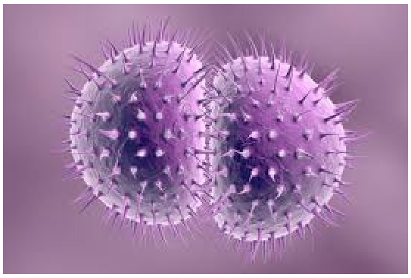


Figure 2.14:Neisseria gonorrhoeae

The bacteria attaches on the epithelial cells of the vagina or male urethra. This results in inflammation and discharge of pus. If left untreated, the infection spreads to the other reproductive parts and may eventually block the passages resulting to infertility. Signs and symptoms of gonorrhea.

Some men with gonorrhea may have no symptoms at all. However, men who do have **symptoms** may have:

- A burning sensation when urinating.
- A white, yellow, or green discharge from the penis.
- Painful or swollen testicles (although this is less common).

Most women with gonorrhea do not have any symptoms. Even when a woman has symptoms, they are often mild and can be mistaken for a bladder or vaginal infection.

Women with gonorrhea are at risk of developing serious complications from the infection, even if they do not have any symptoms.

Symptoms in women can include:

- Painful or burning sensation when urinating.
- Increased vaginal discharge.
- Vaginal bleeding between periods.

Treatment

Gonorrhea can be treated using antibiotics like **penicillin**.

3. Syphilis

Syphilis is transmitted from person to person by direct contact with a syphilitic sore, known as a **chancre**. Chancres occur mainly on the external genitals, vagina, anus or in the rectum. Chancres also can occur on the lips and in the mouth.

Transmission of syphilis occurs during vaginal, anal or oral sex.

Syphilis is caused by a bacteria called ***Treponema pallidum***.

Figure 2.15:Treponema pallidum

The bacterial infection progresses through several stages:

- In the **primary stage**, small hard painless sores develop at the site of infection usually the penis and the vagina.
- The disease enters **secondary stage** several weeks later characterized by rashes on the skin and mild fever. These symptoms subside after a few weeks followed by a latent asymptomatic period.
- In the **tertiary stage**, lesions develop and cause extensive tissue damage that may lead to paralysis, insanity, blindness and eventually death.

Treatment

Antibiotics like **penicillin**, **erythromycin** or **tetracycline** are used to treat syphilis although some strains can be resistant to certain antibiotics.

The following are general ways of reducing STDs and HIV infection:

a) Abstinence is the only sure way to prevent STDs.

b) Being faithful to one trusted partner.

c) Using condoms every time when engaging in sexual intercourse. Condoms are not 100% effective at preventing disease or pregnancy. However, they are extremely effective if used properly.

d) Reduce the number of sexual partners.

e) Avoid sharing towels or underclothing.

f) Get a vaccination for hepatitis B.

g) Get tested for HIV.

h) Avoiding alcohol consumption and abuse of drugs. Individuals who are drunk or on drugs often fail to have safe sex.

2.5 Table summarizing sexual transmitted infections

STI	SYMPTOMS
Chlamydia caused by a bacterium called *Chlamydia trachomatis*	Most women have no symptoms. Women with symptoms may have: • Abnormal vaginal discharge • Burning when urinating • Bleeding between periods Infections that are not treated, even if there are no symptoms, can lead to: • Lower abdominal pain • Low back pain • Nausea • Fever • Pain during sex
Genital herpes caused by a DNA virus	Some people may have no symptoms. During an "outbreak," the symptoms are clear: • Small red bumps, blisters, or open sores where the virus entered the body, such as on the penis, vagina, or mouth • Vaginal discharge • Fever • Headache • Muscle aches • Pain when urinating • Itching, burning, or swollen glands in genital area • Pain in legs, buttocks, or genital area Symptoms may go away and then come back. Sores heal after 2 to 4 weeks.

Gonorrhoea caused by a bacterium called *Neisseria gonorrhea*	Symptoms are often mild, but most women have no symptoms. If symptoms are present, they most often appear within 10 days of becoming infected. Symptoms are: • Pain or burning when urinating • Yellowish and sometimes bloody vaginal discharge • Bleeding between periods • Pain during sex • Heavy bleeding during periods Infection that occurs in the throat, eye, or anus also might have symptoms in these parts of the body.
AIDS caused by a retrovirus called HIV	Some women may have no symptoms for 10 years or more. About half of people with HIV get flu-like symptoms about 3 to 6 weeks after becoming infected. Symptoms people can have for months or even years before the onset of AIDS include: • Fevers and night sweats • Feeling very tired • Quick weight loss • Headache • Enlarged lymph nodes • Diarrhoea, vomiting, and upset stomach • Mouth, genital, or anal sores • Dry cough • Rash or flaky skin • Short-term memory loss

Syphilis caused by a bacterium called *Treponema pallidum*	Syphilis progresses in stages. Symptoms of the primary stage are: • A single, painless sore appearing 10 to 90 days after infection. It can appear in the genital area, mouth, or other parts of the body. The sore goes away on its own. If the infection is not treated, it moves to the secondary stage. This stage starts 3 to 6 weeks after the sore appears. Symptoms of the secondary stage are: • Skin rash with rough, red or reddish-brown spots on the hands and feet that usually does not itch and clears on its own • Fever • Sore throat and swollen glands • Patchy hair loss • Headaches and muscle aches • Weight loss • Tiredness
Trichomoniasis (sometimes called "trich") caused by a protozoan called *Trichomonas vaginalis*	Many women do not have symptoms. Symptoms usually appear 5 to 28 days after exposure and can include: • Yellow, green, or gray vaginal discharge (often foamy) with a strong odor • Discomfort during sex and when urinating • Itching or discomfort in the genital area • Lower abdominal pain (rarely)
Candidiasis caused by a fungus called *Candida albicans*	Severe irritation, extreme itching in the vaginal area, soreness and redness in the vaginal area, painful intercourse in females. In men the symptoms include: red rash on penis, itching or burning on the tip of the penis.

Chancroid is caused by a bacterium.	Symptoms may include genital sores, vaginal discharge, a burning feeling when urinating, and swollen lymph nodes in the groin. It can be spread by vaginal or anal sex or skin-to-skin contact with sores. Chancroid can be treated with antibiotics.

- **DEFICIENCY DISEASES:**

Deficiency diseases these are also known as **malnutrition** or **macro-nutrient deficiencies**. They are diseases that are caused by a dietary deficiency of specific nutrients, especially a vitamin or mineral, possibly coming from insufficient intake, digestion, absorption, or utilization of a nutrient. The deficiency diseases are common in Africa due to the poverty, and bad use of nutrients.

The examples of common deficiency diseases are Kwashiorkor, Marasmus, Vitamin deficiencies.

1. KWASHIORKOR

Kwashiorkor is deficiency disease known as '**wet malnutrition'** caused by eating a food of energy giving food without adequate proteins.

Figure 2.17: Child suffering from kwashiorkor

Signs and symptoms of kwashiorkor

The following are well defined symptoms and signs

- Pitting edema (swelling of the ankles and feet).
- Distended abdomen,
- An enlarged liver with fatty infiltrates,

– Thinning of hair,
– Loss of teeth,
– Skin depigmentation and dermatitis.

Children suffering from kwashiorkor often develop irritability and anorexia.

Mode of Prevention

To prevent from kwashiorkor, a person should be given small but frequent rations in every two to four hours. During the first week, he or she must be given a diet high in sugar and enriched in protein as well as essential elements: sweet milk with mineral salts and vitamins. The diet may include lactases so that children who have developed lactose intolerance can ingest dairy products and antibiotics to compensate for immunodeficiency.

After two to three weeks, the milk is replaced by boiled cereals fortified with minerals and vitamins until the person's mass is at least 80% of normal weight.

Treatment of the disease

– Generally, the disease can be treated by adding protein to the diet; however, it can have a long-term impact on a child's physical and mental development, and in severe cases may lead to death.

2. MARASMUS

Marasmus is also known as "**dry malnutrition**". It is a form of severe malnutrition that usually occurs in children. It typically occurs in developing countries. Marasmus can be life-threatening, but you can get treatment for it.

Causes of marasmus

Nutrient deficiency is the main cause of marasmus. It occurs in children that do not eat enough protein, calories, carbohydrates, and other important nutrients. This is usually due to poverty and a scarcity of food.

Symptoms of marasmus

In children with marasmus, the following are symptoms:

- Chronic diarrhea
- Respiratory infections
- Intellectual disability
- Being underweight
- Stunted growth

- Subcutaneous fat is the layer of fat just under the skin.
- Dry skin and brittle hair
- Children may look older.
- Children are short-tempered and irritable

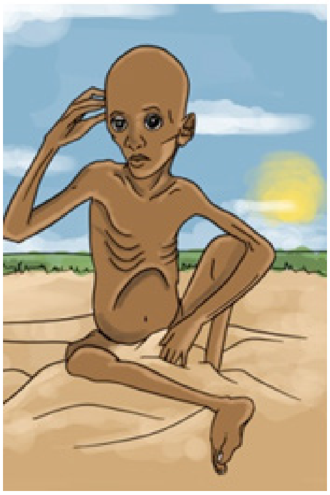


Figure 2.18: Child suffering from marasmus

OTHER DEFICIENCY DISEASES

Most of these diseases are micro-nutrient deficiencies like goitre, anaemia, night blindness, rickets, obesity.

1. Goitre

The goitre is the swelling in the neck caused by lack of an adequate iodine in the diet the pregnant mother

Prevention and treatment

- Eat food rich in iodine
- Go to doctor for treatment and the surgery is done to remove the swelling

2. Anaemia

This disease is due to luck of an adequate Iron mineral in the diet. The iron is essential for formation of haemoglobin pigment of blood contained by red blood cells. If haemoglobin is not formed due to lack of iron, the oxygen will not be transported into the body, hence the person with anaemia becomes tired easily and has little energy to do a given work due to inadequate oxygen in the body.

Signs and symptoms

- Shortness of breath
- Filling weak and tired quickly
- Filling one has no energy to work
- Inside the eyelids and tongue looks pale
- Short attention span

Prevention and treatment

- Regular taking lots of leafy vegetables to provide iron
- Eat food with plenty of calcium and vitamin D

- **VITAMIN DEFICIENCIES**

3. Scurvy

Scurvy happens when there is a lack of vitamin C, or ascorbic acid. The deficiency leads to symptoms of weakness, anemia, gum disease, and skin problems.

This is because vitamin C is needed for making collagen, an important component in connective tissues. Connective tissues are essential for structure and support in the body, including the structure of blood vessels. A lack of vitamin C will also affect the immune system, absorption of iron, metabolism of cholesterol and other functions.

Figure 2.19: Scurvy

Symptoms

Symptoms of vitamin C deficiency can start to appear after 8 to 12 weeks. Early signs include a loss of appetite, weight loss, fatigue, irritability, and lethargy.

Within 1to 3months, there may be signs of:

- Anemia
- Myalgia, or pain, including bone pain

- Swelling, or edema
- Petechiae, or small red spots resulting from bleeding under the skin
- Corkscrew hairs
- Gum disease and loss of teeth
- Poor wound healing
- Shortness of breath
- Mood changes, and depression

Treatment

Treatment involves administering vitamin C supplements by mouth or by injection.

The recommended dosage is:

- 1 to 2 grams (g) per day for 2 to 3 days
- 500 milligrams (mg) for the next 7 days
- 100 mg for 1 to 3 months

Within 24 hours, patients can expect to see an improvement in fatigue, lethargy, pain, anorexia, and confusion. Bruising, bleeding, and weakness start to resolve within 1 to 2 weeks.

After 3 months, a complete recoveryis possible. Long-term effects are unlikely, except in the case of severe dental damage.

Prevention

Scurvy can be prevented by consuming enough vitamin C, preferably in the diet, but sometimes as a supplement.

During pregnancy, women should consume 85 mg of vitamin C, rising to 120 mg while breastfeeding.

Smokers need 35 mg more than nonsmokers every day.

4. Rickets

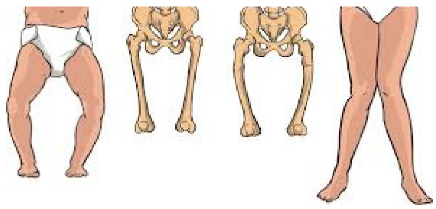


Figure 2.20: Rickets

Rickets is a skeletal disorder that's caused by a lack of Vitamin D, calcium, or phosphate which are nutrients important for the development of strong, healthy bones. The sufferer of rickets may have weak and soft bones, stunted growth, and, in severe cases, skeletal deformities.

Symptoms of rickets

Symptoms of rickets include:

- Pain or tenderness in the bones of the arms, legs, pelvis, or spine
- Stunted growth and short stature
- Bone fractures
- Muscle cramps
- Teeth deformities, such as: delayed tooth formation, holes in the enamel, abscesses, defects in the tooth structure, an increased number of cavities
- skeletal deformities, including: an oddly shaped skull, bowlegs, or legs that bow out, bumps in the ribcage, a protruding breastbone, a curved spine, pelvic deformities

Rickets treatment

Treatment for rickets focuses on replacing the missing vitamin or mineral in the body. This will eliminate most of the symptoms associated with rickets. The exposure to sunlight, if possible is recommended. To consume food products high in vitamin D, such as fish, liver, milk, and eggs is also necessary.

If skeletal deformities are present, the child may need braces to position their bones correctly as they grow. In severe cases, the child may need corrective surgery.

For hereditary rickets, a combination of phosphate supplements and high levels of a special form of vitamin D are required to treat the disease.

Prevention

- The best way to prevent rickets is to eat a diet that includes adequate amounts of calcium, phosphorous, and vitamin D. People with kidney disorders should have their calcium and phosphate levels monitored on a regular basis by their doctors.
- Rickets can also be prevented with moderate sun exposure. We need to expose the hands and face to sunlight a few times a week during the spring and summer months to prevent rickets.

5. Beriberi

Beriberi is a disease caused by a vitamin B-1 deficiency, also known as thiamine deficiency. There are two types of the disease: wet beriberi and dry beriberi.

Wet beriberi affects the heart and circulatory system. In extreme cases, wet beriberi can cause heart rate

Dry beriberi damages the nerves and can lead to decreased muscle strength and eventually,muscle paralysis. Beriberi can be life-threatening if it isn't treated.

Today, beriberi mostly occurs in people with an alcohol use disorder. Still, the disease can be seen in women who have extreme nausea and vomiting in pregnancy, in people with AIDS, and after bariatric surgery.

Symptoms of beriberi

The symptoms of beriberi vary depending on the type.

Wet beriberi symptoms include:

- Shortness of breath during physical activity
- Waking up short of breath
- Rapid heart rate
- Swollen lower legs

Dry beriberi symptoms include:

- Decreased muscle function, particularly in the lower legs
- Tingling or loss of feeling in the feet and hands
- Pain
- Mental confusion
- Difficulty speaking
- Vomiting
- Involuntary eye movement
- Paralysis

Beriberi treatment

Beriberi is easily treated with thiamine supplements. Doctor may prescribe a thiamine shot or pill. For severe cases, a healthcare professional will administer intravenous thiamine.

Prevention

- To prevent beriberi, eat a healthy, balanced diet that includes foods rich in thiamine. These include: beans and legumes, seeds, meat, fish, whole grains, nuts, dairy, certain vegetables, such as asparagus, acorn squash, Brussels sprouts, spinach, and beet greens and breakfast cereals that are enriched with thiamine
- Cooking or processing any of the foods listed above decreases their thiamine content.
- Always be sure to purchase infant formula from a reliable source.
- Limiting alcohol consumption will reduce your risk of developing beriberi

6. Pellagra

Pellagra is a disease caused by low levels of **niacin**, also known as **vitamin B-3**. It's marked by dementia, diarrhea, and dermatitis, also known as "the three Ds". If left untreated, **pellagra** can be fatal.

Symptoms

The main symptoms of pellagra are dermatitis, dementia, and diarrhea. Dermatitis related to pellagra usually causes a rash on the face, lips, feet, or hands. In some people, dermatitis forms around the neck.

Additional dermatitis symptoms include:

- Red, flaky skin
- Areas of discoloration, ranging from red to brown
- Thick, crusty, scaly, or cracked skin
- Itchy, burning patches of skin

As the disease progresses, possible dementia symptoms include: apathy, depression, confusion, irritability, or mood changes, headaches, restlessness or anxiety, disorientation or delusions

Other possible pellagra symptoms include: sores on the lips, tongue, or gums, decreased appetite, trouble eating and drinking, nausea and vomiting

Causes

There are two types of pellagra, known as primary pellagra and secondary pellagra.

Primary pellagra is caused by diets low in niacin or tryptophan. Tryptophan can be converted to niacin in the body, so not getting enough can cause niacin deficiency.

Secondary pellagra occurs when your body can't absorb niacin.

There are things that can prevent from absorbing niacin like: alcoholism, eating disorders, certain medications, including anti-convulsants and immunosuppressive drugs, gastrointestinal diseases, such as ulcerative colitis, cirrhosis of the liver, carcinoid tumors, Hartnup disease

Treatment

Primary pellagra can be treated by dietary changes and a niacin or nicotinamide supplement.

Nicotinamide is another form of vitamin B3. If left untreated, primary pellagra usually causes death after four or five years.

Treating secondary pellagra usually focuses on treating the underlying cause. However, some cases of secondary pellagra also respond well to taking niacin or nicotinamide either orally or intravenously.

7. Night blindness

This is a disease caused by lack of Vitamin A in the diet. The main sources of vitamin A are green leafy vegetables, liver, egg yolk and milk products.

Figure 2.21: Sources of Vitamin A

Symptoms

- Inability of seeing during night

Prevention

- Provide diet with a plenty of vitamin A

WORM DISEASES

In our country, even in other African country many people suffer from worm diseases. There are many worms that can infest people due to poor sanitation. Worms causing infection in people are parasites that live and breed mostly in the intestine. Infection is caused by worms such as roundworms, hookworms and tapeworms.

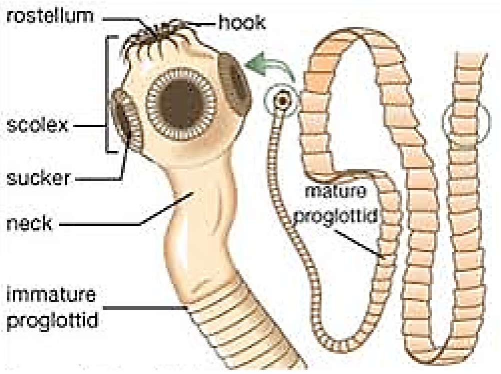


Figure 2.22: Tapeworm structure

1. Ascariasis

Ascariasis is an infection of the and it is the most common roundworm infection. Ascariasis is most common in places without modern sanitation. People get the parasite through unsafe food and water. The infection usually causes no symptoms, but a high number of roundworms (heavier infestations) can lead to problems in the lungs or intestines.

Causes an ascariasis infection

You can become infected with ascariasis after accidentally ingesting the eggs of the *Ascaris lumbricoides* roundworm. The eggs can be found in soil contaminated by human feces or uncooked food contaminated by soil that contains roundworm eggs.

Figure 2.23: structure of Ascaris lumbricoides worm

Children often become infected when they put their hands in their mouths after playing in contaminated soil, even it can also be passed directly from person to person.

Symptoms of ascariasis?

People with ascariasis often have no symptoms. Symptoms become more noticeable when the roundworm infestation grows.

Roundworms in your lungs can cause:

- Coughing or gagging
- Wheezing or shortness of breath
- Aspiration pneumonia (rarely)
- Blood in mucus
- Chest discomfort
- fever

Roundworms in your intestines can cause:

- Nausea
- Vomiting
- Irregular stools or diarrhea
- intestinal blockage, which causes severe pain and vomiting
- Loss of appetite
- visible worms in the stool
- Abdominal discomfort or pain
- Weight loss
- Growth impairment in children due to malabsorption.

Life cycle of the roundworm

After ingestion, the *A. lumbricoides* roundworm reproduces inside your intestine. The worm goes through several stages:

- Swallowed eggs first hatch in the intestine.
- The larvae then move through the bloodstream to your lungs.
- After maturing, the roundworms leave your lungs and travel to your throat.
- You'll either cough up or swallow the roundworms in your throat. The worms that are swallowed will travel back to your intestine.
- Once they're back in your intestine, the worms will mate and lay more eggs.

- The cycle continues. Some eggs are excreted through your feces. Other eggs hatch and return to the lungs.

Environmental risk factors for ascariasis include:

- lack of modern hygiene and sanitation infrastructure
- use of human feces for fertilizer
- living in or visiting a tropical or subtropical climate
- exposure to an environment where dirt might be ingested

You can limit your exposure to roundworms by avoiding unsafe food and water. Keeping your immediate environment clean also helps. This includes laundering clothing exposed to unsanitary conditions and cleaning cooking surfaces well.

You should make sure to take precautions if you're visiting a remote area. It's important to:

- Always wash your hands with soap and water before eating or preparing food.
- Boil or filter your water.
- Inspect food preparation facilities.
- Avoid unclean common areas for bathing.
- Peel or cook unwashed vegetables and fruit in regions that lack sanitation infrastructure or that use human feces for fertilizer.

Complications of ascariasis

Dangerous complications, including:

- **Intestinal blockage.** Intestinal blockage occurs when a mass of worms blocks your intestines, causing severe pain and vomiting. Intestinal blockage is considered a medical emergency and requires treatment right away.
- **Duct blockage.**Duct blockage occurs when the worms block the small passageways to your liver or pancreas.
- **Nutritional deficiency.** Infections that lead to loss of appetite and poor absorption of nutrients put children at risk of not getting enough nutrients, which can affect their growth.

Children are more likely to have gastrointestinal complications because the smaller size of their intestines increases their chances of having an intestinal blockage.

How ascariasis is treated

Doctors usually treat roundworm with antiparasitic drugs. Medications most commonly used include:

- Albendazole (Albenza)
- Ivermectin (Stromectol)
- Mebendazole (Vermox)

If you have an advanced case, you may need other treatment. Your doctor may recommend surgery to control a larger infestation. You'll need surgery if the roundworms are completely blocking your intestines.

The best way to avoid ascariasis is by:

- Practicing good hygiene. That means always wash your hands with soap and water before eating or handling food, and after using the bathroom. Teach your children to do the same.
- Dining only at reputable places.
- Drinking only bottled water and avoiding raw fruits and vegetables unless you're able to wash and peel them yourself when you're in places without modern sanitation.

2. Schistosomiasis

- This disease is also known as snail fever and bilharzia, is a disease caused by parasitic flatworms called schistosomes. The urinary tract or the intestines may be infected.
- Symptoms include abdominal pain, diarrhea, bloody stool, or blood in the urine. Those who have been infected for a long time may experience liver damage, kidney failure, infertility, or bladder cancer. In children, it may cause poor growth and learning difficulty

Modes of transmission

Infected individuals release *Schistosoma* eggs into water via their fecal material or urine. After larvae hatch from these eggs, the larvae infect a very specific type of freshwater snail (Vector of the disease). The *Schistosoma* larvae undergo the next phase of their life cycles in these snails, spending their time reproducing and developing. Once this step has been completed, the parasite leaves the snail and enters the water column. The parasite can live in the water for only 48 hours without a human host. Once a host has been found, the worm enters its blood vessels. For several weeks, the worm remains in the vessels, continuing its development into its adult phase. When maturity is reached, mating occurs and eggs are produced. Eggs enter the bladder/intestine and are excreted through urine and feces and the process repeats. If the eggs do not get excreted, they can become engrained in the body tissues and cause a variety of problems such as immune reactions and organ damage.

Humans encounter larvae of the *Schistosoma* parasite when they enter contaminated water while bathing, playing, swimming, washing, fishing, or walking through the water.

Modes of prevention

- Avoiding drinking or coming into contact with contaminated water in areas where schistosomiasis is common.
- Increasing access to clean water and sanitation
- Snail control
- Health education.

Treatment

There are two drugs available, praziquantel and oxamniquine , for the treatment of schistosomiasis. They are considered equivalent in relation to efficacy against *S. mansoni* and safety. Because of praziquantel's lower cost per treatment, and oxaminiquine's lack of efficacy against the urogenital form of the disease caused by *S. haematobium*, in general praziquantel is considered the first option for treatment. Schistosomiasis is treatable by taking by mouth a single dose of the drug praziquantel annually.

Figure 2.24: Praziquantel for Schistosomiasis treatment

3. Elephantiasis lymphatic filariasis

Figure 2.25: Victime of elephantiasis lymphatic filariasis disease

Elephantiasis, also known as Lymphatic filariasis, is a human disease caused by parasitic worms known as filarial worms.Most cases of the disease have no symptoms. Some people, however, develop a syndrome called elephantiasis, which is marked by severe swelling in the arms, legs,breasts or genitals. The skin may become thicker as well, and the condition may *become painful.*

The worms are spread by the bites of infected mosquitoes. Three types of worms are known to cause the disease: Wuchereria bancrofti,Brugia malayi and Bruggia timori with Wuchereria bancrofti being the most common. These worms damage the lymphatic system. The disease is diagnosed by microscopic examination of blood collected during the night. The blood is typically examined as a smear after being stained with Giesma stain.

Figure 2.26: Wuchereria bancrofti

Symptoms	None, severe swelling of the arms, legs, or genitals
Causes	Filarial worms
Vector	mosquitos
Prevention	Bed nets, mass deworming
Diagnostic method	Microscopic examination of blood
Treatment	Albendazole with ivermectin or diethylcarbamazine

4. Ankilostomiasis

Figure 2.27: Victim of ankilostomiasis and drugs for treatment

Ankilostomiasis is ahookworm disease caused by infection with Ancylostoma hookworms. Ankilostomiasis is caused when hookworms, present in large numbers, produce an iron deficiency anemia by sucking blood from the host's intestinal walls.

Signs and symptoms

Depending on the organism, the signs and symptoms vary.Ancylostoma duodenale and Necator americanus can enter the blood stream while Ancylostoma braziliensis cannot.

Transmission

Figure 2.28: One way of hookworm infection

The infection is usually contracted by people walking barefoot over contaminated soil. In penetrating the skin, the larvae may cause an allergic reaction. It is due to the itchy patch at the site of entry that the early infection gets its nickname "ground itch". Once larvae have broken through the skin, they enter the bloodstream and are carried to the lungs (however, unlike ascaris, hookworms do not usually cause pneumonia). The larvae migrate from the lungs up the windpipe to be swallowed and carried back down to the intestine. If humans come into contact with larvae of the dog hookworm or the cat hookworm, or of certain other hookworms that do not infect humans, the larvae may penetrate the skin. Sometimes, the larvae are unable to complete their migratory cycle in humans. Instead, the larvae migrate just below the skin producing snake-like markings.

Prevention

- Control of this parasite should be directed against reducing the level of environmental contamination.
- Treatment of heavily infected individuals is one way to reduce the source of contamination.
- improve access to sanitation e.g. toilets

- Wearing shoes when you walk outdoors, especially in areas that might have feces in the soil
- Drinking safe water
- Properly cleaning and cooking food
- Practicing proper handwashing

Treatment

The drug of choice for the treatment of hookworm disease ismebendazole which is effective against both species, and in addition, will remove the intestinal worm Ascaris also, if present. The drug is very efficient, requiring only a single dose and is inexpensive.

An infection of *N. americanus* parasites can be treated by using benzimidazoles, albendazole, and mebendazole.

Application activity 2.1

1. List the ways in which cholera is transmitted from person to person.
2. Explain why there is such a high risk of cholera following natural disasters such as earthquakes, hurricanes, typhoons and floods.
3. Explain why there is a high death rate from TB in countries with a high proportion of the population who are HIV-positive.
4. TB is an opportunistic infection. Why?
5. Describe how malaria is transmitted.
6. Describe the biological factors that make malaria a difficult disease to control.
7. Describe the precautions that people can take to avoid catching malaria.
8. Which of the following diseases is transmitted by an insect vector?

a) Cholera

b) HIV/AIDS

c) Malaria

d) TB

9. Tuberculosis is a serious infectious disease.

a) Name the causative agent of tuberculosis.

b) Explain how tuberculosis is transmitted.

c) State the regions of the world with the highest number of cases of tuberculosis.

d) Suggest reasons for the high number of tuberculosis in some parts of the world.

10. The table shows the number of cases of cholera and deaths from the disease for the five countries with the greatest outbreaks as reported to the WHO in 2010.

Country	Region	**Total number of cases**	**Number of deaths**	**Case fatality rate %**
Haiti	Caribbean	179 379	3 990	
Cameroon	West Africa	10 759	657	6.10
Nigeria		44 455	1 712	3.85
Democratic Republic of Congo		13 884	182	1.31
Papua New Guinea	Australasia	8 997	95	1.06
Total	All regions of the world	317 534	7 543	2.38

a) Describe how cholera is transmitted.

b) With reference to the table:

i. Calculate the case fatality rate for Haiti in 2010.

ii. Suggest why the case of fatality rate varies between countries.

iii. Explain why it is important that the WHO collects data on outbreaks of cholera.

c) Explain why there no epidemics of cholera in highly economically developed countries such as Australia, Malaysia and USA.

2.2. Hygiene practices

Activity 2.2

Discuss the possible hygiene practices you always have every morning at your school.

It is important to understand family health issues, because poor personal and environmental hygiene may cause hygiene related diseases. It is therefore important to acquire knowledge and skills on personal and environmental hygiene in order to avoid such diseases.

2.2.1. Personal hygiene

Personal hygiene and sanitation is very important because:

- It insures proper growth and development of children.
- It helps to prevent diseases especially hygiene related diseases.
- It prevents bad smell it helps to keep the environment clean, tidy and beautiful.
- It makes the environment appealing and attractive.

The personal hygiene may be maintained through the hygiene practices below:

- Washing the body regularly with clean water and soap.
- Wearing clean clothes.
- Living in clean environment with adequate fresh air.
- Eating adequate balanced diet. Young children should be fed between 5 to 6 times per day. Their diet should be rich in proteins.
- Having regular exercises.

To insure personal hygiene, the important aspects below are considered:

Care of body

To prevent skin diseases and bad smell one needs:

- Washing the body regularly with clean water and soap.
- Avoid sharing clothes, socks and towels.
- Wearing clean under wears.
- Stay in clean environment.
- Wear clean clothes.

Care of the feet

- Washing the feet regularly with water and soap.
- Keeping the feet dry to avoid fungi or foot rot and bad smell.
- Wearing clean socks.
- Avoid sharing socks.
- Keep nails short and clean.
- Airing your feet daily.
- Apply some oil like Vaseline to keep the feet smooth.

Care of hands

- Wash hands regularly with clean water and soap.
- Keep nails short and clean.
- Wash hand before touching and preparing the food
- Wash hand before eating.
- Wash hand after visiting the toilet.
- Apply some oil like Vaseline to keep the hands smooth.

Care of hair

- Wash your head regularly with clean water and soap.
- Keep your hair well combed.
- Oil your hair to prevent dandruff.

Care of teeth

- Brush your teeth daily with a tooth brush, clean water and tooth paste.
- Avoid eating too much sweet, biscuits and sugary foods, as they can cause tooth decay and dental cavities.
- Eating foods that help build strong teeth like milk, eggs, vegetables, fruits and fish.
- To visit dentist regularly for checkups.
- To avoid putting sharp dirty objects in the mouth.
- Pregnant mothers should feed on dies rich in Calcium which is used to make teeth.

Care for eyes, ears and nose

These sensory organs are very important. We must care for them well. Injury may result in permanent disability such as: blindness, deafness and lack ability to detect smells.

Care of the eyes

- Wash eyes with clean water.
- Protect your eyes from foreign objects and dusts.
- Protect your eyes from too much or too low light. You always read under adequate light.

Care for ears

- Wash ears with clean water and soap.
- Never insert hard objects in the ear, this may damage your ear and cause deafness.
- Avoid very loud noise.
- Clean ears with cotton around a matchstick or use ear buds and use it gently.

Care for the nose

- Never insert hard objects in the nose.
- Keep the nose clean by blowing it regularly.
- Avoid being hit in the nose.

2.2.2. Environmental hygiene

Our surrounding environment including water, air and soil should be protected and kept clean. There should be different hygiene practices to prevent soil pollution, water pollution and air pollution.

Application activity 2.2

1) What are possible hygiene activities are required to care for;

    a) Eyes

    b) Nose

    c) Feet

2) Explain the general human body hygiene practices.

2.3 Human immune system: immunity, structure and role of antibodies, immunization and vaccine

Activity 2.3

The human body is always exposed to environment full of pathogens and it remains healthy. How is this possible?

IMMUNITY is a process by which the body of a living organism defends itself against pathogens. **The immune system** is a protective system that is made of a series of defenses that fight against diseases by: recognizing, attacking, destroying and remembering each type of pathogen that enters the body. It does this by producing specialized cells which inactivate pathogens.

Defense mechanisms against infections

The immune system includes two general categories of defense mechanisms against infections: ***nonspecific defense and specific defense.***

2.3.1 Nonspecific defenses

They include physical barriers (skin) and chemical barriers (mucus, tears and sweat) which prevent foreign pathogens from entering the body. Nonspecific defenses occur into two lines of defense:

a) First line of defense: its function is to keep pathogen out of the body. This role is carried out by: the skin, sweat, tears and mucus. The most important nonspecific defense is **the skin.** The skin epidermis consists of layers of dead cells called **keratinocytes** (which have been **keratinized:** their cytoplasm is replaced by a protein called **keratin).** The keratinized layers of dead cells act as an effective barrier to pathogens and cannot normally be penetrated by bacteria or viruses.

Likewise, the mucous that line the digestive,respiratory, nose and genitals block the entry of harmful microbes. Beyond theirrole as a physical barrier, the skin and mucous membranes counter pathogens with chemicaldefenses. For example, secretions from sebaceous and sweat glands give the skin an acidic PH ranging from3 to 5, which kills bacteria. Many secretions of the body including: tears, mucus and saliva contain **lysozyme**, ananti-**microbial enzyme** that breaks the walls of bacteria. Also, stomach acid and digestive enzymes destroy many pathogens which are swallowed with the food.

b) The second line of defense: Microbes which have managed to penetrate the first line of defense face the second line of defense which depends mainly on **phagocytosis,inflammatory response** and on **certain antimicrobial proteins**.

i. Phagocytosis:

When pathogens are detected in the body, the immune system produces millions of **white blood cells** which fight the infection. Many of this white blood cells are **phagocytes,** which engulf and destroy bacteria.

The word **Phagocyte** comes from Greek where: ***phag*** means: **to eat** and ***kutos*** means **cell**. Thus phagocytes are cells that engulf and destroy pathogens. There are two types of phagocytes:

- **Neutrophils** are the common phagocytes produced in **bone marrow** and carried in blood to be released in **tissue fluid**. They will be released in large number as a result of infection.

  The phagocytic cells called neutrophils constitute about 60 % to 70% of all white blood cells (leucocytes). The neutrophils enter the infected tissue, engulfing and destroying microbes there.

- **Macrophages** are large cells manufactured in bone morrow and travel in blood as **monocytes.** They tend to be settle in **lymph nodes, liver** and in **spleen**.

How phagocytes work: when pathogens enter the body, phagocytes move towards them, they engulf and destroy them. Once the phagocyte is bound to the pathogen, it will envelop it by folding its membrane inwards. The pathogen is trapped inside the **vacuole** called **phagosome. Lysosomes** fuse with the phagosome and release **enzymes** called **lysins** into it. These enzymes digest pathogens and the end products are harmless nutrients that can be absorbed into the cytoplasm.

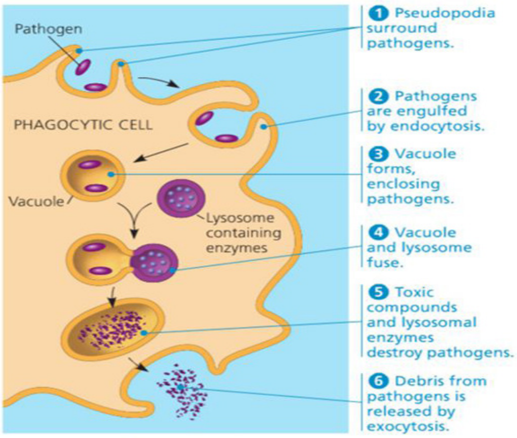


Figure 2.29.Phagocytosis of microbes

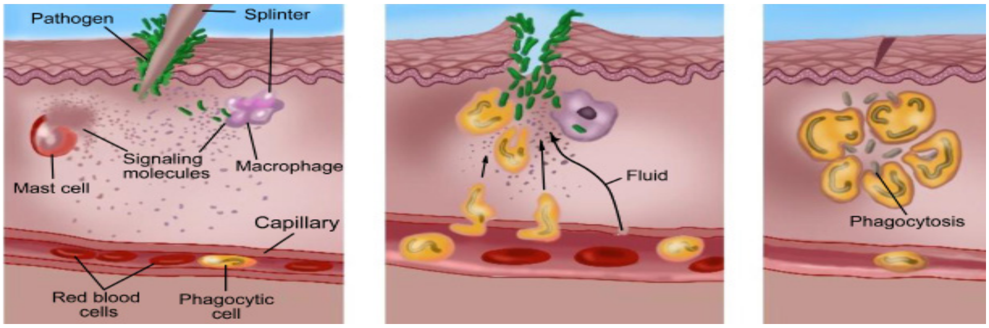
ii. Inflammatory response

One result of phagocytosis is **inflammation** or **inflammatory response** that is characterized by: **redness, hotness, swollen and painful** at the site of local infection. **An inflammatory response** is **a nonspecific defense reaction to tissue damage caused by injury or infection.**

The tissues injured by bacteria or physical damage (like a cut) release chemicals such as **histamine** and **prostaglandins.** These chemicals work as signals which induce an increased **heart rate** and **increased blood capillary permeability** (so that white blood cells get to the site of infection faster).

Infected cells also release chemicals which attract phagocytes. When **phagocytes** and **macrophages** arrive at the site of injury, they engulf and destroy pathogens and the tissues heal.

The inflamed tissues contains many bacteria and phagocytes, many of which die and form the **pus**. The increased body temperature slows or stops the growth of pathogens. The fever and increased number of leucocytes are two indications that the body is working hard at fighting infections



1 Activated macrophages and mast cells at the injury site release signaling molecules that act on nearby capillaries.

2 The capillaries widen and become more permeable, allowing fluid containing antimicrobial peptides to enter the tissue. Signaling molecules released by immune cells attract additional phagocytic cells.

3 Phagocytic cells digest pathogens and cells debris at the site, and the tissue head.

Figure 2.30.Inflammatory response at the injury site.

iii. Anti-microbial proteins

Two groups of proteins: **interferons** and the **complement system** provide short-term, nonspecific defense to viral and bacterial infections. **Interferons** are proteins secreted by virus-infected cells which **inhibit the synthesis of viral proteins** in affected cells and help **to block viral replication**. They diffuse to neighboring cells and stimulate them to produce antiviral proteins, which prevent viruses from multiplying within them.

Interferons also **activate natural killer cells** and **macrophages**, which destroy infected host cells before they release more viruses. Interferons can also **promote destruction of cancer cells.** The **complement system** consists of about 30 proteins in blood plasma that function together to fight infections. These proteins circulate in an inactive state and are activated by substances on the surface of many microbes. Activation results in a cascade of biochemical reactions leading to lysis (bursting) of invading cells. The complement system also functions in inflammation.

2.3.2 Specific defense/immunity: third line of defense

If pathogens are able to get past the body's non-specific defenses, the immune system reacts with a series of specific defenses that attack the **particular disease-causing agent.** These defenses are called **immune response.** A substance that triggers (causes) this response is known as an **antigen.** Viruses, bacteria and other pathogens may serve as **antigens**. The cells of the immune system that recognize **specific** antigens are two types of **lymphocytes**:

a) B lymphocytes (B cells): which originate in the **bone marrow** and migrate to the lymph nodes where they proliferate into **plasma cells** which produce **antibodies.**

B cells provide immunity against antigens and pathogens in the body fluid. B lymphocytes give rise to the **humoral immunity or antibody-mediated immunity.**

b) T lymphocytes (T cells): originate in bone marrow and migrate into the **thymus.** They **don't produce antibodies**, but they themselves provide defense against antigens and pathogens **inside living cells.** T lymphocytes give rise to the **cell-mediated immunity.**

Humoral immunity

When pathogens invade the body, their antigens are recognized by few B cells of the body. These B cells grow and divide rapidly, producing large number of **plasma cells** and **memory cells.** Plasma cells produce and release antibodies. **Antibodies** are proteins that recognize and bind to antigens. They are carried in the bloodstream to attack the pathogen at the site of infection. As antibodies overcome pathogens, the plasma cells die out and stop producing antibodies.

Once the body has been exposed to a pathogen, millions of **memory B cells** remain capable of producing antibodies **specific to that pathogen.** These memory B cells, greatly reduce the chance that the disease could develop a second time. If the same antigen enters the body a second time, a second response occurs. The memory B cells divide rapidly, forming new plasma cells. Plasma cells produce the specific antibodies to destroy the pathogen as faster as possible.

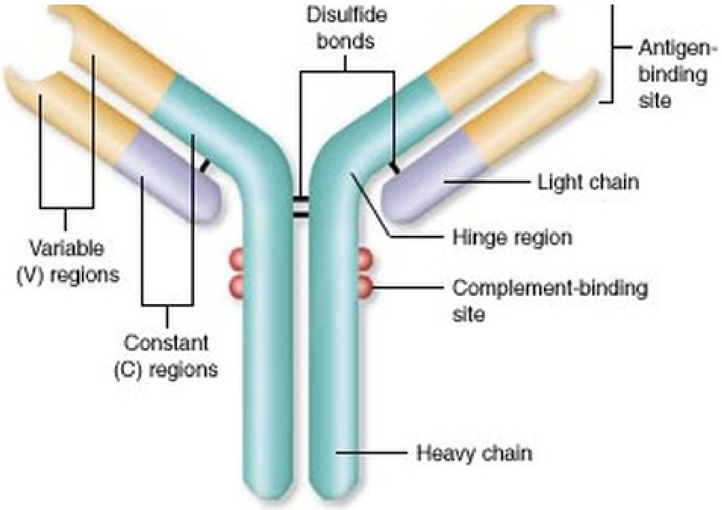


Figure 8.31: Structure of an antibody (To be redrawn)

An antibody is shaped like the letter **Y**, and has two identical **antigen-binding sites**. The shape of the binding site allows the antibody to recognize a specific antigen with a complementary shape. The different shapes give antibodies the ability to recognize a large variety of antigens. A healthy adult cane produce about 100 million different types of antibodies.

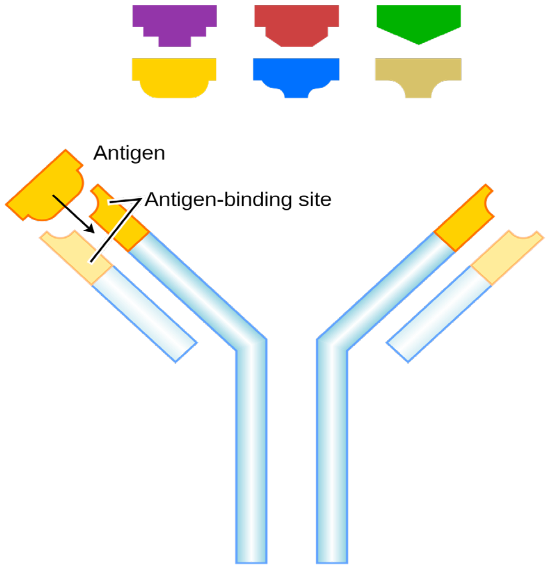


Figure 2.32. Antigen-biding site of an antibody and corresponding antigen

Cell-mediated immunity

It is the body's primary defense against its own cells when they have become **cancerous** or **infected by viruses**. The cell-mediated immunity is also important in fighting infection caused by fungi and protists. When viruses and other pathogens get inside living cells, antibodies alone cannot destroy them. During cell-mediated immunity, T cells divided and differentiated into: **killer T cells (cytotoxic T cells), helper T cells, suppressor T cells and memory T cells.**

Killer T cells track down and destroy bacteria, fungi, protozoa and foreign tissues containing antigens. Helper T cells produce memory T cells. The memory T cells, like memory B cells, will cause a secondary response, if the same antigen enters the body again. As pathogens are brought under control, suppressor T cells release substances that shut down the killer T cells.

Types of immunity

Immunity can be **active or passive.** In **active immunity**, the body makes its own antibodies after exposure to an antigen, whereas in **passive immunity**, the body acquires antibodies produced by other person or other animals. Either active immunity or passive immunity can be **naturally or artificially.** Thus, there are four types of immunity:

a) Natural active immunity

In natural active immunity, the body makes its own antibodies, in response to an antigen.

b) Artificial active immunity

In artificial active immunity, the body makes its own antibodies, as a result of **vaccination** against diseases. **Vaccination (immunization)** is the production of immunity as a result of injection of **weakened pathogens** which cannot cause diseases to the body, but which can induce production of specific antibodies to those pathogens.

Figure 2.33: Person being immunized

c) Natural passive immunity

Natural passive immunity is a temporary immunity resulting from **acquiring** antibodies produced by another individual. The only natural passive immunity is when a foetus acquires antibodies from the mother, either through the placenta before birth, or through the breast feeding after birth. This immunity protects the child against most infectious diseases for the first few months of its life, or longer, if the infant is breast-fed.

d) Artificial passive immunity

It is a temporary immunity that results from the injection of the serum containing antibodies from another organism. In this passive form of immunity, a **recipient** is not induced to produce his or her own antibodies, but is supplied with them, from an outside source. For example: the horse serum well prepared, can then be used to protect humans against diseases.

The trouble with the protection induced by this immunity is that it is short-lived. Nowadays, the passive immunity is normally used only in emergencies, when is too rate for active immunization to work quickly enough.

Application activity 2.3

I. Multiple Choice Questions

1. Humoral immunity is carried out by the

    a) B lymphocytes

    b) T lymphocytes

    c) Phagocytes

    d) T lymphocytes, phagocytes and NK cells

2. Plasma cells represent

    a) B lymphocytes which are actively secreting antibodies.

    b) T lymphocytes which are actively secreting cytokines

    c) Monocytes which have entered tissues

    d) CTL which are secreting perforins.

3. Live attenuated vaccine types have the disadvantage over the inactivated vaccine types as

    a) They require booster shots

    b) They do not confer life-long immunity

    c) They may mutate to virulent form

    d) They do not stimulate the immune system strongly.

4. Immune response is

    a) The defense mechanism of our body.

    b) Reaction of the cells and fluids of the body.

    c) A substance that destroys or inhibits the growth of other microorganisms

    d) None of the above

II. Long Answer Type Questions

1. With an illustrative diagram, state the origin and describe the mode of action of phagocytes.

2.4. Common addictive substances and their effects

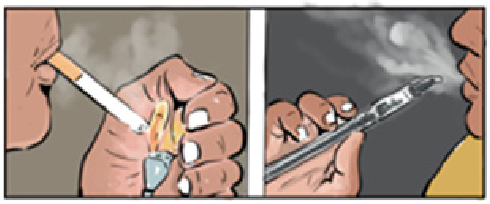
Application activity 2.4

Carefully, Analyze the substances 1-7 in figure above and answer to the following questions

1. Among those substances which one you use in daily life?
2. Which do you think are dangerous to life?
3. Suggest one effect of each of the dangerous substances

Tobacco, Alcohol and drugs addiction is the physical and psychological need to continue using these substance, despite its harmful or dangerous effects.The signs and symptoms of drug addiction drug vary according to the individual and the substances he or she uses.

2.4.1. Tobacco smoking and its effects



a) smoker

b) Tobacco destroyes the heart

Figure 2.34: Tobacco smoking and heart attack

Smoking harms nearly every organ in your body. Among heavy smokers, two in three will die from a disease caused by smoking. Tobacco smoke is made up of thousands of chemicals and many of them are very harmful. Around 70 of them cause cancer. Cigarette smoke contains over 4000 different chemicals. Many of them are harmful. The most harmful substances in cigarette smoke include: **nicotine, carbon monoxide and tar.**

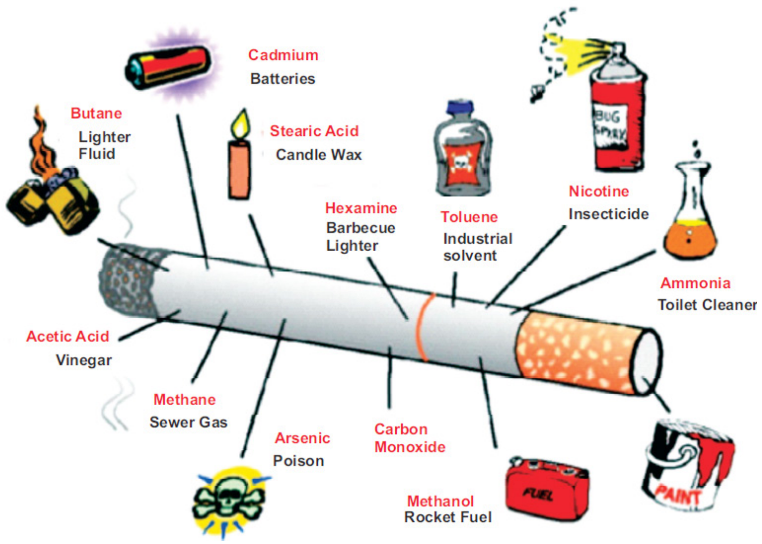


Figure 2.35: Cigarette smoke components

Cigarette smoke contains over 4,000 chemicals, including 43 known cancer-causing (carcinogenic) compounds and 400 other toxins. These cigarette ingredients include nicotine, tar, and carbon monoxide, as well as formaldehyde, ammonia, hydrogen cyanide, arsenic, and DDT. **Nicotine** is highly addictive.

a) Effects of Tar and carcinogens in tobacco smoke on the gas exchange system

Tar is a combination of severe chemicals lying on the lining of the airways and alveoli. This increases the diffusion distance for Oxygen entering the blood and CO_2 leaving the blood. The lumen of airways gets smaller and this restricts the flow of air to the alveoli. The tar paralyses or destroys the cilia on the surface the airways, so they are unable to move the mucus away. Bacteria and viruses trapped in mucus are not removed. They can multiply in the mucus and may block the bronchioles and affect breathing process. A combination of **bacteria, viruses and mucus** in airways and alveoli causes the lungs to be more susceptible to infections. Smokers are more likely to be attacked by influenza and pneumonia.

Tar contains also the **carcinogen compounds** which cause cancer. When the tar lies on the surfaces of airways, carcinogens enter the cells of lung tissues. They enter the nucleus of these cells and have a direct effects on their genetic material. Any change on genetic material is called **mutation**, if mutations affect the genes that control cell division, then uncontrolled cell division take place. **This is cancer**. Lung cancer often takes 20-30 years to develop, and a cancer may grow for many years before it is discovered.

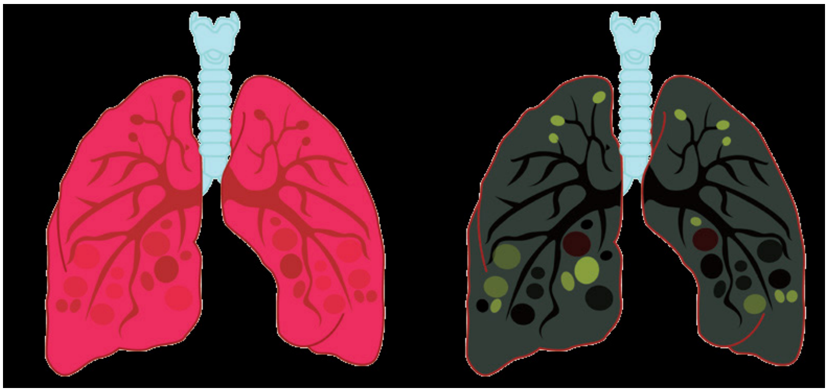


Figure 2.36: Healthy (Left) and tar coated lung (Right)

b) Effects of Nicotine and carbon monoxide on the cardiovascular system

i. ***Carbon monoxide (CO):*** is fatal in large amount. This poisonous gas is also found in car exhaust fumes. CO enters the red blood cells and combines with haemoglobin more rapidly than Oxygen, and form the carboxyhaemoglobin. This reduces the oxygen-carrying capacity of blood, preventing your lungs, heart, and other organs from getting oxygen they need to function properly. CO can also damage the lining of arteries, and may rise the heart beat rate.

ii. ***Nicotine:*** is a poisonous alkaloid drug that is additive. 60 mg of nicotine placed on the tongue would kill an individual within minutes. It is absorbed by the body very rapidly, reaching the brain in less than 30 seconds.

It is a highly toxic chemical and its manufacture, use and sale is controlled under the State Poisons Acts, except where it occurs in tobacco.This exception of tobacco is for political reasons, not because nicotine is deemed ‘safe’ in cigarettes. Nicotine, once inhaled, affects the body very quickly. **It causes changes to the structure and the working of the brain, which lead to nicotine addiction**. Nicotine also ***raises heart rate, blood pressure***, releases hormones (adrenaline) affecting the central nervous system, and ***constricts small blood vessels (arterioles)*** under the skin. In the long term, nicotine may be a factor in ***causing coronary disease.*** It is believed to be involved in the development of gastrointestinal disorders and problems during pregnancy, and is linked with the development of cancers.

c) Contribution of tobacco smoking to atherosclerosis and coronary heart disease

i. **Atherosclerosis** is the deposition of fatty substances in the walls of the arteries. The CO in the cigarette smoke can damage the inner lining of arteries. This encourages the deposit of fatty substances like cholesterol on the walls of arteries. This reduces the lumen of arteries, which reduces blood flow, and causes high blood pressure.

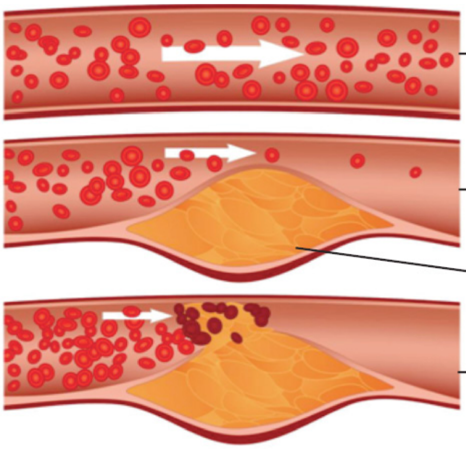


Figure 2.37: Showing the process of blocking arteries by plaque in coronary heart disease

ii. **Coronary heart disease (CHD)** is a disease of the heart caused by malfunction of the coronary artery. Coronary arteries are the arteries which carry blood to the heart.

The nicotine and carbon monoxide found in cigarette enter the lungs and diffuse into blood in blood capillaries, that conducting them into coronary arteries. This causes the atherosclerosis in coronary arteries, which reduces the blood flow in the heart muscles which receive less oxygen for respiration. This can lead to coronary heart diseases, which take three forms: In circulatory system, they cause changes which lead to cardiovascular diseases like:

iii. **Angina:** a severe pain in the chest, which may extend down the left arm or up into the neck.

iv. **Heart attack** or **myocardial infections:** caused by a clot in the coronary arteries, blocking the flow of blood to the heart muscles.

v. **Heart failure:** when the heart cannot sustain its pumping action. This can be caused by the blockage of the major coronary arteries.

d) Symptoms of lung cancer and chronic obstructive pulmonary diseases (COPD)

- **Chronic obstructive pulmonary disease:** is a combination of diseases that include chronic bronchitis, emphysema and asthma. The symptoms of COPD are a combination of symptoms of chronic bronchitis, and of emphysema.
- **Chronic bronchitis:** is the inflammation of the airways. This is accompanied by damage to the cilia and the over production of mucus. The symptoms are: irritation in lungs, continual coughing, and coughing up mucus that is often filled with bacteria and white blood cells.
- **Emphysema:** is the loss of elasticity in alveoli, which causes the alveoli to bust. The symptoms are: short breath, hard exhalation, the blood is less well oxygenated and fatigue occurs.
- **Lung cancer:** the symptoms of lung cancer can be recognized by: continual coughing, shortness of breath, pain in the chest and the blood coughed up in the sputum is often the first sign of the lung cancer.

e) Evidences linking cigarette smoking to diseases and early death.

i. Links of cigarette smoking to early death

- Regular smokers are three times more likely to die prematurely than a non-smoker.
- 50% of regular smokers are likely to die of a smoking-related disease
- The more cigarettes a person smokes per day, the more he is likely to die prematurely.

ii. Links of cigarette smoking to lung cancer

- A smoker is 18 times more likely than a non-smoker to develop lung cancer.
- 25% of smokers die of lung cancer.
- A heavy smoker (more than 25 cigarettes a day) is 25 times more likely than a non-smoker to die of lung cancer
- The chances of developing lung cancer reduce as soon as a person stops smoking.

iii. Links to other lung diseases

- COPD is rare in non-smokers
- 98% of people with emphysema are smokers.
- 20% of smokers have emphysema

2.4.2. Alcohol

Alcohol is any organic compound in which the hydroxyl functional group (–OH) is bound to a carbon. The term *alcohol* originally referred to the primary *alcohol* ethanol (ethyl *alcohol)* which is used as a drug and is the main*alcohol* present in *alcoholic* beverages.

Alcohol is produced by adding yeast on a liquid that contains sugar in absence of oxygen. This yeast ferment sugar to produce energy, alcohol and alcohol.

Most popular alcohol containing drinks include fermented drinks such as beer and wine, other drinks such as vodka, whiskey, scotch, and gin are made by distillation

Figure 2.38: Different fermented and distilled alcoholic drinks

Effects of alcohol

The effects of alcohol vary from person to person. While some people may be able to limit their drinking, others have a difficult time controlling their alcohol consumption.

Effects of alcohol include: Slurred speech, vision impairment, lack of coordination, extreme shifts in mood, memory lapses and slowed breathing.

The most immediate alcohol effects are on the nervous system. The small dose of alcohol slows down the rate of nervous system functions. So, alcohol is a depressant.

The pregnant women who drink regularly, run the risk of" **fetal alcohol syndrome**"or damage to the developing babies due to the effect of alcohol.

People who have become addicted to alcohol suffer from a disease called **alcoholism**. If someone cannot work effectively without alcohol, that indicates an alcohol abuse problem.

Taking alcohol in excess leads to damage of neurons in the brain, cells in the liver. The damage of liver cells causes the live to become less able to deal with high amount of alcohol, then the formation of the scar tissue known as **cirrhosis** in liver occurs. Finally the drinker may die from the chronic liver failure.

Basing on the effect of alcohol on nervous system, driving can lead to sudden accident that may kill people.

Figure 2.39: Accident as bad effect of alcohol

2.5.3. Drugs

Drug is any substance that cause a change in the body. Drugs affect the body in different ways, because some are very powerful and dangerous and their possession is not allowed. Other drugs like penicillin and codeine are drugs that can be used under the supervision of doctor.

All drugs (legal and illegal ones) have the capacity of harming life if they are abused. In this section, some of the most commonly abused drugs and the way they affect the body will be considered.

Drugs affect the particular system of the body like digestive and circulatory systems.

The following are the most powerful drugs that can also affect the nervous system and their negative side effects.

Figure 2.40 Marijuana plantation

Figure 2.40: Hallucinogens (LSD and PCP)

a) MARIJUANA (Also called Hashish or Hash)

i. Negative effects of using marijuana

- **Addiction**: Marijuana is physically addictive and psychologically addictive, especially as it concerns younger.
- **Memory Loss**: People who always use marijuana developed a poorer verbal memory in middle age than people who didn't smoke.
- **Social Anxiety Disorders:** Regular use of marijuana can lead to mental health issues such depression, anxiety and even schizophrenia.
- **Paranoia**: researches indicated that the use of marijuana can lead users to feel a sense of paranoia as a result of the changes in their sensory perception
- **Heart Damage**: Marijuana can also significantly raise a person's heart rate for up to three hours. Even, people who use marijuana are more likely to have a stroke https://www.livescience.com/58210-stroke-heart-failure-linked-to-marijuana.html at some point in their lives than people who didn't use it.
- **Other effect are: Lung problems**, **low testosterone**, **appetite irregularities**, **risk of greater potency**, **decrease in motor Responses**, **poor decisions.**

b) HALLUCINOGENS

Hallucinogens are **drugs** that cause hallucinations. Users see images, hear sounds and feel sensations that seem very real but do not exist. Some **hallucinogens** also produce sudden and unpredictable changes in the mood of those who use them.

There are many types of hallucinogens but the two common types such as LSD(Lysergic acid diethylamide) and PCD(Phencyclidine) are the ones which are used.

LSD is a powerful hallucinogen that interferes with the normal transmission of nerve impulses in the brain. Its effects vary from person to person and all people who use LSD regularly have a**bad trip.** Some of LSD users have lost touch with reality after only one single dose.

PCP produces fillings of strength and great power. High dose of PCP heart attacks. The users of PCP often become extremely violent and are danger to themselves and others.

c) STIMULANTS

These are drugs that speed up the actions of nervous system. The most powerful stimulants are **Amphetamines,** these chemically resemble natural neurotransmitters found in the body (Compounds that pass nerve impulse from one neuron to another). Once amphetamine enters the blood stream, it floods the body and behaves like neurotransmitters. This causes the nervous system to increase its activity producing a feeling of strength and energy in the user body. Later the user suffers from fatigue and depression as the nervous system becomes unable to handle the overstimulation produced by amphetamines after their dose wears off.

Long-term use of amphetamines causes hallucinations, circulatory problems. Psychological difficulties.

d) DEPRESSANTS

These are drugs that reduce the rate of nervous system activity. These drugs are also known as **downers.** People become dependent on them as long as they use them. Example of downers is **barbiturates.** Use of the barbiturates with alcohol is fatal, because the nervous system becomes so depressed and breath stops.

The barbiturates abuse is danger because it brings about serious medical problems that must be immediately treated once the user stops supplying the drugs to the body.

e) COCAINE

This drug is compound extracted from leaves of **coca plant.** Users supply it to the body by smoking it, sniffing it or inject it into the bloodstream.

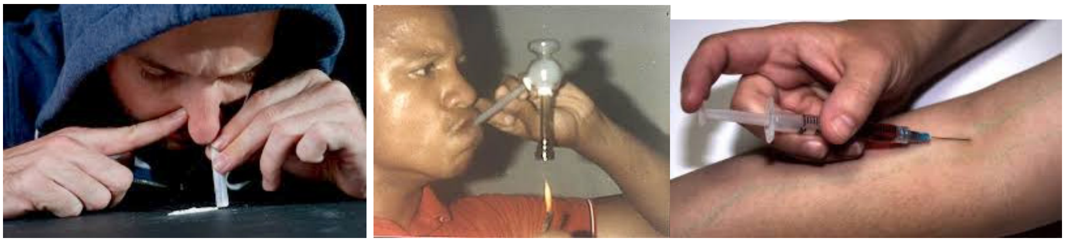


Figure 2.41: People sniffing, smoking and injecting cocaine

Cocaine stimulate the release of neurotransmitter called **dopamine** which is normally released by the brain if person is satisfied during lunch or dinner. So, cocaine creates feeling of pleasure and satisfaction

i. Effects of using cocaine

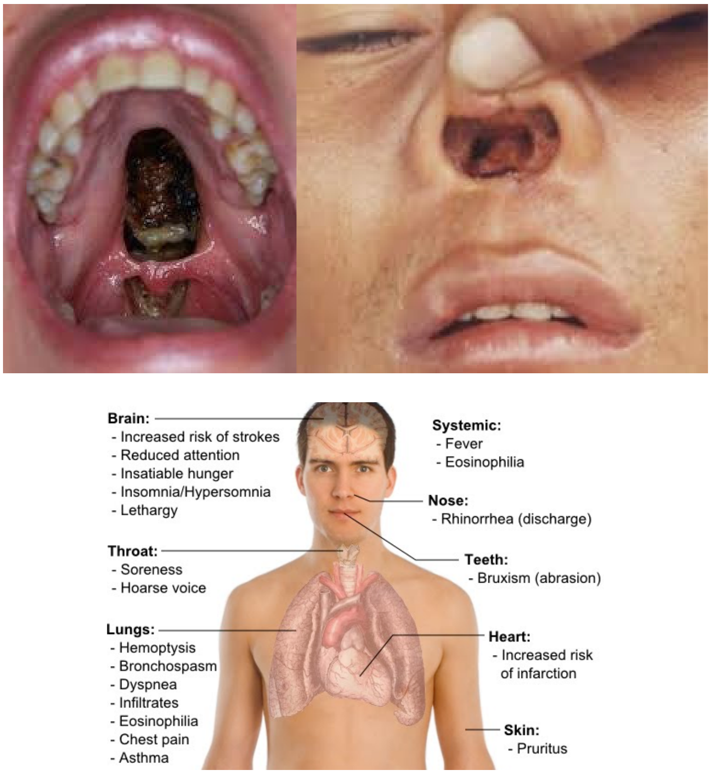


Figure 2.42: Some negative effects of using cocaine

- Heavy use of cocaine leads to lung damage similar to emphysema. Overdose stops breathing.
- Use of cocaine increases the heart rate and blood pressure leading to risk of irregular heartbeat or even heart attack.
- Cocaine causes extreme mood changes, irritability. Long-term use can lead to psychological problems.

- Cocaine causes the users to experience the sensation of bugs crawling over the skin.
- Cocaine usage reduces a desire for food, leading to body weight loss.

f) OPIATES

This is a group of drugs produced from the **opium poppy.** The most common opiates are **opium** produced directly from the opium poppy. Other examples of opiates are **morphine** and **heroin** which are forms of opium. Apart from heroin, other opiates can be used under supervision of doctor to reduce severe pain as they are used as pain killers. If opiates are taken in large dose, they can result to death.

In addition, opiates such as heroin, are example of drugs that cause a strong physical dependence. The regular user becomes addicted and the nervous system becomes also dependent on the supply of drugs. Any attempt of withdrawal or stopping the use of drug will cause severe pain, nausea, chills and fever.

Application activity 2.4

I. Choose whether the following statements are True (T) or False (F)

1. Smoke from cigarettes can make non-smokers sick.
2. Smoking can affect a person's ability to smell and taste food.
3. Secondhand smoke kills about 3,000 non-smokers each year from lung disease.
4. It takes about ten seconds for nicotine absorbed into the bloodstream to reach the brain.
5. Smoking is a difficult habit to quit.
6. Nicotine, the chemical found in cigarettes, is an addictive drug.
7. A smoker is twice as likely to have a heart attack as a non-smoker is.
8. Cigarette brands that are heavily advertised on TV, in magazines, on billboards, and on T-shirts are the brands more teens buy.
9. One out of every ten smokers will die of a smoking-related sickness.
10. More germs get into your lungs when you smoke.

II. Suggest the components of a tobacco smoke

III. Give the effects of alcohol on human body health

SKILLS LAB 2:

After studying this unit" Common diseases and hygiene", and after finishing their studies as well as working as cooperative, Student-teachers will help society by creating a center for people workshop about nutrition, hygiene and sanitation, so that different diseases can be eradicated from Rwanda society.

They will be helping people to fight against malnutrition by talking about deficiency diseases and how they can prevent them. Here every house should have its own vegetable plantation around kitchen.

Sensitization about general body hygiene, food hygiene, clothes hygiene, home hygiene, water sanitation will be the first priority. And again, according to what they have acquired from the school student-teacher will help people to know all method of cooking like:

a) Boiling: this is a method involving cooking food completely covered with water and boiling it until fully cooked

b) Steaming: this is cooking food using steam from boiling water.

c) Frying: this method involves cooking food with hot fat or oil.

d) Stewing: this involves cooking food with low quantities of water.

e) Roasting: this involves cooking food with very hot radiant heat

f) Baking: this involves cooking food using a direct heat

g) Grilling: this involves cooking food with direct heat using a grill.

These methods will be very important in preventing from being infected by disease germs from uncooked food. Again good storage and preservation are very significant in preventing many infectious diseases.

Conclusion: This unit will lead student-Teachers when they are still at school or at home to protect their own life, and even the society life.

End unit assessment 2

I. Choose whether the given statements are True (T) or False (F)

1. Innate immunity is present at birth.
2. Breast milk confers protection to newborn by providing IgE type of antibodies.
3. Antibodies can work by promoting phagocytosis of microbial agents.
4. Antibiotics help a patient in mounting an effective immune response.
5. Treating tuberculosis is becoming difficult because Mycobacterium tuberculosis has become resistant to a number of antibiotics.
6. High fever is a generalized allergic reaction caused by release of active mediators from mast cells.
7. Secondary immune response appears much faster because of the presence of memory cells persisting from previous infection.
8. Vaccination against snakebite is an example of passive immunization.
9. Allergies are of two types—innate and adaptive.
10. Beta-lactam antibiotics kill bacteria by blocking synthesis of their cell walls.

II. Long answers type questions

1. Answer the following questions

a) Name the causative agent of tuberculosis.

b) Explain how tuberculosis is transmitted.

c) State the regions of the world with the highest number of cases of tuberculosis.

d) Suggest reasons for the high number of tuberculosis in some parts of the world.

2. State why vaccination programs are able to eradicate smallpox but not measles, TB, malaria or cholera.
3. Compare roles of B cells and T cells in the immune response.

4. Name organism which have the following effects on health

	Name
Cause malaria	
Transmits malaria	
Cause influenza	
Causes Ancylostomiasis	
Provide penicillin	
Elephantiasis	
Transmits venereal disease	
Scurvy	
Causes body's bad smell	
Creates feeling of pleasure and satisfaction	

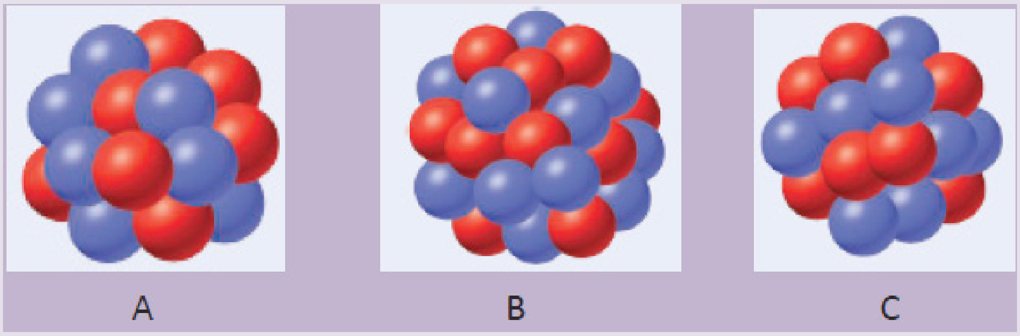
UNIT 3: STRUCTURE OF AN ATOM

Key unit competence

Calculate relative atomic mass (R.A.M) of different elements.

Introductory Activity

The illustrations A, B, and C below show three atomic nuclei of different elements. Study the illustrations carefully and answer the questions below.



1. How many blue and red spheres do you see in each of the diagrams above?
2. What do the three diagrams A, B, and C have in common?
3. Based on your knowledge concerning atomic structure, what do you think that

   a) the blue spheres represent?

   b) the red spheres represent? Provide explanations.
4. Are there some other particle(s) missing from the above diagrams? If yes name the particle(s).
5. What could you obtain if the atom is broken down?

Each country has its own culture (language, traditions and norms, attitudes and values, etc.). Our culture defines our identity which is unique to each Rwandan citizen and differentiates us from foreigners; if one element of our culture is rejected or disappears, we become a different Rwandan people. When we introduce foreign cultures to replace ours, we can lose our identity. However, some of our cultural elements such as language can be shared with others to build the social relationship.

Similarly, in the atom, the number of protons within the nucleus defines the atomic number, which is unique to each chemical element; the atomic number or the number of protons of an atom defines its identity. If a proton is added or removed from an element, it becomes a different element. Electrons around the nucleus can be lost, gained, or shared to create bonds with other atoms in chemical reactions to produce useful substance, but this does not change the identity of the elements involved.

3.1. The constituents of an atom, their properties and the outline of their discovery

Activity 3.1

1. Chemists study the structures, physical properties and chemical properties of material substances. These consist of matter.

   a) What is matter?

   b) From the list that follows, show what is matter and what is not matter: gold, energy peanuts, light, smoke, ideas, sounds. Provide explanations

2. List the components of matter and describe each component.
3. Regardless of some exceptions, all atoms are composed of the same components. True or False? If this statement is true why do different atoms have different chemical properties**?**
4. The contributions of Joseph John Thomson and Ernest Rutherford led the way to today's understanding of the structure of the atom. What were their contributions?
5. Explain the modern view of the structure of the atom?
6. Using your knowledge about atom, what is the role each particle plays in an atom?

Atoms are the basic units of elements and compounds. In ordinary chemical reactions, atoms retain their identity. An *atom* is the smallest identifiable unit of an *element*. There are about 91 different naturally occurring elements. In addition, scientists have succeeded in making over 20 synthetic elements (elements not found in nature but produced in Laboratories of Research Centres).

An element is defined as a substance that cannot be broken down by ordinary chemical methods in simpler substances. Some examples of elements include hydrogen (H), helium (He), potassium (K), carbon (C) and mercury (Hg). In an element, all atoms have the same number of protons or electrons although the number of neutrons can vary. A substance made of only one type of atom is also called element or elemental substance, for example: hydrogen (H_2), chlorine (Cl_2), sodium (Na). Elements are the basic building blocks of more complex matter.

A compound is a matter or substance formed by the combination of two or more different elements in fixed ratios. Consider, Hydrogen peroxide (H_2O_2) is a compound composed of two elements, hydrogen and oxygen, in a fixed ratio (2:2).

3.1.1. Discovery of the atom constituents

The oldest description of matter in science was advanced by the Greek philosopher Democritus in 400 BC.

He suggested that matter can be divided into small particles up to an ultimate particle that cannot any more be divided, and called that particle **atom**. Atoms came from the Greek word *atomos* meaning indivisible.

The work of Dalton and other scientists such as Avogadro, etc., contributed more so that chemistry was beginning to be understood. They proposed new concept of atom, and from that moment scientists started to think about the nature of the atom. What are the constituents of an atom, and what are the features that make atoms of the various elements to differ?

In 1808 Dalton published *A New System of Chemical Philosophy,* in which he presented his theory of atoms:

1. Dalton's Atomic Theory

a) Each element is made up of tiny particles called atoms.

b) The atoms of a given element are identical; the atoms of different elements are different in some fundamental way(s).

c) Chemical compounds are formed when atoms of different elements combine with each other. A given compound always has the same relative numbers and types of atoms.

d) Chemical reactions involve reorganization of the atoms—changes in the way they are bound together. The atoms themselves are not changed in a chemical reaction.

Figure 3.1: John Dalton's Atomic Model

2. Discovery of Electrons and Thomson's Atomic Model

In 1897 J. J. Thomson (1856–1940) and other scientists conducted several experiments, and found that atoms are divisible. They conducted experiments with gas discharge tubes. A gas discharge tube is shown in Figure 3.2.

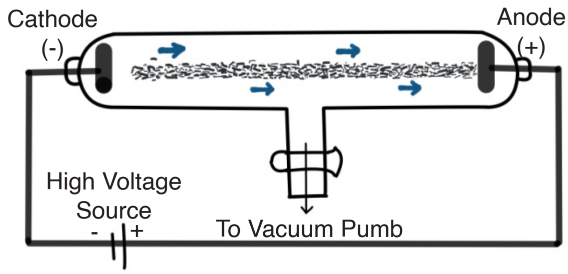


Figure 3.2: Gas discharge tube showing cathode rays originating from the cathode

The gas discharge tube is an evacuated glass tube and has two electrodes, a cathode (negative electrode) and an anode (positive electrode). The electrodes are connected to a high voltage source. Inside the tube, an electric discharge occurs between the electrodes.

The discharge or 'rays' originate from the cathode and move toward the anode, and hence are called **cathode rays.** Using luminescent techniques, the cathode rays are made visible and it was found that these rays are deflected away from negatively charged plates. The scientist J. J. Thomson concluded that the cathode rays consist of negatively charged particles, and he called them *electrons.*

Thomson postulated that an atom consisted of a diffuse cloud of positive charge with the negative electrons embedded randomly in it. This model, shown in Figure 3.3, is often called the *plum pudding model* because the electrons are like raisins dispersed in a pudding (the positive charge cloud), as in plum pudding.

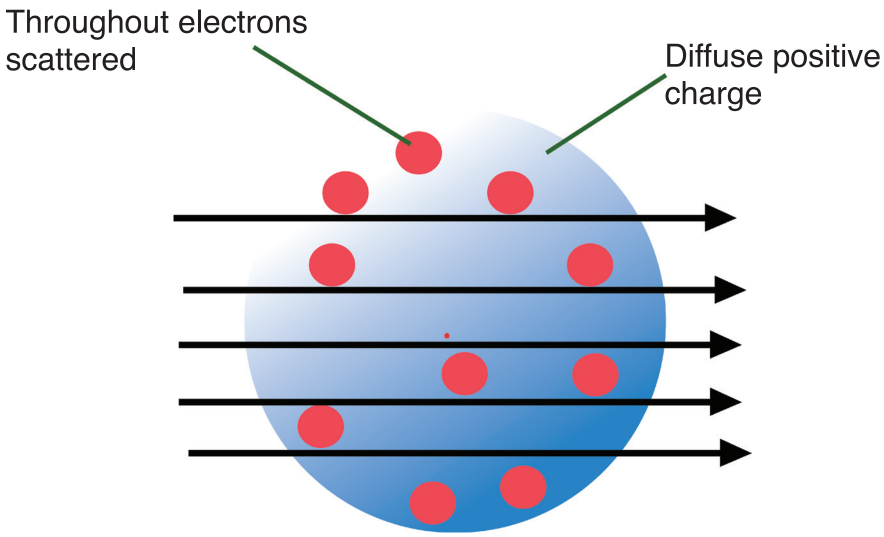


Figure 3.3.The plum pudding model of the atom.

In 1909 Robert Millikan (1868–1953) conducted the famous charged oil drop experiment and came to several conclusions: He found the magnitude of the charge of an electron equal to $-1.602\times10^{-19}C$.From the charge-to-mass ratio(*e*/*m)* determined by Thomson, the mass of an electron was also calculated.

$$\frac{charge}{mass} = -1.76x10^{8}\,Coulomb/gram$$

$$Mass = \frac{-1.602\times10^{-19}}{-1.76\times10^{8}} = 9.11\times10^{-29}g = 9.11\times10^{-31}kg$$

3. Discovery of Protons and Rutherford's Atomic Model

In 1886 Eugene Goldstein (1850–1930) observed that a cathode-ray tube also generates a stream of positively charged particles that move towards the cathode. These were called **canal rays** because they were observed occasionally to pass through a channel, or "canal," drilled in the negative electrode (Figure 3.4). These *positive rays*, or *positive ions*, are created when the gaseous atoms in the tube lose electrons. Positive ions are formed by the process

Atom ⟶ cation + e^- (energy absorbed)

Different elements give positive ions with different *e*/*m* ratios. The regularity of the *e*/*m* values for different ions led to the idea that there is a subatomic particle with one unit of positive charge, called the **proton**. The proton is a fundamental particle with a charge equal in magnitude but opposite in sign to the charge on the electron. Its mass is almost 1836 times that of the electron.

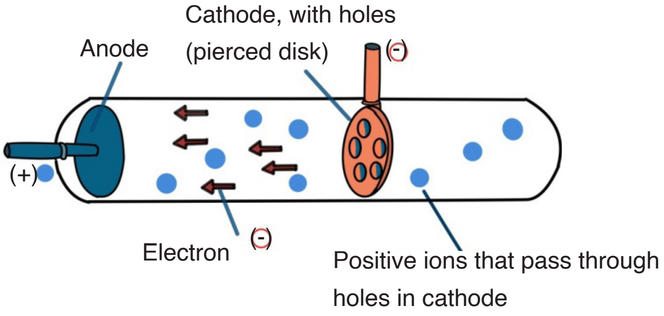


Figure 3.4: A cathode-ray tube with a different design and with a perforated cathode

The proton was observed by Ernest Rutherford and James Chadwick in 1919 as a particle that is emitted by bombardment of certain atoms with α-particles.

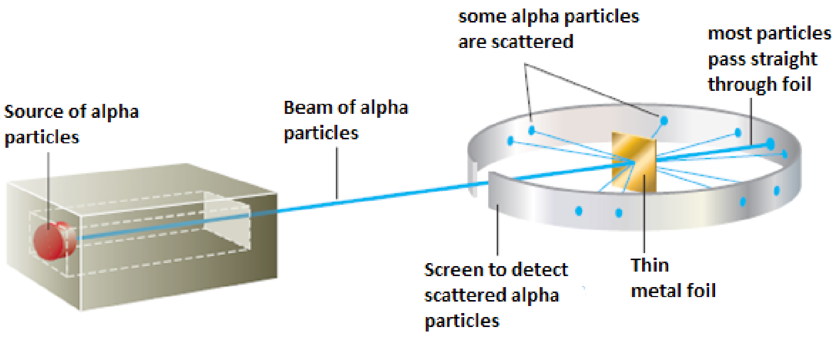
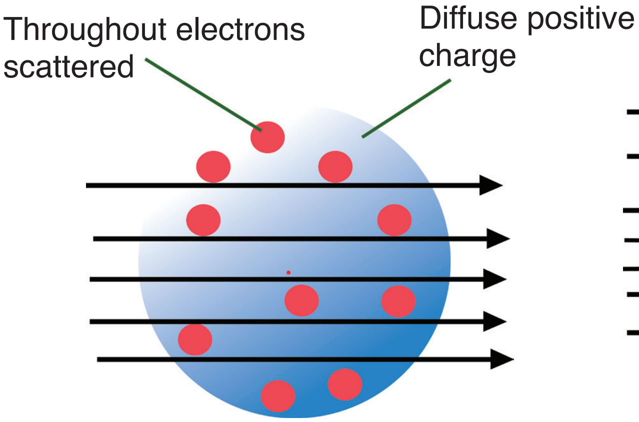


Figure 3.5: Rutherford's experiment on α-particle bombardment of metal foil

Rutherford reasoned that if Thomson's model were accurate, the massive α-particles should crash through the thin foil like cannonballs through gauze, as shown in Figure 3.6(a). He expected α-particles to travel through the foil with, at the most, very minor deflections in their paths. The results of the experiment were very different from those Rutherford anticipated. Although most of the α- particles passed straight through, many of the particles were deflected at large angles, as shown in Figure 3.6(b), and some were reflected, never hitting the detector. This outcome was a great surprise to Rutherford. Rutherford knew from these results that the plum pudding model for the atom could not be correct. The large deflections of the α-particles could be caused only by a centre of concentrated positive charge that contains most of the atom's mass, as illustrated in Figure 3.6(b). Most of the α-particles pass directly through the foil because the atom is mostly empty space. The deflected α-particles are those that had a "close encounter" with the massive positive centre of the atom, and the few reflected α-particles are those that made a "direct hit" on the much more massive positive centre.

In Rutherford's mind these results could be explained only in terms of a nuclear atom—an atom with a dense centre of positive charge (the nucleus) with electrons moving around the nucleus at a distance that is large relative to the nuclear radius.



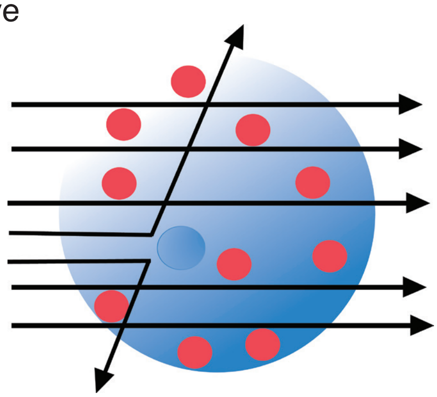


Figure 3.6 (a): The expected results of the metal *Figure 3.6 (b): Actual results foil*
experiment if Thomson's model were correct

4. Discovery of Neutrons

In spite of the success of Rutherford and his co-workers in explaining atomic structure, one major problem remained unsolved.

If the hydrogen contains one proton and the helium atom contains two protons, the relative atomic mass of helium should be twice that of hydrogen. However, the relative atomic mass of helium is four and not two.

This question was answered by the discovery of James Chadwick, English physicist who showed the origin of the extra mass of helium by bombarding a beryllium foil with alpha particles.

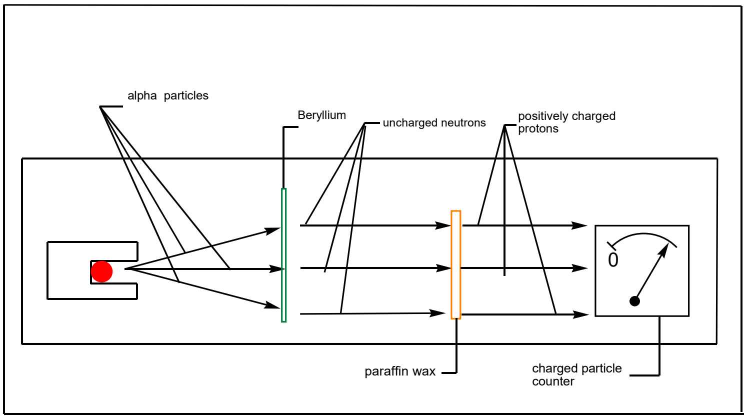


Figure 3.7: Chadwick's experiment

In the presence of beryllium, the alpha particles are not detected; but they displace uncharged particles from the nuclei of beryllium atoms. These uncharged particles cannot be detected by a charged counter of particles.

However, those uncharged particles can displace positively charged particles from another substance. They were called **neutrons**. The mass of the neutron is slightly greater than that of proton.

Figure 3.8 shows the location of the elementary particles (protons, neutrons, and electrons) in an atom. There are other subatomic particles, but the electron, the proton, and the neutron are the three fundamental components of the atom that are important in chemistry.

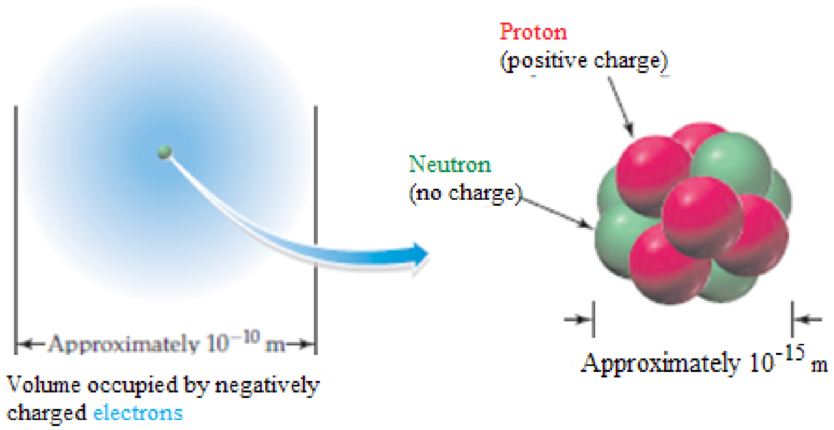


Figure 3.8: The protons and neutrons in an atom are contained in the tiny volume of the nucleus. Electrons are distributed within the sphere surrounding the nucleus.

As a result of the experiments described above, it is found that atoms consist of very small, very dense nuclei surrounded by clouds of **electrons** at relatively great distances from the nuclei. All nuclei contain **protons**; nuclei of all atoms except the common form of hydrogen also contain **neutrons**.

5. Properties of sub-atomic particles

Protons and neutrons are collectively known as nucleons. Both protons and neutrons have a mass almost equal to that of hydrogen atom. The neutron has no charge whereas the proton carries one positive charge. The electron with one negative charge occupies the space outside the nucleus.

The following table summarizes the relative masses, the relative charges and the position within the atom of these sub-atomic particles.

Table 3.1: Subatomic particles and some of their properties

Particle	Absolute charge(Coulomb)	Relative charge	Mass (kg)	Relative masse
Neutron(n)	0	0	1.675×10^{-27}	1.0087 amu*
Proton(p or P^+)	$+1.6\times10^{-19}$	+1	1.673×10^{-27}	1.0073 amu
Electron(e^-)	-1.6×10^{-19}	-1	9.11×10^{-31}	0.00054858 amu

(*amu: atomic mass unity, 1 amu=1.67×10^{-27}kg)

Application activity 3.1

1. In an experiment, it was found that the total charge on an oil drop was 5.93×10^{-18} C. How many negative charges does the drop contain?
2. All atoms of the elements contain three fundamental particles. True or false? Give an example to support your answer.
3. Compare the atom constituents

a) in terms of their relative masses

b) in terms of their relative charges

4. Explain why:

a) J.J Thomson concluded that all atoms have the same negatively charged particles.

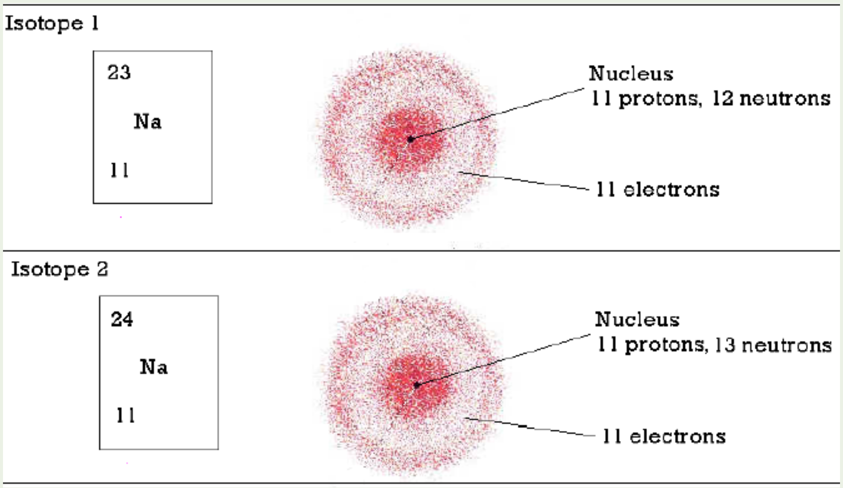
b) Most alpha particles pass straight through tin metal foil.

c) Some alpha particles are scattered.

3.2 Concept of atomic number, mass number, isotopic mass and relative atomic mass

Activity 3.2

The diagram below shows a representation of sodium isotopes ($^{A}_{Z}Na$). Observe it and answer to the questions that follow.



1. Find the values of A and Z for isotope 1 and isotope 2.
2. From your observation, how do you define the isotopes of an element?
3. How is A, the mass number, determined?
4. What information is provided by the atomic number, Z?
5. What is the relationship between the number of protons and the number of electrons in an atom?
6. Where are the electrons, protons, and neutrons located in an atom?
7. The mass of an atom is concentrated in the centre. Try to find an explication to this.
8. Say which one(s) of the following statements is(are) correct and which one(s) is(are) wrong: (i) isotopes differ in their number of electrons, (ii) isotopes differ in their mass numbers, (iii) isotopes differ in their number of protons, (iv) isotopes differ by their number of neutrons, (v) all the statements are wrong.

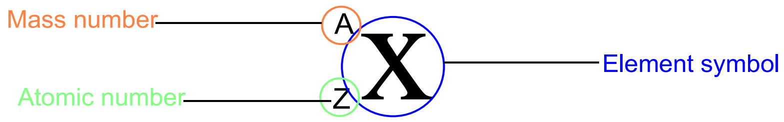
- The **atomic number** or **proton number, Z,** denotes the number of protons in an atom's nucleus. It corresponds to the order of the element in the periodic table.
- The **mass number or nucleon number, A,** denotes the total number of protons and neutrons in an atom.

Mass number = number of protons + number of neutrons

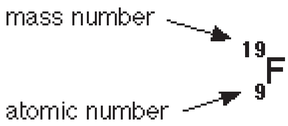
= atomic number + neutron number

- The number of neutrons can be obtained by subtracting the atomic number from the mass number.
- Chemists use the following shorthand to represent an atom. The mass number is shown as a superscript (top number) and the atomic number is shown as a subscript (bottom number) beside the symbol of the element.

By convention, the atomic number is usually written to the left subscript of the elemental notation, and the mass number to the left superscript of the elemental notation as represented by the example below, where X represents any elemental symbol.



Example:



Some atoms of the same element have the same atomic number and different mass numbers. This means a different number of neutrons. Such atoms are called **isotopes** of the element**.** They are nuclides of the same element.

Example:

	Protons	Neutrons	mass number
carbon-12	6	6	12
carbon-13	6	7	13
carbon-14	6	8	14

Isotopes of an element have the same *chemical* properties because they have the same number of electrons.

- When elements react, it is the *electrons* that are involved in the reactions: this means that the isotopes of an element cannot be differentiated by chemical reactions.
- Because isotopes of an element have different numbers of neutrons, they have different *masses*, and isotopes have slightly different *physical* properties.
- The mass of a single isotope is its **isotopic mass**. The **relative isotopic mass** of an isotope is the relative mass of that isotope compared with the isotope which is given a mass of 12.00 units (12.00 atomic mass units). That is, relative isotopic mass relates to the relative atomic mass scale on which one isotope of the carbon element, **carbon-12,** is taken as the reference standard for atomic masses and is given a relative mass of 12 units, precisely 12 **atomic mass units (a.m.u)**.

$$\text{Relative isotopic mass} = \frac{\text{mass of 1 isotope of the element}}{\frac{1}{12}\text{ x mass of 1 atom of } {}^{12}_{6}\text{C}}$$

- **Atomic mass unit (a.m.u)** is a unit of mass used to express "relative atomic masses". It is 1/12 of the mass of the isotope of carbon-12 and is equal to $1.66054\text{x}10^{-27}$kg.
- The relative isotopic masses of all other atoms are obtained by comparison with the mass of a carbon-12 atom.
- On that scale, the relative atomic mass of a proton and that of a neutron are both very close to one unit (1.0074 and 1.0089 units respectively). Since the relative mass of an electron is negligible (0.0005units), it follows that all isotopic masses will be close to whole numbers.
- However relative atomic masses of elements are not close to whole numbers because natural occurring elements are often mixtures of isotopes.

Application activity 3.2

1. How do you call the members of each of the following pairs? Explain.

a) $^{35}_{17}Cl$ and $^{37}_{17}Cl$

b) $^{63}_{29}Cu$ and $^{65}_{29}Cu$

2. Write, using the periodic table, the correct symbols to identify an atom that contains

a) 4 protons, 4 electrons, and 5 neutrons;

b) 23 protons, 23 electrons, and 28 neutrons;

c) 54 protons, 54 electrons, and 70 neutrons; and

d) 31 protons, 31 electrons, and 38 neutrons.

3. Use the list of the words given below to fill in the blank spaces. Each word will be used once.

Atomic number, Mass number, Protons, Electrons, Isotopes, Neutron

a) The atomic number tells you how many ____________________ and ____________________ are in an atom.

b) ____________________ is the number written as subscript on the left of the atomic symbol.

c) The total number of protons and neutrons in an atom is called the ______________________________.

d) Atoms with the same number of protons but different number of neutrons are called ______________________________.

e) The subatomic particle that has no charge is called a ________________________.

3.3 Calculations of the relative atomic masses of elements

Activity 3.3

Using textbooks and internet connection, explain the concept of relative mass and attempt to solve the problems below.

1. Argon has three naturally occurring isotopes: argon-36, argon-38 and argon-40. The reported relative atomic mass of Argon (Ar) from the periodic table is 39.948, which isotope do you think is the most abundant in nature? Explain.
2. Calculate the average atomic mass of an element with two naturally occurring isotopes: ^{85}X (72.15%, 84.9118 amu) and ^{87}X (27.85%, 86.9092 amu). Identify this element.
3. Boron has two naturally occurring isotopes. Find the percent abundances of ^{10}B and ^{11}B given the isotopic mass of ^{10}B = 10.0129 amu and the isotopic mass of ^{11}B = 11.0093 amu.

Relative atomic mass, symbolized as R.A.M (Ar), is defined as the average of the relative isotopic masses of the different isotopes weighted in the proportions in which they naturally occur.

Thus, the different isotopic masses of the same elements and the percentage abundance of each isotope of an element must be known in order to accurately calculate the relative atomic mass of an element.

Notice: Remember that mass number is not the same as the relative atomic mass or isotopic mass! The mass number is the total number of protons and neutrons while relative atomic mass is the average of the isotopic masses.

Let A_1, A_2, A_3,…, A_n be an abundance of n isotopes of the same chemical element with atomic mass M_1, M_2, M_3,…, M_n respectively, the relative atomic mass (R.A.M) is given by the following equation:

$$\text{RAM} = \frac{A_1M_1 + A_2M_2 + A_3M_3 + \cdots + A_nM_n}{A_1 + A_2 + A_3 + \cdots + A_n}$$

Example 1

Oxygen contains three isotopes ^{16}O, ^{17}O, and ^{18}O. Their respective relative abundances are 99.76%, 0.04%, and 0.20%. Calculate the relative atomic mass of oxygen.

Solution:

Relative isotopic mass of ^{16}O is 16 and its relative abundance is 99.76%;

Relative is otopic mass of ^{17}O is 17, abundance 0.04%;

Relative isotopic mass of ^{18}O is 18, abundance 0.20%.

$$\text{Relative atomic mass of oxygen} = \frac{(99.76 \times 16) + (0.04 \times 17) + (0.20 \times 18)}{99.76 + 0.04 + 0.20}$$

$$=16.0044$$

By applying the same formula, the relative abundance of the isotopes may be calculated knowing the relative atomic mass of the element and the atomic masses of the respective isotopes.

Example 2

Chlorine contains two isotopes ^{35}Cl and ^{37}Cl, what is the relative abundance of each isotope in a sample of chlorine if its relative atomic mass is 35.5?

Solution:

$$35.5 = \left(\frac{A \times 35}{100}\right) + \left(\frac{100 - A}{100}\right) \times 37$$

Note that if the abundance of the isotope of atomic mass 35 is A%, the abundance of the isotope of mass 37 will be (100 – A) %.

0.35A + (100 – A) x 0.37 = 35.5

0.35A– 0.37A =35.5 – 37

– 0.02A = – 1.5

A= 1.5/0.02 = 75

Therefore, the abundance of the isotope of relative atomic mass 35.5 is 75% while that for the isotope ^{17}Cl is 100 – 75 = 25%.

Application activity 3.3

1. Three isotopes of magnesium occur in nature. Their abundances and masses are listed in the following table. Use this information to calculate the relative atomic mass of magnesium.

Isotope	% abundance	Mass (amu)
^{24}Mg	78.99	23.98504
^{25}Mg	10.00	24.98584
^{26}Mg	11.01	25.98259

2. The atomic weight of gallium is 69.72 amu. The masses of the naturally occurring isotopes are 68.9257 amu for ^{69}Ga and 70.9249 amu for ^{71}Ga. Calculate the percent abundance of each isotope.

SKILLS LAB 3

Using adequate materials construct any three models of atoms of your choice. These models show shells and all electrons. These atoms should be any three of this list: Cl, C, H, O, N, B, F.

End unit assessment 3

I. Multiple choice questions

1. Which of the following is true regarding a typical atom?

a) Neutrons and electrons have the same mass.

b) The mass of neutrons is much less than that of electrons.

c) Neutrons and protons together make the nucleus electrically neutral.

d) Protons are more massive than electrons

2. Which of the following statements is(are) *true?* For the false statements, correct them.

a) All particles in the nucleus of an atom are charged.

b) The atom is best described as a uniform sphere of matter in which electrons are embedded.

c) The mass of the nucleus is only a very small fraction of the mass of the entire atom.

d) The volume of the nucleus is only a very small fraction of the total volume of the atom.

e) The number of neutrons in a neutral atom must equal the number of electrons.

3. Each of the following statements is true, but Dalton might have had trouble explaining some of them with his atomic theory. Give explanations for the following statements.

a) Atoms can be broken down into smaller particles.

b) One sample of lithium hydride is 87.4% lithium by mass, while another sample of lithium hydride is 74.9% lithium by mass. However, the two samples have the same chemical properties.

II. Short and long answer questions

1. What are the three fundamental particles from which atoms are built? What are their electric charges? Which of these particles constitute the nucleus of an atom? Which is the least massive particle of the fundamental particles?

2. Verify that the atomic weight of lithium is 6.94, given the following information:

   ^{6}Li, mass = 6.015121 u; percent abundance = 7.50%

   ^{7}Li, mass = 7.016003 u; percent abundance = 92.50%

3. Lithium has 2 naturally occurring isotopes. Lithium-6 has an atomic mass of 6.015 amu ; lithium-7 has an atomic mass of 7.016 amu. The atomic mass of lithium 6.941 amu. What is the percentage of naturally occurring Li-7 ?

4. Observe the table below and complete by the missing data.

Atoms	A	Z	protons	neutrons	electrons	Symbol of nuclide R, X or Y
R	20		8			
X^{2-}		18		20		
Y^{3+}	45	21				

UNIT 4: UNIFORM CIRCULAR MOTION

Key unit competence

Analyse and solve problems related to circular motion.

Introductory Activity 4

Read the following statement and analyse them how it happens thereafter answer the next questions

a) The rotation of the blades on the ceiling fan.

b) A ball rolling on a floor in a constant velocity.

c) An artificial satellite orbiting the Earth at a constant height.

d) A stone which is tied to a rope and is being swung in circles.

e) A car turning through a curve in a race track.”

1. Refer to the above examples, elaborate other examples on where circular motion can be applied in real life situation
2. From what you elaborate what are the factors that help the body to be in circular motion?
3. Observe the following image thereafter answer the question below

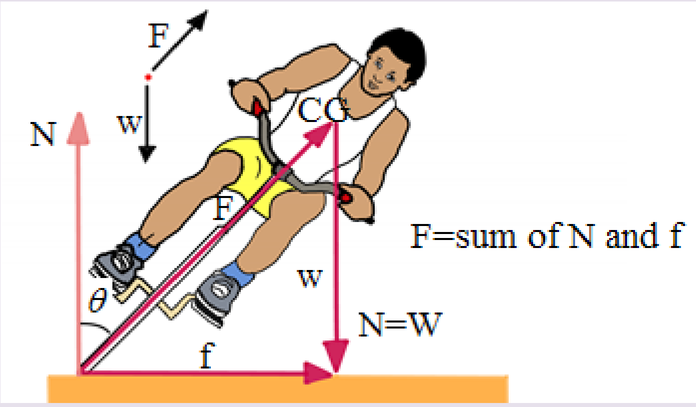


Figure4.1 A bicyclist negotiating a turn on level ground

What happen for this bicyclist to turn on level ground easily?T

4.1. Definition of key terms in circular motion

Activity 4.1

Study carefully the motion of the ball shown below.

From your observation of below figure, how can a body move in that circular path? Explain your reason

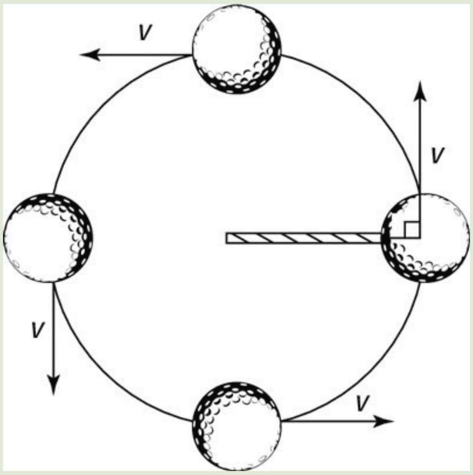


Figure 4.2: Showing the path taken by a ball moving in a circular path

Circular motion: is movement of an object along the circumference of a circle, or rotation along a *circular* path. It is a *motion* with constant.

Angular displacement: is the *angle* in radians (degrees, revolutions) through which a point revolves around a centre or line has been rotated in a specified sense about a specified axis.

Linear velocity: is themeasure of how fast the dot is moving along the circumference of the circle

Angular velocity: is the rate at which the central angle swept out by the object changes as the object moves around the **circle**, and it is thus measured in radians per unit time.

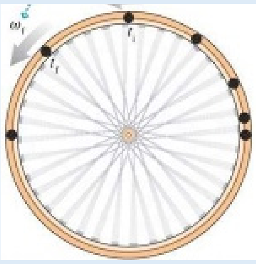
Period: The period is the time taken for a full revolution of the motion.

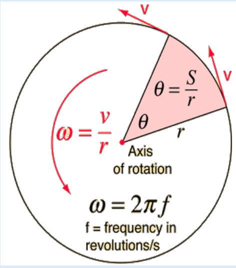
Frequency: is the number of rotation per unit time.

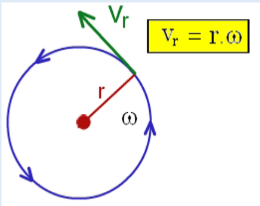
Angular acceleration: also called rotational **acceleration**, is a quantitative expression of the change in **angular** velocity that a spinning object undergoes per unit time. It is a vector quantity, consisting of a magnitude component and either of two defined directions or senses.

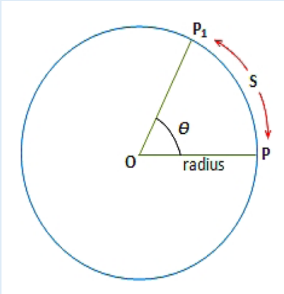
Linear acceleration: is the rate of change of linear velocity

Application activity 4.1









A B C D

After observing the above pictures, what A, B, C and D represent in circular motion?

4.2 Relationship between angular and linear parameters

Activity 4.2

Write your observation on the image below

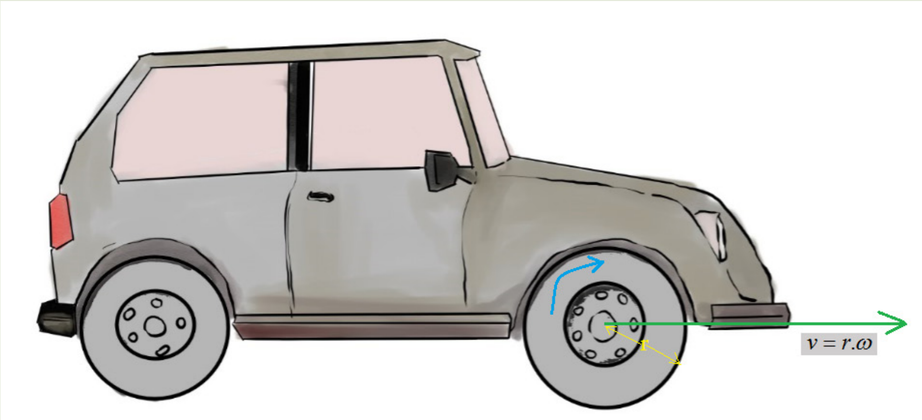


Figure 4.3 A car moving at a velocity, **v,** *to the right has a tire rotating with angular velocity ω*

1. What do variables v, ω and r mean in the expression illustrated on the figure 4.3
2. What does ω show in the movement of the wheel in the illustration above.

4.2.1 Angular Velocity

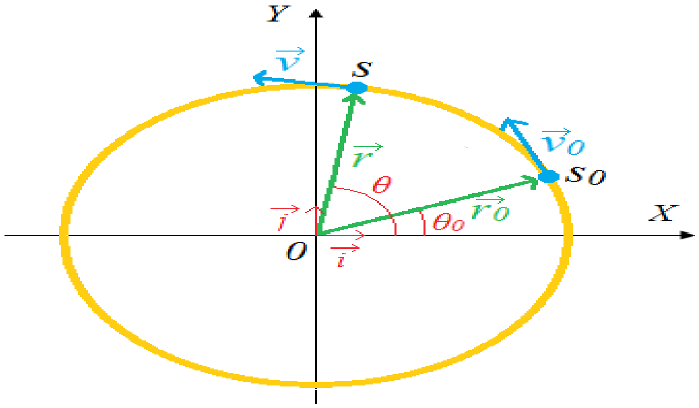


Figure 4.4. Uniform circular motion

To indicate the angular position of a particle, or how far it has rotated we specify the angle θ of a line joining the centre of the particle and its position with respect to some reference line, such as the x axis. Consider an object moving in a circle of radius r with a uniform speed v round a fixed point 0 as centre**.**

When an object rotates the angular displacement $\Delta\theta = \theta - \theta_0$, the average angular velocity is defined as

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{\theta - \theta_0}{t - t_0} \qquad (1)$$

The linear displacement or **the Arc** of the object along the circle is

$$\Delta s = s - s_0 = r\Delta\theta$$

The linear average velocity

$$v = \frac{\Delta s}{\Delta t} = r\frac{\Delta\theta}{\Delta t} = r\omega \qquad (2)$$

We define the instantaneous angular velocity as the very small angle $\boldsymbol{\Delta\theta}$, through which the object turns in the very short time interval Δt :

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt} \qquad (3)$$

The instantaneous linear velocity

$$v = \lim_{\Delta t \to 0} \frac{\Delta\theta . r}{\Delta t} = r\frac{d\theta}{dt} \qquad (4)$$

The angular velocity is generally specified in radians per second (rad / s) whereas the instantaneous linear velocity is expressed in (m / s).

4.2.2 Periodic time and frequency

The period *T* is the time needed for the object to make one complete revolution. During this time, the object travels a distance equal to the circumference of the circle. The frequency *f* is referred to as the number of revolutions made by an object in one second. The unit of frequency is **Hertz**.

$$f = \frac{1}{T} \qquad (5)$$

The object's angular speed is then represented by

$$\omega = \frac{2\pi}{T} = 2\pi f \qquad (6)$$

4.2.3 The average angular acceleration

The average angular acceleration is defined as the change in angular velocity divided by the time required to make this change:

$$\beta = \frac{\Delta\omega}{\Delta t} = \frac{\omega - \omega_0}{t - t_0} \qquad (7)$$

The average linear acceleration

$$a = \frac{\Delta s}{\Delta t} = \frac{r\Delta\omega}{\Delta t} = r\beta \qquad (8)$$

The instantaneous angular acceleration is

$$\beta = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt} \qquad (9)$$

The instantaneous linear acceleration

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = r\frac{\Delta \omega}{\Delta t} = r\frac{d\omega}{dt} \qquad (10)$$

The angular acceleration is generally specified in radians per second (rad / s^2) whereas the instantaneous linear acceleration is expressed in (m / s^2).

Application activity 4.2

1. A ball at the end of a string is revolving uniformly in a horizontal circle of radius 2 meters at constant angular speed 10 rad/s. Determine the magnitude of the linear velocity of a point located :

   a) 0.5 meters from the center

   b) 1 meter from the center

   c) 2 meters from the center

2. The blades in a blender rotate at a rate of 5000 revolution per minute. Determine the magnitude of the linear velocity :

   a) a point located 5 cm from the center

   b) a point located 10 cm from the center

3. A point on the edge of a wheel 30 cm in radius, around a circle at constant speed 10 meters/second.

   What is the magnitude of the angular velocity?

4. The angular speed of wheel 20 cm in radians is 120 revolutions per minute. What is the distance if the car travels in 10 seconds.

4.3 Acceleration in circular motion

Activity 4.4

A car executing a turn, after a certain speed limit, a car will start drifting.

a) Why at that limitation of the speed the car start travelling? Explain your reasoning

4.3.1. Tangential and Centripetal acceleration

In the circular motion, the tangential acceleration a_T always points in the direction tangent to the circle and changes the rate of velocity in terms of magnitude because their vectors are always in the same or opposite direction. The tangential acceleration can be considered as the linear acceleration. The centripetal acceleration (**normal acceleration** or **radial acceleration**) a_N changes the velocity in terms of direction and its vector is perpendicularly directed inward the circle.

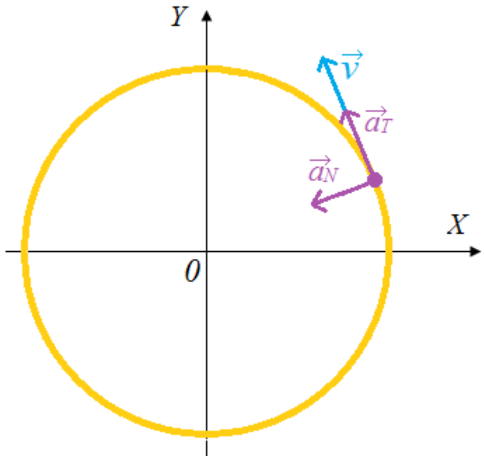


Figure 4.5: Tangential and centripetal acceleration

Since the velocity is constant, the tangential component of acceleration doesn't exist in UCM:

$$a_T = \frac{dv}{dt} = 0$$

Consequently, the tangential component of the acceleration is also zero. Only, the normal component of the acceleration exists in UCM. Thus, the velocity v changes in direction but not in magnitude. The figure below shows the representation of the angular velocity $\vec{\omega}$ using a distant reference frame $\vec{i}, \vec{j}, \vec{k}$.

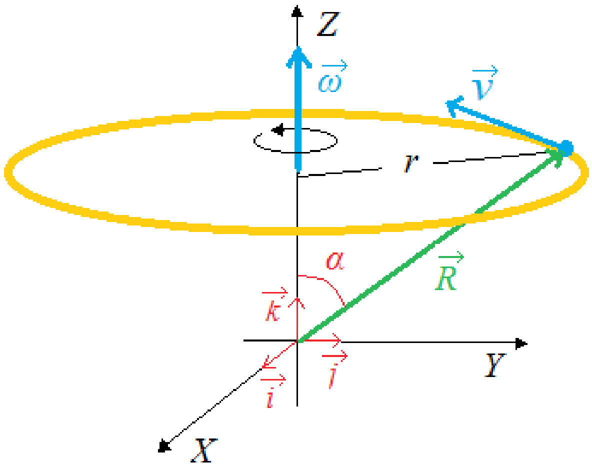


Figure 4.6: Angular velocity

The centripetal component of the acceleration is directed along the radius. From the above figure we can notice that $r = R\sin\alpha$.

$$v = r\omega = \omega R\sin\alpha$$

This relation indicates that the vector $\vec{v}$ can be expressed in the vector form by the equation:

$$\vec{v} = \vec{\omega}\times\vec{R} \qquad (1)$$

It follows that

$$a_N = \frac{dv}{dt} = \omega\sin\alpha\left(\frac{dR}{dt}\right)$$

$$\Rightarrow \vec{a}_N = \frac{d\vec{v}}{dt} = \vec{\omega}\times\left(\frac{d\vec{r}}{dt}\right)$$

$$\vec{a}_N = \vec{\omega}\times\vec{v} \qquad (2)$$

Introducing the equation (1) into (2)

$$\vec{a}_N = \vec{\omega}\times\vec{v} = \vec{\omega}\times\left(\vec{\omega}\times\vec{R}\right) \qquad (3)$$

The magnitude of the centripetal acceleration is given by

$$a_N = \omega v\sin\alpha$$

Since $\vec{\omega}\perp\vec{v}$, its magnitude is

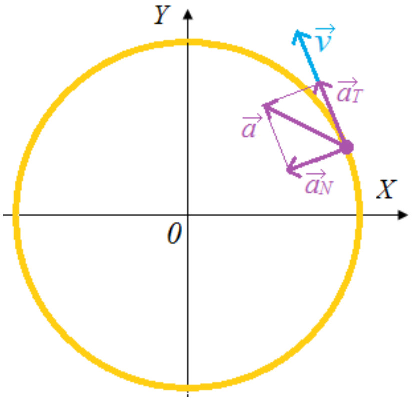
$$a_N = \omega v$$

As $v = r\omega$, we also find that

$$a_N = \frac{v^2}{r} = r\omega^2 \qquad (4)$$

4.3.2. Acceleration in a non-uniform circular motion

Circular motion at a constant speed occurs when the acceleration of the object is directed toward the centre of the circle (Only the centripetal component is available). If the acceleration is not directed toward the centre but is at an angle, as shown in figure below, the acceleration has two components; the centripetal and the tangential component.



The tangential component of the acceleration is the rate that changes the magnitude of the velocity

$$a_T = \frac{dv}{dt} = \frac{d(r\omega)}{dt} = r\frac{d\omega}{dt} = r\beta$$

The centripetal acceleration arises from the change in direction of the velocity and, as we have seen, is given by

$$a_N = r\omega^2 = v\omega = \frac{v^2}{r}$$

If the tangential acceleration is in the direction of motion i.e. parallel to $\vec{v}$, the speed is increasing and if it is antiparallel to $\vec{v}$ is the speed is decreasing. In either case, $\vec{a}_T$ and $\vec{a}_N$ are always perpendicular to each other; and their directions change continually as the object moves along its circular path. The total vector acceleration is the sum of these two:

$$\vec{a} = \vec{a}_T + \vec{a}_N$$

the magnitude of $\vec{a}$ at any moment is

$$a = \sqrt{a_N^2 + a_T^2}$$

4.3.3. Distance time graph of circular motion

When an object executes a circular motion of constant radius *R*, its projection on an axis executes a motion of amplitude ***a*** that repeats itself back and forth, over the same path.

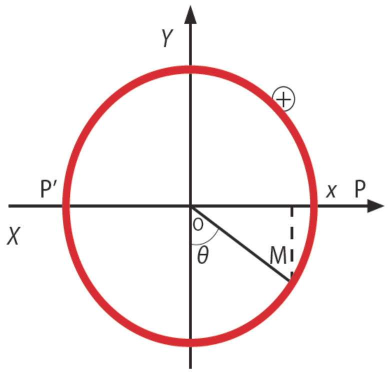


Figure 4.7: A circular motion can be projected on an axis

When M executes a uniform circular motion, its projection on X-axis executes a back and forth motion between positions P and P' about O.

Considering the displacement and the time, we find the following graph

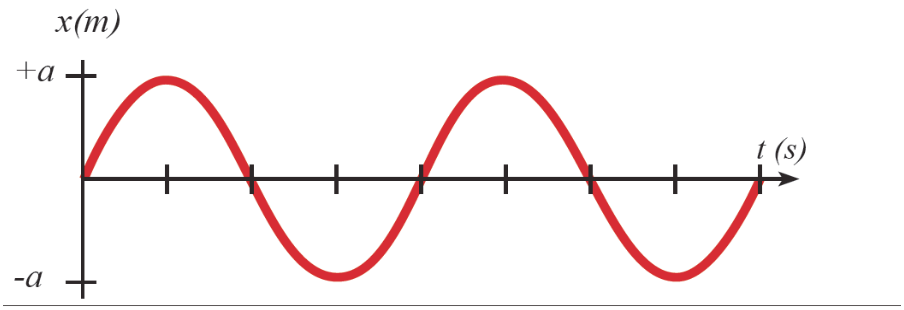


Figure 4.8: Displacement –time graph

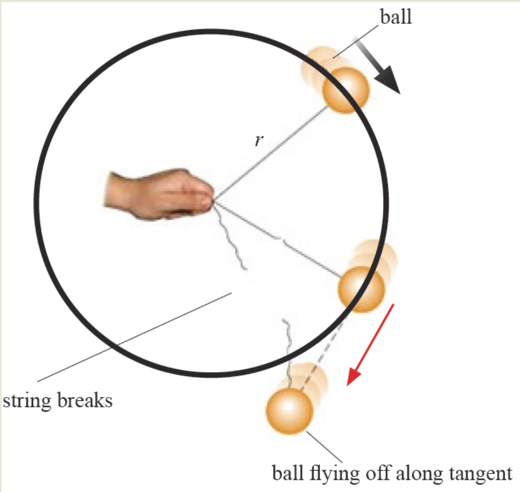
Application activity 4.3

1. A ball is attached to a string that is 1.5m long. It is spun so that it completes two full rotations every second. What is the centripetal acceleration felt by the ball?
2. Imagine a car driving over a hill at a constant speed. Once the car has reached the apex of the hill, what is the direction of the acceleration?

4.4 Centripetal force

Activity 4.4

Observe the following figure and answer the question below:



What would happen when a ball is attached to a string and is swung round in horizontal circle? Explain your reasoning

If you try to move / run in a circular path, you will finally notice that you keep moving in a circle even when you try to stop. There is a force that keeps you more in a circular path called **centripetal force**. Since a body moving in a circle (or a circular arc) is accelerating, it follows from Newton's first law of motion that there must be force acting on it to cause the acceleration.

This force, like the acceleration, will also be directed toward the centre and is called the *centripetal force*. The value *F* of the centripetal force is given by Newton's second law, that is:

$$F = m\gamma = \frac{mv^2}{r}$$

Where m is the mass of the body and v is its speed in circular path of radius R. If the angular velocity of the body is ω, we can also say, since $V = R\omega$,

$$\boldsymbol{F = mR\omega^2}$$

Example

The spin-drier of a washing machine revolving at 900 revolutions per minute shows down uniformly to 300 revolutions per minute while making 50 revolutions. Find (a) the angular acceleration and (b) the time required to turn through these 50 revolutions.

Solution

$$900\, rev/\min = 15.0\, rev/s = 30.0\pi\, rad/s\ and\ 300\, rev/\min = 5.0\, rev/s = 10.0\pi\, rad/s$$

(a) From $\omega^2 = \omega_0^2 + 2\alpha\theta$,we have

$$\alpha = \frac{\omega^2 - \omega_0^2}{2\theta} = \frac{(10.0\pi\, rad/s)^2 - (30.0\pi\, rad/s)^2}{2(100.0\pi\, rad/s)} = -4.0\pi\, rad/s^2$$

(b) Because $\omega_{av} = \frac{1}{2}(\omega + \omega_0) = 20.0\pi\, rad/s, \theta = \omega_{av} t$ yields

$$t = \frac{\theta}{\omega_{av}} = \frac{100.0\pi\, rad/s}{20.0\pi\, rad/s} = 5.0\, s$$

Application activity 4.4

1. A 3.0 kg mass is tied to a rope and swung in a horizontal circle. If the velocity of the mass is 4.0 m/s and the radius of the circle is 0.75 m, what is the centripetal force and centripetal acceleration of the mass?
2. A 200-gram ball, attached to the end of a cord, is revolved in a horizontal circle with an angular speed of 5 rad s-1. If cord's length is 60 cm, what is the centripetal force?
3. A student of mass 50kg decides to go on the ride. The coefficient of static friction between the student and wall is 0.8. If the diameter of the ride is 10m, what is the maximum period of the ride's rotation that will keep the student pinned to the wall once the floor drops? g =10m/s2

SKILLS LAB

Go on YouTube, watch video about "Trucks fail to Negotiate Dangerous Bend in Road". It is a social issue which relationship with Circular motion.

1. What did you see on the video and what happen?

2. If you are engineer, how you will solve this problem?

3. Brainstorm with your classmates about the property needed to Design a safety road by used scientific knowledge in Circular motion.

End unit assessment 4

1. Why do we need a force to keep a body moving uniformly along a circular path?
2. When an object moves in a circular path the net force is called? Explain your answer
3. When a particle moves in a circle with constant speed its acceleration is? Explain your reason
4. Is acceleration constant in circular motion? Defend your reasoning
5. A hot wheels track has a vertical loop with a radius of 20 cm.

   a) What is the minimum speed the car can have at the highest point without falling off of the track?

   b) If the actual speed is 1.8 m/s, what is the normal force? (use m=20 grams)
6. A 1200 kg car drives at a constant speed of 14 m/s around a circular track (r=80.0 m).

   a) What is the size of the net force acting on the car?

   b) What is the physical agent providing that force?

   c) What is the maximum frictional force that can act on the tires if the static coefficient

   of friction is 0.30? Will the car's tires start slide? If not, how fast can the car move before it does start sliding?
7. A0.45kg ball, attached to the end of a horizontal cord, is rotated in a circle of radius 1.3m on a friction less horizontal surface. If the cord will break when the tension in it exceeds 75N, what is the maximum speed the ball can have?

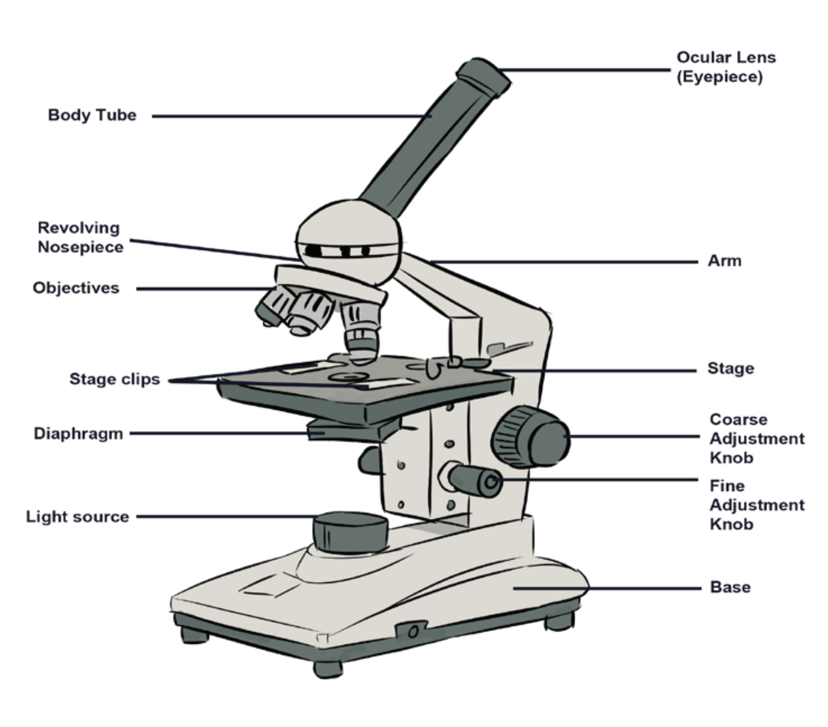
UNIT 5: CELL STRUCTURE

Key unit competence

Distinguish between the types of microscopy and their principle uses and relate the structure of cell to their functions.

Introductory Activity

Carefully, analyze the following diagram and the related questions



This is one of materials used in Biology.

a) Have you ever seen and manipulated it?

b) Observe the parts of the material, discuss and group them into the following:

i. Suporting parts

ii. Magnifying parts

iii. Adjusting parts

iv. Lighting parts

c) Point out scientific activities that require the use of this material in biology

5.1. Cell theory and microscopes

Activity 5.1

Using your knowledge acquired from ordinary level, textbooks and internet search

Explain:

a) The meaning of cell theory

b) The functions of the components of the compound light microscope

5.1.1. Cell theory

Cytology is the study of the structure and function of cells. A **Cell** is the basic unit of life surrounded by a cell membrane and containing organelles. All living organisms are made of cells and nothing less than a cell can truly be said to be alive. The word cell comes from the Latin *cellula,* meaning a small room or cubicle, and was first used by **Robert Hooke** in his book *Micrographia*, published in 1665. Hooke was observing slides of cork taken from the bark of an Oak tree under the compound microscope. He decided that the slides were made up of a lot of many small chambers that he called cells that range in size are from 1μm – 1mm.

Living organisms are classified into **unicellular organisms** made by only one cell, such as bacteria, whereas animals and plants are composed of many millions of cells built into tissues and organs. They are called **multicellular organisms**. In a multicellular organism, cells divide and thereafter they undergo differentiation or specialisation for specific functions.

In biology, the historic scientific *theory of cells is called cell theory*. The cell theory states that all living organisms are made up of *cells*, and *cells* are the basic unit of structure function in all living organisms. The main principles of cell theory is that all known living organisms are made up of one or more cells, all cells come from pre-existing cells by division and cells contain the hereditary information that is passed from cell to cell during cell division.

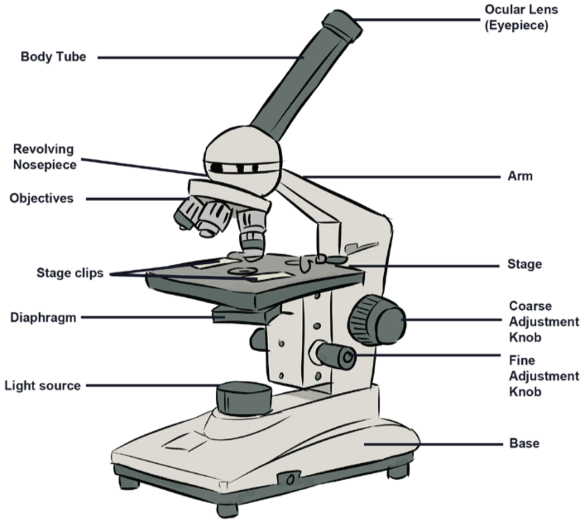
5.1.2. Microscopes: Compound-light microscope and Electron microscopes

Microscopy is the technical field of using microscopes to view objects and areas of objects that cannot be seen with the naked eye. The microscope was created by Zacharias Janssen in the late 16th century.

Prior to the invention of the microscope, the details of objects on slides were limited. Single microscopes were similar to using a magnifying glass such as hand lens. The invention of the light microscope in the 17th century by Antony van Leeuwenhoek made cells visible for the first time and, for hundreds of years afterwards. Electron microscope invented in the 1930s enables the researchers to see very small organelles which cannot be seen by using light microscopes. The purpose of the use of a microscope is to magnify small objects such as cells or to magnify the fine details of a larger object in order to examine minute specimens that cannot be seen by the naked eye.

a) Compound Light Microscope

The optical microscope, often referred to as light microscope is a type of microscope which uses visible light and a system of lenses to magnify images of small samples.



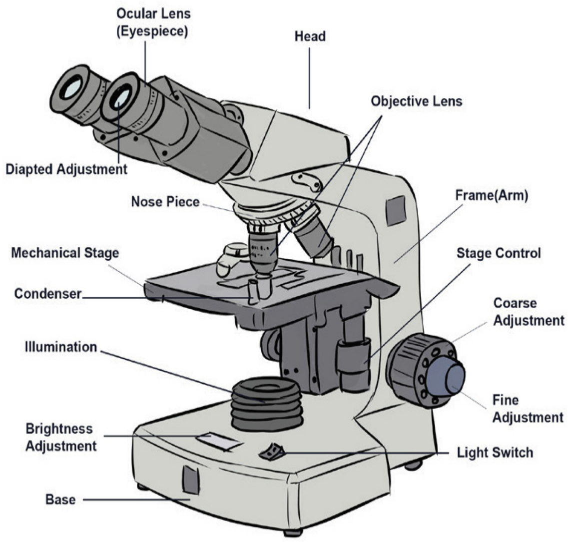


Figure 5.1. Monocular light microscope (1) and Binocular light microscope (2)

The parts of light microscope and their roles:

- **Base:** supports and stabilizes the microscope on the table or any other working place
- **Light source:** It is made by lamp or mirror which provides light for viewing the slide.
- **Stage:** is a platform used to hold the specimen in position during observation.
- **Stage clips:** are pliers used to fix and hold tightly the slide on stage.
- **Arm:** supports the body tube of microscope
- **Body tube**: maintains the proper distance between the objective and ocular lenses
- **Arm:** used for holding when carrying the microscope and it holds the body tube which bears the lenses.
- **Coarse focus adjustment**: moves stage up and down a large amount for coarse focus
- **Fine focus adjustment**: moves stage up and down a tiny amount for fine focus
- **Objective lenses**: focuses and magnifies light coming through the slide
- **Revolving nosepiece**: rotates to allow use of different power objectives
- **Slide:** is a transparent pane on which a specimen is placed.

- **Eye piece/ocular lens**: magnifies image produced by objective lens
- **Condenser**: It will gather the light from the illuminator and focus it on the specimen lying on the stage. The function of the condenser is to focus the light rays from the light source onto the specimen.
- **Iris diaphragm lever**: This allows the amount of light passing through the condenser to be regulated to see the object.

All parts of a microscope work together to magnify a specimen to be observed. Light from the source is focused on the specimen by the **condenser** lens. It then enters the **objective** lens, where it is magnified to produce a **real image**. The real image is magnified again by the **ocular** lens to produce a **virtual image** that is seen by the eye.

Advantages and limitations of the light microscope

Magnification: Most light microscopes can magnify a specimens up to a maximum of X1500.

Resolution: It is the degree at which it is possible to distinguish clearly between two objects that are very close together. It is the smallest distance apart that two separate objects can be seen clearly as two objects. The resolution for the:

- Human eye is 100*μ*.
- Light microscope is 200 nm
- Electron microscope is 0.20 nm.

The maximum resolution of the light microscope is 200 nm. This means that if two objects are closer together than 200 nm, they will be seen as one object. The light microscopes are used widely in education, laboratory analysis and research. But because they do not have high resolution, they cannot give detailed information about internal cell structure.

Specimens: a wide range of specimens are viewed using the light microscope. These include: unicellular organisms, small sections from large plants and animals, and smear preparation of blood or cheek cells.

Preparation of specimens for the light microscope

A lot of biological materials are not coloured, so you cannot see details. Also, some material distorts when you try to cut it into thin sections. Preparation of slides to overcome these problems involves the following steps:

a) **Staining:** Coloured stains are chemicals that bind on or in the specimens. This allows the specimens to be seen. Some stains bind to specific cell structures. For example, acetic orcein stains DNA dark red, while gentian violet stains bacterial cell walls.

b) **Sectioning:** Specimens are embedded in wax, where thin sections are then cut without distorting the structure of the specimen. This is particularly useful for making sections of soft tissue, such as brain. Safety measures might be taken. Make sure that hands are washed with soap and warm water after theexperiment. Use a disinfectant to wipe down all surfaces where bacteria mayhave been deposited for example. Be sure that some substances and animalsmight be harmful to the life.

Measuring cells

Cells and organelles can be measured with a microscope by means of an eyepiece called graticule. This is a transparent scale, usually having 100 divisions (Figure 5.2, A). The eyepiece graticule is placed in the microscope eyepiece so that it can be seen at the same time as the object to be measured (Figure 5.2, B). At this figure (Figure 5.2, B), the cell lies between 40 and 60 on the scale, so that it measures 20 eyepiece units in diameter (60 – 40 = 20).

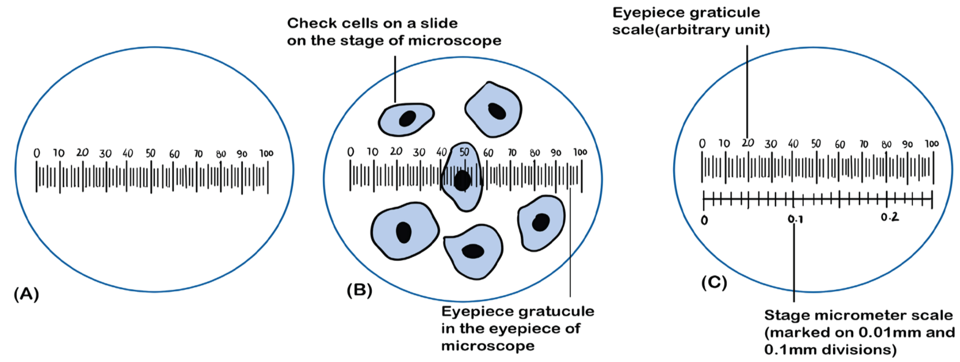


Figure 5.2. Measuring the length of cell using a graticule in a light microscope

Note that it is not possible to know the actual size of the eyepiece units until the eyepiece graticule scale is calibrated. To calibrate the eyepiece graticule scale, a miniature transparent ruler called a stage micrometre scale is placed on the microscope stage and is brought into focus. This scale may be fixed onto a glass slide or printed on a transparent film. It commonly has subdivisions of 0.1 and 0.01 mm. The images of the two scales can then be superimposed (Figure 5.2, C). If in the eyepiece graticule, 100 units measure 0.25 mm, the value of each eyepiece unit equals $\frac{0.25}{100} = 0.0025\,mm$

By converting mm to µm, the value of eyepiece equal $\frac{(0.25 \times 1000)}{100} = 2.5\,\mu m$

The diameter of the cell shown superimposed (Figure 5.2, B) measures 20 eyepiece units. Its actual diameter equals 20 × 2.5 µm = 50 µm. This diameter is greater than that of many human cells because the cell is a flattened epithelial cell.

There is a relationship between the actual size, magnification and image size, where:

Actual size = image size / magnification.

Magnification = image size / actual size.

Image size = Magnification x actual size.

c) Electron microscope

An electron microscopes use a beam of accelerated electrons as a source of illumination. Electron beams have a much smaller wave length of 0.004 nm, 100 000 times shorter than light wavelength, and therefore have greater resolving powers and can produce higher effective magnifications than light microscopes. Electron microscopes are used to study the details of internal structures (the ultrastructures) of cells. Most modern TEMs can distinguish objects as small as 0.2nm. This means that they can produce clear images magnified up to 500,000 times greater than that of the human eye.

There are two types of electron microscopes:

- Transmission electron microscope (TEM).
- Scanning electron microscope (SEM)

a) Transmission electron microscope (TEM)

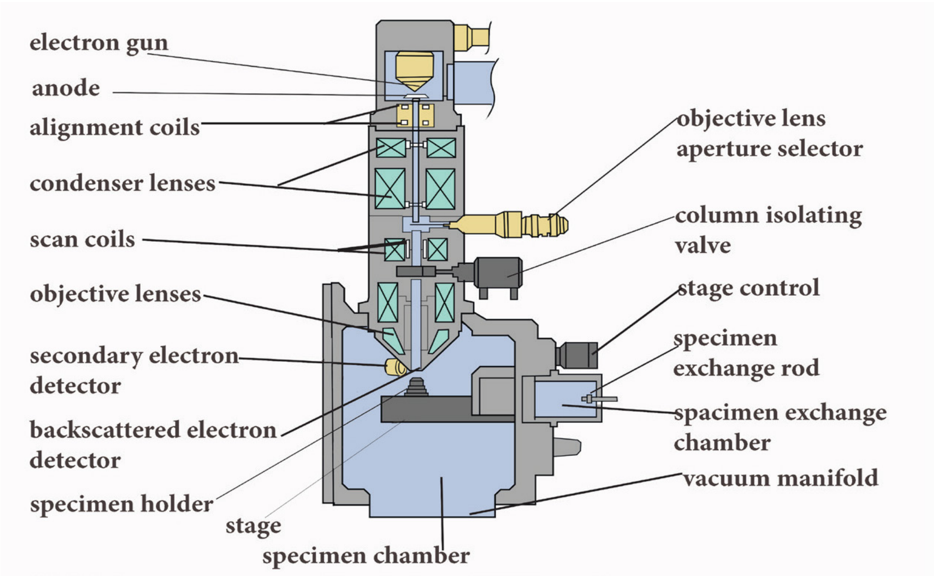


Figure 5.3 Transmission electron microscope

- The electron beam passes through a very thin prepared sample.
- Electrons pass through the denser parts of the sample less easily, so giving some contrast.
- The final image produced is two-dimensional.
- The magnification possible with a TEM is X500 000.

b) Scanning electron microscope (SEM)

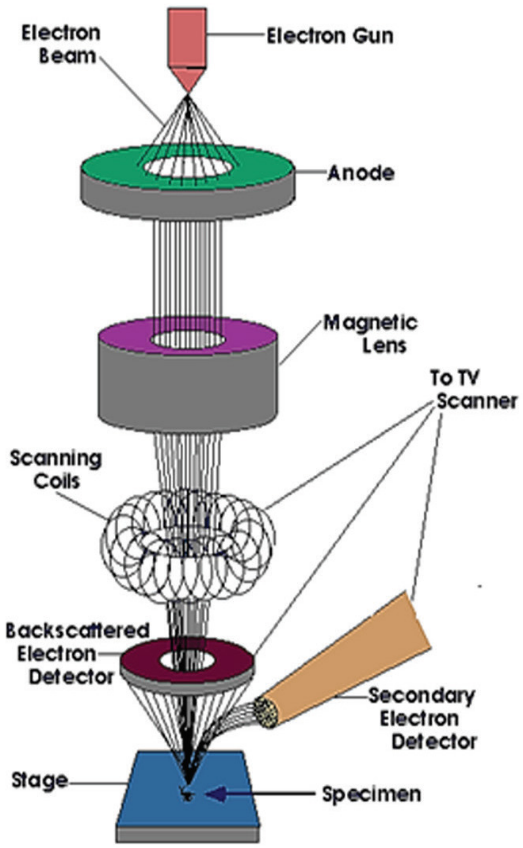


Figure 5.4 Image of Scanning Electron Microscope (SEM)

- The electron beam is directed onto a sample. Electrons do not pass through the specimen.
- They are bounced off the sample.
- The final image produced is a three-dimensional.
- The magnification possible with an SEM is about X100 000.

Advantages and disadvantages of the electron microscope

a) Advantages of electron microscope

Light microscope has a higher resolution and are therefore able of a higher magnification estimated up to 2000 X more than in the light microscope. Electron microscopes therefore allow for the visualization of too small structures, such as cell organelles that would normally be not visible by optical microscopy. The SEM produces a 3D images that can reveal the detail of cellular and tissue arrangement. This is not possible by using light microscopes.

b) Disadvantages of electron microscope

Despite the advantages, electron microscope presents a number of disadvantages and limitations.

- These type of microscope are extremely expensive and the maintenance costs are high.
- Samples must be completely dry so that it is impossible to observe living specimens and moving specimens (they are dead).
- It is not possible to observe colors because electrons do not possess a color. The image is only black-white images/ grey images.
- The energy of the electron beam is very high, the sample is therefore exposed to high radiation, and therefore not able to live.
- The space requirements are high, so that they may need a whole room.
- Electron beams are deflected by molecules in air, so samples have to be placed in a vacuum.

Application activity 5.1

1. What is the importance of a light microscope?
2. How can you apply microscope technique rules?
3. Discuss the advantages and disadvantages (limitations) of an electron microscope.
4. Discuss the advantages and disadvantages of the types of electron microscopes in medicine and biology research.
5. Make a comparative study between light and electron microscope focussing on the advantages of each type of microscope.

5.2. Eukaryotic and prokaryotic cell

Activity 5.2

Under microscope, observe mounted slides of bacteria, and plant cells. Draw and label the parts that are common in both plant and bacterial specimens

Eukaryotic cells contain membrane-bound organelles, including a true nucleus enclosed in a nuclear envelope. They include cells of: plants, animals, fungi and protoctista.

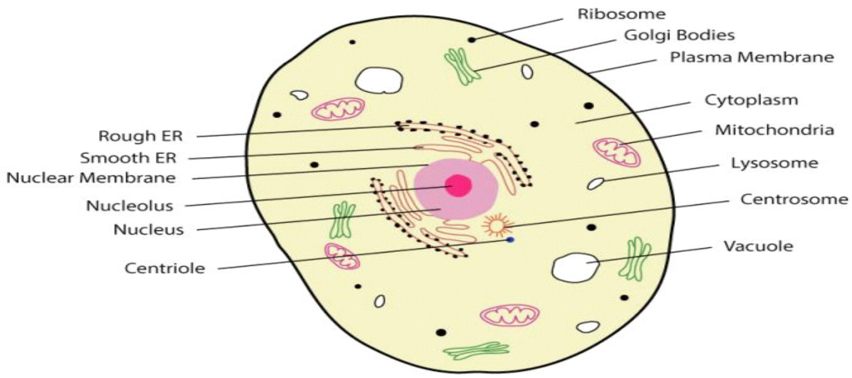


Figure 5.4: Eukaryotic cell

Prokaryotes are organisms having cells with no true nuclear envelope. Prokaryotic cells do not contain a nucleus or any other membrane-bound organelle. Prokaryotes include bacteria and blue-green algae. They make up the **monera** kingdom.

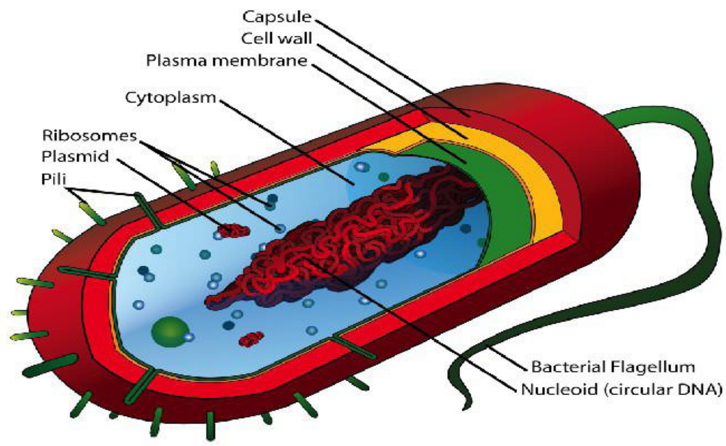
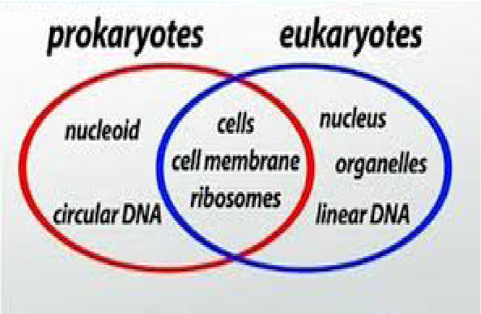


Figure 5.5: prokaryotic cell

Comparison between prokaryotic and eukaryotic cells



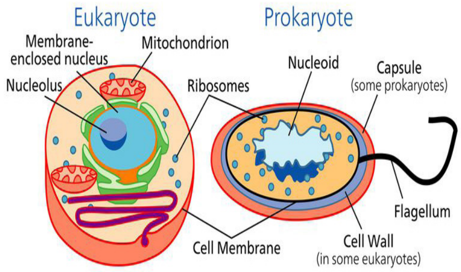


Figure 5.6: comparison between prokaryotic and eukaryotic cells.

Table 5.3. Comparison between prokaryotic and eukaryotic cells

Criterion	**Prokaryote**	**Eukaryotic Plant cell**	**Eukaryotic Animal cell**
Cell membrane	Present	Present	Present
Cell wall	Present	Present	Absent
Nuclear envelope	Absent	Present	Present
Chromosome	Circular	Threadlike	Threadlike
Mitochondria	Absent	Present	Present
Chloroplast	Absent	Present	Absent
Endoplasmic reticulum	Absent	Present	Present
Golgi body	Absent	Present	Present
Ribosomes	Small (70S)	Big (80S)	Big (80S)
Vacuole	Absent	Big	Absent
Lysosomes	Absent	Present	Present
Centrioles	Absent	Absent	Always present

Application activity 5.2

1. Define a prokaryote and eukaryote.
2. In a form of a table differentiate prokaryotic cells from eukaryotic cells.

5.3. Description of plant and animal cell

Activity 5.3

Observe two electron photographs, one containing a plant cell another an animal cell.Record a description of their features, such as shape and internal parts.

5.3.1. Structure of animal and plant cells

When viewed under light microscope, the most obvious features observed are the very large nucleus and a clear cytoplasm surrounded by a cell membrane. However, under electron microscope, it is possible to identify a range of organelles in plant and animal cells.

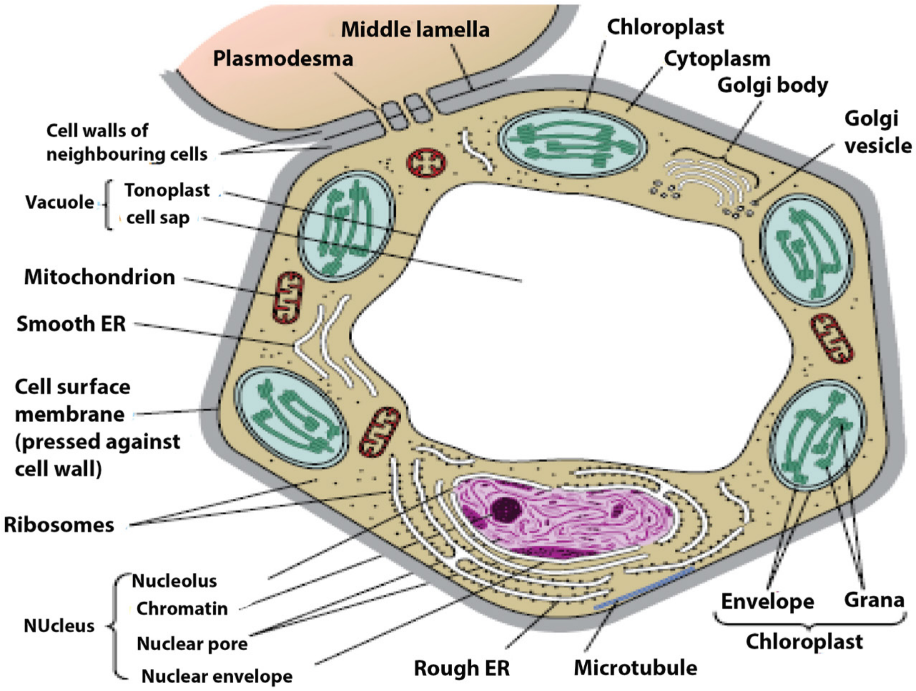


Figure 5.7: Ultrastructure of a typical plant cell (Adapted from Cambridge International AS and A Level Biology Course Book Fourth Edition)

Ultrastructure of a plant cell contains different parts like:

Cell wall, cell membrane, cytoplasm with organelles. Organelles found in the cytoplasm of a plant cell include: chloroplast, mitochondria, Golgi apparatus, endoplasmic reticulum, ribosomes, big central vacuole, and the nucleus which contains chromosomes. The plant cell also has a regular shape, with a relatively bigger size than animal cell.

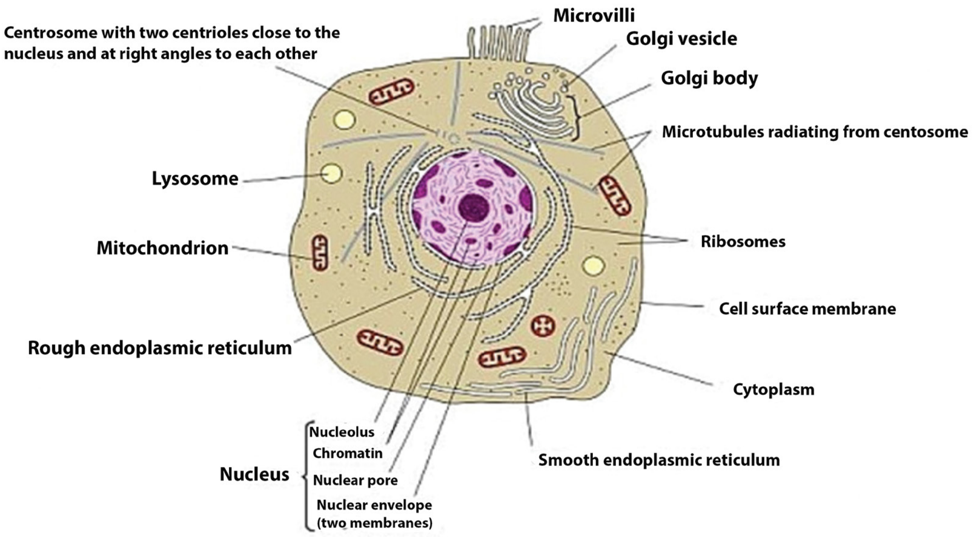


Figure 5.8: A generalized animal and cells showing structures visible under electron microscope. Adapted from Cambridge International AS and A Level Biology Course Book Fourth Edition.

Ultrastructure of an animal cell contains different parts like:

Cell membrane, cytoplasm with organelles. Organelles found in the cytoplasm of an animal cell include: mitochondria, Golgi apparatus, endoplasmic reticulum, centrioles, ribosomes, small or absent vacuole, and the nucleus which contains chromosomes. The animal cell also has irregular shape, with a relatively smaller size than a plant cell.

5.3.2. Functions of cell organelles

The previous sections described the structures of plant and animal cells. This unit will explain the function of each part of both animal cell and plant cell.

1. Organelles surrounded by membranes

a) Nucleus

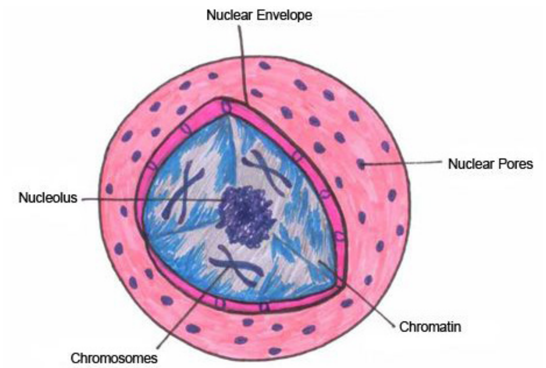


Figure 5.9. Cell nucleus

The cell nucleus contains nearly all the cell's DNA with the coded instructions for making proteins and other important molecules. The nucleus is surrounded by **a double nuclear envelope**, which allow materials to move into and out of the nucleus through nuclear pores. The granules found in the nucleus are called **chromatin** which consist of DNA bound to protein. When a cell divides, the chromatin condenses into chromosomes containing the genetic information that is passed from parents to their offspring. The nucleus contains a dense spherical structure called **nucleolus** in which assembly of ribosomes begins. The nucleus controls all activities of the cell.

b) Endoplasmic reticulum (ER)

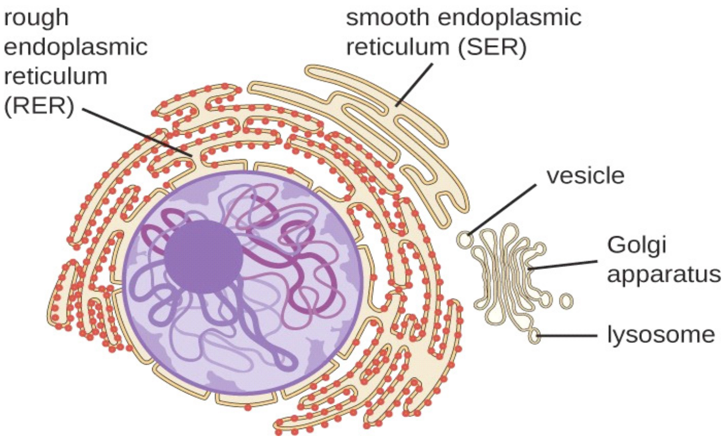


Figure 5.10. Endoplasmic reticulum

The ER consists of a series of flattened membrane-bound sacs called ***cisternae.*** The rough ER is surrounded with ribosomes. The rough ER transports proteins made on attached ribosomes. The smooth ER does not have ribosomes, and it involves in making lipids that the cell needs.

c) Golgi apparatus

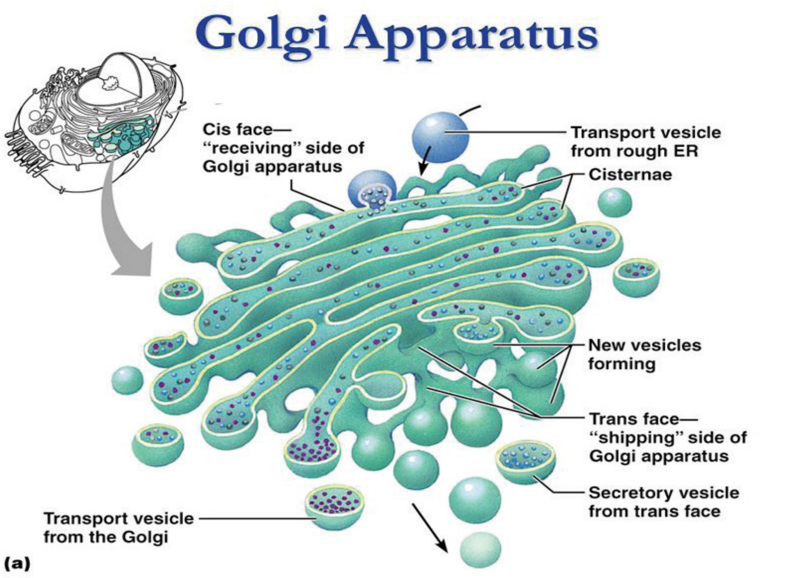


Figure 5.11.Golgi apparatus.

The Golgi apparatus is a stack of membrane-bound, flattened sacs, which receives proteins from the ER and modify them. It may add sugar molecules to them. The Golgi apparatus then packages the modified substances into vesicles that can be transported to their final destinations throughout the cell or outside of the cell.

d) Mitochondria

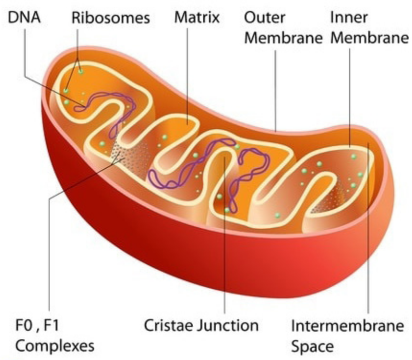


Figure 5.12.Mitochondrion.

Mitochondrion have two membranes separated by a fluid-filled space. The inner membrane is highly folded to form **cristae.** The central part of the mitochondrion is called **matrix.** The mitochondria are the site where the process of cell respiration takes place to produce **Adenosine triphosphate (ATP),** a universal energy carrier to be used in cell metabolism.

e) Chloroplasts

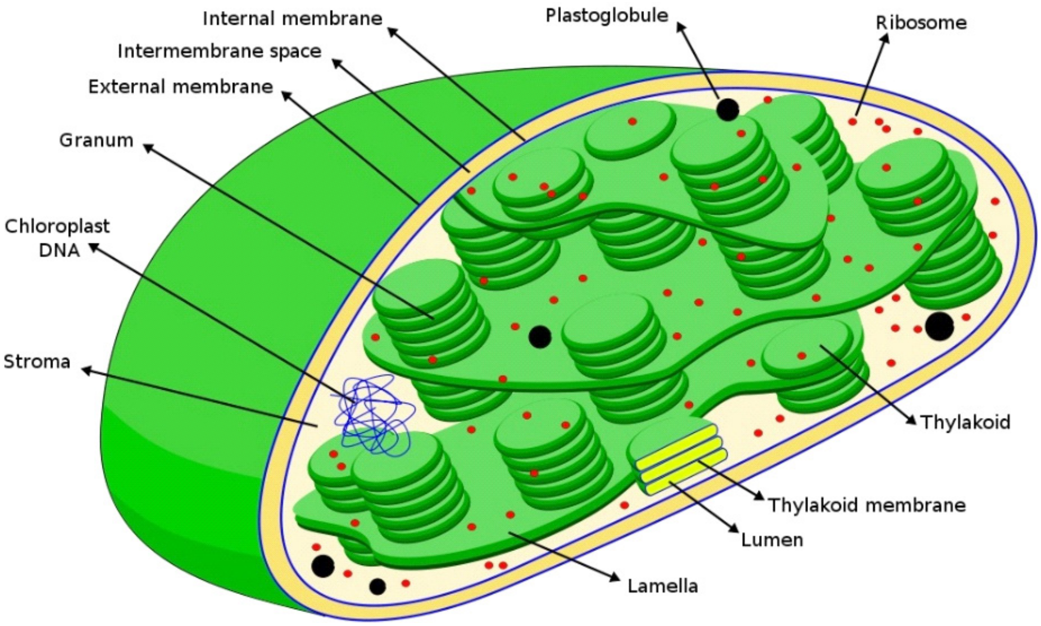


Figure 5.13: Chloroplast

Chloroplasts are the site of **photosynthesis** in plant cells. These are found in plant cells and in cells of some protoctists. They also have two membranes separated by a fluid-filled space. The inner membrane is continuous, with **thylakoids.** A stalk of thylakoids is called a **granum (plural: grana)**. Chlorophyll molecules are present on the thylakoid membranes.

f) Lysosomes

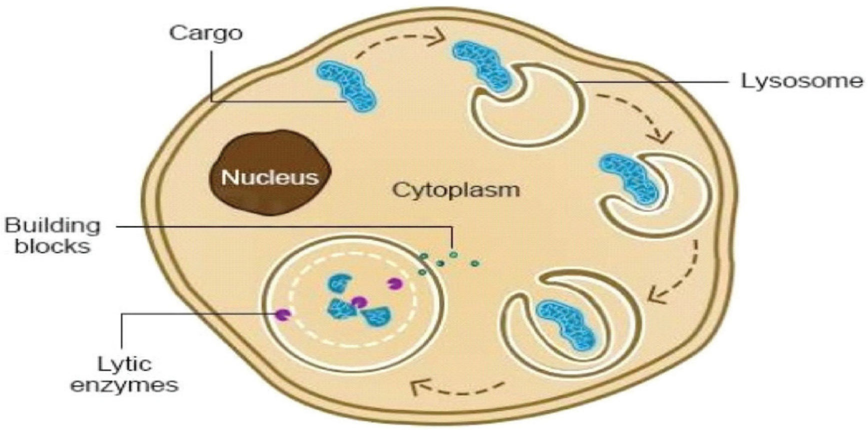


Figure 5.14: Lysosome

These are spherical sacs surrounded by a single membrane. They contain powerful **digestive enzymes.** Their role is to break down materials such as white blood cells, and destroy invalid microorganisms. In acrosome, lysosomes help the sperm to penetrate the egg by breaking down the material surrounding the egg.

Organelles without surrounding membranes

a) Ribosomes

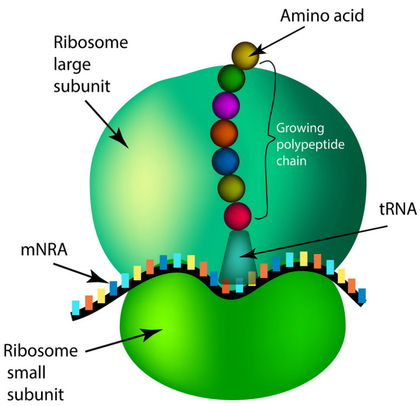


Figure 5.15: Ribosome

Ribosomes are the site of protein synthesis in the cell. Some are in cytoplasm; others are bound to ER. Ribosomes consist of two major components (two subunits): the small ribosomal subunit, which reads the RNA, and the large subunit, which joins amino acids to form a polypeptide chain. Each subunit is composed of one or more ribosomal RNA (rRNA) molecules and a variety of ribosomal proteins (r-protein). Ribosomes act as an assembly line where coded information (mRNA) from the nucleus is used to assemble proteins from amino acids. Cells that are more active in protein synthesis are often packed with ribosomes.

b) Centrioles

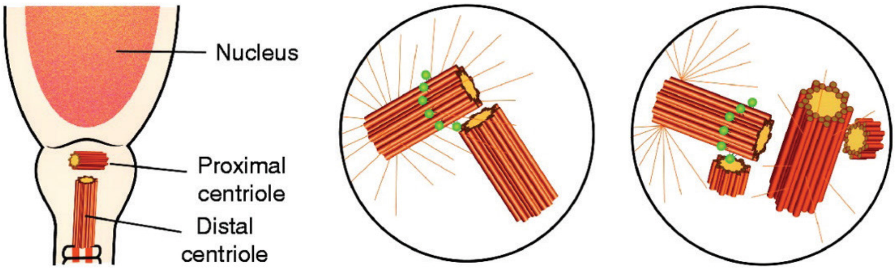


Figure 5.16.Centrioles. (Adapted from: Heide Schatten and Qing-Yuan Sun1)

Centrioles are small tubes of protein fibres (microtubules), which are involved in animal cell division. They form fibres, known as **spindle,** which move chromosomes during nuclear division.

c) Vacuole

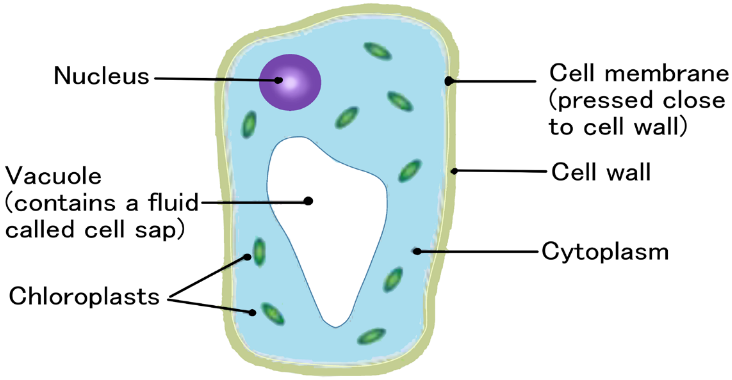


Figure 5.17: Plant cell with Vacuole

A vacuole is a saclike structure that is used to store materials such as water, salts, proteins, and carbohydrates. In many plant cells there is a single, and large central vacuole filled with liquid. The pressure of central vacuole in this cells makes it possible for plants to support heavy structures such as leaves and flowers. Some animals and some unicellular organisms contain

contractile vacuoles which contract rhythmically to pump excess water out of the cell.

d) Cytoskeleton

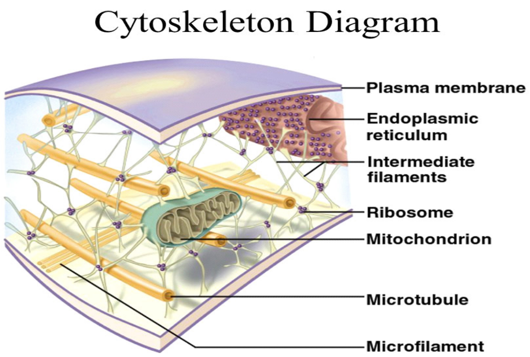


Figure 5.18: cytoskeleton

Cytoskeleton is a network of protein filaments that helps the cell to maintain its shape. It is also involved in movement. The main components of cytoskeleton are microfilaments made of a protein called **actin**, microtubules made of a protein called **tubulins**, and intermediate filaments.

Did you realize that a cell has many organelles with different functions? But all are important and work together for the survival of the cell. Likewise, in human society, we can work together in peace and harmony despite of the difference of our abilities, disabilities or physical appearance.

The structure of the cell membrane is based on **fluid mosaic model.** The term **fluid mosaic** is used to describe the molecular arrangements in membranes. The main features of the fluid mosaic model are:

- A bilayer of phospholipid molecules forming the basic structure.
- Many protein molecules floating in the phospholipid bilayer. Some are free, others are bound to other components or to structures within the cell.
- Some extrinsic proteins are partially embedded in the bilayer on the inside or the outside face while other intrinsic proteins are completely spanning the bilayer.

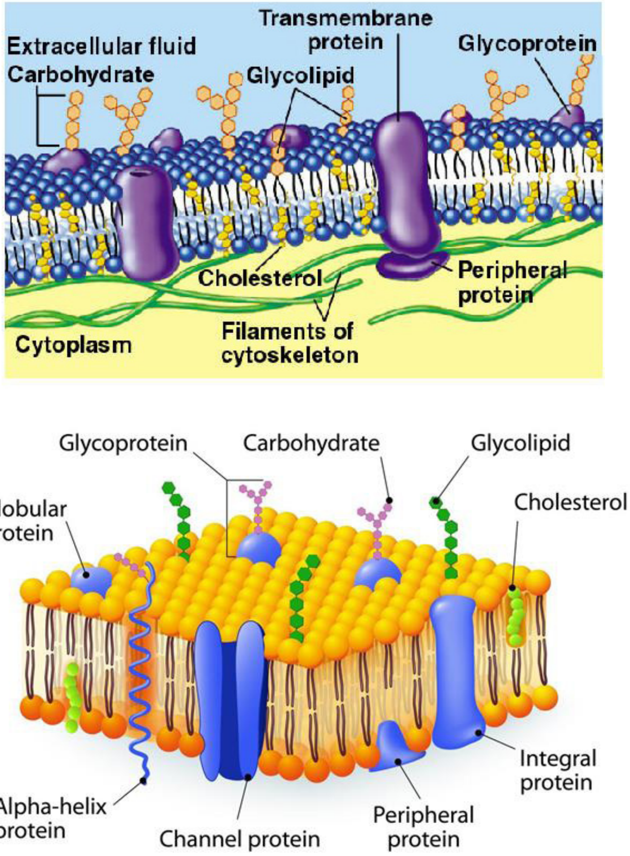


Figure 5.19. Fluid mosaic model of a cell membrane

The basic structure of phospholipids has two parts: **hydrophilic part** which means water loving and which consists of the phosphate head**,**and **hydrophobic part** which means water hating and which consist of fatty acids. If phospholipid molecules are completely surrounded by water, a bilayer can form phosphate heads on each side of the bilayer stick into water, while the hydrophobic fatty acid tails point towards each other.

Types of protein found in the cell membrane

Various types of proteins are found in the cell membrane. They include:

- **Carrier proteins:** They fix or attach molecules and facilitate them to cross through the cell membrane by active transport.
- **Channel proteins:** they act as pores by pumping substances and allow facilitated diffusion.
- **Receptors:** They act as receptors of enzymes and neurotransmitters
- **Glycoproteins:** They act as receptor proteins which recognize the substance to pass through the membrane

- **Integrated proteins:** They define the shape of the cell
- **Immune proteins (antigens):** found in the membrane on the red blood cell, they recognize the antibodies.

5.3.3. Roles of different components of cell membrane

a) Cholesterol

- Gives the membranes of some eukaryotic cells the mechanical stability.
- It fits between fatty acid tails and helps make the barrier more complete, so substances like water molecules and ions cannot pass easily and directly through the membrane.

b) Channel proteins

- Allow the movement of some substances across the membrane.
- Large molecules like glucose enter and leave the cell using these protein channels.

c) Carrier proteins

- Actively move some substances across the cell membrane. For example, magnesium and other mineral ions are actively pumped into the roots hair cells from the surrounding soil.
- Nitrate ions are actively transported into xylem vessels of plants

d) Receptor sites

- Allow hormones to bind with the cell so that a cell response can be carried out.
- Glycoproteins and glycolipids may be involved in cells signaling that they are self to allow recognition by the immune system.
- Some hormone receptors are glycoprotein and some are glycolipid.

e) Enzymes and coenzymes

- Some reactions including metabolic processes in photosynthesis take place in membranes of chloroplasts.
- Some stages of respiration take place in membranes of mitochondria, where **Enzymes** and **coenzymes** may be bound to these membranes.
- The more membrane there is, the more enzymes and coenzymes it can hold and this helps to explain why mitochondrial inner membranes are folded to form **cristae,** and why chloroplasts contain many stacks of membranes called **thylakoids.**

Properties of the cell membrane

- It is mainly made of lipids, proteins and carbohydrates.
- It is semi-permeable or partially permeable and allow some substances to pass through but prevents others to cross depending on their size, charges and polarity.
- It is positively charged outside and negatively charged inside and has a hydrophilic pole and a hydrophobic pole
- It is a bilayer, sensitive, flexible, has inorganic ions and its proteins and lipids may be mobile and contains different types of enzymes and coenzymes.
- It is perforated of pores and recognizes chemicals messengers including hormones and neurotransmitters.

Functions of a cell membrane

- The cell membrane acts as a selective barrier at the surface of the cell, and controls the exchange between the cell and its environment.
- The membrane proteins act as pores where chemicals pass through.
- **Glycocalyx** including glycoprotein and glycolipid are involved in the cell protection, the process by which cell adhesions are brought about and also in the uptake and entry of selected substances.

5.3.4. Comparison between animal and plant cell

By referring to the diagrams which show the structure of animal cell and plant cell, similarities and differences between animal cell and plant cell can be identified.

a) Similarities between animal cell and plant cell

- Both animal and plant cells have a cell membrane, a cytoplasm and a nucleus.
- Both animal and plant cells have a true nucleus bounded by an envelope.
- Both animal and plant cells have mitochondria, Golgi apparatus, Reticulum endoplasmic, lysosome, big ribosomes (80S), peroxisome, microtubules.
- The protoplasm is enveloped by a bounding cell membrane called **plasmalemma.**
- The protoplasm is composed of a dense round structure called nucleus which is surrounded by a less dense jelly-like cytoplasm.

- The cytoplasm contains numerous organelles such as mitochondria, Golgi bodies, secretory vacuoles, endoplasmic reticulum.
- Mitochondria appear as very small darkly staining, rod-like structures.
- Golgi bodies are semi-transparent irregular, and membrane bound structures.
- Vacuoles contain secretions, food- particles, or decomposing organic substances.
- Chemically, both plant and animal cells are made up of water (80-90%), proteins (7-13%), lipids (1-2%), carbohydrates (1-1.5%) and inorganic salts.
- The cytoplasmic organelles are suspended in a semi-fluid jelly matrix called **cytosol**.

b) Difference between animal and plant cells

Table 5.4: comparison between animal and plant cell

Criterion	Animal Cell	Plant Cell
Shape	Ovoid or spherical/ irregular	Polygon / regular
Plastids/ chloroplasts	Absent	Present
Centrioles	Present	Absent
Vacuole	Small or absent	Central /Big with a tonoplast
Cell wall	Absent	Present
Microvilli	Present	Absent
Plasmodesmata	Absent	Present
Size	Relatively small	Relatively large

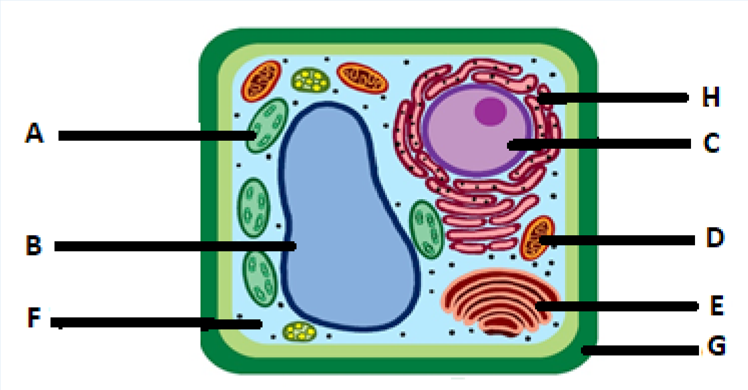
Application activity 5.3

1. Describe the structure of:

a) Animal cell

b) Plant cell

2. The diagram below shows the structures which would be visible in a plant cell examined under an electron microscope.



a) Identify the parts labelled in this plant cell and:

b) State one function for A, B, C, E,D,G, F, and H

c) Explain two functions of the cytoskeleton?

3. What structures do both animal and plant cells have in common?

4. Answer by true or false:

a) All organelles of a cell are well seen through a compound light microscope.

b) Chloroplasts are found in both animal and plant cells.

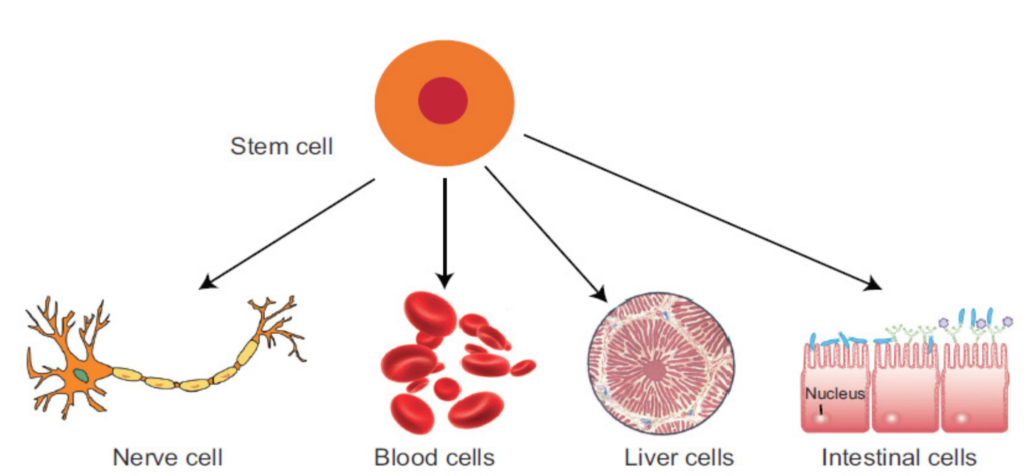
c) Mitochondria are found only in animal cells.

5. With your pencil, draw and show the full ultrastructure of both animal and plant cells.

5.4 Specialized cells

Activity 5.4

By analyzing the figure, identify the cells on the figure and explain the importance of those cells



5.4.1: Specialized animal cells and their functions

Differentiation refers to the changes occurring in cells of a multicellular organism so that each different type of **cell becomes specialized to perform a specific function**.

a) Red blood cells

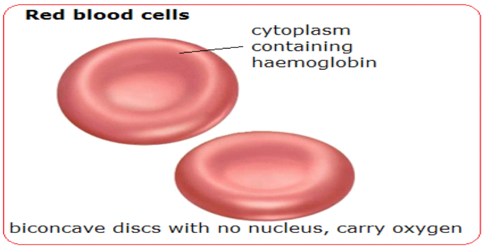


Figure 5.20: Red blood cell

All blood cells are produced from undifferentiated stem cells in the bone marrow but the cells destined to become **erythrocytes** (red blood cells) lose their nucleus, mitochondria, Golgi apparatus and rough endoplasmic reticulum. They are packed full of the protein called haemoglobin**.** The shape of this cells change so that they become biconcave discs**,** and they are then able to transport Oxygen in the body.

b) Sperm cell

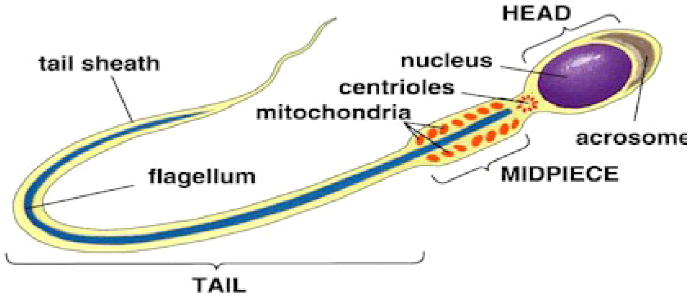


Figure 5.21: Sperm cell

Sperm cells are specialized to fertilize the egg. Its specialization involves many changes in shape and organelles content.

By shape: the sperm cells are very small, long and thin to help them to move easily, and they have a flagellum which helps them to move up the uterine tract towards the egg.

By organelles content: sperm cells contain numerous mitochondria which generate much energy for their movement. Their acrosome releases specialized lysosomes contains many enzymes on the outside of the egg. These enzymes lyse the wall of the egg, and facilitate the sperm nucleus to penetrate easily. In content, the sperm cell nucleus contains the half number of chromosomes of the germ cell in order to fulfil its role as a gamete of fertilizing the egg.

c) Nerve cells

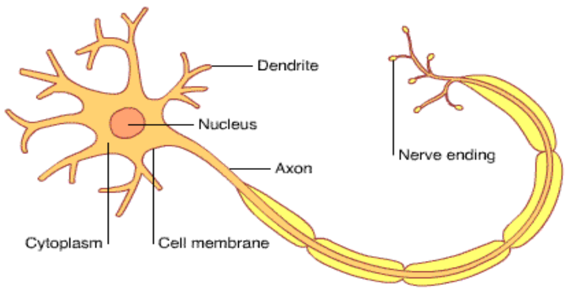


Figure 5.22: Neuron

Nerve cells also known as a neuron are specialized cells to carry nervous information in the body. It is an electrically excitable cell that receives, processes, and transmits information through electrical and chemical signals. These signals between neurons occur via specialized connections called synapses. Specialized animal cells have different functions. Some of them are summarized in the following table.

Table 5.5: Specialized animal cells and their functions.

The specialized cell	Specialization	function
Erythrocytes	They don't have nucleus, mitochondria, Golgi apparatus, and rough ER. However, they have biconcave shape and possess haemoglobin	Transport of Oxygen in the body
Sperm	They have many mitochondria, flagella, acrosome with enzymes, half number of chromosomes, being small, thin and long	Fertilization of the egg
Nerve cell	Have excitability and conductivity characteristics, acrosome, axon, node of Ranvier, Myelin sheaths, and dendrite	Conduction of nervous information.
Epithelial cells	Having different size and shape	Protection of the body, secretion of mucus, digestive enzymes, hormones and sweat. They reproduce to replace dead ones
Smooth muscle cells	Smooth muscle fibres do not have striation	Allow the motion
Pigment cells	They contain colouring substances which determine their colour. For example Melanocytes which secrete melamine for the skin colour	Determine the colour
Flame cells	They contain excretory structures. They are specialized excretory cells found in the simplest freshwater invertebrates, including flatworms.	They function like a kidney, removing waste materials by excretion.

Nematocysts	Nematocysts are specialized stinging cells specific to Coelenterates. They are also called Cnidae and hence the coelenterates are also called Cnidarians. The cells that produce nematocysts are called nematoblasts.	They act as organs of offence and defense. Their venomous coiled thread (bladder) can be projected in self-defense or to capture prey.

5.5.2: Specialized plant cells and their functions

a) Root hair cells

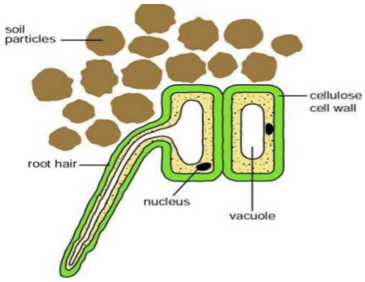


Figure 5.23: Root hair cell.

The root hair cells have hair-like projection from their surface out into the soil. This increase the surface area of root available to absorb water and minerals from the soil.Root hairs are tip-growing cells that originate from epidermal cells called trichoblasts. Their role is to extend the surface area of the root to facilitate absorption of mineral nutrients and water.

b) Palisade cells

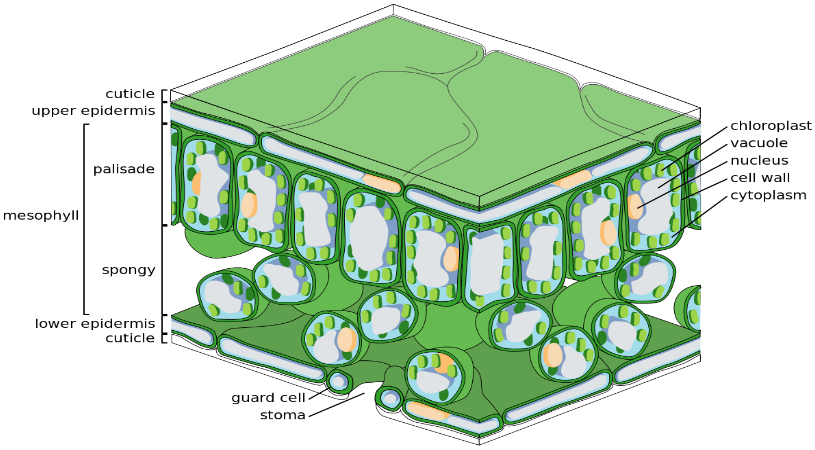


Figure 5.24: Palisade cells

Palisade cells are plant **cells** located in leaves, right below the epidermis and cuticle. They are vertically elongated, a different shape from the spongy mesophyll **cells** beneath them in the leaf. Their big number of chloroplasts allow them to absorb a major portion of the light energy used by the leaf in the process of photosynthesis.

c) Parenchyma cells:

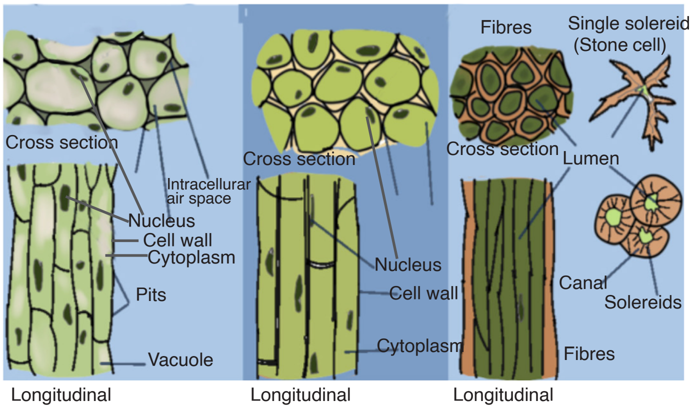


Figure 5.25: Parenchyma cells

Parenchyma cells are alive at maturity. They function in storage, photosynthesis, and as the bulk of ground and vascular tissues. Palisade **parenchyma cells** are elongated **cells** located in many leaves just below the epidermis. Parenchyma is composed of relatively simple, undifferentiated parenchyma cells. In most plants, metabolic activity such as respiration, digestion, and photosynthesis occurs in these cells because they retain their **protoplasts**(the cytoplasm, nucleus, and cell organelles) that carry out these functions. Parenchyma cells are capable of cell division, even after they have **differentiated** into the mature form.

d) Guard cells

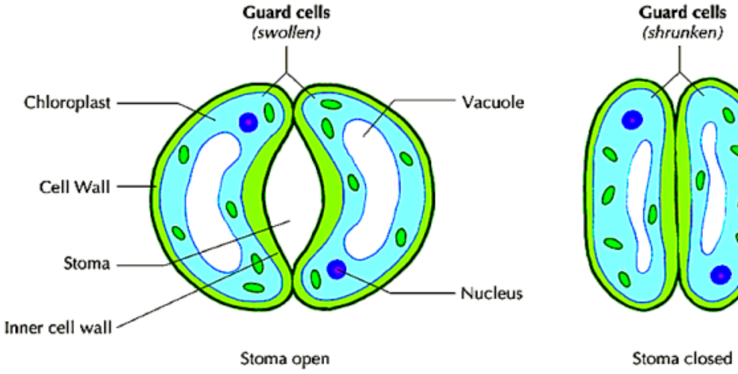


Figure 5.26: Guard cells

Guard cells are cells surrounding each stoma. They help to regulate the rate of transpiration by opening and closing the stomata. Guard cells are specialized cells in the epidermis of leaves, stems and other organs that are used to control gas exchange. They are produced in pairs with a gap between them that forms a stomatal pore.

Application activity 5.4

1. Explain why differentiation to produce erythrocytes involves a change in shape.
2. Red blood cells cannot divide as they have no nucleus. State two other biological processes that red blood cells cannot carry out.
3. Discuss the advantages of cell specialization for living things

SKILLS LAB

After finishing the studies, assuming that the understood the unit 5, student-teachers will be able to use microscope to investigate the presence of microorganisms that can cause diseases in food and beverages. This will help in prevention of diseases

End unit assessment 5

Section A. Multiple choice questions

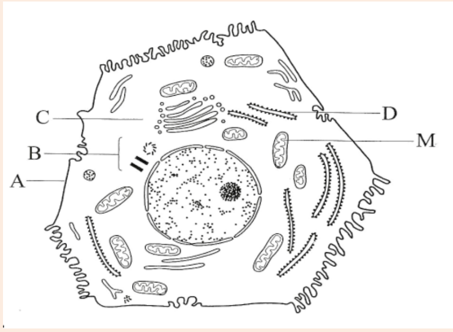
1. Which organelle converts the chemical energy in food into a form that cells can use?
    a) Chromosome
    b) Chloroplast
    c) Nucleus
    d) Mitochondrion
2. The cell membranes are constructed mainly of:
    a) Carbohydrate gates
    b) Protein pumps
    c) Lipid bilayer
    d) Free-moving proteins
3. In many cells, the structure that controls the cell's activities is the:
    a) Nucleus
    b) Nucleolus
    c) Cell membrane
    d) Organelle
4. Despite differences in size and shape, all cells have cytoplasm and a
    a) Cell wall
    b) Cell membrane
    c) Mitochondria
    d) Nucleus
5. If a cell of an organism contains a nucleus, the organism is a (an)
    a) Plant
    b) Eukaryote
    c) Animal
    d) Prokaryote

Section B: Questions with short answers

1. How does a cell membrane differ from a cell wall?
2. What is meant by the fluid mosaic model of the cell membrane?
3. State the properties of the cell membrane.
4. Discuss at least 4 types of the proteins in the cell membrane and their roles.
5. Explain why muscle cells contain a lot of mitochondria, whereas most fat storage cells do not.
6. What kind of information is contained in chromosomes?
7. You examine an unknown cell under the microscope and discover that the cell contains chloroplasts. What type of organism could you decide that the cell came from?

Section C: Essay questions

1. Describe the structure and function of the cell membrane and cell wall.
2. Describe the basic structure of the cell membrane.
3. Explain two common characteristics of chloroplasts and mitochondria. Consider both function and membrane structure.
4. The diagram below shows the structure of a liver cell as seen using an electron microscope.



a) Name the parts labelled A, B, C and D.

b) The magnification of the diagram above is 12 000. Calculate the actual length of the mitochondrion labelled M, giving your answer in μm. Show your working.

c) Explain the advantage to have a division of labour between different cells in the body.

UNIT 6: CELL AND NUCLEAR DIVISION

Key unit competence

Describe the stages of the cell cycle and explain the significance of cell and nuclear division in organisms.

Introductory Activity

Analyze the figure of the house built in bricks below. The bricks came from the valley where they are made, and then have been used to build this house.

Figure 6.1: A house in bricks. Adapted from: https://www.google.com/url?sa

1. Is it possible to build a house like this by using only one brick?
2. Explain what happened for this house to be built at this level?

3. Link the analogous example of building a house by using bricks with growth of and increasing in size of a human body from the body size of a one day new baby to the body size of adult person.
4. Is it possible for the body of an adult person to be made by only one cell?
5. Where are cells which make the adult human body come from?
6. How are they produced?

6.1. Cell cycle

Activity 6.1

Visit your smart classroom/library using search engine or textbooks and discuss more information about the main phases of the cell cycle and present them on manila paper.

The cell cycle is a series of events of cellular growth and division that has five phases such as:

- The first growth phase (G_1),
- The synthesis phase (S),
- The second growth phase (G_2),
- Mitosis (M),
- Cytokinesis.

The three first phases (G1, S, and G2) of the cell cycle collectively are known as **interphase** (the phase between two mitotic divisions).

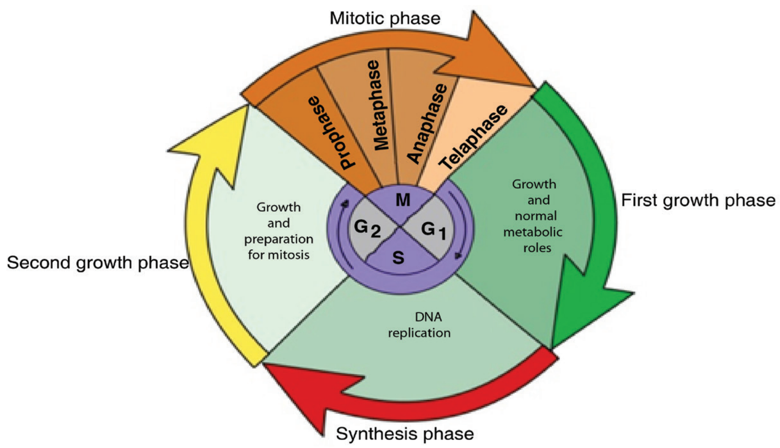


Figure 6.2: cell cycle

During the cell cycle, the cell grows, grows its DNA and divides into two daughter cells.

6.1.1. The first growth phase (G1)

During this phase, a cell undergoes rapid growth and the cell performs its routine functions. The cell spends most of its life in the G_1 phase. If the cell is not dividing, it remains in this phase. The time taken for the completion of G1 phase varies among species and the type of cells. But on an average, it takes **around 11 hours** for the completion of this phase.

6.1.2. The synthesis phase (S)

DNA synthesis or DNA replication takes place in this phase. The S phase takes around 8 hours to complete.

6.1.3. The second growth phase (G2)

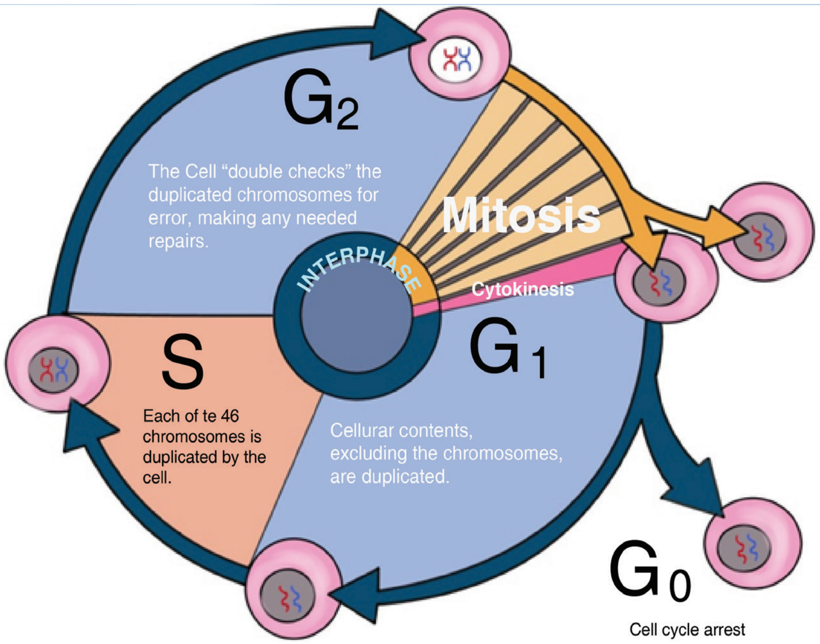
It is the short period, in which the cell continues to grow, making proteins and manufacturing many organelles necessary for cell division. This phase serves as an intermediate between the synthesis phase and the mitotic phase. It takes around four hours to complete

6.1.4. Mitosis

This is the phase of nuclear division in which one nucleus divides through four phases (prophase, metaphase, anaphase and telophase) and becomes two nuclei.

6.1.5. Cytokinesis

In this phase, the cytoplasm divides in half, producing two daughter cells, each containing a complete set of genetic material.



The figure 6.3: Events of cell cycle

Application activity 6.1

1. What do you understand by the cell cycle?
2. Describe all phases of the cell cycle.
3. Predict what may happen if the cytokinesis does not take place in the succession of cell cycle.

6. 2. Mitosis and meiosis: stages and results

Activity 6.2

Using your knowledge from ordinary level, textbooks internet, discuss and present the phases of mitosis and meiosis on manila papers.

6.2.1. Mitosis

Mitosis is a type of cell division that produces two daughter cells having the same number and kind of chromosomes as the mother cell. It takes place only in eukaryotes, where the nuclear division (karyokinesis) occurs. This phase takes **around 1 hour** to complete. The mitotic cell division is more rapid at the meristematic region of plant and root tip as it is the growing region of the plant. The mitotic phase is divided into four steps that include **Prophase, Metaphase, Anaphase** and **Telophase.**

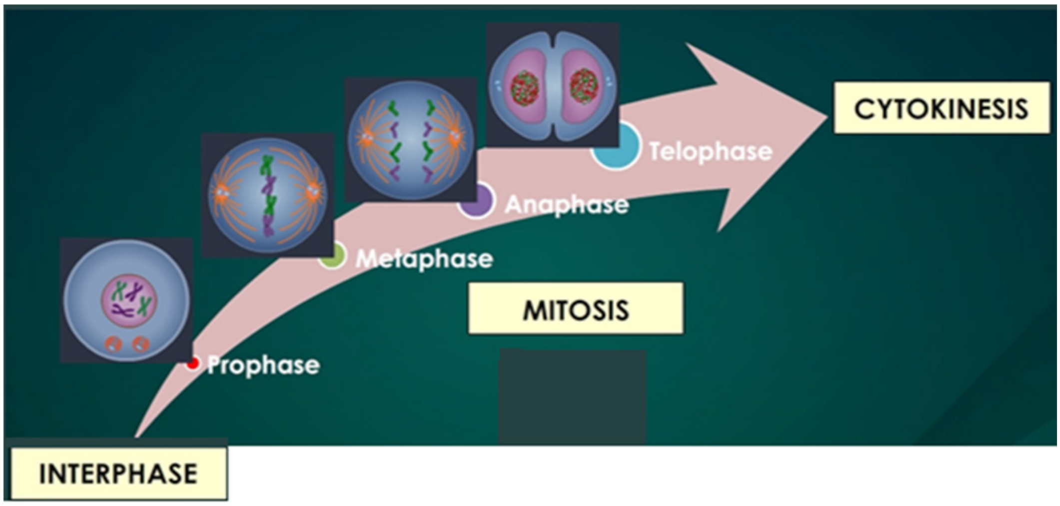
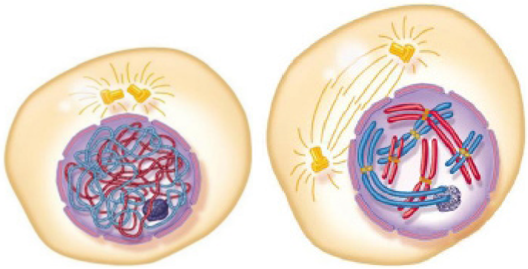


Figure 6.4. The process of mitosis.

6.2.1.1. Prophase

Prophase is the first and longest phase of mitosis. During prophase:

- The DNA and histone proteins coils up into visible chromosomes, each made up of two sister chromatids held together by the centromere.
- The nucleus disappears as the nuclear envelope and nucleolus break apart.
- The centrioles begin to move to opposite ends, or poles, of the cell.
- As the centrioles migrate, the fiber-like spindle begins to elongate between the centrioles. In plant cells, the spindle forms without centrioles. The spindle plays an essential role moving chromosomes and in the separation of sister chromatids.



End of interphase Prophase

Figure 6.5: prophase

6.2.1.2. Metaphase

During **metaphase, t**he spindle which attaches to the centromere of each chromosome helps the chromosomes to line up at the center of the cell by forming the equatorial plate also known as the metaphase plate. Each sister chromatid is attached to a separate spindle fiber, with one fiber extending to one pole, and the other fiber extending to the other pole.

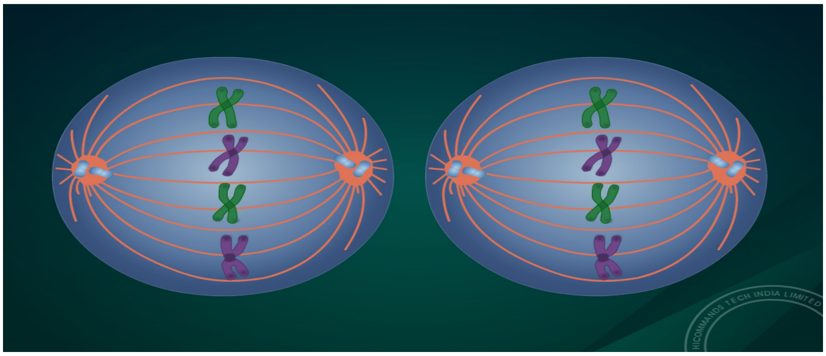


Figure 6.6: process of metaphase

6.2.1.3. Anaphase

During Anaphase:

- Centromeres divide,
- The sister chromatids separate and pulled apart by the shortening of the spindles,
- One sister chromatid moves to one pole of the cell, and the other sister chromatid moves to the opposite pole, (sister chromatids take the name of chromosomes as soon as they separate).
- At the end of anaphase, each pole of the cell has a complete set of chromosomes, identical to the amount of DNA at the beginning of G1 of the cell cycle.

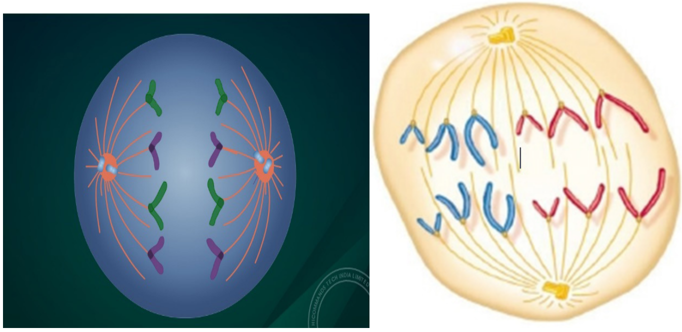


Figure 6.7: process of Anaphase

6.2.1.4. Telophase

During telophase which is the opposite of prophase:

- The spindle disappears,
- Formation of two nuclei,
- The nuclear envelopes surround the two nuclei.

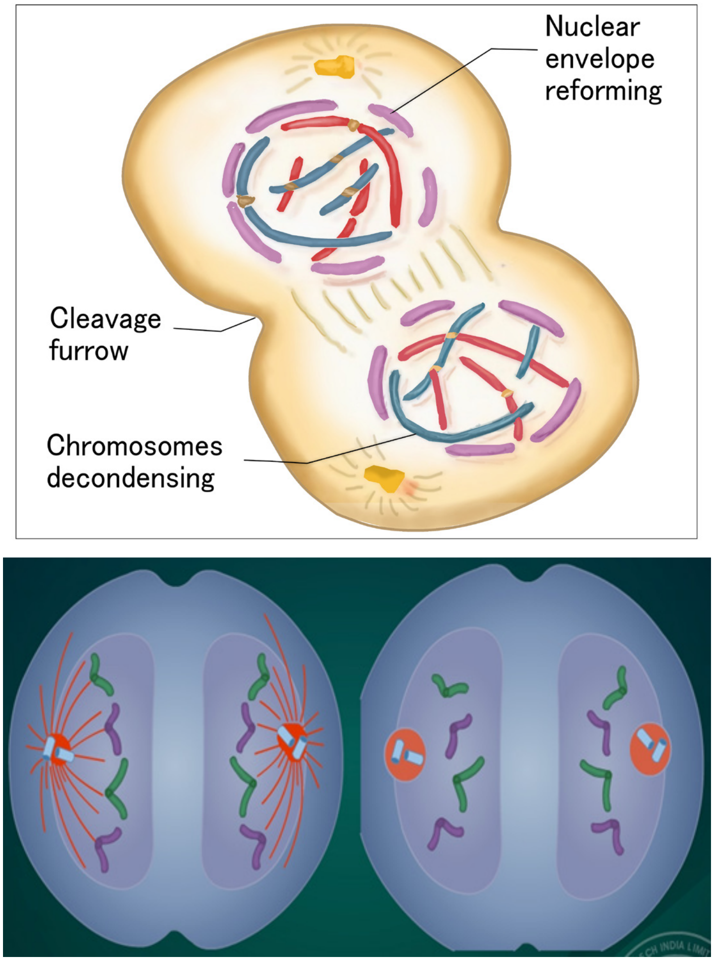


Figure 6.8: The process of telophase.

Cytokinesis

During this phase, the cytoplasm divides in half, producing two daughter cells, each containing a complete set of genetic material as the mother cell.

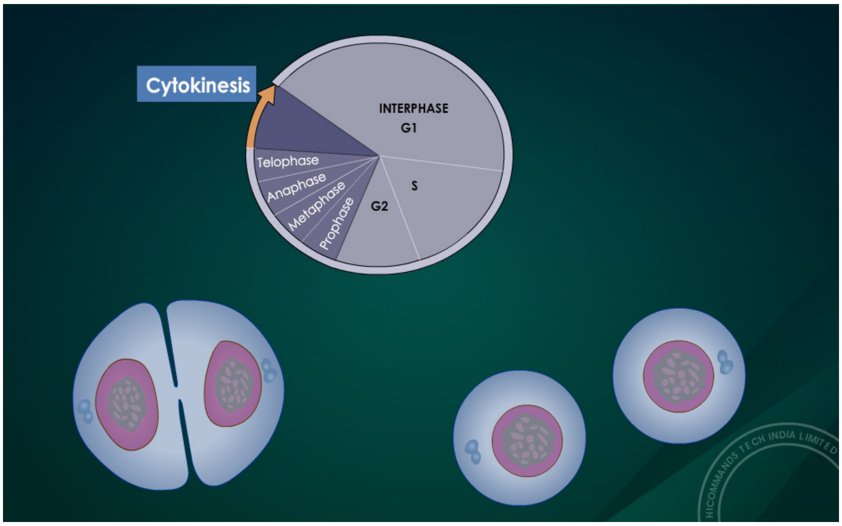


Figure 6.8: the process of cytokinesis

Table 6.1: A table showing phases of cell cycle with one important event at each phase

S. No.	Phase	Main Event
1.	**MITOTIC PHASE (M)**	
	Prophase	• Condensation of chromosomes in the nucleus
	Prometaphase	• Spindle fibres gets attached to the chromosomes and start aligning chromosomes at metaphase plate
	Metaphase	• Chromosomes align at the metaphase plate
	Anaphase	• Chromosomes are separated in two clusters at the two poles
	Telophase and Cytokinesis	• The two clusters of chromosomes have reached the poles and formed two daughter cells • In cytokinesis, separation of cytoplasm has taken place

2.	INTERPHASE	
	G0	• It is a resting phase.
	G1	• The cell prepares itself for DNA replication.
	S	• DNA replication takes place.
	G2	• The cell resumes growth before the cell enters the next phase i.e. mitotic phase.

6.2.2 Meiosis

In sexual reproduction, meiosis produces haploid gametes that fuse together during fertilization to produce a diploid zygote. Meiosis involves two divisions without an interphase in between, starting with one diploid cell and generating four haploid cells. Each division, named meiosis I and meiosis II, has four stages: prophase, metaphase, anaphase, and telophase.

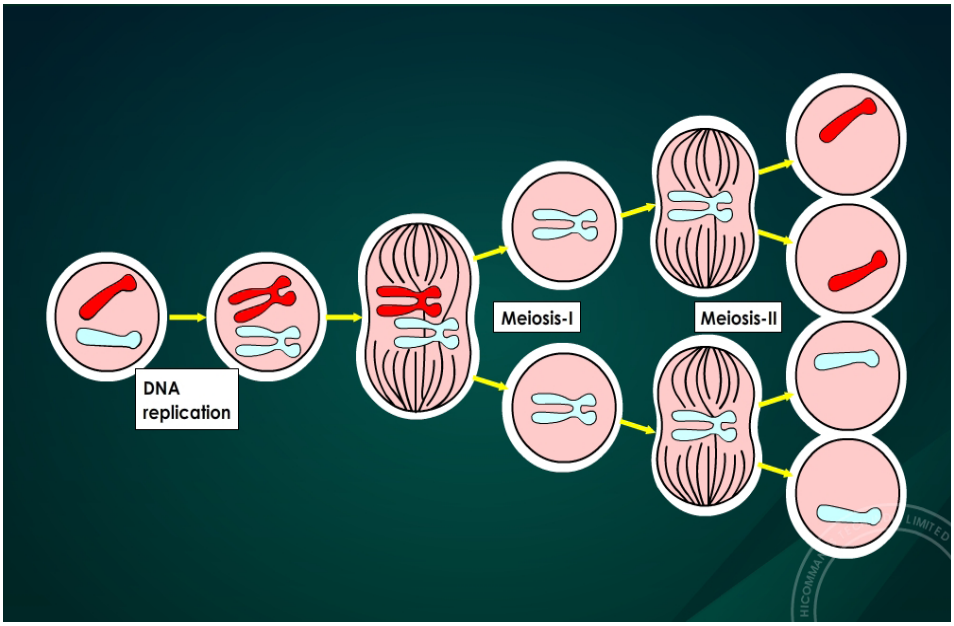


Figure 6.9: process of meiosis

During meiosis the number of chromosomes is reduced from a diploid number (2n) to a haploid number (n). During fertilization, **haploid gametes** come together to form a **diploid zygote**, and the original number of chromosomes (2n) is restored.

8 Stages of meiosis are summarized below:

Prophase I: Prophase I is very similar to prophase of mitosis, but with one very significant difference. In prophase I, the nuclear envelope breaks down, the chromosomes condense, and the centrioles begin to migrate to opposite poles of the cell, with the spindle fibers growing between them.

During this time, the **homologous chromosomes** form **pairs**. These homologous chromosomes line up gene-for-gene down their entire length, allowing **the crossing-over** to occur.

This process permits **the exchange of genetic material between maternal and paternal chromosomes**. Thus, crossing-over results in **genetic recombination** by producing a new mixture of genetic material. This is an important step in creating genetic variation.

Metaphase I: In metaphase I, the 23 pairs of homologous chromosomes line up along the equator of the cell.

Anaphase I: During anaphase I the spindle fibres shorten, and the homologous chromosome pairs are separated from each other. One chromosome from each pair moves toward one pole, with the other moving toward the other pole, resulting in a nucleus with 23 chromosomes at one pole and the other 23 at the other pole. The sister chromatids remain attached at the centromere.

Telophase I: The spindle fibres disappear and the nucleus reforms. This is quickly followed by cytokinesis and the formation of two haploid cells, each with a unique combination of chromosomes, some from the father and the rest from the mother.

After cytokinesis, both cells immediately enter meiosis II, without replication of the DNA. **Meiosis I** is described as **reductional division** as it reduces by half the number of chromosomes of the mother cell. **Meiosis II** is **equational division**, and it occurs like a normal mitosis, separating the sister chromatids from each other.

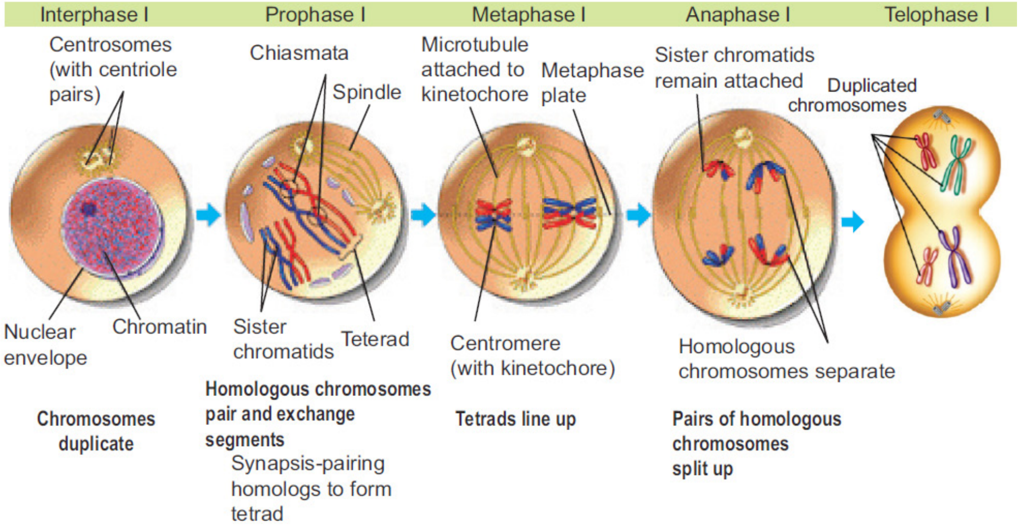
Prophase II: Once again the nuclear membrane breaks down, and the spindle begins to reform as the centrioles move to opposite sides of the cell.

Metaphase II: The 23 chromosomes, each made out of two sister chromatids, occupy the equator of the cell.

Anaphase II: The centromere divides and sister chromatids are separated and move to opposite poles of the cell. As the chromatids separate, each is known as a chromosome. Anaphase II results in a cell with 23 chromosomes at each end of the cell; each chromosome contains half as much genetic material as at the start of anaphase II.

Telophase II: The nucleus reforms and the spindle fibers break down. Each cell undergoes cytokinesis, producing **four haploid cells**, each with a unique combination of genes and chromosomes.

Meiosis I



Meiosis II

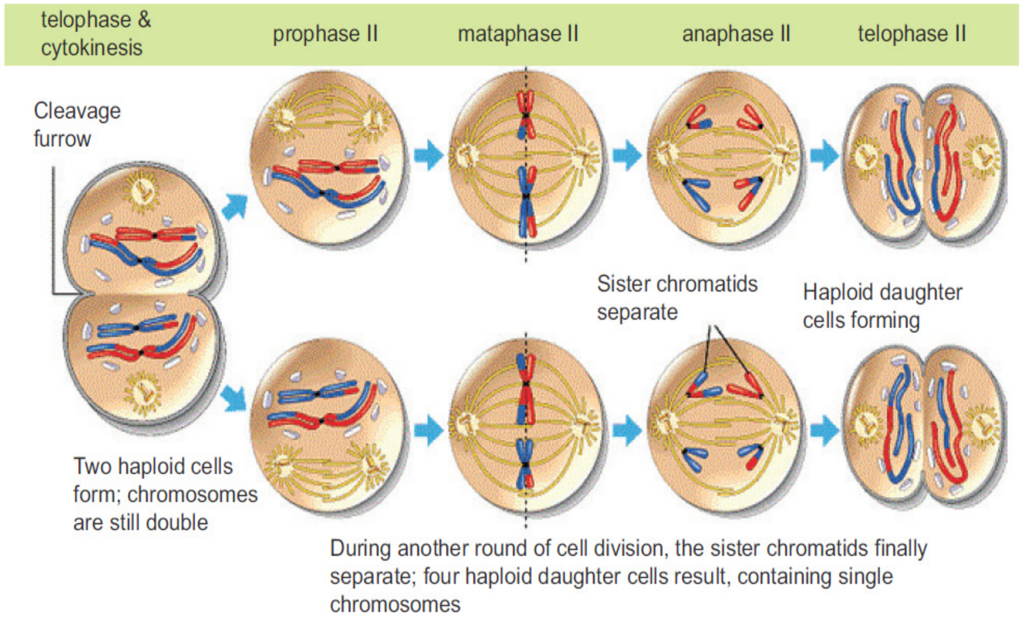


Figure 6.11: the process of meiosis

Comparison of Mitosis and Meiosis

Table 6.2: Comparison between mitosis and meiosis

S. No.	Property	Mitosis	Meiosis
1.	**Occurrence**	Somatic cells	Germ cells/sex cells
2.	**Number of daughter cells**	Two diploid cells (2n)	Four haploid cells (1n)
3.	**Genetic composition**	• The two daughter cells are genetically identical to the parent cell. • It is equational division	• The four daughter cells are genetically different from parent cell and form each other. • It is reduction division
4.	**Number of divisions**	Prophase, prometaphase, metaphase, anaphase, and telophase	**Meiosis I:** Prophase I, Metaphase I, Anaphase I, Telophase I **Meiosis II:** Prophase II, Metaphase II, Anaphase II, Telophase II
5.	**DNA Replication**	Occurs during S phase of interphase prior to mitosis	Occurs during S phase of interphase prior to meiosis I
6.	**Functions in the animal body**	• It enables multicellular adult to arise from zygote • It helps in production of cells in growth and repair • Asexual reproduction in some animals	• It produces gametes (sperms and eggs) • It reduces the number of chromosome by half from diploid (2n) to haploid (1n) • It introduces genetic variation among the gametes
7.	**Synapsis**	It does not occur	Synapsis through synaptonemal complex
8.	**Crossing over**	It does not occur	Crossing over occurs between two non-sister chromatids during meiosis I

9.	**Chiasmata**	No chiasmata formation	Chiasmata, sites of crossing over, formation occurs
10.	**Homologs on the metaphase plate**	Individual chromosomes aligned at metaphase plate	Homologous pairs of chromosomes are aligned at metaphase plate during metaphase I
11.	**Sister chromatids**	Sister chromatids separate at anaphase	During meiosis I, the replicated chromosomes of each homologous pair move toward opposite poles at anaphase I; however, sister chromatids separate only at anaphase II
12.	**Cytokinesis**	Cytokinesis occurs after mitosis	Cytokinesis doesn't occur after meiosis I but occurs after meiosis II
13.	**Centromeres**	Division of centromeres take place at anaphase	Division or cleavage of centromeres takes place only at anaphase II
14.	**Chromosomes at metaphase plate**	Chromosome pairs are aligned at metaphase plate	Duplicated chromosome pairs are aligned at metaphase plate

Haploid and diploid conditions of the cell

During the formation of gametes,the number ofchromosomes is reduced by half, and returned to the full amount when the two gametes fuse during fertilization. The cells of human beings, most animals and many plants (except for their gametes) are diploid abbreviated as 2n. They contain two sets of chromosomes in their nuclei. The haploid cells have only one set of chromosomes, abbreviated as n. Ploidy is a term referring to the number of sets of chromosomes.

Organisms with more than two sets of chromosomes are termed polyploid. Chromosomes that carry the same genes are termed homologous chromosomes.Meiosis is a special type of nuclear division which segregates one copy of each homologous chromosome into each new "gamete". Mitosis maintains the cell's original ploidy level (for example, one diploid 2n cell producing two diploid 2n cells; one haploid n cell producing two haploid n cells; etc.). Meiosis, on the other hand, reduces the number of sets of chromosomes by half, so that when gametic recombination fertilizationoccurs the ploidy of the parents will be re-established.

Two successive nuclear divisions occur, Meiosis I (Reduction) and Meiosis II (Division). Meiosis produces 4 haploid cells. Mitosis produces 2 diploid cells. The old name for meiosis was reduction/ division. Meiosis I reduces the ploidy level from 2n to n (reduction) while Meiosis II divides the remaining set of chromosomes in a mitosis-like process (division). Most of the differences between the processes occur during Meiosis I.

Application activity 6.2

1. Give two reasons why cells divide.
2. As a cell increases in size, which increases more rapidly, its surface area or its volume?
3. Describe what happens during each of the four phases of mitosis.
4. Describe what happens during interphase.
5. How is cytokinesis in plant cells similar to cytokinesis in animal cell?
6. The diagram shows meiosis in an animal cell.

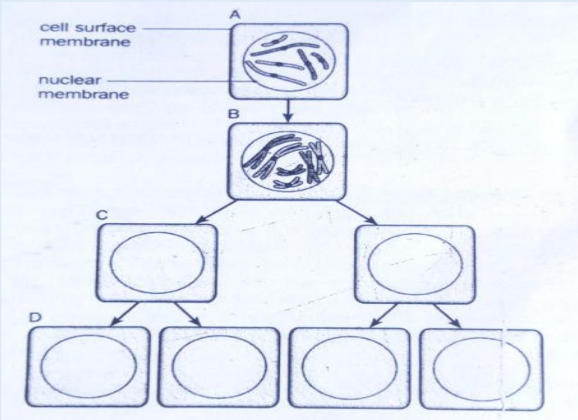


Figure to be redrawn

a) What is the diploid number of chromosomes in this cell?

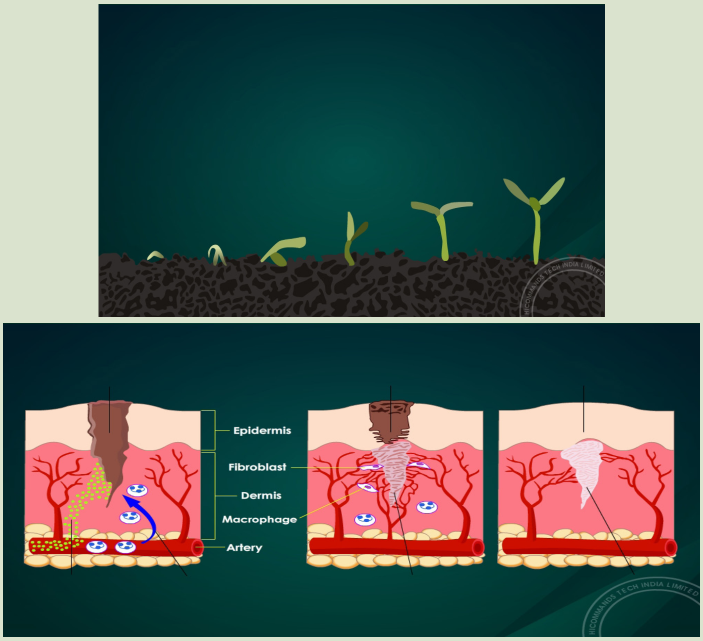
b) Where do you think this cell could be found in an animal?

c) What is the stage of cell division shown at B? Give a reason for your choice.

6.3. Mitosis and meiosis roles in living organisms

Activity 6.3

Observe figures below and explain the significance of mitosis in living organisms



Growth by mitosis   A repair of tissue by mitosis B

Figure 6.12: Growth by mitosis A and repair of tissue by mitosis B

In the early development of an organism, the embryonic cells rapidly proliferate and differentiate into specialized cells of adult tissues and organs. As cells differentiate from time to time, their rate of proliferation usually decreases. As a result, most cells in adult animals are arrested at the G0 stage.

Some cells at this phase may resume the cell cycle and proliferate when they receive certain signals. Some of the differentiated cells enter the Go resting phase and wait for the signal to resume the cell cycle to repair injured tissue. There are numerous examples such as skin fibroblast, endothelial cells, smooth muscle cells, and liver cells. Skin fibroblasts upon receiving growth factor, skin fibroblast start secreting collagen and help in repairing cuts or wounds. Most of the fully differentiated cells no longer possess the capability of cell division. Therefore, they can be replaced by stem cells.

Stem cells are undifferentiated biological cells that can differentiate into specialized cells and can divide (through mitosis) to produce more stem cells. The prominent role of stem cells can be seen in—blood cells (hematopoietic system), epithelial cells of the skin, and epithelial cells lining the digestive tract. All of these cells have short life spans, and they must be replaced continually by continual cell proliferation in adult animals, which is done by mitosis.

The life span of blood cells ranges from less than one day to a few months. All of these cells are derived from the same population of hematopoietic stem cells. In fact, there are more than 100 billion blood cells that are lost every day in humans. **If there are no stem cells to replace the loss of these cells, human beings will not be able to survive.** Hence, these cells are continually being replaced by cells produced from hematopoietic stem cells in the bone marrow by means of mitotic division. Meiosis is necessary in gametes formation, and this helps organisms to multiply by reproduction.

The Significance of Mitosis in Cell Replacement and Tissue Repair by Stem Cells

a) **Mitosis allows growth:** A single cell divides repetitively to produce all the cells in an adult organism.

b) **Mitosis allows to repairing and cell replacement:** by producing new cells to replace ones that have been damaged or worn out.

c) **Mitosis is involved in asexual reproduction:** a single parent cell divides into two genetically identical offspring.

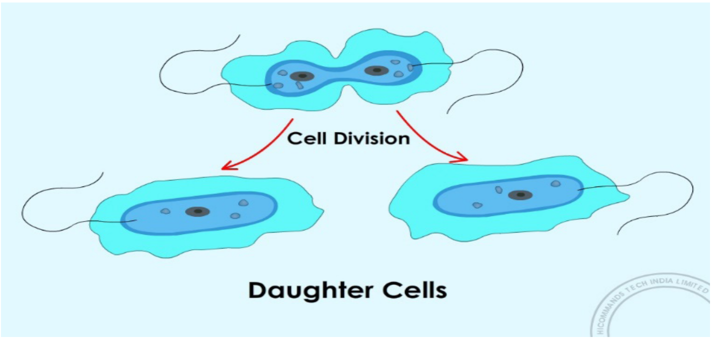


Figure 6. 13:Asexual reproduction by mitosis (to be redrawn)

d) **Mitosis allows geneticstability** by producing two nuclei which have the same number of chromosomes as the parent cell.

e) **Regeneration:** Some animals are able to regenerate whole parts of the body, such as legs in crustacean and arms in starfish. Production of the new cells involves mitosis.

Regulation of the cell cycle

Regulation of the cell cycle helps the living organism to live healthily. The cell divides by mitosis only when required. When receives **signals** from neighboring cells, it responds by dividing or not dividing. The most known **cell cycle regulators** include proteins called **cyclins**, the proteins which regulate the **timing of the cell cycle** in eukaryotic cells. There two types of regulators proteins such as **internal regulators**, and **external regulators** which include **growth factors.**

Many cancers result from uncontrolled cell division, when the regulation of the cycle is lost. Cancerous cells divide much more rapidly than healthy cells. These cells use the blood and nutrients that other cells need and they can stress the environment of the healthy cells. As cancerous cells do not provide any useful function to the organism, they are extremely harmful. **If cancerous cells are allowed to grow uncontrolled**, they will kill the host organism.

Cancer and uncontrolled cell division

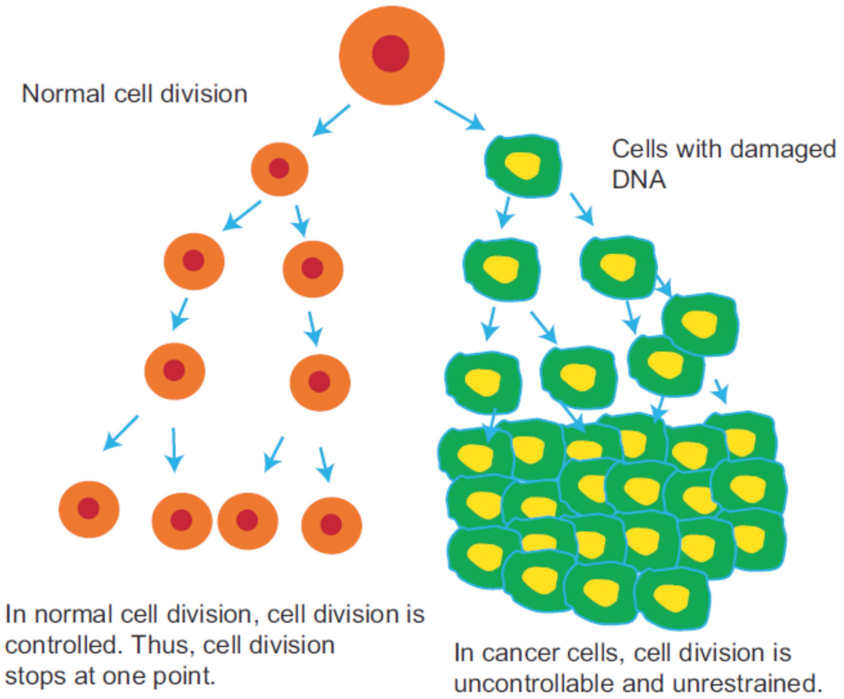


Figure 6.14. For normal cell division and uncontrolled cell division (cancer cells)

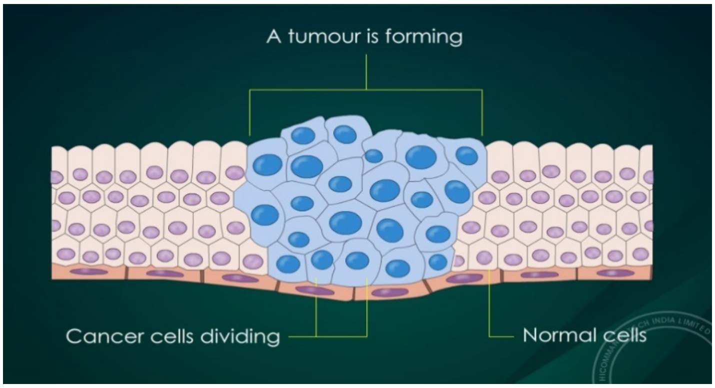


Figure 6.15: tumour formation (to be redrawn)

The problem begins when a single cell in a tissue undergoes **transformation**, the process that converts a normal cell to a cancer cell. The body's immune system normally recognizes a transformed cell asan abnormal and destroys it.

However, if the cell escapes immune system, it may proliferate to form **atumor** (a mass of abnormal cells within an otherwise normal tissue). There are three types of tumors: **benign tumors, malignant tumors and metastasis**.

i. **Benign tumour:** it is a lump of the abnormal cells that remains at the original site**.** Most benign tumors do not cause seriousproblems and can be removed by surgery.

ii. **Malignant tumors**: these are cells abnormal cells that have become invasive enough to impair with the functions of one or more organs. An individual with a malignant tumor is said to have **cancer**.

iii. **Metastasis**: Cancer cells may also separate from the original tumor, enter the blood and lymph vessels, and invade other parts of the body, where they proliferate to form more tumors. This spread of cancer cells beyond their original site is called **metastasis**.

Many **cancers can be inherited**, such as breast cancer, others are triggered by **viral infections**, **tobacco smoke** (e.g. lung cancer) and **radiations** (e.g. skin cancer). All cancers have one thing in common: the control over the cell cycle has broken down.

Significance of Meiosis

a) The need for reduction prior to fertilization in sexual reproduction

Generally, a cycle of reproduction consists of meiosis and fertilization. Before sexual reproduction occurs, gametes undergo meiosis and produce haploid cells. Thus during sexual reproduction, one haploid (1n) gamete comes from the paternal side and another haploid (1n) gamete comes from the maternal side; then, they both fuse to form a zygote, which is diploid (2n). The fusion of gametes to form zygote or new cell is called as fertilization or syngamy . If meiosis does not occur before sexual reproduction, the chromosome number would double up with each fertilization. And after few generations, the number of chromosomes in each cell would become impossibly large. For example in humans, in just 10 generations, the 46 chromosomes would increase to about 47104 (46×2^{10}).

b) Role and Significance of Meiosis in Producing Gametes

Gametogenesis is a biological process by which diploid cells undergo cell division and differentiation to form mature haploid gametes. It occurs through meiosis. In humans, the male gamete (sperm) is produced by a process called spermatogenesis and the female gamete (egg) is produced by a process called oogenesis through meiotic division. Here gametes function takes place soon after meiosis but in plants it happens after gametophyte formation sexual reproduction of plants starts with spore formation. Sporophyte is a diploids generation of flowering plant where haploid spores are produced by meiosis which in turns undergoes mitosis to form multi-celled haploid gametophytes. These haploid gametophytes differentiate to produce gametes—sperm and egg cells. Similarly, embryo sac is formed by reduction division. Each of the cells of embryo sac is haploid. Two of the nuclei fuse to produce diploid nucleus.

c) The Role of Meiosis in Reproduction of Plants

Generally, plants reproducing sexually have life cycle consisting of two phases

- A multicellular gametophyte or haploid stage:
- It is a haploid stage with n chromosomes. It alternates with a multicellular sporophyte stage.
- ***A multicellular sporophyte or diploid stage***:

  It is a diploid stage with 2n chromosomes, made up of n pairs. A mature sporophyte produces spores by meiosis, a process which reduces the number of chromosomes from 2n to 1n.

Alternation of generations (also known as mutagenesis) refers to the occurrence in the plant life cycle of both a multicellular diploid organism (sporophyte) and a multicellular haploid organism (gametophyte), each giving rise to the other. This is in contrast to animals, in which the only multicellular phase is the diploid organism (such as the human man or woman), whereas the haploid phase is a single egg or sperm cell. In bryophytes (mosses and liverworts), the dominant generation is haploid, so that the gametophyte comprises the main plant. On the contrary, in tracheophytes (vascular plants), the diploid generation is dominant and the sporophyte comprises the main plant.

d) Independent Assortment of Chromosomes

Specifically at metaphase I, each homologous pair of chromosomes positioned independently of the other pairs. As a result, each homologous pair sorts out its maternal and paternal homologue into daughter cells independently of every other pair. This act of separating homologous pairs independently is called independent assortment. The random orientation of homologous pairs of chromosomes due to independent assortment in meiosis I (metaphase) increases genetic variation in organisms.

e) Crossing Over and Random Fertilization

During crossing over, DNA segments of the two parents-paternal and maternal are combined into a single chromosome producing recombinant chromosomes, which are non-identical with their sister chromatids. In humans, an average of one to three crossing over events occurs per chromosome pair, depending on the position of their centromeres and on the size of the chromosome. Thus, crossing over is an important event of meiosis that brings genetic variation in sexual life cycles.

Besides independent assortment and crossing over, the **random fertilization** during sexual reproduction also increases genetic variation in organisms. During random fertilization, the male gamete and female gamete fuse to form zygote. The most interesting thing is that this zygote has the possibility of about 70 trillion diploid combinations. The number 70 trillion comes from possible combinations of male and female gametes which are $2^{23} \times 2^{23} = 70$ trillion. The possibility of this enormous number of combinations makes each and every one of us unique physically and genetically.

f) Non-disjunction of Chromosomes

Proper separation of chromosomes during meiosis is essential for the normal growth in humans. Any set of chromosomes that do not separate properly during meiosis results in improper separation of chromosomes or non-disjunction, which is a serious issue in human genetics. **Non-disjunction** is a condition in which the homologues or sister chromatids **fail to separate** properly during meiosis. It can lead to the gain or loss of chromosome, a condition called as **aneuploidy**. Example: **Down syndrome** is an **autosomal trisomy**. It is also called as **trisomy 21**, where non-disjunction results in an embryo with three copies of chromosome 21 instead of the usual two copies of chromosome 21. The origin of trisomy's condition is through non-disjunction of chromosome 21 during meiosis. Failure of paired homologues to separate during either anaphase I or II may lead to gametes with 23 + 1 chromosome composition instead of the normal 23 gamete chromosome composition. Therefore, instead of 46 normal chromosomes, Down syndrome patient will have 47 chromosomes with three copies of chromosome 21 instead of the normal 2 copies. It was first discovered by John Langdon Down. The chance of occurrence is one infant in every 800 live births.

The most common symptoms of **Down syndrome** or **trisomy 21**are:

- They are short.
- They may also have protruding, furrowed tongues, which causes the mouth to remain partially open.
- They are mentally retarded.
- They have a prominent epicanthic fold in the corner of each eye; and typical flat face and round head.
- Usually, there is a wide gap between the first and the second digits on their feet

Organisms and the significance of cell division

a) Spindle fibres formation,

Spindle fibers are microtubules that move chromosomes during cell division. They are found in eukaryotic cells. Spindle fibers moves chromosomes during mitosis and meiosis to ensure that each daughter cell gets the correct number of chromosomes. The spindle apparatus consists of spindle fibers, motor proteins, chromosomes, and, in some cells, structures called asters (which are star-shaped structures form around each pair of centrioles during mitosis. They help to manipulate **chromosomes** during **cell division** to ensure that each **daughter cell** has the appropriate complement of chromosomes). In **animalcells,** spindle fibers are produced from cylindrical microtubules called **centrioles**. Centrioles are separated by asters to generate spindle fibers during the **cell cycle**. Centrioles are located in a region of the cell known as the **centrosome**.

Synapsis

In prophase I, homologous chromosomes become closely associated in **synapsis**. Synapsis includes the formation of an elaborate structure called the **synaptonemal complex**, consisting of homologous chromosomes paired closely along a **lattice or zipper-like structure** of proteins between them. The components of synaptonemal complex include a meiosis-specific form of **cohesin** that helps the two homologous chromosomes to be closely associated along their length.

Some events that occur along with synapsis are:

- The nuclear envelope breaks down.
- Two pairs of centrosome migrate to opposite poles.
- Spindle fibres formation occurs.

Bivalents

These arethe two homologous chromosomes attached at chiasmata. The homologous chromosomes consist of two sister chromatids each.

Chiasma formation and movement of chromosomes

Chiasmata is the region of crossing over between two homologous chromosomes during prophase I of meiosis. At the chiasmata, homologous chromosomes exchange genes, allowing genetic information from both the paternal and maternal chromatids to be exchanged, and a recombination of paternal and maternal genes can be passed down to the progeny. This process is important in diploid organisms to ensure variation in the progeny.

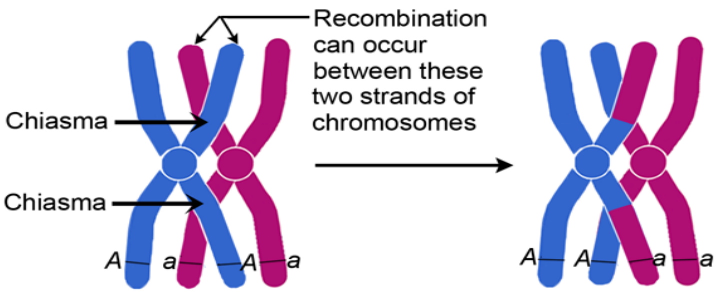


Figure 6.16: Process of crossing over

Process of chiasmata formation.

At prophase I of meiosis, after the homologous pair of chromosomes pair up in the process called synapsis, the non-sister chromatids overlap, forming an X-shape. They then exchange their alleles at the point of crossing over. The X-shape the homologous pair together until the cell progresses to anaphase.

Movement of chromosomes.

In **early Prophase I**, chromosomes change their size and become short and thick. This is the first movement they make during meiosis

In **late Prophase I**, homologous chromosomes become fully shortened and thickened lie side by side (in a process called synapsis).

In metaphase I, Pairs of homologous chromosomes migrate to the equatorial plane of the cell.

Each chromosome moves independently of all the others and the phenomenon is called **independent assortment**.

During anaphase I, the homologous chromosomes separate and begin to move to the opposite poles of the cell, pulled by the shrinking spindle fibers.

In telophase I, the movement of the homologous chromosomes to the poles is completed.

During **Prophase II** chromosomes again become thicker and shorterbegin to move to the equatorial plane of the cell. Spindle fibers once again begin to form at the poles.

During **metaphase II** the chromosomes become aligned on the equatorial plane and spindle fibers attach to the centromeres.

In **anaphase II**, the centromeres divide, separating the sister chromatids, that move to the opposite poles due to the spindle fibers pulling.

In **telophase II**, the movement of the chromosomes to the poles is completed and the spindle disappears

Application activity 6.3

1. Discuss possible functions of mitosis in living organisms.
2. Appreciate the role of cyclins in the process of cell cycle.
3. Describe the three types of tumors.
4. Descried the process of tumor formation.

SKILLS LAB

Cell division is essential biological process that contributes to growth and reproduction that help in well being of all living organisms. Due to this knowledge of cell division, student-teachers will use different techniques out of school to make the food producing plants growing rapidly by providing them food substances increasing the rapid cell division.

End unit assessment 6

I. Choose whether the following statements are True (T) or False (F)

1. A typical cell spends most of its time in interphase.
2. Mitosis is a process where a single cell divides into three identical daughter cells.
3. Cytokinesis is a division of cytoplasm.
4. The process of mitosis is basically divided into 5 phases.
5. Meiosis is divided into three stages: Meiosis I, Meiosis II and Meiosis III.
6. The unrestrained, uncontrolled growth of cells in human beings results into a disease called cancer.
7. Cancer occurs due to failure in controlling cell division.
8. Proper separation of chromosomes during meiosis is not essential for the normal growth in humans.
9. The life span of blood cells ranges from less than one day to a few months.

II. Multiple Choice Questions

1. In telophase, the nuclear envelope re-forms around the........... set of haploid daughter chromosomes.

(a) one (b) two (c) three (d) four

2. .... is a condition in which the homologues or sister chromatids fail to separate properly during meiosis.

(a) Disjunction (b) Non-disjunction (c) Down syndrome (d) None of these

3. Which of the event is correct in anaphase

a) Sister chromatids separate and give rise to daughter chromosomes.

b) Chromosomes are aligned at metaphase plate.

c) Cytokinesis starts occurring.

d) Chromosomes begin to uncoil.

4. One round of oogenesis produces

(a) One egg (b) Two eggs (c) Three eggs (d) Four eggs

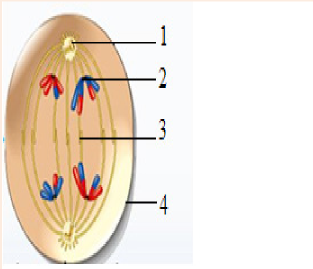
5. In mitosis, which of the following occurs?

(a) Chiasmata formation (b) DNA replication

(c) Synapsis (d) None of these

III. Long Answer Type Questions

1. Describe the main stages of cell cycle.
2. In your own words, explain what is meant by homologous pairs of chromosomes.
3. In your own words, describe the process of mitosis.
4. In your own words, describe the process of meiosis.
5. Outline the significance of mitosis in cell replacement and tissue repair by stem cells.
6. In your own words, explain how uncontrolled cell division can result in the formation of a tumour.
7. What is the need for reduction prior to fertilization in sexual reproduction?
8. In your own words, explain the importance of effective cell division.
9. Outline the role of meiosis in gametogenesis in humans and in the formation of pollen grain and embryo sacs in flowering plants.
10. Explain how crossing over and random assortment of homologous chromosomes during meiosis and random fusion of gametes at fertilization leads to genetic variation, including the expression of rare recessive alleles.
11. Analyse the following diagram and answer the questions below



a) Identify the stage of cell division shown in the figure.

b) Label the structures marked as (1), (2), (3) and (4).

c) Which type of cell is involved in this division?

d) What will happen if the structure marked (3) is not formed?

12. How can you correlate the spread of HIV virus with the process of Mitosis? Knowing the viral disease and its spread, discuss in brief the stigma and discrimination faced by those affected by HIV and AIDS.

UNIT 7: ELECTRON CONFIGURATIONS OF ATOMS

Key unit competence

Relate Bohr's model of the atom with hydrogen spectrum and energy levels, practice writing electronic configurations using s, p, d, f orbitals.

Introductory Activity

Figure 7.1: Bookshelf

At the beginning of this century, it was already known that atoms were made of protons at the center (the nucleus) and electrons orbiting around them. Niels Bohr proposed that the energy of an electron in an atom is not continuous, but quantized.

To understand this better, think about a bookshelf as shown in the Figure 7.1 above.

1. If each of the books were electrons, what will be considered as to be each shelf?
2. Each shelf is different from the others. What differentiate one shelf from the other?
3. A book cannot be placed half way between consecutive shelves, it can only be placed within one shelf. Deduce from this what is predicted by Bohr, if you remember what shelves and books are representing.
4. The places corresponding to each of the allowed orbit are referred to as energy levels. Each shelf is labeled with the number n (n=1, 2, 3, etc). Suppose that this is the same for the atomic model to be equivalent for the shelf. What is the technical term for these numbers?
5. Formulate the simple, abbreviated way you can use to represent the books in each shelf including the number they occupy.

7.1. Bohr's atomic model and concept of energy levels

Activity 7.1

An atom is known to be further composed by other subatomic particles.

1. State three main subatomic particles.
2. Make a research and reveal the subatomic particles discovered with the contribution of Rutherford.
3. Draw the structure of how you think boron atom would be looking like, labeling each of the charged particles. Remember that the proton number of boron is 5.
4. Suggest the reason why the electrons, in an atom, occupy different levels.
5. Describe what would happen to the electron to change the level it occupied.

The Bohr Model has an atom consisting of a small, positively-charged nucleus orbited by negatively-charged electrons. Here is a closer look at the **Bohr Model**, which is sometimes called the ***Rutherford-Bohr Model***.

Overview of the Bohr Model

Niels Bohr proposed the ***Bohr Model of the Atom*** in 1915. Because the Bohr Model is a modification of the earlier Rutherford Model, some people call Bohr's Model the *Rutherford-Bohr Model*. The modern model of the atom is based on quantum mechanics. The Bohr Model contains some errors, but it is important because it describes most of the accepted features of atomic theory in a simple way and tries to answer the following questions failed to answer by Rutherford.

- Why do atomic spectra consist of discrete (separate) lines?
- Why do atoms absorb or emit light of certain frequencies?
- Why do the spectral lines converge to form a continuum?

Unlike earlier models, the Bohr Model explains the "*Rydberg formula for the spectral emission lines of atomic hydrogen*".

The Bohr Model is a **planetary model** in which ***the negatively-charged electrons orbit a small, positively-charged nucleus similar to the planets orbiting the Sun***(except that the orbits are not planar).

Bohr used the term energy levels (or shells) to describe these orbits of differing energy. He said that the energy of an electron is quantized, meaning "electrons can have one energy level or another but nothing in between"

The energy level that an electron normally occupies is called its ***ground state***. But it can move to a higher-energy, less-stable level, or shell, by ***absorbing energy***. This higher-energy, less-stable state is called the electron's ***excited state***.

After it is done being excited, the ***electron can return to its original ground state by releasing the energy it has absorbed***, as shown in the diagram below.

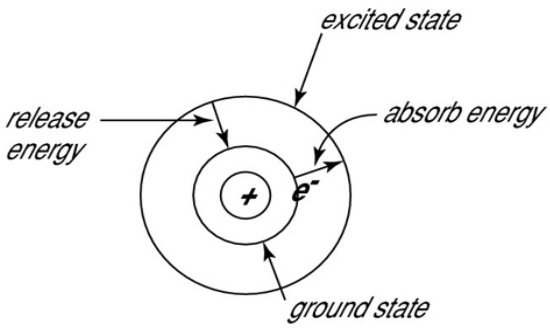


Figure 7.1.: Electron transition in the atom

Sometimes the energy released by electrons occupies the portion of the ***electromagnetic spectrum*** (the range of wavelengths of energy) that humans detect as visible light. Slight variations in the amount of the energy are seen as light of different colours.

Bohr referred to Max Planck's recently developed quantum theory, according to which energy can be absorbed or emitted in certain amounts, like separate packets of energy, called **quanta**. The energy change is accompanied by absorption of radiation energy of $\Delta E = E_2 - E_1 = hv$ where,

- **h** is a *constant* called **"Planck's constant"** and
- v is the *frequency* of radiation absorbed or emitted.
- The value of **h** is 6.626 x 10^{-34} Js.

Each of these small "packets" of energy is called ***photon*** also called "***quantum of energy***". Energy can be gained or lost only in whole-number multiples of the quantity ***hv***, that is,

$\Delta E = nhv$.

The absorption and emission of light due to electron jumps are measured by use of spectrometers.

Bohr found that *the closer an electron is to the nucleus, the less energy it needs, but the farther away it is, the more energy it needs*. So Bohr numbered the electron's energy levels.

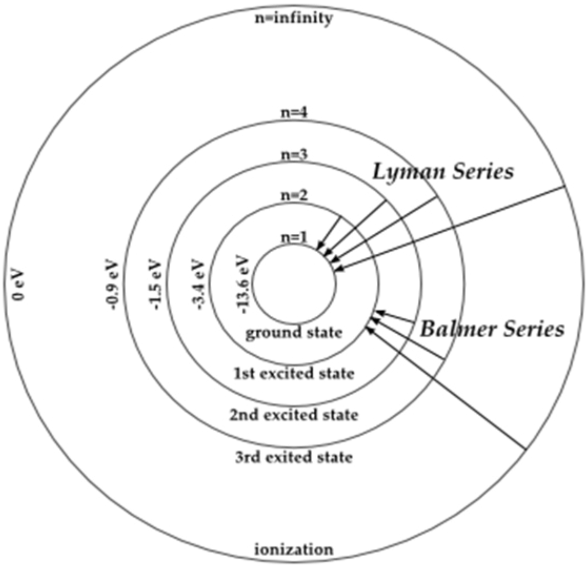


Figure 7.2.: The higher the energy-level number, the farther away the electron is from the nucleus and the higher the energy.

Bohr also found that the various energy levels can hold differing numbers of electrons: *Energy level* **1** may hold up to ***2 electrons***, *energy level* **2** may hold up to ***8 electrons***, and so on.

In summary, the postulates of BohrAtomic Model are as follows:

- Electrons revolve around the nucleus in a fixed circular path termed "orbits" or "shells" or "energy levels".
- The orbits are termed as "stationary orbits".
- Every circular orbit will have a certain amount of fixed energy and these circular orbits were termed orbital shells. The electrons will not radiate energy as long as they continue to revolve around the nucleus in the fixed orbital shells.
- The different energy levels are denoted by integers such as n=1 or n=2 or n=3 and so on. These are called as quantum numbers. The range of quantum number may vary and begin from the lowest energy level (nucleus side n=1) to highest energy level. Learn the concept of an Atomic number here.
- The different energy levels or orbits are represented in two ways such as 1, 2, 3, 4, … or K, L, M, N, … shells. The lowest energy level of the electron is called the ground state.
- The change in energy occurs when the electrons jump from one energy level to other. In an atom, the electrons move from lower to *higher energy level by acquiring the required energy. However, when an electron loses energy it moves from higher to lower energy level.*

Bohr Model of Hydrogen

The *simplest example of the Bohr Model* is for the **hydrogen atom** (Z = 1) or for a hydrogen-like ion (Z > 1), in which *one negatively-charged electron* orbits a small positively-charged *nucleus*.

Electromagnetic energy will be absorbed or emitted if an electron moves from one orbit to another. Only certain electron orbits are permitted. The radius of the possible orbits increases as $\mathbf{n^2}$, where **n** is the *principal quantum number* which represents the number of energy levels in a given atom.

Main Points of the Bohr Model

- Electrons orbit the nucleus in orbits that have a set size and energy.
- The energy of the orbit is related to its size. The lowest energy is found in the smallest orbit.
- Radiation is absorbed or emitted when an electron moves from one orbit to another.

Weakness of Bohr's Model

The Bohr model works well for very simple atoms such as hydrogen (which has 1 electron) but not for more complex atoms. Although the Bohr model is still used today, especially in elementary textbooks, a more sophisticated and complex model (the quantum mechanical model) is used much more frequently.

Application activity 7.1

1. State any weakness of the Bohr Model.
2. Outline three postulates of Bohr.
3. In Bohr atom, what is represented by the distance between an orbital and the nucleus of an atom?
4. Explain why some people call Bohr's Model the Rutherford-Bohr Model.
5. Give the meaning of each of the following terms:

a) Electromagnetic spectrum

b) Quantized

c) Photon

6.Try to describe the atomic structure in the same way as Bohr can do.

7.2. Absorption and emission spectra and energy associated

Activity 7.2

Observe the picture below, discuss with your colleagues and answer the following questions.

Figure 7.3.: A multicoloured arch in the sky

1. What do you see on the above photo?
2. State the physical phenomenon which is related to the given picture.
3. Think of any other means of producing the same pattern. List two of them.
4. What property can you attribute to light with reference to the above process?

The colours we see in a rainbow never fail to captivate us! Did you know that even though we identify the distinct colours of a rainbow, it is actually a continuous range of colours? A similar range of colours appears when white light passes through a prism; this range of colours is a spectrum. A rainbow is a multicoloured arch in the sky, produced by prismatic refraction of light within droplets of rain in the air or any prismatic refraction of light showing a spectrum of colours.

7.2.1. Spectrum

Ordinary white light consists of waves of all wavelengths in the visible range. This is why, when white light passes through a prism, a *series of coloured bands are seen* called ***spectrum***. This dispersion of white light demonstrates that white light contains all the wavelengths of colour and *is thus considered to be continuous*. Each colour blends into the next with no discontinuity. Since the colours merge into each other i.e. violet merges into blue, blue into green and so on, we call it a "***continuous spectrum***".

The interaction of electromagnetic radiation with matter causes the atoms and molecules to absorb energy and go to a higher energy state. Since this state is unstable, they need to emit radiations to return to their normal states. This gives rise to emission and absorption spectra.

7.2.2. Emission and absorption spectra

1. Emission spectrum

Every substance reacts differently when it interacts with light. The material starts off with being in the ground state, where all molecules are stable and settled. However when heat, energy or light is applied to a substance, some of the molecules transition into a higher energy state or an excited state. During this state ***the molecules are unstable and try to emit the energy in order to reach the state of equilibrium***. The molecules emit energy in the form of photons or light. The difference between the substance in ground state and excited state is then used to determine the emission level of the substance.

Each element or substance has a unique emission level or the amount of energy it radiates; this helps the scientists identify elements in unknown substances. The emission of an element is recorded on an emission spectrum or atomic spectrum. The emittance of an object measures how much light is emitted by it. The amount of emission of an object varies depending on the spectroscopic composition of the object and temperature. The frequencies on an emission spectrum are recorded in ***light frequencies***, where the colour of the light determines the ***frequency***.

The frequencies can be determined using the formula $E_{photon} = hv$, where

- 'E_{photon}' is *the energy of the photon*,
- '**v**' is *its frequency*, and
- '**h**' is *Planck's constant*.

Emission can happen in the form of light and rays, such as gamma and radio. The spectrum is a dark wavelength with bands of color on it, which is used to determine the emission of the object.

The **emission spectrum** is the spectrum of radiation emitted by a substance that has absorbed energy. Atoms, molecules, and ions that have absorbed radiation are called '**excited**'.

2. **Absorption spectrum**

The **absorption spectrum** is the opposite of the emission spectrum. Absorption can be plotted in a *wavelength, frequency* or *wave number*. There are two types of absorption: *atomic absorption spectra* and *molecular absorption spectra*.

Absorption is used:

- To determine the presence of a particular substance in a sample, or the quantity of the present substance in the sample.
- In molecular and atomic physics, astronomical spectroscopy and remote sensing. Absorption is primarily determined by the atomic and molecular composition of the material.

They can also depend on temperature, electromagnetic field, interaction between the molecules of the sample, crystal structure in solids and temperature.

In order to determine the absorption level of a substance, *a beam of radiation is directed at the sample and the absence of light that is reflected through the object can be used to calculate the absorption.* The absorption spectrum is usually light colored, with dark bands that run through it. These dark bands are used to determine the absorption of the object.

Absorption spectrum is the plotting of the energy that is absorbed by an element or substance. It is the spectrum formed by electromagnetic radiation that has passed through a medium, in which radiation of some frequencies is absorbed.

Emission and absorption spectra are techniques that are used in chemistry and physics. **Spectroscopy** is the study of emission and absorption spectra. It is the interaction of radiation and matter. Using spectroscopy, a scientist can figure out the composition of a certain matter. This is really beneficial,

of dealing with unknown substances. Emission spectra and absorption spectra are different from each other but still related.

7.2.3. Comparison between absorption and emission spectra

Absorption Spectra	**Emission Spectra**
An absorption spectrum can be defined as a spectrum obtained by transmitting electromagnetic radiation through a substance	An emission spectrum can be defined as a spectrum of the electromagnetic radiation emitted by a substance
Produced when atoms absorb energy	Produced when atoms release energy
Show dark lines or gaps	Show coloured lines
An atom obtains a higher energy level when an absorption spectrum is given by atom	An emission spectrum is given when an excited atom obtains a lower energy level
Account for wavelengths absorbed by a substance	Account for the wavelengths emitted by a substance
Absorption spectra records the wavelengths absorbed by the material.	Emission spectra records wavelengths emitted by materials, which had been stimulated by energy before.
Dark colored, with light bands that run through it. These dark bands are used to determine the absorption of the object.	*Light colored*, with dark bands that run through it. These light bands are used to determine the types of photons emitted by the object.
The type of light wavelengths that are absorbed helps figure out *how much quantity* of a substance is present in the sample.	The type of photons emitted helps figure out *the type of elements* that the substance is formed of.

Application activity 7.2

1. State the meaning of the term “Spectrum”.
2. Why do we say that the spectrum of the white light is continuous?
3. Find out some differences between emission and absorption spectra by filling the table below.

Criteria	Emission Spectrum	Absorption Spectrum
Definition		
Look		
Wavelengths recorded		
What is figured out		

7.3. Hydrogen spectrum and spectral line series

Activity 7.3

Think about any spectrum you have come across with. This might be composed of vertical lines (that form that spectrum).

1. Formulate the name that can be dedicated to such spectrum.
2. If atoms and molecules are heated to sufficiently high temperatures, they emit light of certain wavelengths. Do you think the spectrum drawn to be emission or absorption (spectrum)?
3. Describe the look that spectrum would have.
4. The vertical lines described in the spectrum above are different for one element to another. How these separate lines can be used to identify the element?

Unlike visible white light which shows a continuous spectrum of all wavelengths, the emission spectra of atoms in the gas phase emit light only at specific wavelengths with dark spaces between them. This is called **line spectra** or **atomic spectra** since the emitted radiation is identified by bright lines in the spectra. Each element has its own unique **line emission spectrum**.

Did you know that just the way fingerprints are used to identify people; the characteristic lines in an atomic spectrum are used to identify unknown atoms!

Line Spectrum of Hydrogen

Hydrogen molecules dissociate when we pass electric discharge through gaseous hydrogen. Subsequently, the energetically excited H_2 atoms ***emit electromagnetic radiation of discrete frequencies giving rise to a spectrum*** emitted light is analysed with a **spectrometer** and discrete bright lines in a dark background are observed.

The well-defined separation of lines is experimental evidence for the existence of *separate*, *discrete* or '*quantized*' energy levels in the atom. No two gases give the same exact line spectrum.

The hydrogen spectrum has many series of lines. In 1885, the scientist **Balmer** showed that if spectral lines are expressed as wavenumber, then the visible lines of the hydrogen spectrum obey the following formula:

$$\textbf{\textit{Wavenumber}} = 109,677\left(\frac{1}{2^2}-\frac{1}{n^2}\right)\ cm^{-1} \text{ where } n \geq 3.$$

The value 109,677 is the ***Rydberg constant*** for hydrogen.

We call this series of lines, **Balmer series**. These lines are the only lines in the hydrogen spectrum that ***appear in the visible region of electromagnetic radiation***. The 3 → 2 transition produces the first line of the Balmer series. For hydrogen (Z = 1) this produces a photon having wavelength 656 nm (red light).

Johannes Rydberg, a Swedish spectroscopist, showed that all series of lines in the hydrogen spectrum can be described by the formula:

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^{\,2}}-\frac{1}{n_2^{\,2}}\right) \quad \text{where} \quad \mathbf{n_2 > n_1}$$

$\mathbf{R_H}$ = 1.09677 x 10^7 m^{-1}

λ is the wavelength;

n_1 *is the initial energy level*

n_2 *is the final energy level*

The lines that correspond to **n_1 = 1, 2, 3, 4, 5** are called **Lyman**, **Balmer**, **Paschen**, **Brackett** and **Pfund** series, respectively.

Series	n_1	n_2	Spectral Region
Lyman	1	2,3, …	Ultraviolet
Balmer	2	3,4, …	Visible
Paschen	3	4,5, …	Infrared
Brackett	4	5,6, …	Infrared
Pfund	5	6,7, …	Infrared

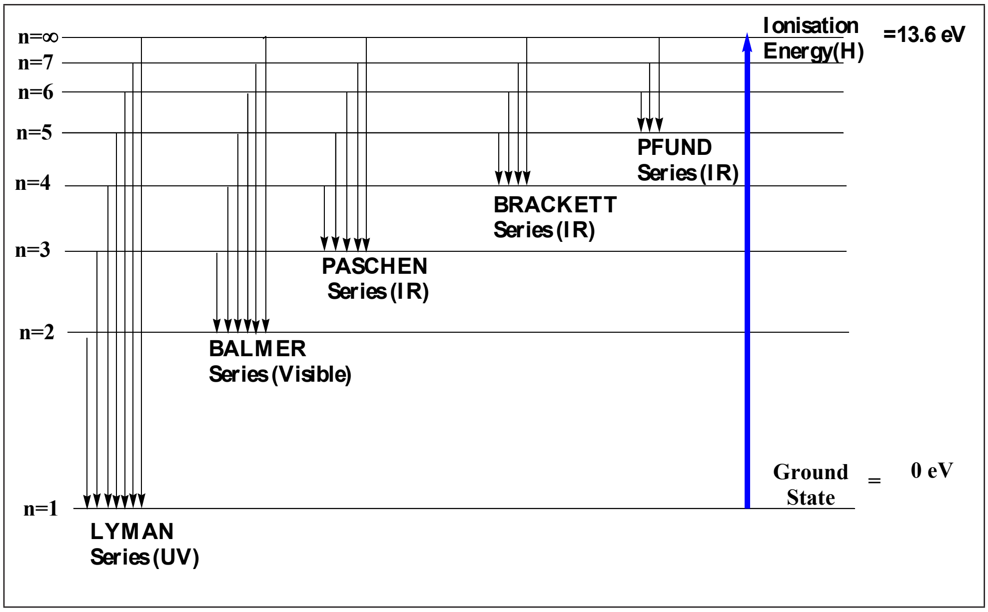


Figure 7.4: Energy-Level diagram and emission line spectra for the hydrogen atom.

The hydrogen atom has the simplest line spectrum of all elements. For heavier atoms, the line spectrum becomes more and more complex. However, there are certain features that are common to all line spectra:

- Line spectrum of every element is unique.
- There is regularity in the line spectrum of each element.

Now, that we understand the line spectrum of hydrogen, let us understand the *features of the hydrogen atom*, its *structure*, and its *spectrum*.

In each series, the ***intervals between the frequencies of the lines become smaller and smaller towards the higher frequency end of the spectrum*** until the lines *run together* or *converge* to form a continuum of light.

Explanation of Line Spectrum of Hydrogen

Bohr's model can explain the line spectrum of the hydrogen atom. Radiation is absorbed when an electron goes from orbit of lower energy to higher energy; whereas radiation is emitted when it moves from higher to lower orbit.

The energy gap between the two orbits is: $\Delta E = E_f - E_i$ where:

- f is the *final orbit*,
- i is the initial orbit

Since, $E_n = -R_H(\frac{1}{n^2})$, we can now say:

$$\Delta E = \left(-R_H / n_f^2\right) - \left(-R_H / n_i^2\right) = R_H\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) = 2.18\times10^{-18} J\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

The ***frequency*** and ***wavenumber*** associated with the absorption and emission of the photon can also be calculated:

$$v = \Delta E / h = \frac{R_H}{h}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) = 2.18\times10^{-18} J / 6.626\times10^{-34} Js\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) = 3.29\times10^{15}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) Hz$$

Example: Calculate the *frequency* and after the *wavelength* of the hydrogen line that corresponds to the transition of the electron from the n = 4 to the n = 2 states.

Answer:

$R_f = 3.29 \times 10^{15}\ s^{-1}$, $n_1 = 4$ and $n_2 = 2$

$$v = R_f\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$= 3.29\times10^{15}\left(\frac{1}{4^2} - \frac{1}{2^2}\right)$$

$$= -6.168\times10^{14} s^{-1}$$

(The negative frequency or wavelength is physically meaningless, so the sign is ignored)

$\lambda = \frac{c}{n}$, $c = 3 \times 10^8\ ms^{-1}$ and $= 6.168 \times 10^{14}\ s^{-1}$

$\lambda =$ 4.8638×10^{-7} m = **486.38 *nm***

Note that: Wavenumber $= \nu/c = R_H/hc\ (1/n^2_i - 1/n^2_f)$

$$= 3.29 \times 10^{15}\ s^{-1} / 3 \times 10^{8}\ ms^{-s}\ (1/n^2_i - 1/n^2_f)$$

$$= 1.09677 \times 10^{7}\ (1/n^2_i - 1/n^2_f)\ m^{-1}$$

When $n_f > n_i$, the term in brackets is ***positive*** and ***energy is absorbed***.

When $n_i > n_f$, ΔE is ***negative*** and ***energy is released***.

Note: The spectrum of white light ranges from violet (at 7.5 x 10^{14} Hz) to red (at 4 x 10^{14} Hz). When this light passes through an object or medium, the wave with the shortest wavelength (violet) deviates the more than the one with the longest wavelength (red).

WORKED EXAMPLES

1. Find the wave length and frequency in Balmer series associated with a drop of an electron from the fourth orbit.

Answer

$\frac{1}{\lambda} = R(\frac{1}{n_1^2} - \frac{1}{n_2^2})$ $= 109667(\frac{1}{2^2} - \frac{1}{4^2})$ $= 109667(\frac{1}{4} - \frac{1}{16})$ $= 109667x\frac{3}{16}$	$\frac{1}{\lambda} = \frac{20562.5625}{1}$ $\lambda = 4.86 \times 10^{-5}$cm $\upsilon = \frac{C}{\lambda}$ $= \frac{3x10^8 m/s}{4.86x10^{-7} m}$ $= 6.17$ x1014 s^{-1}

2. Find the wave length, frequency and energy of the third line in the Lyman series.

Answer:

$$\frac{1}{\lambda} = R(\frac{1}{n_1^{\ 2}} - \frac{1}{n_2^{\ 2}})$$
$$= 109667(\frac{1}{1^2} - \frac{1}{4^{\ 2}})$$
$$= 109667(\frac{1}{1} - \frac{1}{16})$$
$$= 109667x\frac{15}{16}$$
$$\frac{1}{\lambda} = \frac{102812.8125}{1}$$
$$\lambda = \frac{1}{102812.8125}$$

$\lambda = 9.73 \text{ x } 10^{-6}$ cm

$$\upsilon = \frac{C}{\lambda}$$
$$= \frac{3x10^8 m/s}{9.73x10^{-8} m}$$
$= 3.08 \text{ x } 10^{15} \text{ s}^{-1}$

E = hυ

$= 6.63 \text{ x } 10^{-34} \text{ x } 3.08 \text{ x } 10^{15}$

= 2.042 x 10^{20}J/atom

3. A certain source emits radiation of wavelength 500.0 nm. What is the energy, in kJ, of one mole of photons of this radiation?

Solution:

Convert *nm* to *m*: 500.0 nm = 500.0 x 10^{-9}m = 5.000 x 10^{-7}m

Determine the frequency: λν = c   Let ν be x

(5.000 x 10^{-7} m) (x) = 3.00 x 10^{8} m/s

x = 6.00 x 10^{14} s^{-1}

Determine the energy: E = hν

= (6.626 x 10^{-34} J s) (6.00 x 10^{14} s^{-1})

= 3.9756 x 10^{-19} J

Important point: this is the energy for one photon.

Determine energy for one mole of photons: (3.9756 x 10^{-19} J) (6.022 x 10^{23} mol^{-1}) = **239.4 kJ/mol**

Note: If you wished to do a direct calculation, you could use this equation:

E = hc / λ. Just make sure that the units for **c** and λ match.

Application activity 7.3

1. What is the meaning of infinity level in the hydrogen spectral lines?
2. Given a transition of an electron from n=2 to n=5. Calculate

   a) Wavelength

   b) Frequency

   c) Energy

3. Explain how atomic emission spectra arise and how they relate to each element on the periodic table.
4. How do the lines on the atomic spectrum relate to electron transitions between energy levels?
5. Explain the difference between atomic absorption and emission spectra.
6. Describe how the absorption and emission spectra of the gases in the atmosphere give rise to the Greenhouse Effect.
7. Use the figure below to answer the following questions.

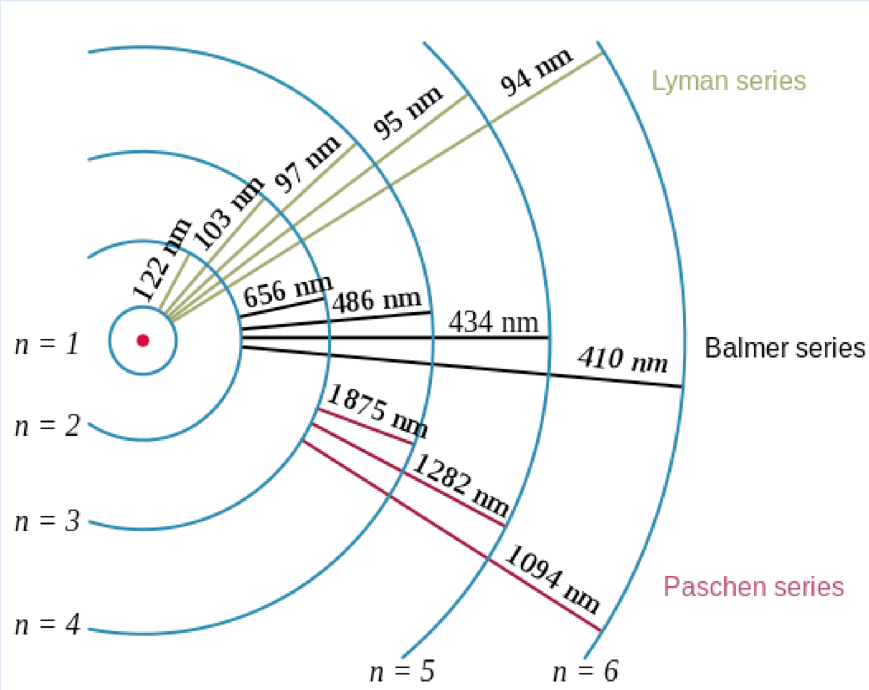


Figure 7.6.: Spectral line series

a) What colour is the light emitted by hydrogen when an electron makes the transition from energy level 5 down to energy level 2? (Use the figure above to find the energy of the released photon.)

b) I have a glass tube filled with hydrogen gas. I shine white light onto the tube. The spectrum I then measure has an absorption line at a wavelength of 474 nm. Between which two energy levels did the transition occur?

8. Calculate the wavelength of a line in the Balmer series that is associated with energy transition, E_4 to E_2 ($E_4 = -1.362\times10^{-19}$ J, $E_2 = -5.448\times10^{-19}$J).

7.4. Concept of orbitals and quantum numbers

Activity 7.4

1. Recall the main weakness of the Atomic Bohr's Model.
2. What do you understand with the term "orbit" in the atomic structure?
3. Suppose that the orbit you talked about above is subdivided into other sub-parts, said orbitals. Formulate a definition of an "orbital".
4. There are numbers used to locate the orbitals. These are of four types. One usually encountered is qualified to be "principal".

a) What is the name given to those numbers?

b) Make a research and state them.

c) The principal one gives relevant information about the given atom. State at least two points that are revealed when this principal number is given.

We have seen the weakness and critics against the atomic Bohr's model. In order to answer the questions not answered by that model, other atomic models were proposed. One of those models is the **Quantum Model** that has been developed by the Australian physicist ***Erwin Schrödinger*** (1887-1961). The model is based on a mathematical equation called **Schrödinger equation**.

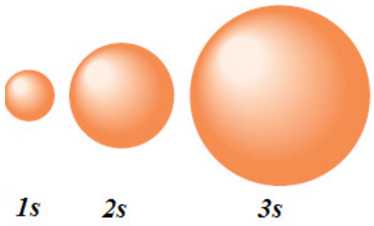
7.4.1. Orbitals

This Quantum Model is based on the following assumptions or hypotheses:

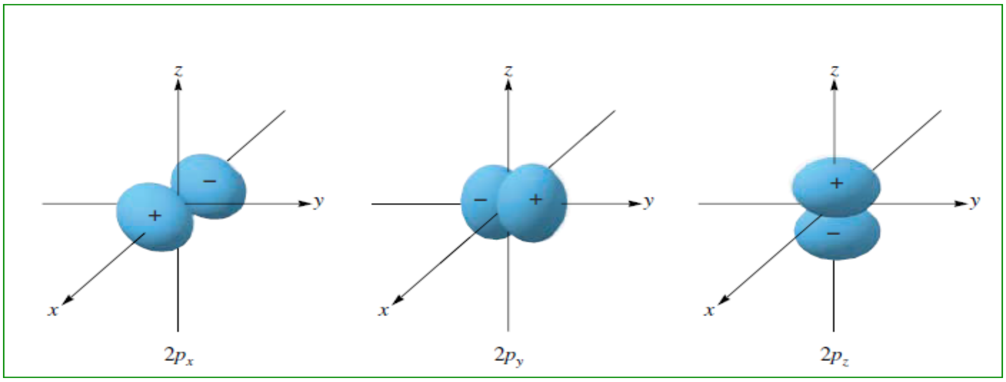
- An electron is in continuous movement around the nucleus but cannot be localized with precision; only the high probability of finding it in a certain region around the nucleus can be known.
- The region where the probability of finding electron is high, at more than 95%, is called "**orbital**"; in other words, the orbital is the volume or the space (tridimensional) around the nucleus where there is a high probability of finding the electron.

The orbitals are of 4 types. They are named **s, p, d, f**. The **s, p, d**, and **f** stand for **sharp**, **principal**, **diffuse** and **fundamental**, respectively.

1. *"s"* orbitals are spherically shaped.



2. *"p"* orbitals are often described as dumb-bell shaped.



3. *"d"* orbitals and "*f*" orbitals are not easily visualized.

7.4.2. Quantum numbers

Without going into the mathematical development of the Schrödinger equation, we can say that the energy of the electron depends on the orbital ***where it is located*** and an atomic orbital is described by a certain number of "**quantum numbers**" according to the solution of Schrodinger equation. Quantum numbers are ***a set of numbers that describe the state of an electron in an atom*** (and they are derived from quantum mechanical treatment).

Four numbers, called ***quantum numbers***, were introduced to describe the characteristics of electrons and their orbitals:

- Principal quantum number: **n**
- Angular momentum quantum number: **ℓ**
- Magnetic quantum number: $\mathbf{m_\ell}$
- Spin quantum number: $\mathbf{m_s}$

1. The Principal Quantum Number

The principal quantum number n describes the average distance of the orbital from the nucleus (the size of the shell) — and the energy of the electron in an atom. It can have positive integer (whole number) values: 1, 2, 3, 4, and so on. Thelarger the value of n, the higher the energy and the larger the orbital. Chemists sometimes call the orbitals electron shells. The shells (values of n) can be represented by letters K, L, M, N, O, P.

2. The Angular Momentum Quantum Number

The **angular momentum quantum number ℓ** is also called **Secondary Quantum number** or **Azimuthal Quantum Number**. It describes ***the shape of the orbital***, and the shape is limited by the principal quantum number **n**: The angular momentum quantum number ℓ can have positive integer values from **0 to n–1**. For example, if the **n** value is **3**, three values are allowed for **l: 0, 1 and 2. l=0(s), l=1(p), l=2(d), l=3(d).**

The value of ℓ defines the shape of the orbital, and the value of n defines the size. Orbitals that have the same value of n but different values of l are called subshells.

3. The Magnetic Quantum Number

The magnetic quantum number is designated as: m_ℓ. It describes *how the various orbitals are oriented in space*.

The value of this number depends on the value of ℓ. The values allowed are integers from **– ℓ** to **0** to **+ℓ**. For example, if the value of ***l*** = 1 (p orbital), you can write three values for this number: **–1, 0,** and **+1.** This means that thyou can write three values for this number: –1, 0, and +1. This means that there are three different p orbitals for the subshells. The orbitals have the same energy but different orientations in space.

The three p orbitals correspond to magnetic quantum number values of **–1, 0**, and **+1**, oriented along the **x, y**, and **z** axes.

4. The Spin Quantum Number

The fourth and final quantum number is the spin quantum number, designated as: m_s This number describes *the direction the electron is spinning in a magnetic field* — either *clockwise* or *counterclockwise.* Only two values are allowed: **+1/2** or **–1/2**. For each subshell, there can be only two electrons, one with a spin of +1/2 and another with a spin of –1/2.

Table 7.1.: Relationship between the n, ℓ, m_l and m_s

Principal quantum number (n)	Secondary quantum number (l) [0 to (n-1)]	Magnetic quantum number (m) [-l to +l]	Spin quantum number (m_s)		Number of electrons in each shell [$2n^2$]
1	s	0	+½	-½	2
2	s	0	+½	-½	8
	p	-1	+½	-½	
		0	+½	-½	
		1	+½	-½	
3	s	0	+½	-½	18
	p	-1	+½	-½	
		0	+½	-½	
		1	+½	-½	
	d	-2	+½	-½	
		-1	+½	-½	
		0	+½	-½	
		1	+½	-½	
		2	+½	-½	

Application activity 7.4

1. Define the following terms:

   a) Orbital

   b) Quantum number

2. Give the different types of orbitals stating their shapes where it is possible.

3. We have four quantum numbers. Use the knowledge of quantum numbers to complete the table below.

Quantum number	What it reveals
Spin	
	Different orientations of the orbitals
	Size of the shell
Azimutal	
	Energy of electron in an atom

4. Which of the following sets of quantum numbers are not allowed? For each incorrect set, state why it is incorrect.

$$(a)\ n = 3, l = 3, m_l = 0, m_s = -\frac{1}{2}$$

$$(b)\ n = 4, l = 3, m_l = 2, m_s = -\frac{1}{2}$$

$$(c)\ n = 4, l = 1, m_l = 1, m_s = +\frac{1}{2}$$

$$(d)\ n = 2, l = 1, m_l = -1, m_s = -1$$

$$(e)\ n = 5, l = -4, m_l = 2, m_s = +\frac{1}{2}$$

$$(f)\ n = 3, l = 1, m_l = 2, m_s = -\frac{1}{2}$$

7.5. Rules governing the electronic configurations

Activity 7.5

1. Write electronic configuration of the following atoms using K, L, M, N… orbit representations: Ca (z= 20), Cl (Z= 17), Sr (Z=38)
2. Potassium contains 19 electrons while sulphur contains 16. It is found that the potassium ion (K^+) has 18 electrons like the sulphide ion (S^{2-}).

a) Explain why the two ions contain the same number of electrons.

b) What is the element and its group on the Periodic table which is isoelectronic with the ions mentioned?

3. State two differences between

a) Calcium atom (Ca) and its ion (Ca^{2+}).

b) Nitrogen (N) and its ion (N^{3-})

The electron configuration of an atom is *the representation of the arrangement of electrons distributed among the orbital shells and subshells*. Commonly, the electron configuration is used to describe the orbitals of an atom in its ground state, but it can also be used to represent an atom that has ionized into a cation or anion by compensating with the loss of or gain of electrons in their subsequent orbitals.

Many of the physical and chemical properties of elements can be correlated to their ***unique electron configurations***. The valence electrons, electrons in the outermost shell, are the determining factor for the unique chemistry of the element.

Before assigning the electrons of an atom into orbitals, one must become familiar with the ***basic concepts of electron configurations***. Using the periodic table to determine the electron configurations of atoms is a key, but also keep in mind that there are ***certain rules to follow*** when assigning electrons to different orbitals. The periodic table is an incredibly helpful tool in writing electron configurations.

7.5.1. Rules for assigning electron orbitals

Electrons fill orbitals ***in a way to minimize the energy of the atom***. Therefore, the electrons in an atom fill the principal energy levels in **order of increasing energy** (the electrons are getting farther from the nucleus). The *order of levels filled* looks like this:

1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, *and* ***7p***

One way to remember this pattern, probably the easiest, is to refer to the periodic table and remember where each orbital block falls to logically deduce this pattern. Another way is to make a table like the one below and use vertical lines to determine which sub-shells correspond with each other.

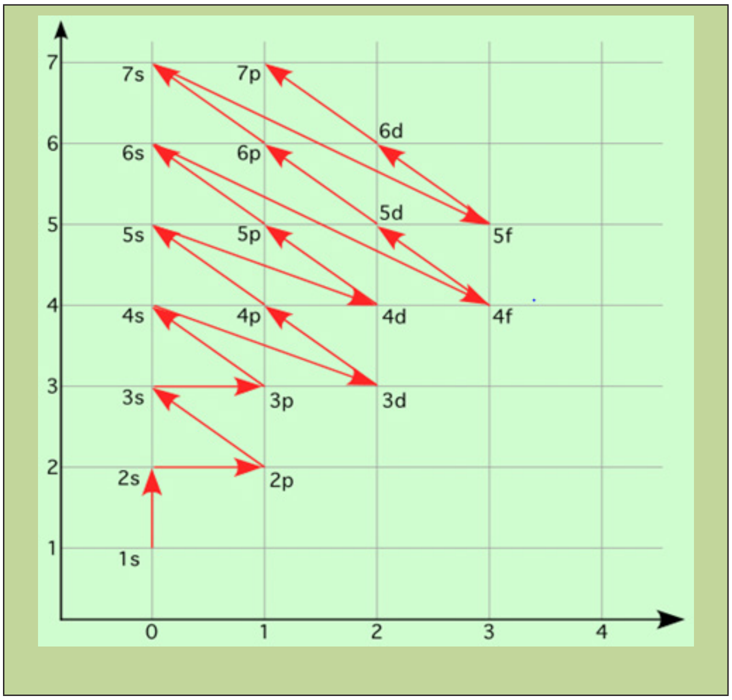


Figure 7.7.:Order of increasing energy of orbitals

1. Pauli Exclusion Principle

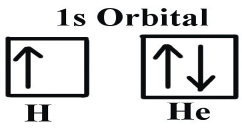
The Pauli Exclusion Principle states that no two electrons can have the same four quantum numbers.

As said before, the first three (n, ℓ, and m_ℓ) may be the same, but the fourth quantum number must be different. A single orbital can hold a maximum of two electrons, which must have opposing spins; otherwise they would have the same four quantum numbers, which is forbidden. One electron is spin up (m_s = +1/2) and the other would spin down (m_s = -1/2). This tells us that each subshell has double the electrons per orbital. The s subshell has 1 orbital that can hold up to 2 electrons, the p subshell has 3 orbitals that can hold up to 6 electrons, the d subshell has 5 orbitals that hold up to 10 electrons, and the f subshell has 7 orbitals with 14 electrons.

Example: Hydrogen and Helium

The first three quantum numbers of an electron are n=1, l=0, m_l=0. Only two electrons can correspond to these, which would be either m_s = -1/2 or m_s = +1/2.

As we already know from our studies of quantum numbers and electron orbitals, we can conclude that these four quantum numbers refer to the **1s** subshell. Visually, this can be represented as:



As shown, the 1s subshell can hold only two electrons and, when filled, the electrons have opposite spins.

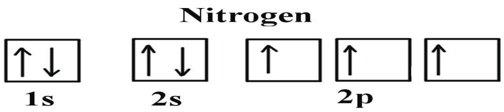
If only one of the $\mathbf{m_s}$ values are given then we would have $\mathbf{1s^1}$ (denoting hydrogen); if both are given we would have $\mathbf{1s^2}$ (denoting helium).

2. Hund's Rule

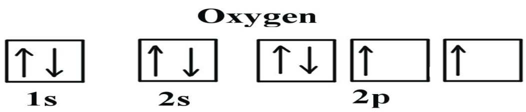
When assigning electrons in orbitals, each electron will first fill all the orbitals with similar energy (also referred to as "degenerate") ***before pairing with another electron in a half-filled orbital***. Atoms at ground states tend to have as many unpaired electrons as possible. When visualizing this process, think about how electrons are exhibiting the same behavior as the same poles on a magnet would if they came into contact; as the negatively charged electrons fill orbitals they first try to get as far as possible from each other before having to pair up.

Example: Oxygen and Nitrogen

If we look at the correct electron configuration of the Nitrogen (Z = 7) atom, a very important element in the biology of plants: $\mathbf{1s^2}$ $2s^2$ $2p^3$



If we look at the element after Nitrogen in the same period, Oxygen (Z = 8) its electron configuration is: $\mathbf{1s^2}$ $2s^2$$\mathbf{2p^4}$ (for an atom).



Oxygen has one more electron than Nitrogen and as the orbitals are all half filled, the electron must pair up.

3. The Aufbau Principle

Aufbau comes from the German word "aufbauen" meaning "*to build*." ***When writing electron configurations, orbitals are built up from atom to atom.***

Example: 3rd Row Elements

Following the pattern across a period from B (Z=5) to Ne (Z=10), the number of electrons increases and the subshells are filled. This example focuses on the p subshell, which fills from boron to neon.

B (Z=5) configuration: $1s^2\ 2s^2\ 2p^1$

C (Z=6) configuration: $1s^2\ 2s^2\ 2p^2$

N (Z=7) configuration: $1s^2\ 2s^2\ 2p^3$

O (Z=8) configuration: $1s^2\ 2s^2\ 2p^4$

F (Z=9) configuration: $1s^2\ 2s^2\ 2p^5$

Ne (Z=10) configuration: $1s^2\ 2s^2\ 2p^6$

According to the Aufbau Process, ***when writing the electron configuration for an atom, orbitals are filled in order of increasing atomic number***. However, there are some exceptions to this rule.

SOME EXCEPTIONS TO AUFBAU PROCESS
Although the *Aufbau rule* accurately predicts the electron configuration of most elements, there are notable exceptions among the transition metals and heavier elements. The reason these exceptions occur is that some elements are more stable with fewer electrons in some sub-shells and more electrons in others. ***Examples:*** Chromium and copper (in Period 4) Chromium: Z:24 [Ar] $3d^5 4s^1$ Copper: Z:29 [Ar] $3d^{10} 4s^1$

7.5.2. Writing electron configurations

When writing an electron configuration, first write the **energy level** (the period), then the **subshell** to be filled and the **superscript**, which is ***the number of electrons in that sub-shell***. The total number of electrons is the atomic number, **Z**.

The rules above allow one to write the electron configurations for all the elements in the periodic table. Three methods are used to write electron configurations:

- Spdf notation
- Orbital diagrams
- Noble gas notation

Each method has its *own purpose* and each has its own drawbacks.

4. spdf Notation

The most common way to describe electron configurations is to write distributions in the spdf notation. Although the distributions of electrons in each orbital are not as apparent as in the diagram, the total number of electrons in each energy level is described by a ***superscript*** that follows the relating energy level.

To write the electron configuration of an atom, identify the energy level of interest and write the number of electrons in the energy level as its superscript as: $1s^2$. This is the electron configuration of helium; it denotes a full s orbital. The periodic table is used as a reference to accurately write the electron configurations of all atoms.

Example:

Potassium has ***19 electrons***.

- Begin by filling up the 1*s* sublevel. This gives $\mathbf{1s^2}$. Now the $n = 1$ level is filled.
- Since we used 2 electrons, there are 19 – 2 = 17 electrons left
- Next, fill the 2*s* sublevel. This gives $\mathbf{1s^2 2s^2}$
- Since we used another 2 electrons, there are 17 – 2 = 15 electrons left
- Next, fill the 2*p* sublevel. This gives $\mathbf{1s^2 2s^2 2p^6}$. Now the $n = 2$ level is filled.
- Since we used another 6 electrons, there are 15 – 6 = 9 electrons left
- Next, fill the 3*s* sublevel. This gives $\mathbf{1s^2 2s^2 2p^6 3s^2}$
- Since we used another 2 electrons, there are 9 – 2 = 7 electrons left
- Next, fill the 3*p* sublevel. This gives $\mathbf{1s^2 2s^2 2p^6 3s^2 3p^6}$
- Since we used another 6 electrons, there are 7 – 6 = 1 electron left
- Here's where we have to be careful – right after $3p^6$!!
- Remember, 4*s* comes before 3*d*!

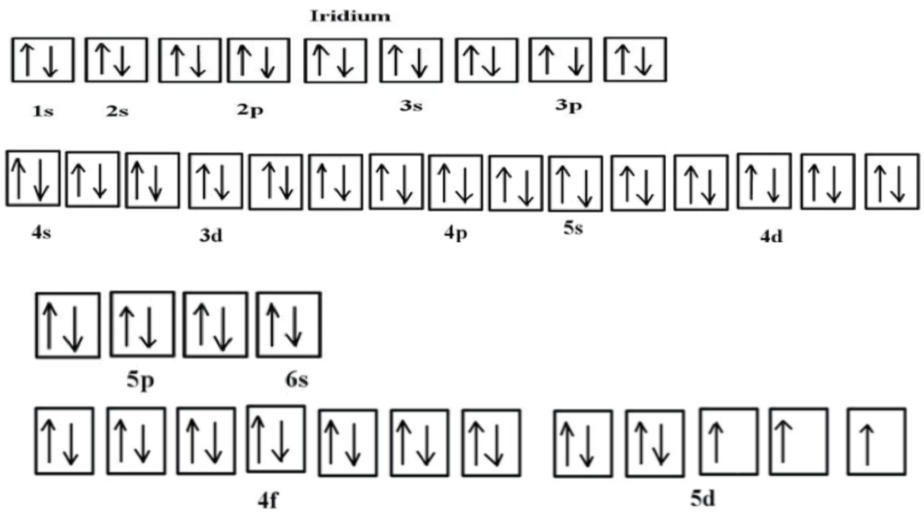
The final electron goes into the 4*s* sublevel. This gives $\mathbf{1s^2 2s^2 2p^6 3s^2 3p^6 4s^1}$

5. Orbital Diagrams

An orbital diagram, like those shown above, is a visual way to reconstruct the electron configuration by showing each of the separate orbitals and the spins on the electrons. This is done by first determining the subshell (s,p,d or f) then drawing in each electron according to the stated rules above.

Example: The atomic number of Iridium (Z) is **77**. Write the electron configuration of Iridium using orbital diagram method.

Answer:



Although drawing out each orbital may prove to be ***helpful in determining unpaired electrons***, it is very ***time consuming*** and often not as practical as the spdf notation, especially for atoms with much longer configurations. Hund's rule is also followed, as each electron fills up each 5d orbital before being forced to pair with another electron.

6. Noble Gas Notation

This brings up an interesting point about elements and electron configurations. As the p-subshell is filled in the above mentioned example of the period from B (Z=5) to Ne (Z=10) about the Aufbau principle, it reaches the group commonly known as the ***noble gases***. The noble gases have the most stable electron configurations, and are known for being relatively inert. All noble gases have their subshells filled and can be used them as a *shorthand way of writing electron configurations for subsequent atoms.*

This method of writing configurations is called ***the noble gas notation***, in which the noble gas in the period above the element that is being analyzed is used to denote the subshells that element has filled and after which the

valence electrons (electrons filling orbitals in the outer most shells) are written. This looks slightly different from spdf notation, as the reference noble gas must be indicated.

Example: Vanadium (V, Z=23)

Vanadium is the transition metal in the ***fourth period*** and ***the fifth group***. The noble gas preceding it is argon (Ar, Z=18), and knowing that vanadium has filled those orbitals before it, ***argon is used as the reference noble gas***. The noble gas in the configuration is denoted in brackets.

To find the valence electrons that follow, subtract the atomic numbers: **23 - 18 = 5**. Instead of 23 electrons to distribute in orbitals, there are **5**. Now there is enough information to write the electron configuration:

Vanadium, V: [Ar] $4s^2$ $\mathbf{3d^3}$

This method streamlines the process of distributing electrons by showing the valence electrons, which determine the chemical properties of atoms. In addition, when determining the number of unpaired electrons in an atom, this method allows quick visualization of the configurations of the valance electrons. In the example above, there are one full s orbital and three half filled d orbitals.

7.5.3. Electron configurations of ions

We already know that *ions are formed when atoms gain or lose electrons*.

A cation (positively charged ion) forms when one or more electrons are removed from a parent atom. For main group elements, the electrons that were added last are the first electrons removed. For transition metals and inner transition metals, however, electrons in the *s* orbital are easier to remove than the *d* or *f* electrons, and so the highest *ns* electrons are lost, and then the $(n-1)d$ or $(n-2)f$ electrons are removed.

An anion (negatively charged ion) forms when one or more electrons are added to a parent atom. The added electrons fill in the order predicted by the Aufbau principle.

Example: What is the electron configuration of: Na^+, P^{3-}, Al^{2+}, Fe^{2+} and Sm^{3+}

Solution

- First, ***write out the electron configuration for each parent atom***. We have chosen to show the full, unabbreviated configurations to provide more practice for students who want it, but listing the core-abbreviated electron configurations is also acceptable.

- Next, ***determine whether an electron is gained or lost.*** Remember electrons are negatively charged, so ions with a positive charge have *lost* an electron. For main group elements, the last orbital gains or loses the electron. For transition metals, the last *s* orbital loses an electron before the *d* orbitals.

Na: $1s^22s^22p^63s^1$. Sodium cation loses one electron, so Na^+: $1s^22s^22p^6$.

P: $1s^22s^22p^63s^23p^3$. Phosphorus trianion gains three electrons, so P^{3-}: $1s^22s^22p^63s^23p^6$.

Al: $1s^22s^22p^63s^23p^1$. Aluminum dication loses two electrons, so Al^{2+}: $1s^22s^22p^63s^1$.

Fe: $1s^22s^22p^63s^23p^64s^23d^6$. Iron (II) loses two electrons and, since it is a transition metal, they are removed from the 4*s* orbital Fe^{2+} = $1s^22s^22p^63s^23p^63d^6$.

Sm: $1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^66s^24f^6$. Samarium trication loses three electrons. The first two will be lost from the 6*s* orbital, and the final one is removed from the 4*f* orbital. Sm^{3+} = $1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^64f^5$.

Application activity7.5

1. The electron energy levels of a certain element can be represented as $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^4$

   a) What is the atomic number of the element?

   b) What is the name of the element?

2. The element nitrogen forms compounds with metals and non-metals. Nitrogen forms a nitride ion with the electron configuration $1s^2\ 2s^2\ 2p^6$.

   a) Write the formula of the nitride ion.

   b) An element forms an ion Q with a single negative charge that has the same electron configuration as the nitride ion. Identify the ion Q.

3. tUsing the noble gas notation, write the electronic configuration of the following atoms/ions.

a) Ge (Z=32)

b) S (Z=16)

c) Co^{2+} (Z=27)

d) Br^{-} (Z=35)

e) Sr (Z=38)

SKILLS LAB

"ELECTRON CONFIGURATION BINGO ACTIVITY"

Introduction

The wave-mechanical model of the atom states that the exact position of an electron at any given moment cannot be determined. Instead, electrons are located in clouds outside the nucleus. These clouds are described by energy level and type of sublevel. An electron configuration may be written to identify the placement of electrons in these levels and sublevels.

Objectives

1. Determine electron configurations for given elements.
2. Identify elements given their electron configurations.

Materials: (per student)

- 1 bingo card
- 25 bingo markers
- 1 periodic table

Procedure

1. Choose 25 elements from the provided list.
2. On your bingo card, fill in each box with either the symbol of the chosen element or its electron configuration. DO NOT WRITE BOTH.

3. Your tutor will call out either the electron configuration or an element.
4. From the question, determine either the element or the electron configuration. Mark your card appropriately. For example, if the question is "Oxygen", you may mark your card only if you have $1s^2$ $2s^2$ $2p^4$. If the question is "$1s^2$ $2s^2$ $2p^6$", you may mark your card only if you have Ne.
5. The winner of the game is the first person to have 5 squares in a row marked.

Element List

Hydrogen	Carbon	Oxygen
Lithium	Beryllium	Neon
Boron	Helium	Chlorine
Nitrogen	Bromine	Phosphorus
Fluorine	Zinc	Aluminum
Argon	Iron	Sodium
Sulfur	Potassium	Calcium
Silicon	Magnesium	Nickel
Arsenic	Krypton	Xenon

Atomic Bingo Game Board

End unit assessment 7

1. For each of the following, choose the letter corresponding to the best answer.

a) The principal quantum number describes the following, except

i. The size of the shell

ii. The energy of an electron in an atom

iii. The shape of the orbital

iv. The average distance of the orbital from the nucleus

b) On the following list of quantum numbers, the one which is not correct is:

i. Principal

ii. Spin

iii. Magmatic Quantum

iv. Azimuthal

c) The electron configuration for gallium (Z=31) is:

i. [Ar] $4s^2 4d^{10} 4p^1$

ii. [Ar] $4s^2 3d^{10} 4p^1$

iii. [Ar] $4s^2 3d^{10} 3p^1$

iv. None of the above.

d) The four other spectral line series, in addition to the Balmer series, are named after their discoverers. They are, except:

i. Lyman

ii. Pfund

iii. Brackett

iv. Planck

2. According to the Aufbau principle, which orbital is filled immediately before each of the following?

   a) 3p

   b) 4p

   c) 4f

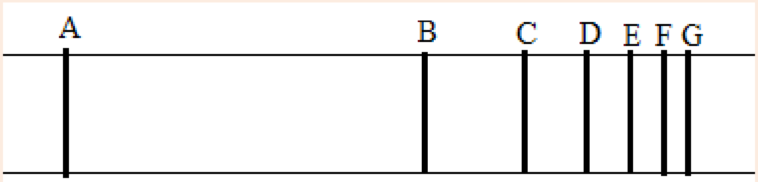
   d) 5d

3. Hafnium element has 72 electrons. Write its s, p, d, f electron configuration.

4. Why are the outer-most electrons the only ones included in the electron dot diagram?

5. The orbital filling diagram has arrows pointing in opposite directions when two electrons occupy the same orbital. What do these arrows indicate?

6. The emission spectrum of hydrogen consists of several series of lines. The series of highest energy is called the Lyman series (see Figure below). Each line in the series is the result of an electronic transition between energy levels.



a) State in which direction the energy increases: A to G or G to A.

b) State in which direction the frequency increases A to G or G to A.

c) Explain why the spectrum consists of lines.

d) What do transitions in the same series all have in common?

7. a) Write the electronic configuration of the following elements/ ions:

“Sodium, magnesium ion (Mg^{2+}), aluminium, aluminium ion (Al^{3+}), oxygen ion (O^{2-})”

b) Identify the common feature of ions in (a) and why do they have such feature.

c) Suggest what happened to aluminium atom when it changed to aluminium ion (Al^{3+}).

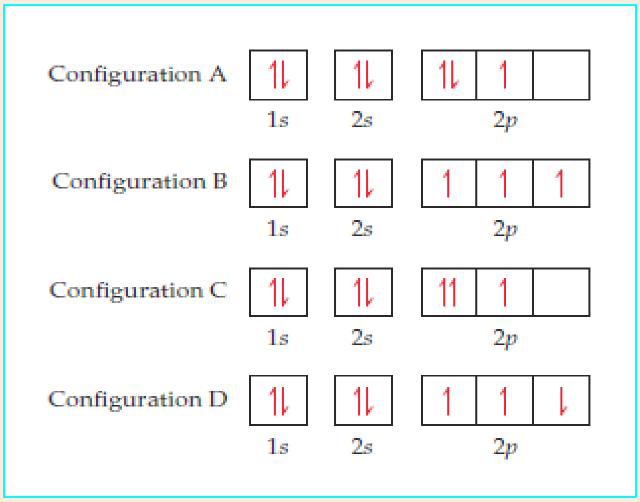
d) Identify the group and the period of aluminium, sodium and oxygen atom.

8. Four possible electron configurations (A, B, C and D) for a nitrogen atom are

a) Which one is the correct electron configuration?

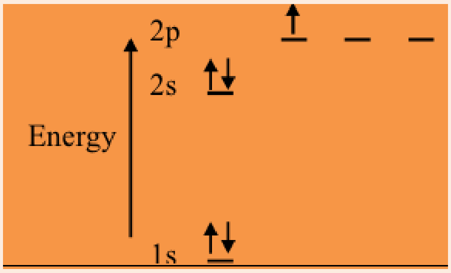
b) Which configurations violate the Pauli Exclusion Principle?

c) Which configurations violate Hund’s rule?



9. Complete the electronic configurations for the sulphur atom, S, and the sulphide ion, S^{2-}. State the block in the Periodic Table in which sulphur is placed and explain your answer.

10. The diagram below shows the electronic structure of boron.



a) The electrons are represented by arrows. What property of the electrons do these ‘up’ and ‘down’ arrows represent?

b) Suggest why electrons which occupy the 2p sub-levels have a higher energy than electrons in the 2s sub-level.

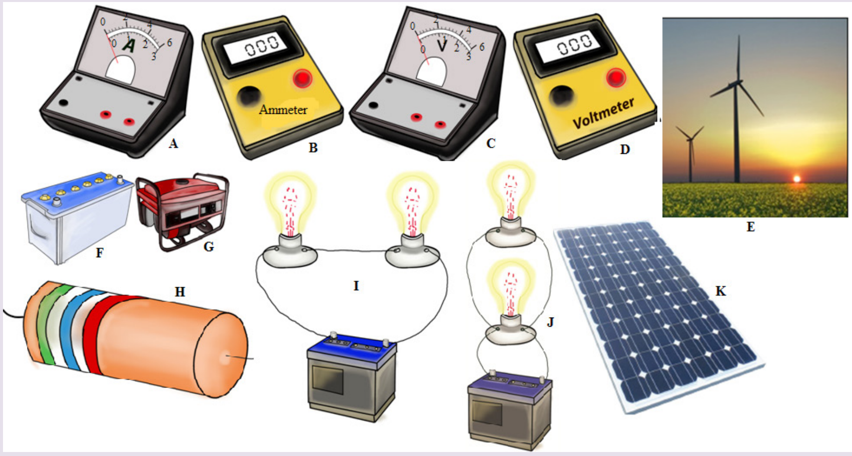
UNIT 8: KIRCHHOFF'S LAWS IN ELECTRIC CIRCUITS

Key unit competence

Analyze complex electric circuits using Kirchhoff's laws.

Introductory Activity 8

Look carefully and try to interpret the following illustrations and answer the questions below:



a) What type of electrical devices available in the illustration above?

b) Suggest the names of the available devices in the illustration above?

c) Is there any complete circuit in the illustration above? What kind of electrical circuits identified in the illustration above?

d) Have you ever used or connected these electrical components somewhere? If yes, what were the difficulties in handling these electrical components in circuit construction?

e) What can be considered to select the best electrical device(s) to be used in electrical circuit construction?

f) What can be put in recognition when manipulating these electrical components to minimize risks in the process of circuit construction?

8.1 Simple electric circuit and its construction

Activity 8.1

Making a simple electric circuit with a battery, bulb(s) , and wires

Task1: Making a series circuit

Provided materials: 1 battery,aswitch,3 pieces of copper wireand bulb(s).

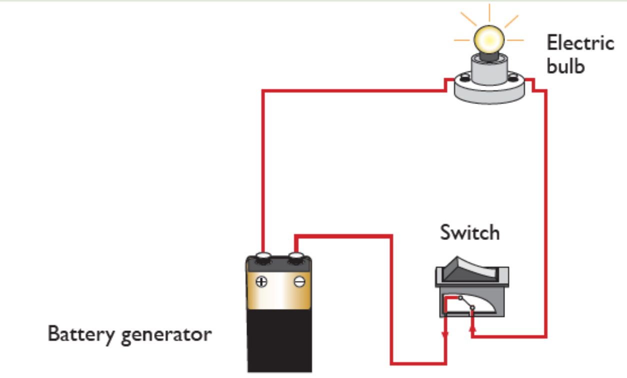


Fig 8.1: Diagram of a simple electric circuit

Technical procedures:

i. Arrange the battery as shown in figure above.
ii. Connect the bulb in series with other components and switch on.
iii. Switch off and explain what happens to the bulb?
iv. Explain what makes the bulb light?

Task 2 : Making a parallel circuit

Provided materials: 1 battery,3 bulbs,Assembled battery holder, 3 bulb holders and 4 pieces of copper wire.

Technical procedures:

i. Construct a complete circuit with one battery and one bulb.
ii. Using other two wires, add a second bulb as shown in the figure below.

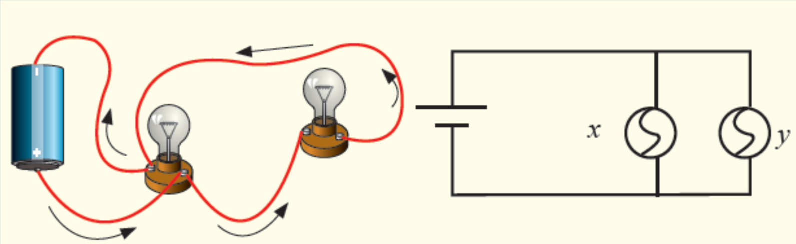


Figure 8.2: *Diagram of A parallel circuit*

iii. What do you notice happened to the first bulb when the second bulb was added?

iv. Look carefully at how a parallel circuit is set up. Write a prediction of what you think will happen if you unscrew one of the bulbs in the parallel circuit. By comparing your prediction and the observation, explain your observation?

v. Unscrew bulb “X”. Describe what happens to bulb “Y”.

vi. Tighten bulb “X” and unscrew bulb “Y”. Describe what happens to bulb “X”.

vii. Based on the performed experiments for series and parallel circuits,

a) What advantages and disadvantages can you recognize in two cases above?

b) Identify the characteristics of a series connection and a parallel connection?

Task 3: Making a simple electric circuit with a bulb, a battery and wires

Provided materials: 2 pieces of copper wire,1 bulb, and 1 battery

Procedure

1. Examine diagrams A-J below. Predict whether the circuit will be complete, and record your prediction on the chart below.
2. Your tutor, with a helper, demonstrate the arrangements to test your predictions. Record your results on the chart below

PREDICTION CHART

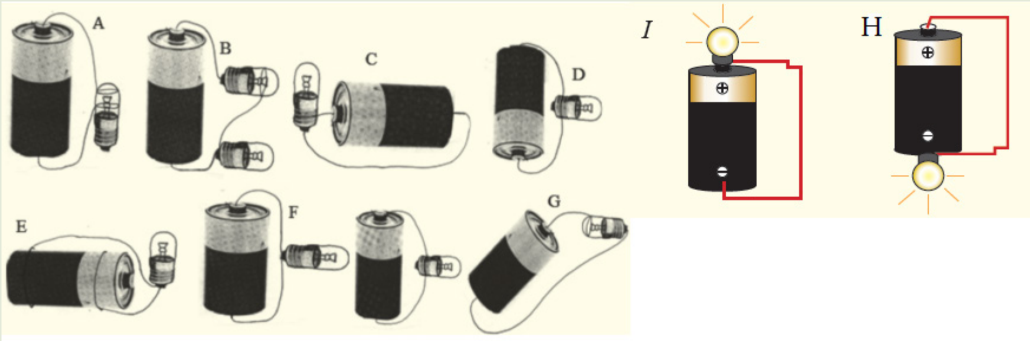
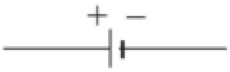
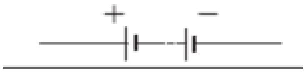
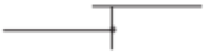
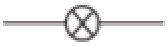


Figure 8.3: Different connections

8.1.1 Electric circuit components and their symbols

In electric circuit diagrams, we represent the actual components with symbols. Table below shows some of the components, their symbols and definition that are used in electric circuit diagrams.

Component	Circuit Symbol	Definition/ Description
cell		small source of electric energy
Battery		large source of electric energy
Power supply		D.C mains
Open switch		Breaks the circuit.
Closed switch		Completes the circuit.
Wires joined		junctions
Connecting wire		joins two or more components in electric circuit.
Lamb/bulb		converts electric energy to heat and light. The best example is the warning light on a car dashboard.
ammeter		measures electric current

voltmeter		measures p.d and voltage
Resistor		is used to restrict the amount of current flow through a device.

Table: *Circuit components and their symbols*

8.1.2 Sample arrangement of electric components in a simple electric circuit.

Remember **the cell provides electrical energy** needed to light the bulb. The bulb converts electrical energy into light and heat energy.

A cell is a kind of a 'pump' which provides electrical energy needed to drive charges along a complete path formed by the wire through the bulb switch and back again to the cell.

When the switch is open, the bulb **does not light**. This is called an **open circuit**. When the bulb lights the circuit is called **closed circuit.**

In a series circuit, the current is the same at all points; it is not used up. In a parallel circuit the total current equals the sum of the currents in the separate branches.

- **Schematic diagram and its corresponding illustrations:**

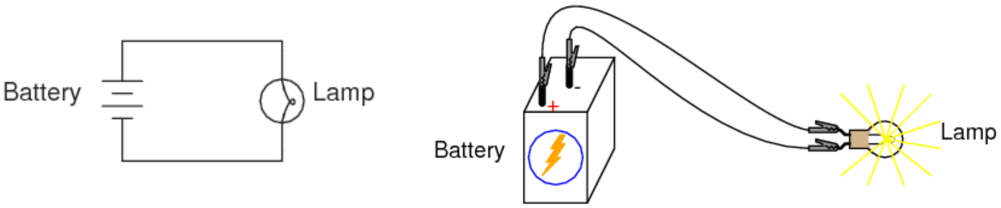


Fig 8.4: Diagram and illustration of simple electric circuit

- **ILLUSTRATION OF BREAK IN ELECTRIC CIRCUITS**

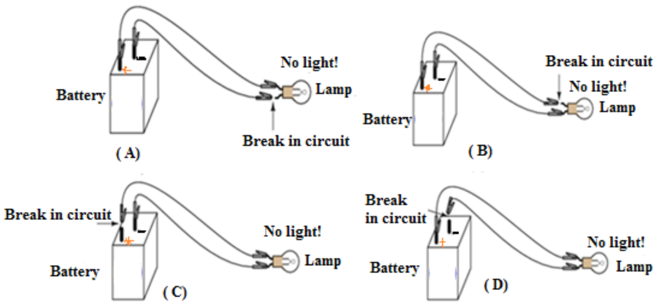


Fig 8.5: Illustration of Break in electric circuit

Application activity 8.1

1. Define the term electric circuit.
2. Draw a diagram for a simple circuit using preferable electric components.
3. What is an open circuit?
4. Draw a labeled diagram of a simple cell.
4. The following are some symbols of electric components.

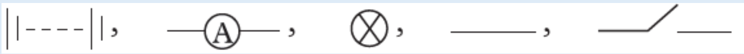


Fig: Symbols of electric components

a) Name the electric components represented by these symbol.

b) Using these symbols, draw a simple circuit diagram.

8.2. Voltage or terminal potential and electromotive force in electric circuit.

Activity 8.2

Provided different dry cells ammeter and voltmeters. Read the value of voltage labeled on each dry cell and complete this table.

Dry cell	Labeled voltage	Measured terminal voltage	observation
1			
2			
3			
4			

Any other comment:

………………………………………………………………………………

………

8.2.1 Potential difference (p.d)

Potential difference is defined as the work done in moving one coulomb of charge from one point to the other in an electrical circuit. The SI unit of potential difference is the volt (V).

In the electric circuit, the electrons move towards the positive terminal of the battery. The battery lifts the electrons up through an electrical height. This electrical height is called a potential.

The positive and the negative terminals have a difference in potential. The potential difference is also known as the voltage.

$$Voltage = \frac{Work\ done}{Charge}$$ (Joules per coulomb).

- **The volt**

Volt is defined as energy consumption of one joule per electric charge of one coulomb.

- **MEASUREMENT OF VOLTAGE**

Figure (A) shows **analog voltmeter** and (B) shows **digital voltmeter** the symbol for a voltmeter. **A voltmeter** is used to measure voltage across a device in an electric circuit.

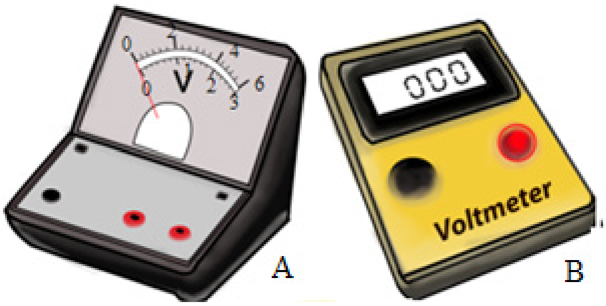
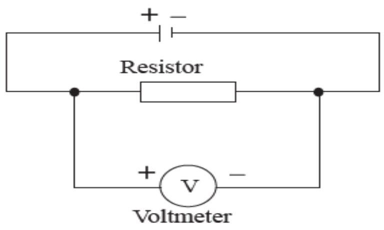


Fig 8.6: Analogue and digital voltmeter.

The **positive terminal of voltmeter** is connected to the wire from the **positive terminal of the cells** and the **negative terminal** to the wire leading to **negative terminal**. A voltmeter is always parallel to the device whose voltage is to be measured.



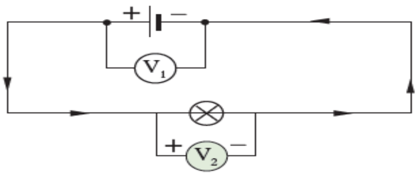


Fig 8.7: Connection of voltmeter in a circuit.

Voltmeters have uniform scales calibrated in **volts or millivolts**. The most used scales have a range of 0 – 5 V and 0 – 1.5 V. Figure below shows a scale of a voltmeter.

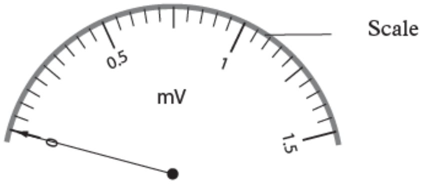


Fig 8.8: Scale of analogue voltmeter.

8.2.2 Electromotive force.

Electromotive **force** is voltage, or the difference in the electric tension or the difference in charge between two points that causes an electric current.

The potential difference between two points of a conductor creates **an electromotive force** *which* pushes free electrons in a conducting material to move towards the positive terminal, creating current.

Electromotive force, or, as it is often written, e.m.f., may be described as that source of energy which enables electrons to move around an electric circuit. It is now necessary to define this quantity.

For anything to move from rest, there must be some energy change. To enable electrons to move round an electrical circuit, they must receive energy from the source of e.m.f. which is usually a battery or a generator.

Note:

- The terminal potential difference (or voltage) of a battery or generator when it delivers a current, I is related to its electromotive force, and its internal resistance r as follows:

  1. When delivering current (on discharge):

Terminal voltage = Electromotive force –Voltage drop in internal resistance

$$V = \varepsilon - Ir$$

2. When receiving current (on charge):
   Terminal voltage = emf + (Voltage drop in internal resistance)
3. When no current exists:
   Terminal voltage = Emf of battery or generator.

All voltage sources have two fundamental parts: a source of electrical energy that has a characteristic electromotive force (emf), and an internal resistance . The emf is the potential difference of a source when no current is flowing.

The numerical value of the emf depends on the source of potential difference. The internal resistance of a voltage source affects the output voltage when a current flows.

The voltage output of a device is called its terminal voltage and is given by, where I is the electric current and is positive when flowing away from the positive terminal of the voltage source.When multiple voltage sources are in series, their internal resistances add and their emfs add algebraically.

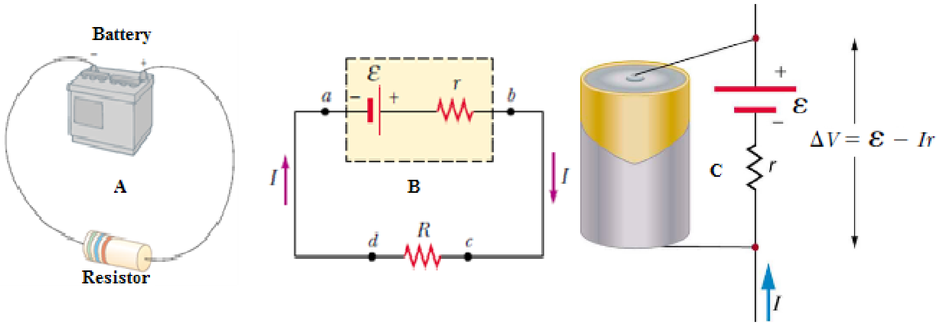


Figure 8.9: The terminal potential difference (or voltage) of a battery

Consider the circuit shown in Figure 8.9.A, consisting of a battery connected to a resistor. We generally assume that the connecting wires have no resistance. The positive terminal of the battery is at a higher potential than the negative terminal. Because a real battery is made of matter, there is resistance to the flow of charge within the battery. This resistance is called **internal resistance** *r*.

For an idealized battery with zero internal resistance, the potential difference across the battery (called its **terminal voltage)** equals its emf. However, for a real battery, the terminal voltage is *not* equal to the emf for a battery in a circuit in which there is a current.

Now imagine moving through the battery from *a* to *b* and measuring the electric potential at various locations. As we pass from the negative terminal to the positive terminal, the potential increasesby an amount . However, as we move through the resistance *r*, the potential decreasesby an amount Ir, where I is the current in the circuit. Thus, the terminal voltage of the battery, $\Delta V = V_b - V_a$

Example 1 :

A battery has an emf of 12.0 V and an internal resistance of 0.05 Ω. Its terminals are connected to a load resistance of 3.00Ω. Find the current in the circuit and the terminal voltage of the battery.

Solution:

It is possible to calculate current from the equation given by:

$$I = \frac{\varepsilon}{R+r} \qquad I = \frac{12.0V}{3.05\Omega} \qquad I = 3.93A$$

And from equation, we find the terminal voltage; $\Delta V = \varepsilon - Ir$,

$$\Delta V = 12.0V - (3.93A)(0.05\Omega) = 11.8V$$

To check this result, we can calculate the voltage across the load

resistance R:

$$\Delta V = IR = (3.93\,A)(3.0\,\Omega) = 11.8V$$

Example 2

The current in the figure below is 0.125 A in the direction shown. For each of the following pairs of points, what is their potential difference, and which point is at the high potential?

a) A, B; b) B, C; c) C,D; d) D,E; e) C,E ; f) E,C.

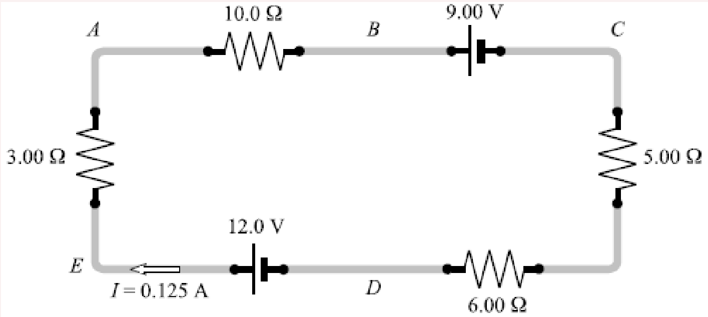


Fig 8.10: Electric circuit

Solution:

Recall the following facts:

1. The current is the same (0.125 A) at all points in this circuit because the charge has no other place to flow.
2. Current always flows from high to low potential through a resistor.
3. The positive terminal of a pure emf (the long side of its symbol) is always the high-potential terminal. Therefore, taking potential drops as negative, we have the following:

$V_{AB} = -IR = -(0.125A)(10.1\Omega) = -1.25V$; A is higher.

$V_{BC} = -\varepsilon = -9.0V$; B is higher.

$V_{CD} = -(0.125A)(5.0\Omega) - (0.125A)(6.0\Omega) = -1.38V$; C is higher.

$V_{DE} = +\varepsilon = +12.0V$; E is higher.

$V_{CE} = -(0.125A)(5.0\Omega) - (0.125A)(6.0\Omega) + 12.0V = +10.6V$; E is higher.

$V_{EC} = -(0.125A)(3.0\Omega) - (0.125A)(10.0\Omega) - 9.0V = -10.6V$; E is higher.

Notice that the answers to e) and f) agree with each other.

Application activity 8.2

1. Define the term potential difference and state its SI units.
2. Name the instrument used to measure voltage.
3. Define a volt.
4. In a circuit, 5 joules are used to drive 2 coulombs of charge across a bulb in a simple circuit. Find the potential difference across the bulb?
5. Name the instrument used to measure potential difference.
6. Two cells, A and B connected in parallel are in series with a bulb as shown in Figure below.

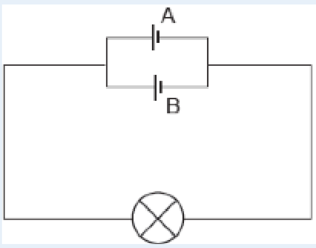


Fig 8.11: Circuit with parallel cells

Copy the diagram and show where the:

a) ammeter should be connected in order to measure the current through cell A.

b) voltmeter should be connected to measure the potential difference across both the bulb and cell B.

7. A dry cell has an emf of 1.52 V. Its terminal potential drops to zero when a current of 25 A passes through it. What is its internal resistance?

8.3. Electric receptors and Sources of electric current

Activity 8.3

Look and interpret the illustrations and try to answer questions that follow:

Figure 8.12: Some sources of electric energy

a) What is a source of electric current based on the images above?

b) What is another name of electric source of energy?

c) Suggest some of electric sources you have found.

d) On the picture above are some sources of electric energy. Name them and tell what the common role they have is.

e) Tell what energy is changed in electric energy for each device.

8.3.1 Sources of electric current

There are several different devices that can supply the voltage necessary to generate an electric current. The two most common sources are generators and electrolytic cells.

Generators use mechanical energy, such as water pouring through a dam or the motion of a turbine driven by steam, to produce electricity. The electric outlets on the walls of homes and other buildings, from which electricity to operate lights and appliances is drawn, are connected to giant generators located in electric power stations. Each outlet contains two terminals. The voltage between the terminals drives an electric current through the appliance that is plugged into the outlet.

Generator electrolytic cells use chemical energy to produce electricity. Chemical reactions within an electrolytic cell produce a potential difference between the cell's terminals. An electric battery consists of a cell or group of cells connected together.

There are many sources of electric current other than mechanical generators and electrolytic cells. Fuel cells or engines, for example, produce electricity through chemical reactions. Unlike electrolytic cells, however, fuel cells do not store chemicals and therefore must be constantly refilled.

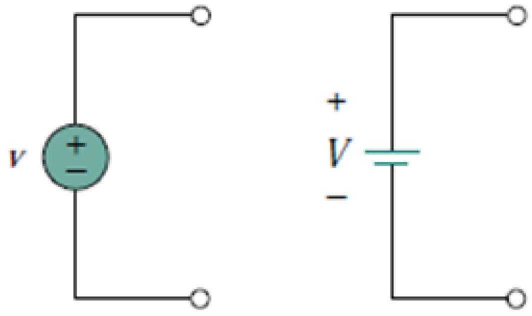
Certain sources of electric current operate on the principle that some metals hold onto their electrons more strongly than other metals do. Platinum, for example, holds its electrons less strongly than aluminum does. If a strip of platinum and a strip of aluminum are pressed together under the proper conditions, some electrons will flow from the platinum to the aluminum. As the aluminum gains electrons and becomes negative, the platinum loses electrons and becomes positive.

The strength with which a metal holds its electrons varies with temperature. If two strips of different metals are joined and the joint heated, electrons will pass from one strip to the other. Electricity produced directly by heating is called thermoelectricity.

Some substances emit electrons when they are struck by light. Electricity produced in this way is called photo-electricity. When pressure is applied to certain crystals, a potential difference develops across them. Electricity thus produced is called piezoelectricity. Some microphones work on this principle.

Notice: An electric generator is a device which is used to produce electric energy, which can be stored in batteries or can be directly supplied to the homes, shops, offices, etc. Electric generators work on the principle of electromagnetic induction. A conductor coil (a copper coil tightly wound onto a metal core) is rotated rapidly between the poles of a horseshoe type magnet. A conductor coil (a copper coil tightly wound onto a metal core) is rotated rapidly between the poles of a horseshoe type magnet. The conductor coil along with its core is known as an armature. The armature is connected to a shaft of a mechanical energy source such as a motor and rotated. The mechanical energy required can be provided by engines operating on fuels such as diesel, petrol, natural gas, etc. or via renewable energy sources such as a wind turbine, water turbine, solar-powered turbine. When the coil rotates, it cuts the magnetic field which lies between the two poles of the magnet. The magnetic field will interfere with the electrons in the conductor to induce a flow of electric current inside it.

Physical sources such as batteries and generators may be regarded as approximations to ideal voltage sources. Figure below shows the symbols for independent voltage sources.



(a) (b)

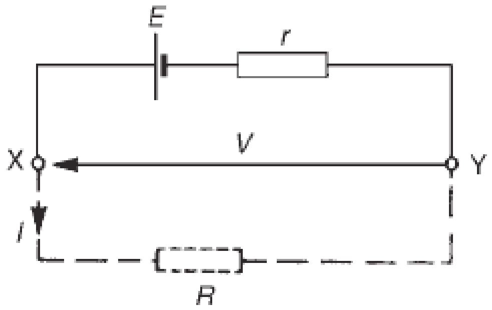
Cells connected in Series or parallel

The **electromotive force (e.m.f.),** ε , of a cell is the p.d. between its terminals when it is not connected to a load (i.e. the cell is on 'no load').

The e.m.f. of a cell is measured by using a **high resistance voltmeter** connected in parallel with the cell. The voltmeter must have a high resistance otherwise it will pass current and the cell will not be on no-load.

The voltage available at the terminals of a cell falls when a load is connected. This is caused by the **internal resistance** of the cell which is the opposition of the material of the cell to the flow of current.

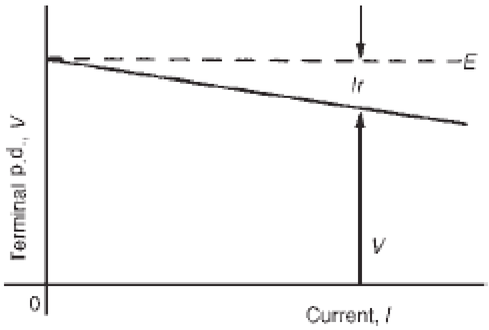
The internal resistance acts in series with other resistances in the circuit. **the** figure below shows a cell of e.m.f. ε volts and internal resistance, r , and XY represents the terminals of the cell.



When a load (shown as resistance R) is not connected, no current flows and the terminal p.d., $V=\varepsilon$. When R is connected a current I flows which causes a voltage drop in the cell, given by $V_r = Ir$. The p.d. available at the cell terminals is less than the e.m.f. of the cell and is given by:

$$V=\varepsilon-rI$$

When different values of potential difference V, across a cell or power supply are measured for different values of current I, a graph may be plotted as shown in figure below. Since the e.m.f. ε of the cell or power supply is the p.d. across its terminals on no load (i.e. when $I=0$), then ε is as shown by the broken line.



Since $V=\varepsilon-rI$ then the internal resistance may be calculated from

$$r=\frac{\varepsilon-V}{I}$$

When a current is flowing in the direction shown in Figure above the cell is said to be **discharging** ($\varepsilon>V$)

When a current flows in the opposite direction to that shown in Figure above the cell is said to be **charging** $\varepsilon<V$

A **battery** is a combination of more than one cell. The cells in a battery may be connected in series or in parallel.

(i) **For cells connected in series:**

Total e.m.f. ε_{eq} sum of cell's e.m.f. $\varepsilon_{eq} = \sum_{j=1}^{j=n} \varepsilon_j$

Total internal resistance r_{eq} = sum of cell's internal resistances

$$r_{eq} = \sum_{j=1}^{j=n} r_j$$

Example 1

1. Three cells each of emf of 1.5 V and internal resistance $0.6\ \Omega$ are connected in series to form a battery. What current passes or flows when the battery is connected across a $5\ \Omega$ resistance and what is the potential difference across the terminal of the battery?

Answer

The current: $I = \frac{\varepsilon_{eq}}{R + r_{eq}} = \frac{n\varepsilon}{R + nr} = \frac{3 \times 1.5}{5 + 3 \times 0.6} = 0.66\ A$

The pd across the terminal of battery:
$V = n\varepsilon - nri = 3 \times 1.5 - 3 \times 0.6 \times 0.66 = 3.31\ V$

(ii) **For cells connected in parallel:**

If each cell has the same e.m.f. and internal resistance:

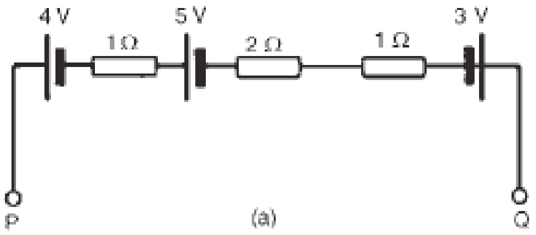
Total e.m.f. ε_{eq} = e.m.f. of one cell i.e. $\varepsilon_{eq} = \varepsilon$

Total internal resistance of n cells $r_{eq} = \frac{r}{n}$

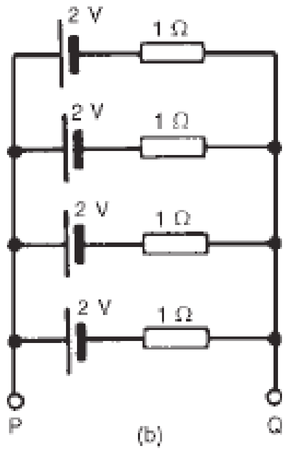
Example

1. For the circuits shown in Fig. the resistors represent the internal resistance of the batteries. Find, in each case:

i. the total e.m.f. across PQ
ii. the total equivalent internal resistances of the batteries



(a)



(b)

Answer

I a) Series circuit: $\varepsilon_{eq} = 4 + 5 - 3 = 6\,V$

b) Parallel circuit: $\varepsilon_{eq} = \varepsilon = 2\,V$

II a. Series circuit: $r_{eq} = nr = 4 \times 1 = 4\,\Omega$

b. Parallel circuit: $r_{eq} = \frac{r}{n} = \frac{1}{4} = 0.25\,\Omega$

8.3.2 Electrical receptors

A receptor is any electrical device that can transform electrical energy into any other form of energy. **Example**: the lamp, the motor, clippers, iron, electric cookers.

Passive receptors (thermal receptors) transform electrical energy into heat energy only by the joule effect. Examples: bulbs, electric irons, electric heaters.

Active receptors are capable of transforming electric energy not only into heat energy but also into other forms of energy. **Examples**: electric motors, batteries (secondary cells).

An active receptor is characterized by its counter-electromotive force and its internal resistance.

The **counter-electromotive force** also known as back electromotive force (cemf). It is its capacity of transforming a part of energy (electricity) in other form of energy (except heat). It is also the voltage, or electromotive force, that pushes against the current which induces it. CEMF is caused by a changing electromagnetic field. Back electromotive force is a voltage that occurs in electric motors where there is relative motion between the armature of the motor and the external magnetic field.

The **internal resistance** of an active receptor is the measure of its capacity to absorb heat energy by the joule effect when a current is flowing through it. Back electromotive force of an active receptor is the ratio:

$$\varepsilon = \frac{P}{I}$$

where P is the Power it transforms into energy other than heat and *I* electric current.

Receptors are often associated in parallel because in series there will be a big loss of energy. And to associate receptors in series, we will need a generator which also will be in series.

In Series

If we have n identical receptors characterized by cemf ε_k and r_k for each receptor, $k = 1, 2, 3, ..., n$ $k = 1, 2, 3, ...n$ all in series with a cell (*E*) and external resistance R_e, the total internal resistances of receptors will be $r_t = nr_k$ and the total cemf $\varepsilon_k = n\varepsilon_k$ Then the intensity is

$$I = \frac{\varepsilon - n\varepsilon_k}{R_e + r + nr_k}$$

In Parallel

As we know that for parallel the potential difference is the same for each blanch, here also if we have n receptors in parallel, the c.e.m.f of one is the same for others. The total internal resistance is

$$r_t = \frac{r}{n}$$

The intensity will be $I = \dfrac{\varepsilon - \varepsilon_1}{R_e + r + \dfrac{r_1}{n}}$

The power consumed by the receptor

The electric energy produced by the cell to the receptor transforms partially into heat (Joule's effect) into chemical energy (voltameter) or into mechanical energy (motor). The energy produced per second by cell is:

$$P = \varepsilon I$$

The energy liberated per second in form of heat is

$$P = I^2(R_e + r + r')$$

In really of principle of conservation of energy, the useful power consumed in receptor is

$$P = \varepsilon I - I^2(R_e + r + r') = \mathrm{I}^2(R_e + r) - I^2(R_e + r + r') = \varepsilon' \mathrm{I}$$

The useful power consumed by the receptor is the product of its $cemf$ to the intensity of the electric current.

The terminal potential difference across the receptor

We know that, the total electric energy absorbed per second by a receptor is V and $I^2 r_i$ changed into heat, $E'I$ into chemical or mechanical energy.

So $VI = \varepsilon' I + I^2 r_k$ and $V = \varepsilon' + I r_k$, this last term represents the drop (fall) of voltage in receptor means the voltage necessary for delivering a current *I* if the receptor has not represented the cemf

By this $I = \dfrac{V - \varepsilon'}{r_k}$ which shows us that the voltage must be greater than the cemf of the receptor.

Application activity 8.3

1. Explain the difference between load resistance in a circuit and internal resistance in a battery.

2. Is the direction of current through a battery always from the negative terminal to the positive terminal? Explain.

3. A real battery with an emf of provides 50 W to an external resistance of 4.

a) Find the internal resistance of the battery.

b) For what value of external resistor the supplied power is 100 W?

4. What is the internal resistance of the battery in the following circuit?

5. A battery has an emf of 15.0 V. The terminal voltage of the battery is 11.6 V when it is delivering 20.0 W of power to an external load resistor R.

a) What is the value of R?

b) What is the internal resistance of the battery?

8.4. Connection of resistors either in series or parallel or mix-up

Activity 8.4

Task1: Arrangement of resistors in series circuits.

Provided materials: Battery cells, three torch light bulbs and 4 conducting wires

Technical procedures:

– Arrange the battery cells as shown in figure below and connect all the two bulbs in series and switch on.

– Remove one bulb and notice what happens based on your observations.

– Arrange the circuit to have two bulbs, and then to have one bulb and notice the observation.

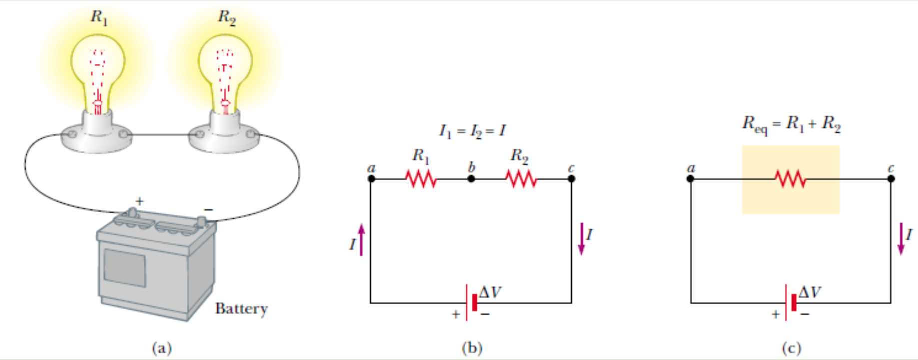


Fig 8.13: Series circuit

Use your observations to answer the following questions:

a) What happens in the circuit with three bulbs when one bulb is removed?

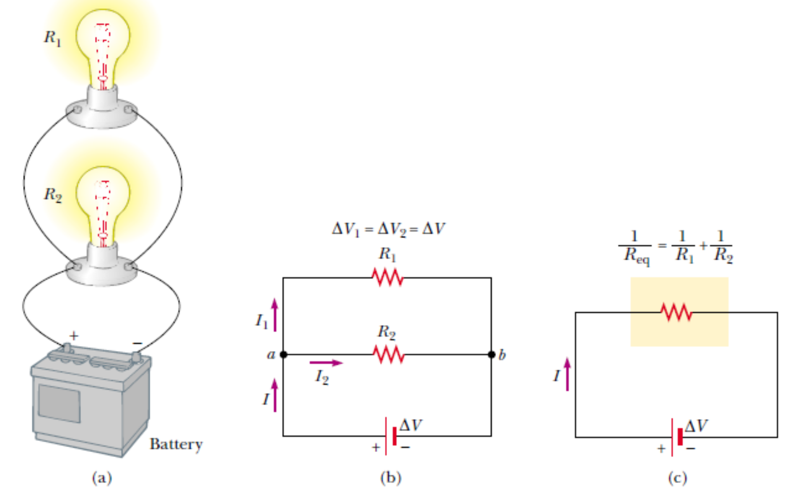
b) What happens when the circuit has two bulbs?

c) What happens when the circuit has one bulb only?

Task 2: Arrangement of resistors in series circuits

Technical Procedures:

- Arrange the battery cells as shown in figure below and connect all the three bulbs in parallel and switch on.
- Remove one bulb and notice your observations. Remove the second bulb and notice your observations.



Use your observation to answer to questions below:

a) Explain what happens in the circuit with two bulbs when one bulb is removed?

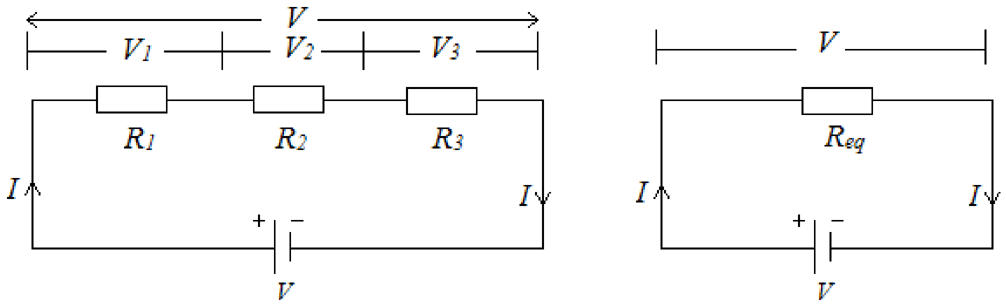
b) What happens when the circuit has two bulbs?

c) What happens when the circuit has one bulb only

Circuits consisting of just one battery and one load resistance are very simple to analyze, but they are not often found in practical applications. Usually, we find circuits where more than two components are connected together. There are two basic ways in which to connect more than two circuit components: series and parallel.

8.4.1 Resistors in series

The defining characteristic of a series circuit is that there is only one path for electrons to flow. Consider three resistors R_1, R_2 and R_3 connected in series across a battery of potential difference V. Across the resistors the potential difference drops are V_1, V_2 and V_3 but the current flow I is constant due to the same amount of charges flowing across each resistor.



$$V_1 = IR_1,\ V_2 = IR_2 \text{ and } V_3 = IR_3$$

The total potential difference across the series combination is

$$V = V_1 + V_2 + V_3 = I\left(R_1 + R_2 + R_3\right) \qquad (1)$$

If R is the equivalent or effective resistance of the series combination, and has same charge Q, then

$$V = IR_{eq}.$$

Substituting V inequation (1)

$$IR_{eq} = I\left(R_1 + R_2 + R_3\right)$$

$$R_{eq} = R_1 + R_2 + R_3 \qquad (2)$$

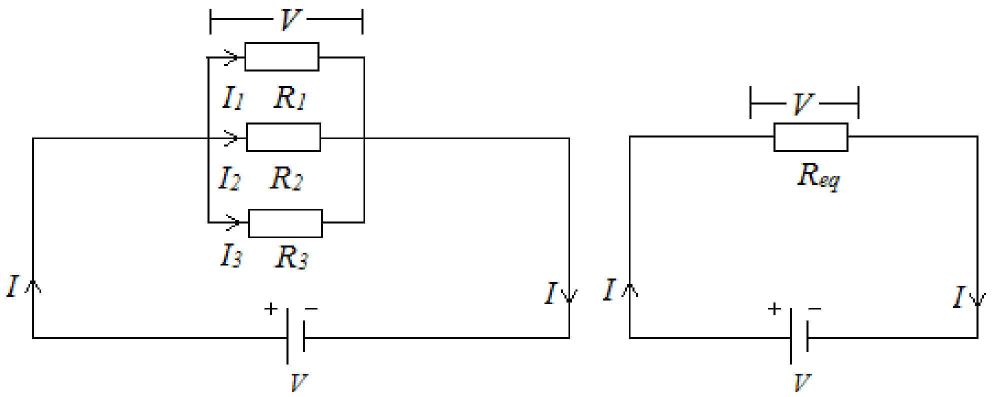
For any n resistors connected in series combination, the effective resistance is

$$R_{eq} = R_1 + R_2 + R_3 + \ldots + R_n$$

8.4.2 Resistors in parallel

The defining characteristic of a parallel circuit is that all components are connected between the same set of electrically common points and the resistors form more than one continuous path for electrons to flow.

Assume three resistors of resistance R_1, R_2 and R_3 connected in parallel across a battery of potential difference V. The potential difference across each resistor is the same and is equal to the potential difference V across the battery, but the current flow splits into three parts I_1, I_2 and I_3 due to the separation of charges



$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2} \text{ and } I_3 = \frac{V}{R_3}$$

The total current $I = I_1 + I_2 + I_3$

$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}\right)$$

If R_{eq} is the resistance of the equivalent resistor,

$$I = \frac{V}{R_{eq}}$$

Hence

$$\frac{V}{R_{eq}} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}\right)$$

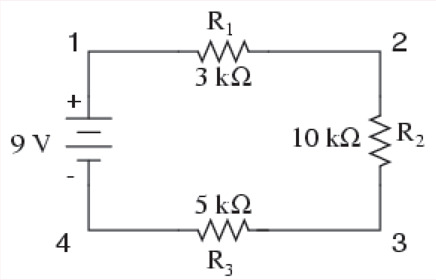
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2}$$

For *n* resistors connected in parallel combination, the effective resistance is

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

Household circuits are always wires so that the lights and appliances are connected in parallel. This way each device operated independently of the others, so if one is turned off the others remain on. This also had the advantage that the voltage supplied to each element is the same.

Example1: Find the equivalent resistance in the circuit below:



Solution:

$$R = R_1 + R_2 + R_3$$
$$R = 3\,k\Omega + 10\,k\Omega + 5\,k\Omega$$
$$R = 18\,k\Omega$$

With a 9V battery, by $V = I\,R$ the total current in the circuit is:

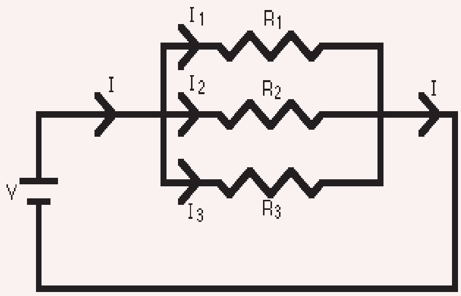
$$I = \frac{V}{R} = \frac{9V}{18k\Omega} = 0.5\,mA$$ The current through each resistor would be 0.5 mA.

Example 2: A parallel circuit is shown in the figure below. In this case the current supplied by the battery splits up, and the amount going through each resistor depends on the resistance.

From the figure below, if the values of the three resistors are

$$R_1 = 8\Omega,\ R_2 = 8\Omega,\ and\ R_3 = 4\Omega \quad .$$

Determine the total resistance of the circuit.



Solution:

The total resistance R is found by

$$\frac{1}{R} = \frac{1}{8} + \frac{1}{8} + \frac{1}{4} = \frac{1}{2}$$

This gives that $R = 2\Omega$

With a 10 V battery, by $V = I\,R$ the total current in the circuit is:

$$I = \frac{V}{R} = \frac{10V}{2\Omega} = 5\,A$$

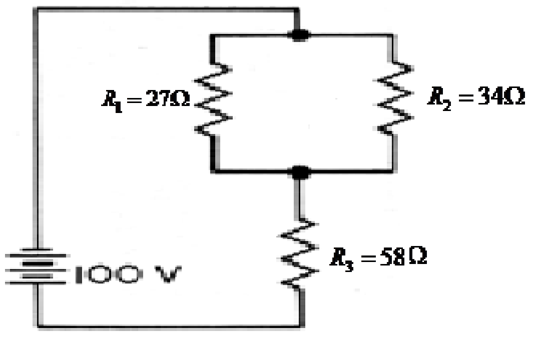
The individual currents can also be found using $I = \frac{V}{R}$ The voltage across each resistor is 10 V, so:

$$I_1 = \frac{10}{8} = 1.25\,A,\ \ I_2 = \frac{10}{8} = 1.25A$$

$$I_3 = \frac{10}{4} = 2.5A$$

Note that the currents add together to 5A, the total current.

Example 3: Interpret the circuit below and determine the total resistance of the circuit.



Solution

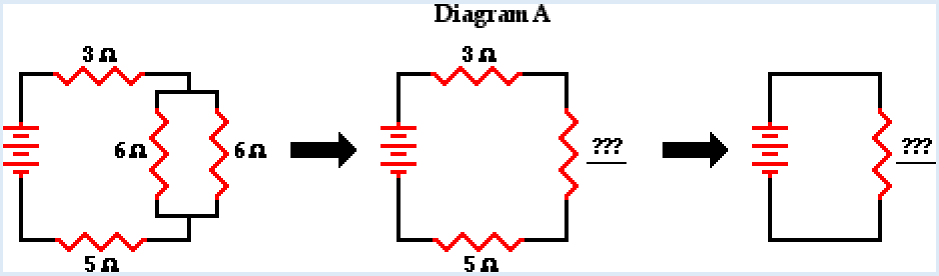
Here we can use the shorter product over sum equation as we only have two parallel resistors.

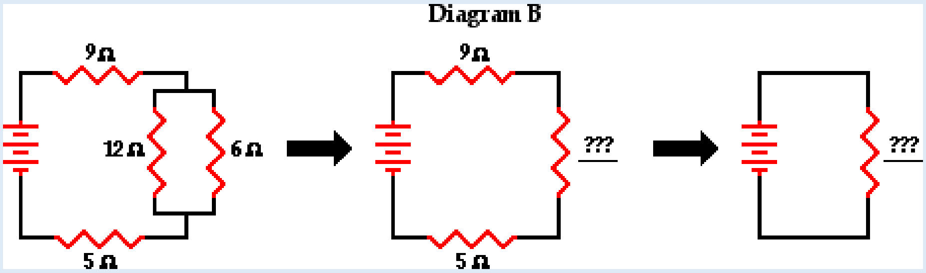
$$R_{1\|2} = \frac{(R_1 \times R_2)}{(R_1 + R_2)} = \frac{27 \times 34}{27 + 34} = \frac{918}{61} = 15.049\Omega$$

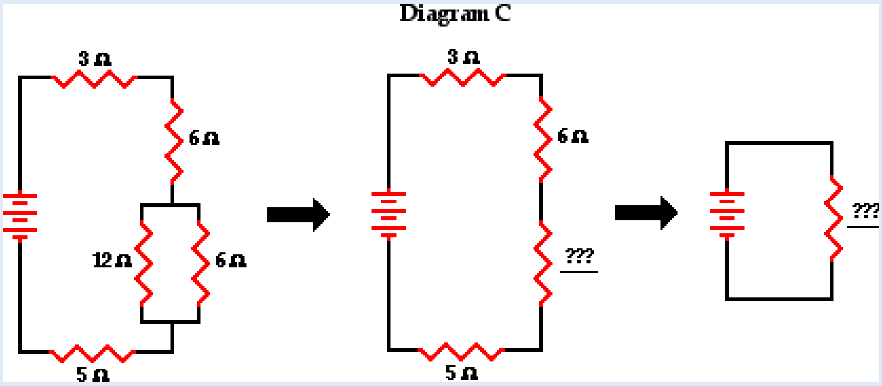
$$R_T = R_{1\|2} + R_3 = 15.049\Omega + 58\Omega = 73.049\Omega$$

Application activity 8.4

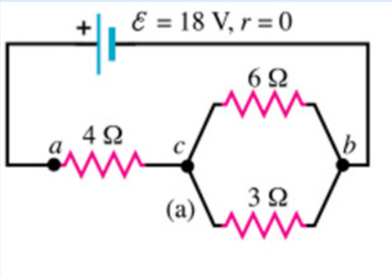
1. Use the concept of equivalent resistance to determine the unknown resistance of the identified resistor that would make the circuit's equivalent.



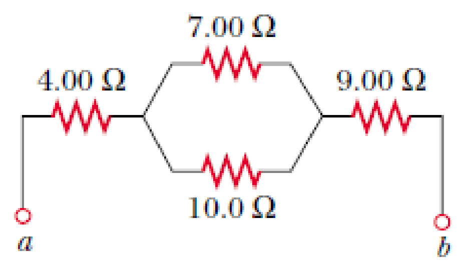




2. A parallel pair of resistance of value of $3\,\Omega$ and $6\,\Omega$ are together connected in series with another resistor of value $4\ \Omega$ and a battery of e.m.f. 18 V as shown on the fig. (a) below. Calculate the current through each resistor.



3. (a) Find the equivalent resistance between points *a* and *b* in Figure below. (b) A potential difference of 34.0 V is applied between points *a* and*b*. Calculate the current in each resistor.



4. Use your understanding of equivalent resistance to complete the following statements:

i. Two $3\,\Omega$ resistors placed in series would provide a resistance which is equivalent to one ___ Ω resistor.

ii. Three $3\,\Omega$ resistors placed in series would provide a resistance which is equivalent to one ___ Ω resistor.

iii. Three $5\,\Omega$ resistors placed in series would provide a resistance which is equivalent to one ___ Ω resistor.

iv. Three resistors with resistance values of $2\,\Omega, 4\,\Omega$ and $6\,\Omega$ are placed in series. These would provide a resistance which is equivalent to one ___ Ω resistor.

v. Three resistors with resistance values of $5\,\Omega, 6\,\Omega$ and $7\,\Omega$ are placed in series. These would provide a resistance which is equivalent to one _____ Ω resistor.

vi. Three resistors with resistance values of $12\,\Omega, 3\,\Omega$ and 21Ω are placed in series. These would provide a resistance which is equivalent to one _____ Ω resistor.

5. As the number of resistors in a series circuit increases, the overall resistance __________ (increases, decreases, remains the same) and the current in the circuit __________ (increases, decreases, remains the same).

6.Imagine that we add a third resistor in series with the first two. Does the current in the battery (a) increase, (b) decrease, or (c) remain the same? Does the terminal voltage of the battery (d) increase, (e) decrease, or (f) remain the same?

7. Imagine that we add a third resistor in parallel with the first two. Does the current in the battery (a) increase, (b) decrease, or (c) remain the same? Does the terminal voltage of the battery (d) increase, (e) decrease, or (f) remain the same?

8.5. Kirchhoff's laws and its applications in solving problems in complex electric circuits

Activity 8.5

A single-loop circuit contains two resistors and two batteries, as shown in figure 5.34 (neglect the internal resistances of the batteries). (a) Find the current in the circuit. (b) What power is delivered to each resistor? What power is delivered by the 12V battery?

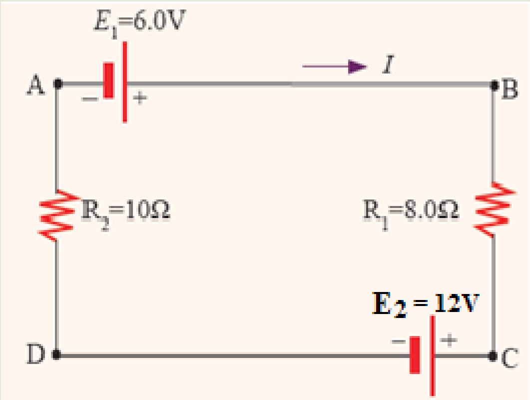


Figure 8.14: Electric circuit with more emf.

8.5.1 Kirchhoff's laws

Simple circuits can be analyzed using the expression V = IR and the rules for series and parallel combinations of resistors. Very often, however, it is not possible to reduce a circuit to a single loop.

The procedure for analyzing more complex circuits is greatly simplified if we use two principles called Kirchhoff's rules developed by the German Physicist Gustav Robert Kirchhoff (1824-1887).

First, here are two terms that we will use often. A junction in a circuit is a point where three or more conductors meet. Junctions are also called nodes of branch points. A loop is any closed conducting path.

In figure below, the points **a** and **b** are junctions, but points **c** and **d** are not. The curved lines show some possible loops in this circuits.

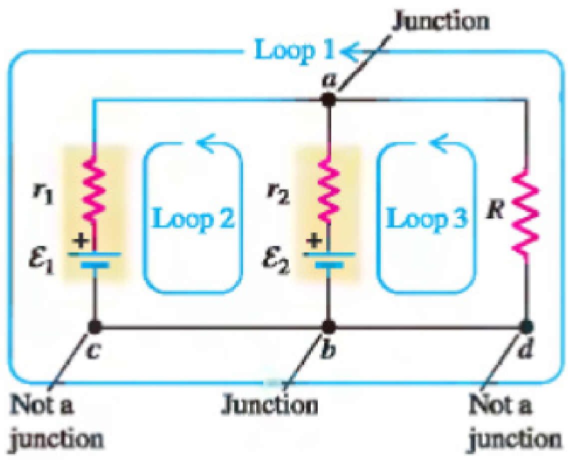


Figure 8.15: A circuit with loups

Kirchhoff's junction rule: "***the algebraic sum of the currents into any junction is zero***." That is,

$$\sum I = 0$$

i.e The sum of the currents entering the junction must equal the sum of the currents leaving the junction.

Kirchhoff's loop rule: "***the algebraic sum of the potential differences in any loop, including those associated with emfs and those of resistive elements must equal zero".*** That is,

$$\sum V = 0$$

Kirchhoff's first rule is a statement of conservation of electric charge. All charges that enter a given point in a circuit must leave that point because charge cannot build up at a point.

Kirchhoff's second rule follows from the law of conservation of energy.

The sum of the increases in energy as the charge passes through some circuit elements must equal the sum of the decreases in energy as it passes through other elements. The potential energy decreases whenever the charge moves through a potential drop $-IR$ across a resistor or whenever it moves in the reverse direction through a sourceof emf. The potential energy increases whenever the charge passes through abattery from the negative terminal to the positive terminal.

When applying Kirchhoff's second rule in practice, we imagine traveling around the loop and consider changes in electric potential, rather than the changes in potential energy.

Problem solving strategy:

1. Junction rule. Assign symbols and directions to the currents in the various junctions. If you guess the wrong direction for a current it does not matter. The end result will be a negative answer for that current and the magnitude will be correct.
2. Loop rule. You must choose a direction for moving around the loop. As you move around the loop the voltage drops and increases should be recorded according to the rules (a-d) below.

a) If a resistor is traversed in the direction of the current, the change in potential across the resistor is $-IR$.

b) If a resistor is traversed in the direction opposite the current, the change in potential across the resistor is $+IR$.

c) If a source of *emf* is traversed in the direction of the *emf* (from – to +) the change in potential is $+\varepsilon$

d) If a source of *emf* is traversed opposite the direction of the emf (from + to –) the change in potential is $-\varepsilon$.

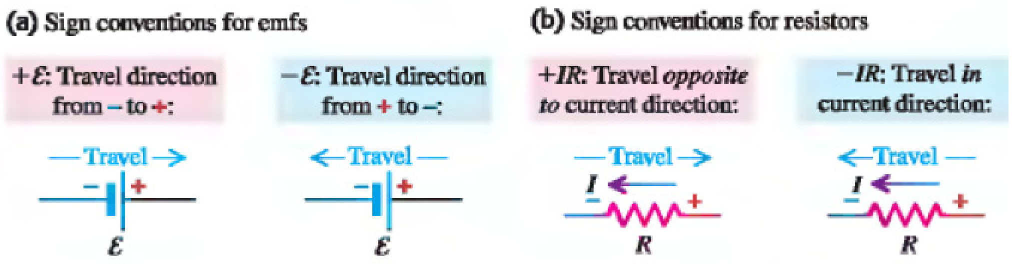


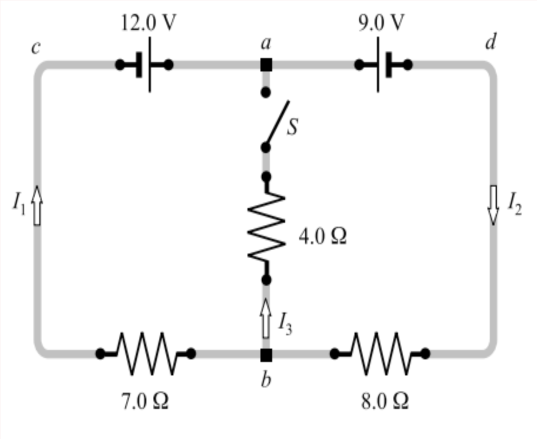
Figure 8.16: Sign conventions

Example

1. In figure below, find I_1, I_2, and I_3 if S is

a) Open

b) Closed



a) When S is open, $I_3 = 0$, because no current can flow through the open switch. Applying the node rule to point a gives

$$I_1 + I_3 = I_2 \ or \ I_2 = I_1 + 0 = I_1$$

Applying the loop rule to loop acbda gives

$$-12.0 + 7.0I_1 + 8.0I_2 + 9.0 = 0$$

Because, $I_2 = I_1$ $\quad$ $15.0I_1 = 3.0 \ or \ I_1 = 0.20A$

Also $\quad I_2 = I_1 = 0.20A$

b) With S close, I_3 is no longer known to be zero. Applying the node rule to point a gives

$$I_1 + I_3 = I_2 \quad (1)$$

Applying the loop rule to loop acba gives

$$-12.0 + 7.0I_1 - 4.0I_3 = 0 \qquad (2)$$

And to loop adba gives

$$-9.0 - 8.0I_2 - 4.0I_3 = 0 \qquad (3)$$

We must solve (1), (2) , and (3) for I_1, I_2 and I_3. From (3)

$I_3 = -2.0I_2 - 2.25$

Substituting tis in (2) also gives

$-12.0 + 7.0I_1 + 9.0 + 8.0I_2 = 0$ or $7.0 I_1 + 8.0I_2 = 3.0$

Substituting for I_3 in (1) also gives

$I_1 - 2.0I_2 - 2.25 = I_2$ or $I_1 = 3.0I_2 + 2.25$

Substituting this value in the previous equation finally gives

$21.0I_2 + 15.75 + 8.0I_2 = 3$ or $I_2 = - 0.44$ A

Using this in the equation for I_1 gives

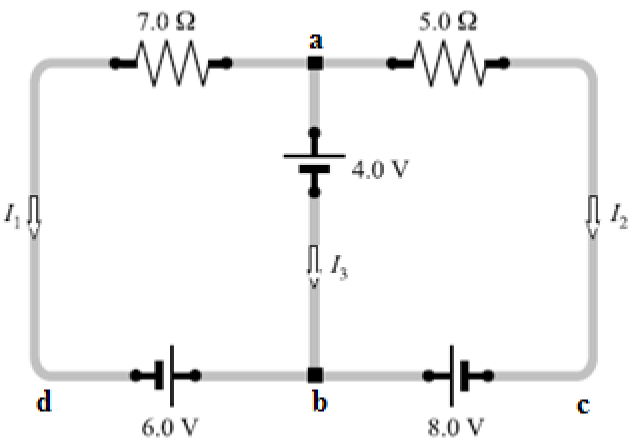
$$I_1 = 3.0 (-0.44) + 2.25 = - 0.93 \text{ A}$$

From (1)

$$I_3 = I_2 - I_1 = (- 0.44) - 0.93 = - 1.37\text{A}$$

8.5.2 Application of Kirchhoff's laws in solving problems in complex electric circuits

Example 1: Find the currents in the circuit given below:



Solution:

This circuit cannot be reduced further because it contains no resistors in simple series or parallel combinations. We therefore revert to Kirchhoff's rules. If the currents had not been labeled and shown by arrows, we would do that first. No special care needed to be taken in assigning the current directions, since those chosen incorrectly will simply give negative numerical values.

We apply the node rule to node b in the figure above.

Current into b = Current out of b.

$$I_1 + I_2 + I_3 = 0 \qquad (1)$$

Next we apply the loop rule to loop adba. In volts,

$$-7.0I_1 + 6.0 + 4.0 = 0 \quad or \quad I_1 = \frac{10.0}{7.0}A$$

(why must the term $7.0I_1$ have a negative sign?) we then apply the loop rule to loop abca. In volts,

$$-4.0 - 8.0 + 5.0I_2 = 0 \ or \ I_2 = \frac{12.0}{5.0}A$$

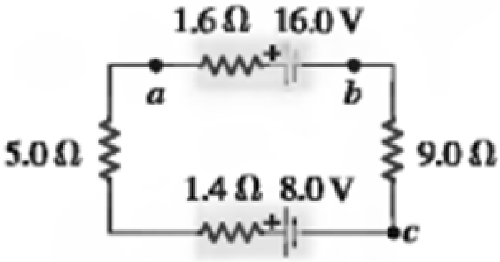
(why must the signs be as written?)

Now we return to equation (1) to find

$$I_3 = -I_1 - I_2 \ , \ I_3 = \left(\frac{10.0}{7.0} - \frac{12.0}{5.0}\right)A, \ I_3 = \frac{-50-84}{35}A \ \ and \ \ I_3 = -3.8A$$

The minus sign tells us that I_3 is opposite in direction to that shown in the figure.

Example 2: The circuit shown in figure below contains two batteries, each with an emf and an internal resistance, and two resistors. Find (a) the current in the circuit (magnitude and direction); (b) the terminal voltage of the 16.0 V battery; (c) the potential difference of a with respect to point c.



Solution

(a) The current is counterclockwise, because the 16 V battery determines the direction of current flow.

$$+16.0V - 8.0V - I(1.6\Omega + 5.0\Omega + 1.4\Omega + 9.0\Omega) = 0$$

$$I = \frac{+16.0V - 8.0V}{(1.6\Omega + 5.0\Omega + 1.4\Omega + 9.0\Omega)} = 0.47\,A$$

(b)

$$V_b + 16.0V - I(1.6\Omega) = V_a, so,$$

$$V_a - V_b = V_{ab} = 16.0V - (0.47\,A)(1.6\Omega) = 15.2V$$

(c)

$$V_c + 8.0V - I(1.4\Omega + 5.0\Omega) = V_a, so,$$

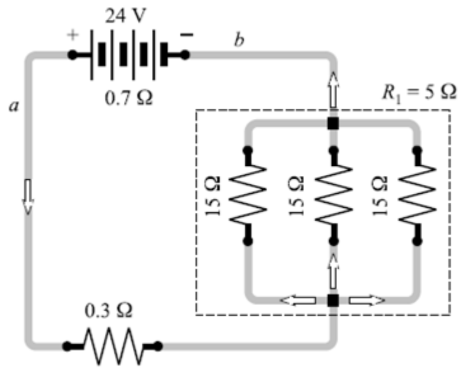
$$V_{ac} = (5.0\Omega)(0.47\,A) + (1.4\Omega)(0.47\,A) + 8.0V = 11.0V$$

Example 3: In figure below, the battery has an internal resistance of 0.7Ω. Find

i. the current drawn from battery,

ii. the current in each resistor,

iii. The terminal voltage of the battery.



Solution

i. For parallel group resistance we have

$$\frac{1}{R_1} = \frac{1}{15\Omega} + \frac{1}{15\Omega} + \frac{1}{15\Omega} = \frac{3}{15\Omega}$$

$$R_1 = 5.0\Omega$$

Then

$$R_{eq} = 5.0\Omega + 0.3\Omega + 0.7\Omega = 6.0\Omega$$

And

$$I = \frac{\varepsilon}{R_{eq}} = \frac{24V}{6.0\Omega} = 4.0\,A$$

ii. Method 1

The three resistor combination is equivalent to $R_1 = 5.0\ \Omega.$ A current of 4.0 A flows through it. Hence, the p.d across the combination is

$$IR_1 = (4.0\,A)(5.0\Omega) = 20.0V$$

This is also the p.d across each 15Ω resistor. Therefore, the current through each 15Ω resistor is

$$I_{15} = \frac{V}{R} = \frac{20.0V}{15\Omega} = 1.3\,A$$

Method 2

In this special case, we know that one – third of the current will go through each resistor. Hence

$$I_{15} = \frac{V}{R} = \frac{4.0V}{3\Omega} = 1.3\,A$$

iii. We start at a and go to b outside the battery:

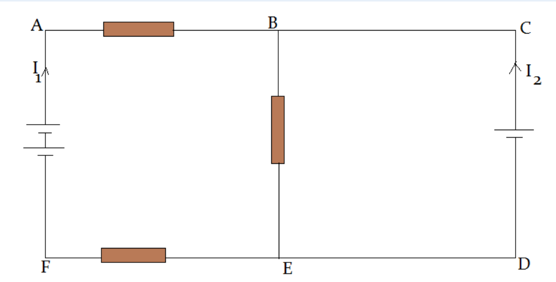
$$V\ from\,a\ \ to\ b = -(4.0A)(0.3\Omega) - (4.0A)(5.0\Omega) = -21.2V$$

The terminal p.d of the battery is $21.2V$. Or, we could write for this case of a discharging battery,

$$ter\min al\ p.d = \varepsilon - Ir = 24V - (4.0A)(0.7\Omega) = 21.2V$$

Application activity 8.5

In the circuit below, each cell has e.m.f of 1.5 V and zero internal resistance. Each resistor has a resistance of $10\,\Omega$. There are currents I_1 and I_2 in the branches as shown.



(a) Use Kirchhoff's first law to write down an expression for the current in BE, in terms of I_1 and I_2

(b) Use Kirchhoff's second law to write down equations for the circuit loops i) ABEFA ; ii) CBEDC

Note that you are not required to solve these equations.

SKILLS LAB

Conduct a survey to find out how people construct electric circuits and apply Kirchhoff's laws in analysis of complex electric circuits before installation process.

Collect and analyze data about when, where, and why people use Kirchhoff's laws in dealing with complex electric circuits.

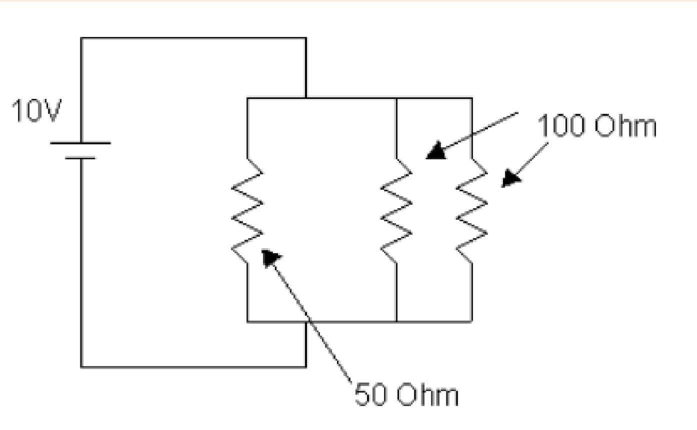
To complete this project you must

- Develop a survey sheet about electric components, demonstration of Kirchhoff's laws and complex electric circuit.
- Distribute your survey sheet to other student-teachers, family members and neighbors.
- Compile and analyze your data.
- Create a report to display your findings in your sheet.

Plan it! To get started, think about the format and content of your survey sheet. Brainstorm what kinds of questions you will ask. Develop a plan for involving student-teachers in your class or other classes to gather more data.

End unit assessment 8

1. State Kirchhoff Current Law and Kirchhoff Voltage Law
2. Distinguish between electric sources of currents from receptors.
3. Find the current across the 10V battery



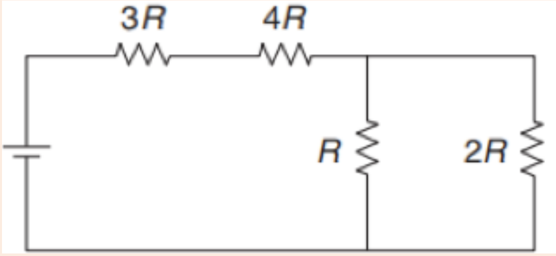
4. The figure below shows four resistors connected in a circuit with a battery.Which of the following correctly ranks the potential difference, ΔV, across the four resistors?

(A) $\Delta V_{4R} > \Delta V_{3R} > \Delta V_{2R} > \Delta V_{R}$

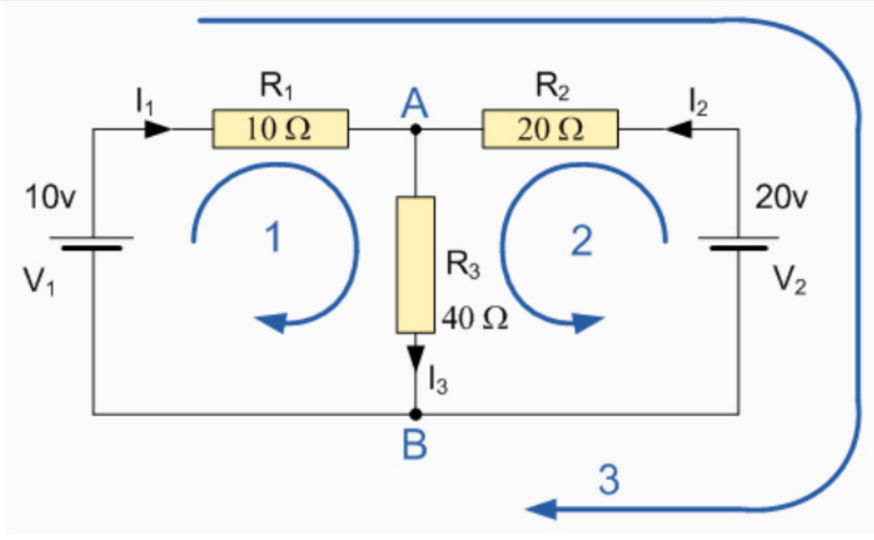
(B) $\Delta V_{4R} > \Delta V_{3R} > \Delta V_{2R} = \Delta V_{R}$

(C) $\Delta V_{4R} = \Delta V_{3R} > \Delta V_{R} > \Delta V_{2R}$

(D) $\Delta V_{2R} = \Delta V_{R} > \Delta V_{3R} > \Delta V_{4R}$



5. Determine the values of the the current flowing through each of the resistors.



UNIT 9: AUTOTROPHIC NUTRITION

Key unit competence:

Explain photosynthesis as an energy transfer process, its limiting factors and adaptations.

Introductory Activity

Make a quick lab

Materials: Large clear plastic cup, sodium bicarbonate solution, elodea plant, large test tube.

Procedure:

- Fill a large clear plastic cup with sodium bicarbonate solution (source of CO_2)
- Place an elodea plant in a large test tube with the cut stem at the bottom. Fill the tube with sodium bicarbonate solution. **Caution:** *hand the test tube carefully*.
- Hold your thumb over the mouth of the test tube. Turn the tube over, and lower it to the bottom of the cup. Make sure there is no air trapped in the tube.
- Place the cup in bright light.
- After at least 20 minutes, look closely at the elodea leaves. Record your observations.

Analyze and conclude:

a) What do you observe on the elodea leaves?

b) What substance accumulated in the leaves? Should the substance be considered as a waste product? Explain.

c) What plant organelle carries out photosynthesis and produces the gas?

All organisms require macromolecules like carbohydrates, proteins and fats for their growth and development. Some organisms produce these organic compounds from inorganic sources on their own. Such organisms are called autotrophs or producers and the process of synthesizing complex compounds from simple inorganic sources is called autotrophic nutrition. While others including humans are heterotrophs or consumers, which depend on autotrophs for source of chemical energy. Green plants are autotrophs and require chlorophyll, sunlight, carbon dioxide, water and minerals for preparing their own food.

9.1. Types of autotrophic nutrition

Activity 9.1

From what you learnt in previous classes about plant nutrition, differentiate the types of autotrophic nutrition.

Autotrophic nutrition is a process by which living organisms make their own food. This process is carried out by photoautotrophs like green plants, green algae and green bacteria; and chemoautotrophs. Living organisms which make their own food are called **autotrophs**, while others, including humans, which cannot make their own food but depend on autotrophs are called **heterotrophs**.

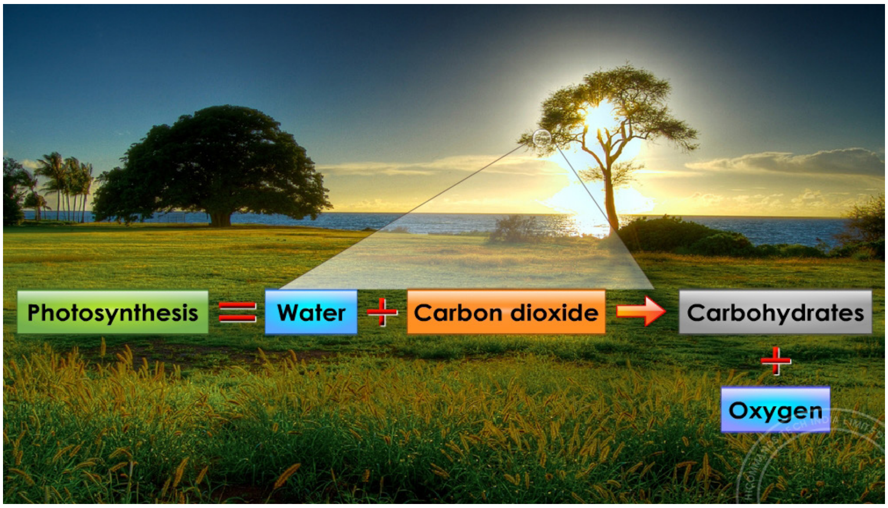


Figure 9.1: photoautotrophism(to be redrawn)

There are two types of autotrophic nutrition such as chemoautotrophic and photoautotrophic nutrition.

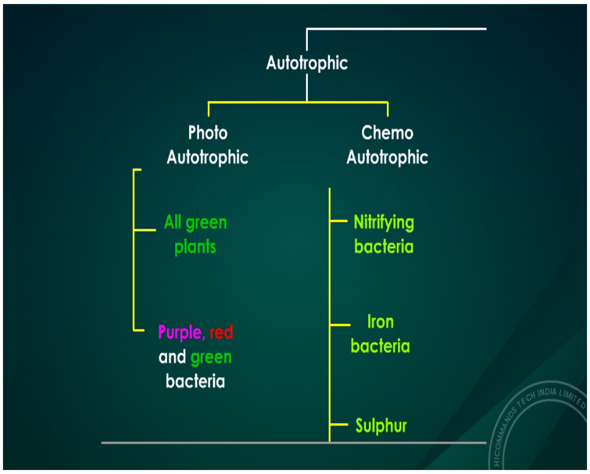


Figure 9.2: types of autotrophic nutrition(to be redrawn)

9.1.1. Chemoautotrophic nutrition

It is an autotrophic nutrition where organisms (mainly bacteria) get energy from oxidation of chemicals, mainly inorganic substances like hydrogen sulphide and ammonia.

$$H_2S + O_2 \longrightarrow 2H_2O + 2S + E.$$

$$(NH_4)_2CO_3 + 3O_2 \longrightarrow 2HNO_2 + CO_2 + 3H_2O + E.$$

9.1.2. Photoautotrophic nutrition

It is an autotrophic nutrition where organisms get energy from sunlight and convert it into sugars. Green plants and some bacteria like green Sulphur bacteria can make their own food from simple inorganic substances by a process called **photosynthesis**. Photosynthesis is a process by which, autotrophs make their own food by using inorganic substances in presence of light energy and chlorophyll.

(Green Sulphur bacteria).

(Green plants).

Application activity 9.1

1. Define Photosynthesis
2. Differentiate;

a) Autotrophs and heterotrophs

b) Chemoautotrophs and photoautotrophs.

3. Animals' life depends on plants. Defend this statement by providing two convincing reasons.

9.2 Structure adaptation and role of chloroplast in the process of photosynthesis

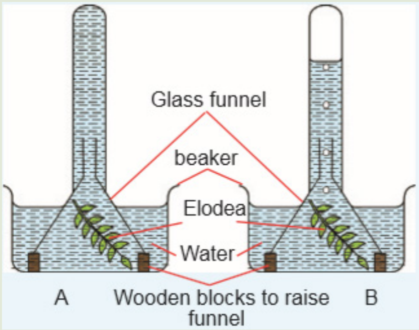
Activity 9.2

To show that oxygen is produced during photosynthesis

Requirements:

Two large beakers, two funnels (glass), two test tubes, water with sodium hydrogen carbonate dissolved in it, splints, match box, water weed e.g. Elodea or Spirogyra

Procedure 1: Prepare two set-ups of apparatus as shown below.



Note:

Set up A placed in a dark cupboard Set up B placed in a bright sunshine

2. Observe the set-up in the dark cupboard.

- What did you notice?

3. Observe the set-up in the bright sunshine.

- What do you notice?

4. Test any gas produced using a glowing splint.

Study questions

a) Explain the necessity of sodium hydrogen carbonate (sodium bicarbonate) dissolved in the water?

b) What happens to the glowing splint when it is exposed to the gas in the test tubes?

- What is your conclusion from the observation?

c) What was the role of the setup that was placed in the dark cupboard?

d) Name the plant cell organelle in which photosynthesis takes place.

Plants are **autotrophs** because they can make their own food by using energy from the sun, carbon dioxide and water as raw materials to make food in a process known as **photosynthesis**. The chlorophyll contain by plants traps light energy from the sun. In the process, oxygen is given off as a by-product.

The process of photosynthesis can be summarized as follows:

$$\text{Water} + \text{Carbon dioxide} \xrightarrow[\text{Sunlight}]{\text{chlorophyll}} \text{glucose} + \text{oxygen}$$

The chlorophyll arefound in chloroplasts.

Chloroplast is an example of a plastid. It is the organelle in a plant cell where photosynthesis takes place. **Chloroplasts** are found in the cytoplasm of the cells found in either palisade cells mesophyll, spongy mesophyll and guard cells in a leaf. Cells that have **chloroplasts** are called **photosynthetic cells**. To find out whether the leaf is the site for photosynthesis, we test for the presence of starch in the leaf.

9.2.1. Structure of the chloroplast

In eukaryotes photosynthesis takes place in **chloroplasts** which is one of plant cell organelles. A chloroplast contains many sets of disc like sacs called **thylakoids**, which are arranged in stacks known as **grana**. Each granum looks like a stack of coins where each coin being a thylakoid. In the thylakoid, proteins are organized with the chlorophyll and other pigments into clusters known as **photosystems**. The photosystems are the light-collecting units of the chloroplast.

The function of thylakoids is to hold the chlorophyll molecules in a suitable position for trapping the maximum amount of light. A typical chloroplast contains approximatively 60 grana, each consisting of about 50 thylakoids. The space outside the thylakoid membranes are made by watery matrix called stroma. The stroma contains enzymes responsible for photosynthesis.

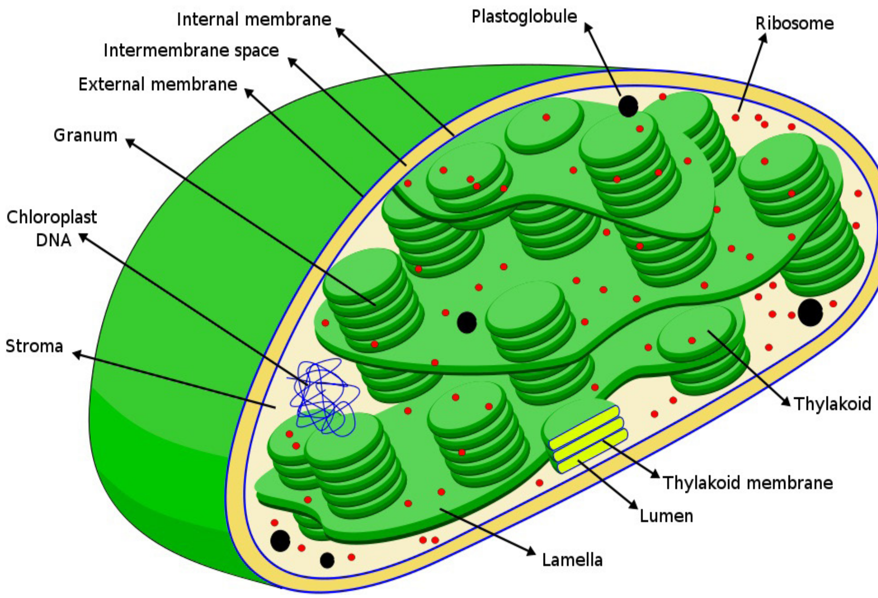


Figure 9.1: Structure of a chloroplast

Note: Photosynthetic prokaryotes have no chloroplasts, but thylakoids often occur as extensions of the plasma membrane and are arranged around the periphery of the prokaryotic cell.

9.2.2. Adaptations for photosynthesis

Activity 9.2.2

Sample a green leaf and analyze its structure. Observe again the illustration showing the internal structure of a leaf to describe the adaptations of the plants and leaf for photosynthesis.

By considering both external and internal structures of the leaf, we can recognize several adaptations for photosynthesis.

a) Adaptation of leaf for photosynthesis considering to its internal structure

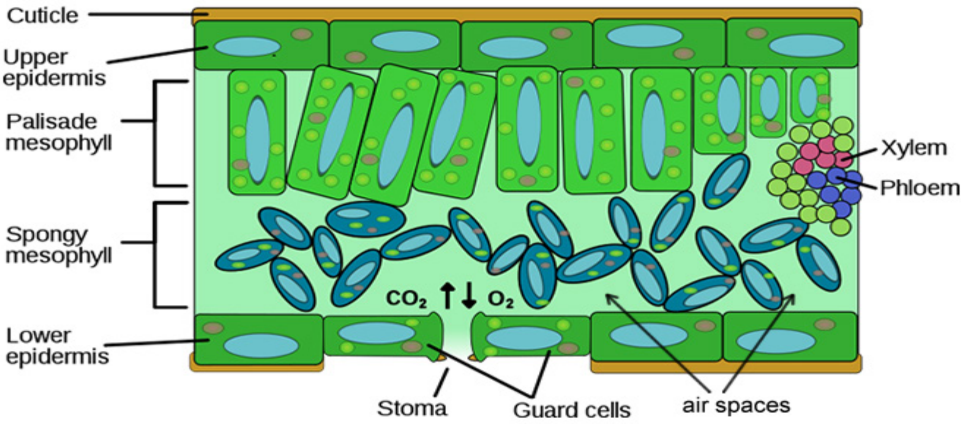


Figure 9.2: internal structure of the leaf and its adaptations to photosynthesis

Parts of the leaf	**Its adaptation for photosynthesis**
Transparent cuticle	It allows to absorb much light. It prevent excessive water from the plant
Upper epidermis	It is made by thin and transparent cells for absorption of much light. They act as barriers to pathogens.
Palisade mesophyll	Its cells are packed with many chloroplasts, so it is the main site for photosynthesis
Spongy mesophyll	It is relatively less packed by chloroplasts, and it contains air spaces which allow gaseous exchange: CO_2 in cells, and O_2 from cells during photosynthesis.
Vascular bundle	It consists of leaf veins: Xylem which bring water and minerals to leaves, phloem which transport sugars and amino acids away to other parts.
Lower epidermis	It is the site for gaseous exchange in and out of the leaf, and it prevent excessive water loss through stomata.
Stomata	Surrounded by guard cells, which allow stomata to open: water moves out during transpiration, CO_2 diffuses in and Oxygen diffuses out during photosynthesis.

Note: when stomata are opened, the rate of photosynthesis may be 10 to 20 times as fast as the maximum rate of respiration. If the stomata are closed, photosynthesis still can continue, using CO_2 produced during cell respiration. The equilibrium can be reached between photosynthesis and cell respiration.

Photosynthesis uses CO_2 from respiration, and respiration uses Oxygen from photosynthesis. However, the rate of photosynthesis under these circumstances will be much slower than when an external source of CO_2 is available. The stomata cannot remain closed indefinitely, they have to be open in order to maintain transpiration of the plant.

b) Adaptation of leaf for photosynthesis considering its external structure

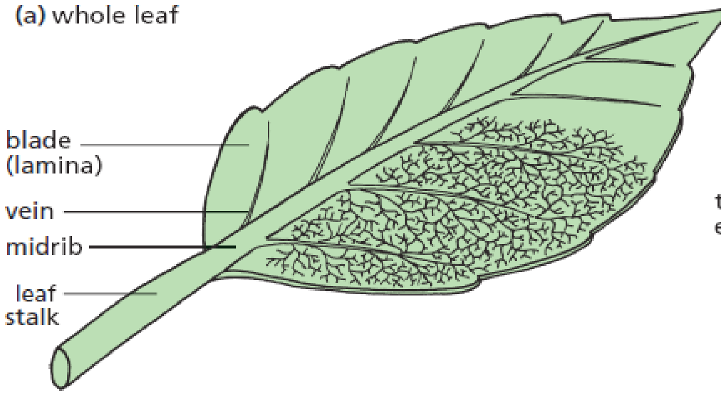


Figure 9.3: External structure of the leaf

- Leaves are thin and flat, this facilitate absorption of the maximum amount of light.
- The cuticle is transparent to allow absorption of light into tissues.
- Presence of a waxy substance on the cuticle to prevent excessive water loss from photosynthetic tissues.
- Presence of the midrib and veins containing vascular tissues like: the Xylem which brings water and minerals from soil to photosynthetic tissues, and Phloem which carry away manufactured organic food from photosynthetic tissues to other parts (translocation).
- Having the leaf stalk which holds the lamina in a good position to receive the maximum amount of the light.

9.2.3. Absorption and action spectra

In addition to water and CO_2, photosynthesis requires light and chlorophyll. The chlorophyll pigment is found in the chloroplasts. The light that our eyes perceive as **white light** is a mixture of different wavelengths. Most of them are visible to our eyes and make up the **visible spectrum.** Our eyes see different wavelengths of visible spectrum as different colours (**violet, blue, green, yellow, orange and red**) except **indigo**which is not visible to our eyes. Plants absorb the light energy by using molecules called **pigments** such as: **chlorophyll a, chlorophyll b, carotene** (orange), **xanthophyll** (yellow) **and phaeophytin** (grey) but **chlorophyll a** is the principle pigment in photosynthesis.

The chlorophyll absorbs light very well in **blue-violet** and **red regions of visible spectrum**. However, chlorophyll does not absorb well the green light, instead it allows the green light to be reflected. That is why young leaves and other parts of the plants containing large amount of chlorophyll **appear green**.

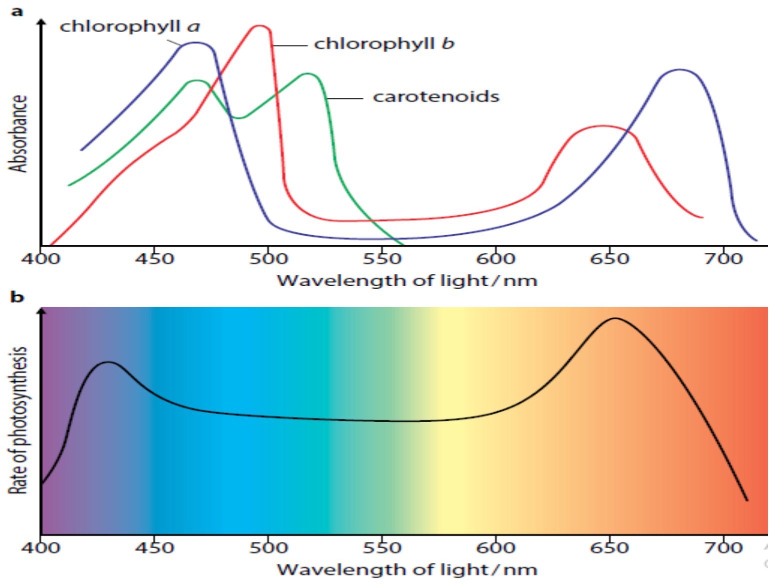


Figure 9.4: Light absorption by leaf pigment

The **chlorophyll a** as a principle and abundant pigment, it is directly involved in light reactions of photosynthesis. Other pigments (**chlorophyll b, carotene, xanthophyll and phaeophytin**) are accessory pigments. They absorb light colors that **chlorophyll a** cannot absorb, and this enables plants to capture more energy from light.

The amount of energy that the pigment can absorb from the light, depends on its **intensity** and its **wavelengths**. So, the greater the intensity of light, the greater amount of energy will be absorbed by the pigment in a given time.

9.2.4. Calvin cycle and the process of photosynthesis in C3 plants

a) Stages and sites of photosynthesis in a chloroplast

The process of photosynthesis occurs through two main stages such as:

- **The light-dependent reactions:** which take place in thylakoids, and
- **The light-independent reactions (Calvin cycle):** which take place in stroma.

Table 9.4: Comparison between light-dependent reactions and The light-independent reactions (Calvin cycle)

Light reaction	Dark reaction
It is the photochemical reaction where water breaks down in presence of light to produce oxygen, $NADPH_2$ and ATP. H_2O ------------------$NADPH_2$ + ATP + $1/2O_2$	It is the carbon reduction reaction where carbon dioxide uses chemical energy to produce sugars. CO_2 +$NADPH_2$ + ATP --------- ------ $C_6H_{12}O_6$
It includes photolysis of water and evolution of oxygen and assimilatory power	It includes fixation of carbon dioxide to produce hexoses
It takes place in thylakoids of chloroplast	It takes place in stroma of chloroplast
It requires light directly	It does not require light directly
It is temperature independent	It is temperature dependent
It is dependent on dark reaction for ADP and NAPD	It is dependent on light reaction for ATP and NAPDH

i. The light-dependent reactions

They require light energy and occur in thylakoids. **They produce Oxygen** gas and convert **ADP** and **NADP$^+$** into **ATP** and **NADPH.**

The light-dependent reactions involve the following steps:

- **Photosynthesis begins when the chlorophyll a in photosystem II absorbs light at different wavelengths of light.**
  - When the light energy hits the chlorophyll a, the light energy is absorbed by its electrons, by raising their energy level.
  - These ***electrons with high potential energy*** (electrons with sufficient

quantum energy) are passed to the **electron-transport chain**.

- Excited electrons are taken up by an **electron acceptor** ($NADP^+$: oxidized Nicotinamide Adenine Dinucleotide Phosphate), and pass along electron transfer chain from **photosystem II** to the **photosystem I**. (Note: The photosystems are the light-collecting units of the chloroplast).

• **Enzymes in thylakoids and light absorbed by photosystem II are used to break down a water molecule into energized electrons, hydrogen ions H^+, and Oxygen.**

$$H_2O \xrightarrow{Enzymes\ and\ light} 2H^+ + \frac{1}{2}O_2 + 2e^-$$

- Oxygen produced is released to be used by living things in respiration.
- Electrons and H^+ from photolysis of water are used to reduce NADP+ to NADPH (Reduced Nicotinamide Adenine Dinucleotide Phosphate).
- The light-dependent reactions also allow generation of ATP (Adenosine Triphosphate) by adding inorganic phosphate to ADP^+ (Adenosine Diphosphate):

$$\mathrm{ADP} + \mathrm{P_i} \xrightarrow{\mathrm{Energy}} \mathrm{ATP}$$

Generally, the light-dependent reactions use light energy, ADP, Pi, NADP+ and water to produce ATP, NADPH and Oxygen. Or simply:

$$\mathrm{12H_2O + 12NADP^+ + 18ADP^+ + 18P_i \xrightarrow{Light\ and\ chlorophyll} 6O_2 + 12NADPH_2 + 18ATP}$$

Both ATP and NADPH are energy carriers which provide energy to sugars (energy containing sugars) in Light-independent reactions.

ii. The light-independent reactions (Calvin cycle)

The light-independent reactions occur in stroma, and consist of reducing CO_2 into sugars by using ATP and NADPH both coming from light-dependent reactions in thylakoids. The Calvin cycle involves three main stages such as:

- Carbon fixation in form of CO_2.
- Carbon reduction from CO_2 to glucose.
- Regeneration of RuBP.

• **Carbon fixation (Carboxylation) in form of CO_2**

Carboxylation: is the process of fixation of carbon in stable organic intermediate, **phosphoglyceric acid.**

The Calvin cycle begins with a 5-Carbon sugar phosphate called **Riburose-1, 5 biphosphate (RuBP)** which fixes the CO_2 from airThis reaction is catalyzed by called **RuBPcarboxylase-oxygenase (RUBISCO).** Rubisco-bis-phospahte (RuBP) is the initial acceptor or substrate for dark reaction.

$$6\ RuBP + 6\ CO_2 + 6H_2O \xrightarrow{RUBISCO} 12\ \text{Phosphoglyceric acid}$$

Reduction or **Glycolytic Reversal**: It is the process involving reduction of carbon. It is a multistep process that utilizes 12 ATP molecules and 12 NADPH for release of one molecule of glucose. The glucose can further be converted into starch for storage or sucrose for transport.

$$12\ \text{Phosphoglyceric acid} + 12ATP \longrightarrow 12\ \text{Di-phosphoglyceric acid} + 12ADP$$

$$12\ \text{Di-phosphoglyceric acid} + 12NADPH \longrightarrow 2\ \text{Phosphoglyceraldehyde} + 12NADP + H_3PO_4$$

$$\underset{(PGAL)}{5\ \text{Phosphoglyceraldehyde5}} \rightleftharpoons \underset{(DHAP)}{\text{Dihydroxy acetone phosphate}}$$

$$3\ PGAL + 3\ DHAP \longrightarrow 3\ \text{Fructose1,6-diphosphate}$$

$$\text{Fructose1,6-diphosphate} \longrightarrow \text{Fructose 6-phosphate}$$

$$\text{Fructose 6-phosphate} \longrightarrow \text{Glucose 6-phosphate}$$

- **Carbon reduction from CO_2 to glucose**

With energy from ATP and reducing power from NADPH, the phosphoglyceric acid is reduced into 3carbon molecules known as glyceraldehyde-3-phosphate or phosphoglyceraldehyde (PGAL).

Each molecule of PGA receives an additional phosphate group from ATP, becoming 1, 3-biphosphoglycerate, and a pair of electrons and H^+ from NADPH reduces the carboxyl group of 3-phosphoglycerate to the aldehyde group of PGAL which stores more potential energy.

ATP gives one phosphate group becoming ADP^+, and NADPH gives H^+ and electrons to become $NADP^+$. Both ADP^+, and $NADP^+$ will be used again in light-dependent reactions.

With 6 turns of Calvin cycle, the plant cell fixes $6CO_2$ molecules which are used to synthesize 2 molecules of PGAL which leave the cycle and combine to make one molecule of glucose or fructose. This glucose can be converted into:

- **Sucrose**: when Oxygen combined with fructose. It is a form by which carbohydrates are transported in plants.

- **Polysaccharides** like starch for energy storage, and cellulose for structural support.
- **Amino acids** when combined with nitrates,
- **Nucleic acids** when Oxygen combined with phosphates, and
- **Lipids**.

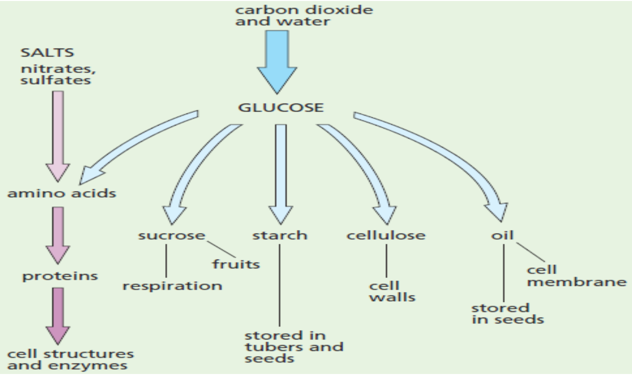


Figure 9.5: Conversion of glucose into other organic substances

- **Regeneration of RuBP**

The remaining ten 3-carbon molecules (PGAL) are converted back into six 5-carbon molecules, ready to fix other CO_2 molecules for the next cycle. The light-independent reactions can be summarized as:

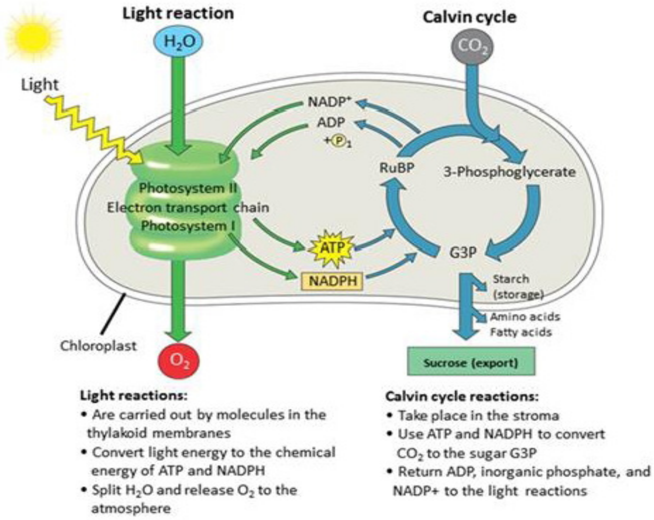


Figure 9.6 Light reaction and Calvin cycle(To be redrawed)

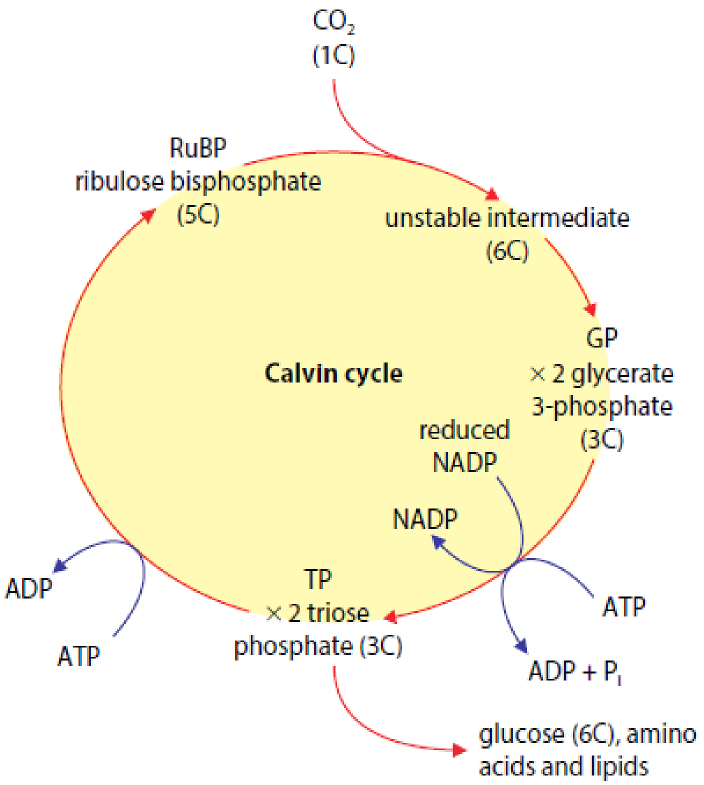


Figure 9.7: Calvin cycle

Photorespiration

In most plants, initial fixation of carbon occurs via Rubisco, the Calvin cycle enzyme that adds CO2 to ribulose biphosphate. Such plants are called C3 plants because the first organic product is a three carbon organic compound, PGA. These plants produce less food when their stomata close on hot and dry days.

The declining level of CO2 in the leaf starves the Calvin cycle. Making matter worse, Rubisco can accept O2 in place of CO2. As O2 concentration overtakes CO2 concentration within the air space, Rubisco adds O2 instead of CO2. The product splits and one piece, a two-carbon compound is exported from the chloroplast. Mitochondria then break the two-carbon molecule into CO2.

The process is called**photorespiration** because it occurs in presence of light (photo) and consumes O2(respiration). However, unlike normal cellular respiration, photorespiration generates no ATP, and unlikephotosynthesis, photorespiration generates no food. In fact, photorespiration decreases photosynthetic output by using material from the Calvin cycle.

Application activity 9.2

1. Describe the structure of a chloroplast.
2. What may happen to the rate of photosynthesis in a photosynthetic cell if the thylakoids in chloroplast are damaged completely?
3. Explain adaptations of both thylakoid and stroma for their functions.
4. Relate the internal structure of the leaf with the process of photosynthesis
5. Explain the involvement of the plant parts bellow in the process of photosynthesis a) Stomata b) Lamina c) Leaf stalk d) Leaf cuticle e) Xylem f) Phloem
6. Why are light and chlorophyll needed for photosynthesis?
7. Describe the relationship between the chlorophyll and the color of plants.
8. How well would a plant grow under pure yellow light? Explain your answer.
9. Appreciate the presence of accessory pigments in leaves for the process of photosynthesis.
10. Differentiate the light-dependent stage and light-independent stage of photosynthesis.
11. Relate the structure of the thylakoid with its function.
12. Explain the stages of the Calvin cycle.

9.3 Rate of photosynthesis: limiting factors of photosynthesis and importance of autotrophic nutrition.

9.3.1. External factors that affect photosynthesis

Activity 9.3.1.a

Aim: To show effect of carbon dioxide on the rate of photosynthesis.

Materials Required: Elodea, beaker, $NaHCO_3$, lamp.

Procedure: Place a pond weed Elodea upside in a test tube containing water at 25°C. Place the tube in a beaker of fresh water.Place excess sodium bicarbonate ($NaHCO_3$) in the water to give a constant saturated solution of CO_2.

Place the lamp at a fixed distance from the plant. Maintain the room temperature at 20°C. Count the number of oxygen bubbles given off by the plant in a one minute period.

Observation: The bubbles are formed of oxygen.

Discussion: Discuss why was $NaHCO_3$ added to water.

1. **CO_2 concentration:** Carbon dioxide is the inorganic substrate for photosynthesis. Increase in concentration up to 0.05% in atmosphere can cause an increase in CO_2 fixation. Carbon dioxide is the major limiting factor, especially in C-3 plants; C-4 plants are more productive even at low concentration of CO_2. Nevertheless, both C-3 and C-4 plants show increase in rate of photosynthesis at high CO_2 concentration and high light intensities. The fact that C-3 plants respond to higher CO_2 concentration by showing increased rates of photosynthesis leading to higher productivity has been used for some green house crops such as tomatoes and bell pepper. They are allowed to grow in carbon dioxide enriched atmosphere as in glasshouses leading to higher yields.

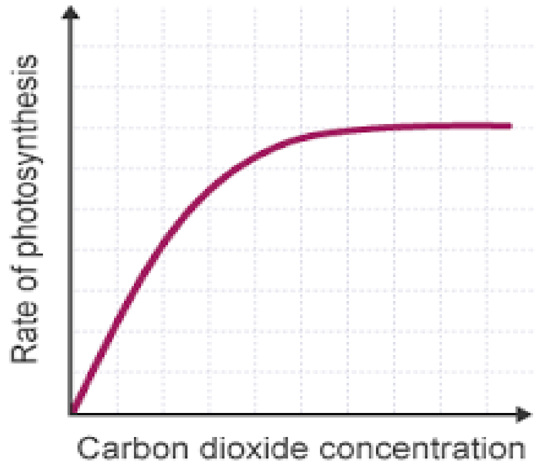


Figure 9.8: Effect of carbon dioxide on the rate of photosynthesis(To be redrawed)

2. **Light:** Light is an important factor to carry out photosynthesis. It is rarely a limiting factor in nature as photosynthesis can occur even at low light intensities. There is a direct relation between light and CO_2 fixation. With increase in light intensity the rate of photosynthesis increases. However, at higher light intensities, rate does not increase linearly but light saturation occurs. At very high light intensity, there is breakdown of chlorophyll molecules called photo-oxidation and the rate of photosynthesis decreases. The quality of light and time of exposure also governs photosynthesis. Green plants show high

rate of photosynthesis at red and blue light.

Light intensity

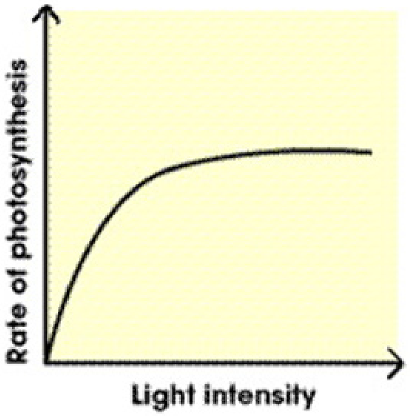


Figure 9.9: Effect of light intensity on the rate of photosynthesis(To be redrawn)

3. **Temperature:** The dark reactions are dependent on temperature as they are enzymatic. Rate of photosynthesis is best at optimum temperature. Different plants have different temperature optima that also depend on their habitats.

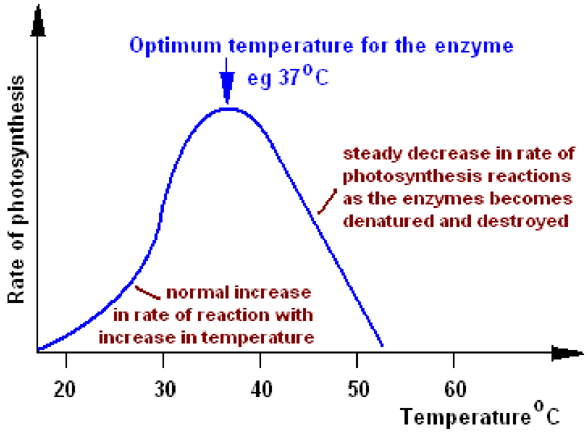


Figure 9.13: Effect of temperature on the rate of photosynthesis (To be redrawn

1. **Water:** Only about 1% of water absorbed by plants is used in photosynthesis. It is an important factor for various metabolic processes in plant. Water may not have direct affect on photosynthesis even though it is one of the reactants in light reaction. In water stress plants wilt and their stomata close. Thus reducing availability of carbon dioxide and decreasing the rate of photosynthesis. Water stress will also alter the hydration of enzymatic proteins, affecting their activities.

2. **Oxygen concentration:** Atmospheric oxygen content affects photosynthesis directly or indirectly. The decrease in rate of respiration at high oxygen concentration was first observed by O. Warburg in 1920 in Chlorella. The phenomenon is called Warburg effect.

3. **Chemical pollutants:** Plant growth has been adversely affected by accumulation of various undesirable chemicals. Heavy metals such as lead, mercury, cadmium seem to be affecting photosynthesis through stomata closure. Air pollutants like SO_2, NO_2 and O_3 are also known to affect photosynthesis at higher concentrations.

9.3.2. Internal Factors

1. **Adaptation of leaf:** Leaves are arranged on plants to minimize overlapping. The shape, size, age and orientation of leaf influences

the absorption of light and thus effects photosynthesis. Most leaves are broad for more absorption of light. The anatomy of leaf is also highly specialized for absorption of light. The epidermis is transparent and also acts as convex lens to focus and intensify light reaching mesophyll cells for maximum absorption.

Application activity 9.3.a

1. Use the graphs to explain how the limiting factors below may influence the rate of photosynthesis:

a) Temperature

b) Light intensity

c) Concentration of CO_2 in air.

2. Student-teacher talked to his Biology group members that:

a) “In Rwanda, the rate of photosynthesis is generally lower at 5:30 AM that it is at 12:30 PM, during a sunny day”. Defend him by providing two convincing reasons.

b) “The rate of photosynthesis is generally higher in Rwanda during the sunny day than in Sahara desert”. Defend him with a convincing reason.

9.3.3. Importance of autotrophic nutrition

a) **Autotrophic nutrition** is a process by which living organisms (autotrophs: photoautotrophs and chemoautotrophs) make their own food. The aututrophism is very essential as it allows production of Oxygen and food for not only themselves but also for heterotrophs. The roles of autotrophic nutrition include:

b) **Independence of green plants from other living organisms to the nutrition point of view.**

This importance relates to their capacity for synthesizing organic molecules from glucose produced by CO_2 and water, this completely make them independents of the other living organisms to the nutrition point of view.

c) **Synthesis of the organic substances: food for the heterotrophs (animal and mushrooms):** The organic substances produced by photosynthesis are the food for the heterotrophs which are unable to synthesize these substances by their own means.

d) **Energy storage**

The autotrophs like green plants, by the process of photosynthesis synthesize certain substances like: the cellulose, starch… which are variables sources of energy.

e) **Production of O_2 for the living organisms' respiration**

The oxygen produced by the photosynthesis is necessary for the living organisms' respiration. Thus without photosynthesis, no oxygen; without oxygen no respiration; without respiration no life on Earth.

f) **Cleaning the atmosphere**

Photoautotrophs absorb carbon dioxide from surrounding air, and release Oxygen (produced by photosynthesis) in atmosphere.

g) **Formation of Ozone layer**

Ozone layer is a thick layer in the atmosphere which is formed Ozone molecule **(O_3).**Oxygen atoms which make ozone molecule are produced by photosynthesis. Ozone layer protects the Earth from high solar radiations, and this allows the existence of the life on the Earth.

Application activity 9.3.b

1. Without autotrophs, the life is impossible on the Earth. By providing possible reasons, defend or disagree with this statement.

End unit assessment 9

Do all these exercises in your exercise book.

I. Choose whether the given statements are True (T) or False (F)

1. Organisms that are heterotrophic can make their own food.
2. Photosynthesis has two stages—light reaction and dark reaction.
3. Environmental factors improve crop yield.
4. Pigment is a material that changes color of reflected or transmitted light.
5. Within leaves, chloroplasts are responsible for respiration.

II. Multiple Choice Questions

1. Green plants require which of the following for photosynthesis?

a) Sunlight (b) CO_2

b) O_2

c) Water

2. What is true about action spectrum?

a) It can be carried out in isolated pigments

b) It gives the function of pigments

c) It is used to identify pigments

d) It does not involve light

3. By looking at which internal structure, you can tell whether a plant is C-3 or C-4?

a) Mesophyll cell (b) Bundle sheath cells

b) Vascular bundles (d) epidermal cells

4. How many ATP are required to produce 2 molecules of glucose?

a) 12 (b) 24

b) 18 (d) 36

5. Autotrophs are commonly called producers because they

a) Produce young plants

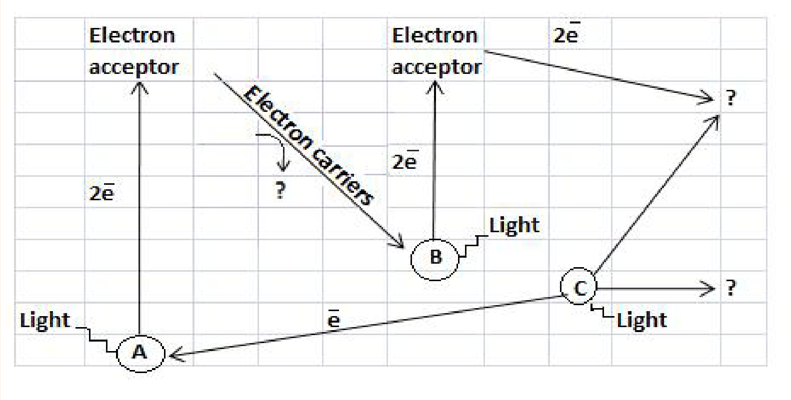
b) Produce CO_2 from light energy

c) Produce sugars from chemical energy

d) Produce water from light energy

III. Long Answer Type Questions

1. State and explain the types of autotrophic nutrition. Also explain the role of light in autotrophic nutrition.
2. Analyse and appreciate the importance of photosynthesis as an energy transfer process.
3. State the role of chloroplast and structure of leaf in photosynthesis. Giving illustrative diagrams, explain your answer.
4. State the pigments involved in light absorption. Throw light on absorption and action spectra of chloroplast pigments.
5. Outline the three main stages of Calvin cycle. State the uses of Calvin cycle intermediaries in plant cell.
6. Summarize the limiting factors affecting photosynthesis. Also state how this can help yield crop production.
7. Investigate the effect of light intensity or light wavelength on the rate of photosynthesis.
8. Describe the relationship between the structure and function in the chloroplast, using diagrams and electron micrographs.
9. Acknowledge the importance of autotrophic nutrition in sustaining the balance of life on Earth. Also state the ways to keep the environment sustained. Predict various facts related to photosynthesis that state the importance of nutrition for all living beings.



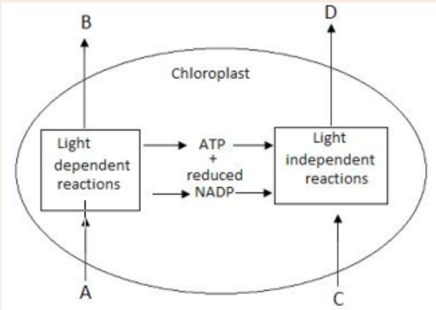
10. The chart below shows the sequence of events that takes place in the light dependent reactions.

a) Identify the point A and B

b) What process is taking place at C?

c) What are the products of the light dependent reaction? (They are indicated by? on the diagram).

11. The diagram below summarizes the movement of materials into and out of chloroplast. Identify the substances moved, indicated by labels A-D.



UNIT 10: THE CHEMICAL BASIS OF LIFE

Key unit competence

Explain the use of biological molecules in living organism.

Introductory Activity 10

Analyze all foods in the figure and answer to the questions below:

a) Among the foods given in figure, which one do you prefer to eat every day? Why?

b) Do you think that there are some missing foods to complete all chemicals of life? Suggest them.

10.1. Biological molecules

Activity 10.1

Discuss chemical elements, sub-units of different types of carbohydrates, lipids and proteins.

What do you know about the function of water to living organisms?

10.1.1 The chemical elements that make up carbohydrates, lipids and proteins

a) Carbohydrates

Carbohydrates comprise a large group of organic compounds which contain carbon, hydrogen and oxygen. The word carbohydrate indicates that these organic compounds are hydrates of carbon. Their general formula is

$Cx(H_2O)y$.

In carbohydrates the ration hydrogen-oxygen is usually 2:1.

Carbohydrates are divided into three groups including the monosaccharide (single sugars), disaccharides (double sugars) and polysaccharides (many sugars). The most common monosaccharide of carbohydrates is glucose with molecular formula $C_6H_{12}O_6$.

b) Lipids

Lipids are a broad group of naturally occurring molecules which include waxes, sterols, fat soluble vitamins (such as vitamins A, D, E and K), monoglycerides, diglycerides, triglycerides, Phospholipids and others.

Lipids are made by carbon, hydrogen and oxygen, but the amount of oxygen in lipids is much smaller than in carbohydrates.

Lipids are grouped into fats which are solid at room temperature and oils which are liquid at room temperature.

c) Proteins

Proteins are organic compounds of large molecular mass. For example, the hemoglobin has a molecular mass of 64500. In addition to carbon, hydrogen and oxygen, proteins always contain nitrogen, usually Sulphur and sometimes phosphorus.

Water

Living organisms contain between 60% and 90% of water, the remaining being the dry mass. Water is made up of only two elements, Hydrogen and Oxygen.

The function of water is defined by its physical and chemical properties that differ from those of most liquids and make it effective in supporting life.

10.1.2. The sub-units that make up biological molecules

a) Sub-units of Carbohydrates

In carbohydrates the following three categories are identified: Monosaccharides , disaccharides and polysaccharides.

i. Monosaccharides

Monosaccharides are the smallest subunits and are made up of single sugar molecules. monosaccharides are the sugars like galactose, fructose and glucose with a general formula $C_6H_{12}O_6$, and these typically take on a ring-shaped structure.

All monosaccharides are reducing sugars capable of acting as a reducing agents because they have a free aldehyde group or a free ketone group.

Sources of Monosaccharides:

Glucose: Fruits and vegetables are natural sources of glucose. It's also commonly found in syrups, candy, honey, sports drinks, and desserts.

Fructose: The primary natural dietary source of fructose is fruit, which is why fructose is commonly referred to as fruit sugar.

Galactose: The main dietary source of galactose is lactose, the sugar in milk and milk products, such as cheese, butter, and yogurt. https://www.healthline.com/nutrition/simple-sugars

ii. Oligosaccharides

These are complex carbohydrate chains made up of two to twenty simple sugars joined together with a covalent bond. The most common oligosaccharide is the disaccharide, and examples of this include sucrose, maltose and lactose whose general formula is $C_{12}H_{22}O_{11}$

A disaccharide is the sugar formed when two monosaccharides are joined by glycosidic bond. Like monosaccharides, disaccharides are soluble in water, have sweet taste, and they are reducing sugars because they are able to reduce **Copper II Sulfate of** benedict solution directly by heating into copper II oxide except sucrose which is non-reducing sugar which are unable to reduce the copper ions in Benedict's solution. This makes the color of Benedict's solution to persist when this sugar is boiled with it.

Sucrose is made up of two monosaccharides **Glucose and fructose**

Maltose is made up of two monosaccharides **Glucose and glucose**

Lactose is made up of two monosaccharides **Glucose and galactose**

In maltose ring, the two rings of glucose are bonded by the -1, 4-glycosidic bond while

in sucrose the glucose and fructose are bonded by -1, 2-glycosidic bond.

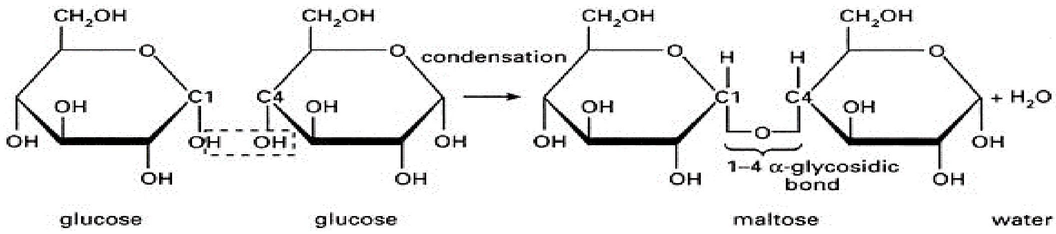


Figure 10.1: Illustration of the formation of maltose

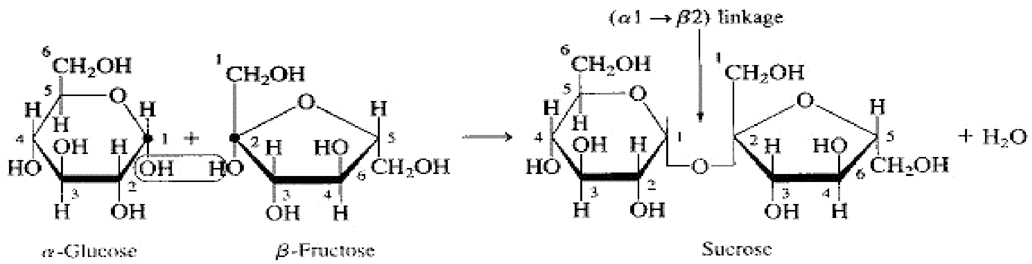


Figure 10.2: Illustration of the formation of sucrose https://www.quora.com/Why-are-glucose-and-fructose-in-the-same-osazone

Table 10.1: different groups of Disaccharides, their structure, enzyme and source

DISACCHARIDE	STRUCTURE	ENZYME FOR HYDROLYSIS	SOURCES
Sucrose(Saccharose)	Glucose+Fructose	Sucrase	Table sugar, molasses, maple syrup, fondant, cakes, candies, chocolate, ice cream, fruits, honey
Lactose(milk sugar)	Glucose+galactose	Lactase	Milk, ice cream, infant formula, milk chocolate, milk candies, certain pills

Maltose(malt sugar)	Glucose+ glucose	Maltase	Spelt, kamut, sweet potatoes, barley malt syrup, high maltose corn syrup beer, or produced from corn

iii. Polysaccharides

These are known for their ability to store energy and are made up of long chains of glucose sugars. The most common polysaccharides are starch(sugar of plant tissues), glycogen (glucose in the human liver and muscles), cellulose (structural polysaccharide in plants; which acts as a dietary fiber when consumed), chitin(sugar found in exoskeleton of arthropods) and murein or peptidoglycan(sugar found in the bacteria cell membrane) . http://www.nutrientsreview.com/carbs/polysaccharides.html

Table 10.2.: different groups of polysaccharides, their composition and source

POLYSACCHARIDE	COMPOSITION	SOURCE
Digestible		
starch	Glucose	Cereal grains (wheat, oats, barley, corn, rice…) and their products (bread, pasta, pastries, cookies), potatoes, tapioca, yam, legumes
Glycogen	Glucose	Shellfish, animal liver
Non-digestible (dietary fiber)		
Cellulose	Glucose	Whole grains, green leafy vegetables, beans, peas, lentils
Hemicellulose	Arabinose + xylose	Cereals bran
Inulin	Fructose and glucose	Wheat, onions, chicory root, leeks; a food additive
Chitin and chitosan	Glucosamine	Dietary supplements, derived from shells of crustaceans
Pectin	Various monosaccharides	Fruits, carrots, sweet potatoes; a food additive

b) Sub-units of Proteins

These are also referred to as macro-nutrients. The proteins are also called body- building food.

The protein molecules are made up of small units called amino acids joined together like links in a chain.

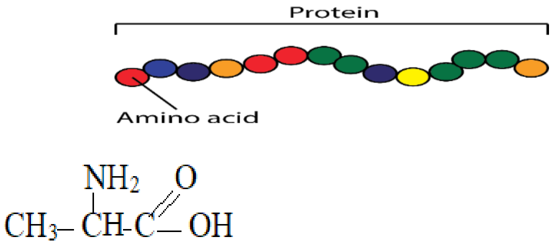


Figure 10.3: Structure of Amino acid

There are 21 different amino acids and each has its own chemical name. Different proteins are made when different numbers and types of amino acids combine through a covalent **peptide bond**. Proteins are therefore known as **polypeptides.**

Examples of proteins:

a) Collagen, myosin and elastin found in meat,

b) Caseinogen, lactalbumin, lacto globulin found in milk,

c) valbumin, mucin and liporitellin found in eggs,

d) Zein found in maize

The 21 different amino acids found in protein are

Arginine, Serine,Selenocysteine, Leusine, Histidine,Threonine, Glycine, Methionine, Lysine, Asparagine, Proline, Phenylalanine, Aspartic acid, Glutamine, Alanine, Tyrosine, Glutamic acid, Cysteine,Valine, Tryptophan, Isoleucine.

They are used to repair, to build, to maintain our bodies; to make muscles and to make breast milk during lactation period. The proteins are classified into two categories: animal or complete proteins and plant proteins or incomplete proteins

c) Sub-units of lipids

Lipids are made by two components namely glycerol and fatty acids. The chemical formula for glycerol is $\mathbf{C_3H_8O_3}$.

Structural formula of glycerol is

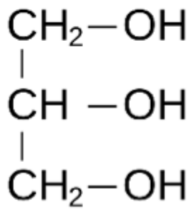


Figure 10.4: structure of glycerol

Sources and classification of lipids

Fats and oils are obtained from both the plants and animals. And fat is present in food either as visible fat or invisible fat.

Visible fat is the one that is easily seen or detected in food for example; fat in meat, butter, margarine, lard, suet and cooking fat and oil.

Cooking oil Cheese Margarine

Figure 10.5: Examples of sources of visible fat

Invisible fat is the part of food that is not easily seen for example fat with in lean meat, egg yolk, flesh of oily fish, groundnuts, soya beans, avocado and fat found in prepared foods, for example, pastry, cakes, biscuits, French fries, pancakes, croquettes.

Cake Meat pie

Figure 10.6: Examples of sources of invisible fat

Lipids are of different types as it is summarized in the following table

Table 10.3: Lipids, structure, main role and features

Lipid	Structure	Main role	Other features
Triglyceride	Glycerol plus fatty acids	Compact energy store, insoluble in water so doesn't affect water potential.	Stored as fat, which also has thermal insulation and protective properties.
Phospholipid	Glycerol plus two fatty acids and a phosphate group	Forms a molecule that is part hydrophobic, part hydrophilic ideal for basis of cell surface membranes	Phosphate groups may have carbohydrate parts attached: These Carbohydrates are involved in cell signaling.
Cholesterol	Four carbon-based ring structures joined together	makes essential molecules such as hormones, fat-soluble vitamins, and bile acids to help you digest your food.	Used to form steroid hormones

Structure of fatty acid

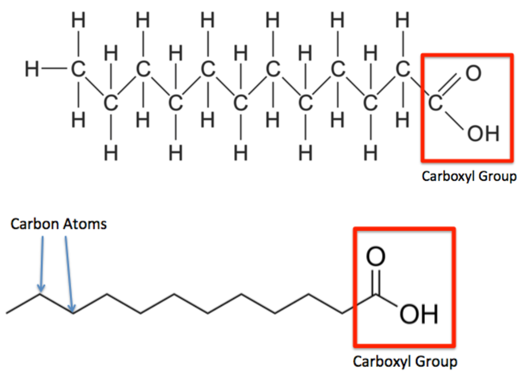


Figure 10.7: Structure of fatty acid

The following are three main types of lipids: Triglycerides, phospholipids and steroids

Triglycerides: these are lipids that are obtained from cooking oils, butter and animal fat. They are made up with: one molecule of glycerol and three molecules of fatty acids bonded together by Ester bonds. The triglycerides play the role like storing energy they have thermal insulation and protective properties

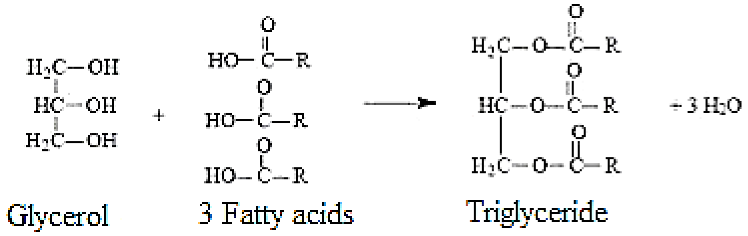


Figure 10.8: structure of triglyceride formed from glycerol and fatty acid.

Sterols: these are lipids that include **steroid hormones** like testosterone and oestrogen, **cholesterol** that is formed four carbon-based rings and it helps in regulation of fluid and strength of the cell membrane.

Phospholipids: They are made up of one molecule of glycerol, two molecules of fatty acids and one phosphate group. The phospholipids form a molecule that is part hydrophobic, part hydrophilic, ideal for basis of cell surface membranes

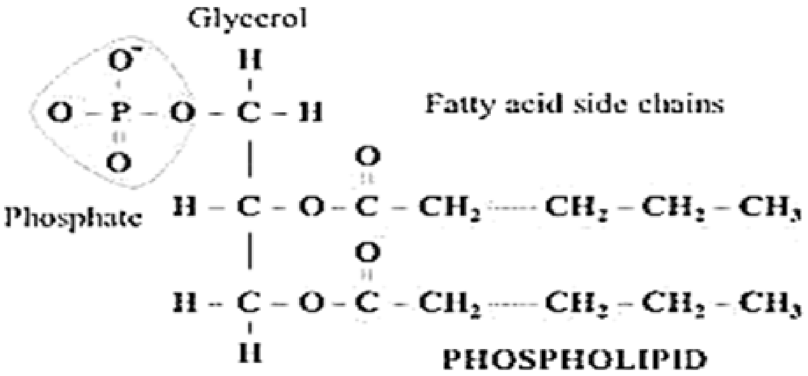


Figure 10.9: structure of phospholipids

10.1.3. The proteins and their functions

Activity 1.1

1. From the books make a research on proteins and answer to the following questions:

   Differentiate globular proteins and fibrous proteins.

2. Take a plastic cord, create the bulk on it and suppose that those are monomers of a long chain of polymer (the whole cord), heat it using a Bunsen burner or another source of fire. Discuss the change that takes place.

Proteins are organic compounds of large molecular mass ranging up to 40000000 for some viral proteins but more typically several thousand. For example, the hemoglobin has a molecular mass of 64500. Proteins are polymers of amino acids and they are not truly soluble in water, but form colloidal suspensions. In addition to carbon, hydrogen and oxygen, proteins always contain nitrogen, usually Sulphur and sometimes phosphorus. Whereas there are relatively few carbohydrates and fats, the number of proteins is limitless. Coined by a Dutch chemist Mulder the word protein etymologically means “of the first importance” due to the fundamental role they play in living cells.

a) Amino acids

Amino acids are group of over a hundred chemicals of which around 20 commonly occur in proteins. They always contain a basic group, the amine group ($-NH_2$) and an acid group ($-COOH$) together with -R group side chain (Figure 10.14). All the amino acid differs one to another by the structure of their side chain.

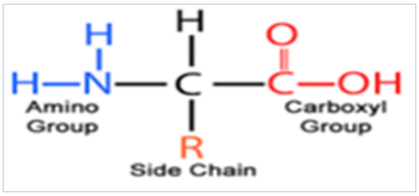


Figure 10.14: The structure of amino acid

Amino acids are divided into two categories including essential amino acid and non-essential amino acid. Essential amino acids are those amino acids which cannot be synthesized by the body. They include isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, arginine and histidine. Non –essential amino acids are synthesized by the organism.

They include alanine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, proline, serine and tyrosine. The simplest amino acid is glycine with H as -R group (Figure 10.15. a). The other one is Alanine with $-CH_3$ as -R group (Figure 10.15.b). All 21 amino acids can be found in diet from animals such as meat, eggs, milk, fish…but diet from plant lack one or two essential amino acids such plant are beans, soy beans…

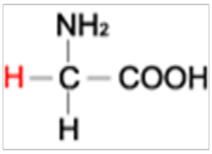


Figure 10.15.a: The structure of the simplest amino acid Glycine.

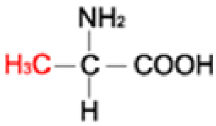


Figure 10.15.b: The structure of Alanine

When an amino acid is exposed to basic solution, it is deprotonated (release of a proton H^+) to became negative carboxylate COO^- while in acid solution it is protonated (gains of a proton H^+) to became ammonium positive ion $-NH_3^+$(Figure 10.16.a and Figure 10.16.b).

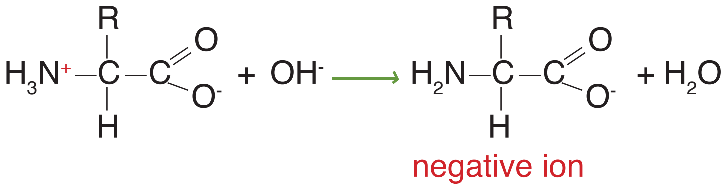


Figure 10.16.a: The amino acid in a basic solution

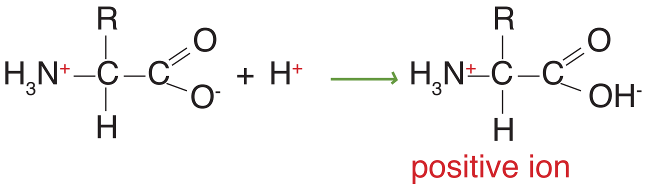


Figure 10.16.b: The amino acid in acid solution

At a physiological pH, usually around 7, the amino acid exists as ZWITTERION (from German means hermaphrodite) it is a molecule with two different charges (positive and negative) at the same time (Figure 10.17).

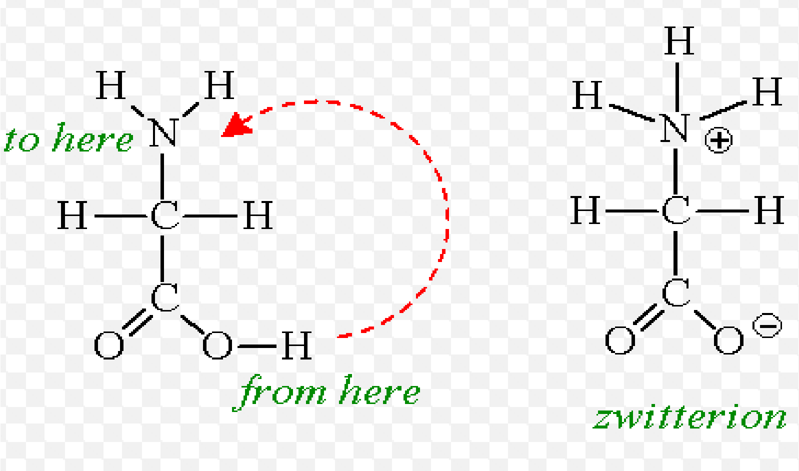


Figure 10.17: Formation of zwitterion in amino acid

Formation and breakage of peptide bond

The formation of peptide bond follows the same pattern as the formation of glycosidic bond in carbohydrates and ester bond in fats. A condensation reaction occurs between the amino group of one amino acid and the carboxyl group of another, to form a dipeptide (fig 10.18).

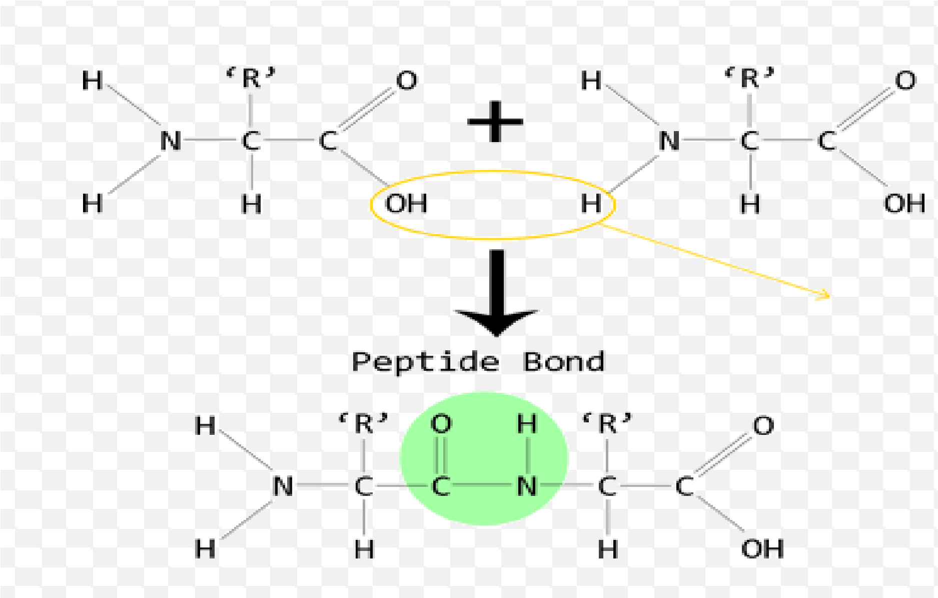
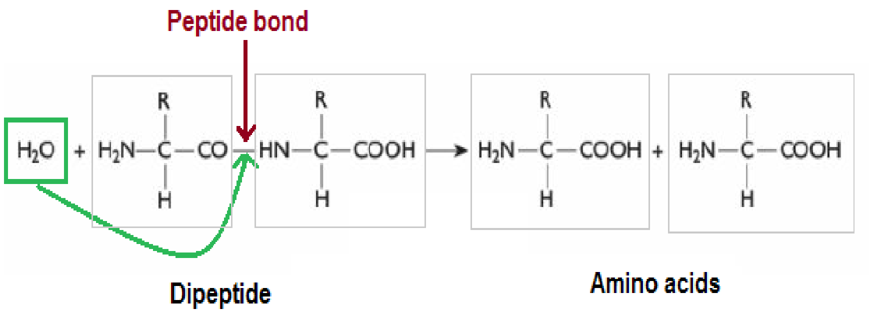


Figure 10.18: formation of the peptide bond

A peptide bond is formed between two amino acids to form a dipeptide molecule, if three amino acids are assembled together it is a tripeptide, four amino acids form a tetrapeptide and so on.

A long chain of amino acid it is called a polypeptide. The polypeptide chain or oligopeptide comprise more than 50 amino acids joined together by a peptide bond.

During digestion, proteins are hydrolyzed and give their monomer amino acids small molecules that can be diffused in the wall of intestine to the organism. In hydrolysis the peptide bond break down by the addition of a water molecule (Figure 10.19).



Hydrolysis reaction

Figure 10.19: Hydrolysis of a peptide bond.

Functions of proteins.

- Proteins such as lipase, pepsin and protease act as enzymes as they play a crucial role in biochemical reaction where they act as catalysts.
- Proteins play an important role in coordination and sensitivity (hormones and pigments).
- Proteins have a transport functions. Example: Haemoglobin transport oxygen
- Proteins in the cell membrane facilitate the transport of substance across the cell membrane.
- Proteins provide a mechanical support and strength.
- Proteins such as myosin and actin are involved in movement.
- Proteins play the role of defense of the organisms. Example: Antibodies are proteins

Application activity 10.1

1. Provided with different kinds of biological molecules such as carbohydrates, proteins, lipids, make a table to show their food source you always take and suggest their functions.
2. Explain what is meant the essential amino acids
3. Describe the formation of a peptide bond?
4. Alanine is an amino acid with -CH3 as a side chain. Writes its structural formulae.
5. Most of the plant lacks one or more of the essential amino acids needed by the body explain how a vegetarian can obtain the essential amino acids.
6. Use the type of reaction above to form glucose from sucrose molecule
7. Describe how the glycosidic bond is formed.
8. Describe the major types of starch

10.2. Water and enzymes

Activity 10.2

1. You are provided with three groups of enzymes: Group A Group B Group C Enzymes Maltase and lactase Dehydrogenase and oxidase Pepsin and renin

	Group A	Group B	Group C
Enzymes	Maltase and lactase	Dehydrogenase and oxidase	Pepsin and renin

Make a research to find out:

a) specific role of each of the six enzymes mentioned above

b) criterion followed to name enzymes of group A, B and C respectively

2. a. What is the medium of reaction in the organisms?

b. If two people are boiling the same quantity of cooking oil and water, which one could evaporate first? Explain your choice.

10.2.1. Water

Living organisms contain between 60% and 90% of water, the remaining being the dry mass. The scientist accepts that life originates from water and most of animals live in water. The function of water is defined by its properties mainly: Its physical properties, solvent properties, heat capacity, surface tension and freezing points. The physical and chemical properties of water differ from those of most other liquids but make it uniquely effective in supporting living activities.

a) Physical properties of water

Water has the high boiling point (100°C) compared to other liquid due to the hydrogen bond that exists among molecules of water. This help the water to exist on the surface in a liquid state otherwise it would evaporate.

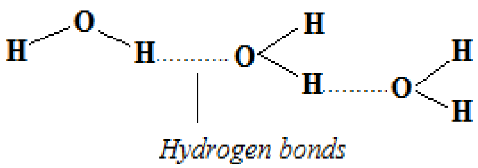


Figure 10.25: Molecular structure of water

Table 10.4: Biological significance of the physical properties of water

Property of water	Significance for living organism
Water is a liquid at room temperature	Provides a fluid environment inside the cells and aquatic environment for organisms to live in.
Universal solvent	The chemical reaction inside the cell happens in aqueous solution. Water is the main transport medium in organisms
Water has high surface tension	Water forms a surface film at an air water interface. This allows some aquatic organisms such as pond skaters to land on the surface of ponds and move over it.
Ice is less dense than liquid water	Ice forms on the surface the body of water and insulates the water below, allowing aquatic life to survive)

Water has adhesion forces	Along with low viscosity adhesion forces help capillarity so that for example, water can move upward through narrow channels in the soil against gravity.
High specific heat capacity	Water being a major component of internal fluids, organisms resist temperature changes and so remain relatively stable.
High latent heat of vaporization	Heat is lost from surface when water evaporates from it. This is used as cooling mechanism; sweating in animals and transpiration in plants
High latent heat of fusion	Cell content and aquatic habitats are slow to freeze in cold weather.
Water is colorless and transparent	Transmission of sunlight helps aquatic plants to photosynthesize.
Water is denser than air	Acts as a habitat for large organisms. It helps supports and disperses reproductive structures such as larvae and large floating fruits like coconuts
Water is difficult to compress	Water is an important structural agent acting as a hydrostastic skeleton in invertebrates(worms) and turgid cells in plants
Water has high tensile strength	Continuous columns of water are pulled up the xylem to the top of the plant during transpiration
Water combines with many organic molecules to from hydrated molecules	Most organic molecules occur in a hydrated form in a cell. If water is removed, their physical and chemical properties are affected; the use and storage of food.

a) Solvent properties of water

Water is a polar molecule due to its chemical arrangement of hydrogen and oxygen atom in asymmetric shape instead of being linear. Most of the substance that are transported in the blood is dissolved in the plasma, the fluid part of the blood. Water occupies around 92% of the constituents of plasma. Thus the oxygen atom has a positive charge and hydrogen atom net positive charges. This is of great importance because all negative and positive ions are attracted by water. Therefore, water is a good solvent because the ionic solids and polar molecules are dissolved in it.

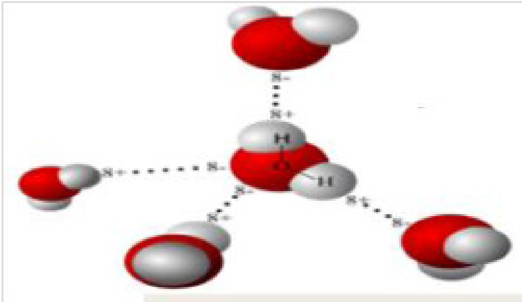


Fig 10.26: Asymmetric model of water

b) Heat capacity and latent heat of vaporization

Large changes of heat results in a comparatively small rise in water temperature this explain why water has a high heat capacity compared to other liquid. The high heat capacity is defined as the amount of heat required to raise the temperature of 1gram to 1^0C.The high thermal capacity of water make the ideal environment for life in plant and animals because it helps in maintaining the temperature even if there will be environmental fluctuations in temperature. The biological importance of this is that the range of temperatures in which biochemical processes can proceed is narrow.

The latent heat of vaporization is a measure of heat energy needed to cause the evaporation of a liquid, which means to change from water liquid to water vapor. During vaporization the energy transferred to water molecules correspond to the loss of energy in the surroundings which therefore cool down. During sweating and transpiration living organisms use vaporization to cool down.

i. Surface tension

The surface tension of water results from its polar nature, and is defined as the ability of the external surface of the liquid to resist to external force due to cohesive nature of its molecules. The high surface tension of water and the cohesion force play a vital role in capillarity thus help the transport of substance in vessels (tracheid of plant) to the stems and to fulfill the blood in the cardiovascular vessels. Water being the second liquid with high surface tension after mercury its surface tension is lowered by the dissolution of ions and molecules and tend to collect at the interface between its liquid phase and other.

ii. Freezing points

Oppositely to other liquid water expand as it freezes, under 40 ^{C} temperatures the hydrogen bond becomes more rigid but more open. This explains why the solid water (ice) is less dense than the liquid water and why the ice floats over water rather than sinking. When the bodies of water freeze the ice float over the liquid act as an insulator and prevent water below it from freezing. This protects the aquatic organisms so that they can survive the winter.

Figure 10.27: Aquatic organisms in winter

10.2.2. Enzymes, their characteristics and actions

a) Criteria for naming enzymes

Activity 10.2.2.a

You are provided with three groups of enzymes:

	Group A	Group B	Group C
Enzymes	Maltase and lactase	Deshydrogenase and oxidase	Pepsine and renine

Make a research from text book or internet to find out:

What is the specific role of each of the six enzymes mentioned above?

What criterion was followed to name enzymes of group A, B and C respectively?

Enzymes are biological catalyst produced by a living organism to control the speed of specific biochemical reactions (metabolism) by reducing its activation energy.

First of all, Individual enzymes are named by adding -ase to the name of the substrate with which they react. The enzyme that controls urea decomposition is called urease; those that control protein hydrolyses are known as proteases.

A second way of naming enzymes refers to the enzyme commission number (EC number) which is a numerical classification scheme for enzymes based on the chemical reactions they catalyse. As a system of enzyme nomenclature, every EC number is associated with a recommended name for the respective enzyme catalysing a specific reaction. They include:

Oxidoreductases catalyse redox reactions by the transfer of hydrogen, oxygen or electrons from one molecule to another. Example: Oxidase catalyses the addition of oxygen to hydrogen to form water.

$$\text{Glucose + oxygen} \quad \text{glucose oxidase} \xrightarrow{Oxidase} \text{gluconic acid +water}$$

- **Hydrolase** catalyses the hydrolysis of a substrate by the addition of water.

$$\text{Sucrose + water} \xrightarrow{Hydrolase} \text{glucose+ fructose}$$

- **Ligases** catalyze reactions in which new chemical bonds are formed and use ATP as energy source.

$$\text{Amino acid + |RNA} \xrightarrow{ligase} \text{amino acid-tRNA complex.}$$

- **Transferases** catalyze group transfer reactions. The transfer occurs from one molecule that will be the donor to another molecule that will be the acceptor. Most of the time, the donor is a cofactor that is charged with the group about to be transferred. Example: Hexokinase used in glycolysis.
- **Lyases** catalyze reactions where functional groups are added to break double bonds in molecules or the reverse where double bonds are formed by the removal of functional groups. For example: Fructose bisphosphate aldolase used in converting fructose 1,6-bisphospate to G3P and DHAP by cutting C-C bond.
- **Isomerases** catalyze reactions that transfer functional groups within a molecule so that isomeric forms are produced. These enzymes allow for structural or geometric changes within a compound. Sometime the

interconverstion is carried out by an intramolecular oxidoreduction. In this case, one molecule is both the hydrogen acceptor and donor, so there's no oxidized product. The lack of a oxidized product is the reason this enzyme falls under this classification. The subclasses are created under this category by the type of isomerism. For example: phosphoglucose isomerase for converting glucose 6-phosphate to fructose 6-phosphate. Moving chemical group inside same substrate.

A third way of naming enzymes is by their specific names e.g. trypsin and pepsin are proteases. Pepsin, trypsin, and some other enzymes possess, in addition, the peculiar property known as autocatalysis, which permits them to cause their own formation from an inert precursor called zymogen.

b) Characteristics of enzymes.

Activity 10.2.2.b

Requirement:

Three test tubes, match box, about 1g of liver, 1g of sands, 1% H_2O_2 and MnO_2 powder.

Procedure:

- Label three test tubes A, B and C respectively.
- Put about 0.1 g of MnO_2 powder in test tube A and 1g of liver in tube B and 0.1g of sand in tube C.
- Pour 5 ml of H_2O_2 (hydrogen peroxide) in each tube. What do you observe?
- Place a glowing splint in the mouth parts of each test tube. What do you observe?

Questions

1. Explain your observations.
2. Write down the chemical equation of the reaction taking place in tube A and B
3. Carry out your further research to find out the characteristics of enzymes

The following are main characteristics of enzymes:

- **Enzymes are protein in nature**: all enzymes are made up of proteins.
- **Enzymes are affected by temperature**. They work best at specific temperatures; for example, enzymes found in human bodies work best at 37^oC. This is called the optimum temperature.
- **Very low temperatures inactivate enzymes**. Therefore enzymes are not able to catalyse reactions.
- **High temperatures beyond the optimum temperature denature enzymes**. The structure of the protein molecule is destroyed by heat.
- **Enzymes work best at specific pH**. Different enzymes have a given specific pH at which they act best.

  This pH is called optimum pH. Some enzymes work best at low pH (acidic medium) while others work best at high pH (alkaline medium). Most enzymes in the human body for instance work best at neutral or slightly alkaline pH. Examples are: lipases, peptidases and amylase. A few enzymes like pepsin that digests proteins in the stomach works best at an acidic pH of 2.
- **Enzymes remain unchanged after catalysing a reaction**. Enzymes are catalysts and can therefore be used over and over again in small amounts without being changed.
- **Enzymes catalyse reversible reactions**. This means that they can change a substrate into products and the products back to the original substrate.

$$A + B \rightleftharpoons C$$

- **Enzymes are substrate-specific**. This means that an enzyme can only catalyse one reaction involving aparticular substrate. This is because they have active sites which can only fit to a particular substrate whose shape complements the active site. For example, pepsin works on proteins but not on fats or starch.
- **Enzymes work rapidly**. Enzymes work very fast in converting substrates into products. The fastest known enzyme is catalase, which is found in both animal and plant tissues.
- **Enzymes are efficient**. This is best described by the fact that:

• They are required in very small amounts.

• They are not used up in a reaction and can therefore be used repeatedly.

- **Enzymes are globular proteins**.

- **Enzymes lower the activation energy (Ea) required for reactions to take place**.

  In many chemical reactions, the substrate will not be converted to a product unless it is temporarily given some extra energy. This energy is called activation energy i.e. the minimum energy required the make a reaction take place.

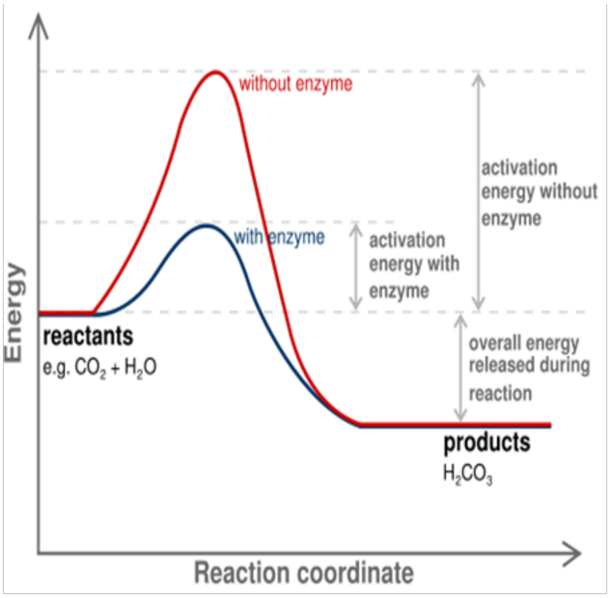


Figure 10.28: An enzyme lowers the activation energy

An enzyme provides a reaction surface for a reaction to take place. This is normally a hollow or cleft in the enzyme which is called the active site, but it is normally hydrophobic in nature rather than hydrophilic. An enzyme provides a reaction surface and a hydrophilic environment for the reaction to take place.

A very small amount of enzymes is needed to react with a large amount of substrate. The turnover number of an enzyme is the number or reactions an enzyme molecule can catalyse in one second. Enzymes have a high turnover number e.g. the turnover number of catalase is 200,000 i.e. one molecule of enzyme catalase can catalyse the breakdown of about 200,000 molecules of hydrogen peroxide per second into water and oxygen at body temperature.t

A cofactor is the best general term to describe the non-protein substances required by an enzyme to function properly. This term covers both organic

molecules and metal ions. A co-enzyme is an organic molecule that acts as a cofactor. A prosthetic group is a cofactor that is covalently bound to the enzyme.

Factors affecting enzyme action

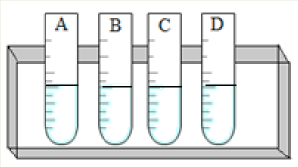
Activity 10.2.2.c

You will need

Eight test tubes containing 2 cm3 starch solution, amylase solution, and cold water (ice) water bath, iodine solution, HCl solution, and droppers

Procedure:

1. Label your test tubes A-D as follows:



2. Add 1 cm^3 of starch solution to each test tube
3. Keep tube A and B in cold (ice) and tube C and D in the water bath at 35°C for 5 minutes.
4. Add 1 cm^3 of 1M HCl on test tubes B and D, then shake the mixture to stir.
5. Add 1 cm^3 of amylase solution on each test tube. Shake and therefore keep A and B in cold and C and D in water bath for 10 minutes.
6. Take a sample from each tube and mix it with one drop of iodine. Use a different tile for each test tube. Record and interpret your observation and then draw a conclusion.

Enzymes activities can be limited by a number of factors such as the temperature, the pH, the concentration of the substrate or the enzyme itself and the presence of inhibitors.

i. Temperature

At zero temperature, the enzyme cannot work because it is inactivated. At low temperatures, an enzyme-controlled reaction occurs very slowly. The molecules in solution move slowly and take a longer time to bind to active sites. Increasing temperature increases the kinetic energy of the reactants. As the reactant molecules move faster, they increase the number of collisions of molecules to form enzyme-substrate complex.

At optimum temperature, the rate of reaction is at maximum. The enzyme is still in active state. The optimum temperature varies with different enzymes.

The optimum temperature for enzymes in the human body is about 37°C. When the temperature exceeds the optimum level, the enzyme is denatured.

The effect is irreversible. However, some species are thermophilic that is they better work at high temperatures; others are thermophobic, that is they better work at low temperatures. For example, some thermophilic algae and bacteria can survive in hot springs of 60°C.

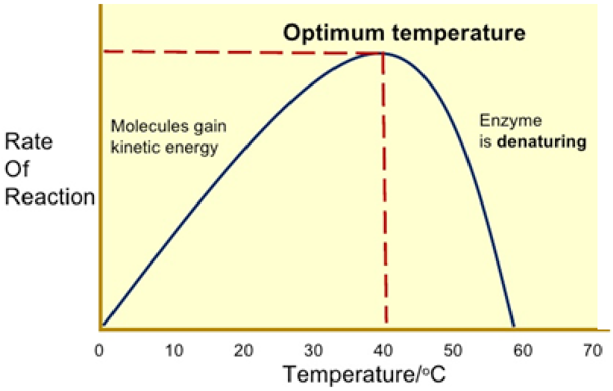


Figure 10.29: Effect of heat on the enzyme controlled reaction

The rate doubles for each 10°C rise in temperature between 0°C and 40°C. The temperature coefficient Q10 is the number which indicates the effect of rising the temperature by 10°C on the enzyme-controlled reaction. The Q10 is defined as the increase in the rate of a reaction or a physiological process for a 10°C rise in temperature. It is calculated as the ratio between rate of reaction occurring at (X + I0) °C and the rate of reaction at X °C. The Q10 at a given temperature x can be calculated from:

$$Q10=\frac{\text{Rateofreactionat}(x+10)^{\circ}C}{\text{Rateofreactionat}x^{\circ}C}$$

Worked out example

The rate of an enzyme-controlled reaction has been recorded at different temperatures as follows:

Temperature / °C	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0
Rate / mgs^{-1}	0.01	0.1	0.2	0.4	0.8	0.4	0.2	0.02

Calculate the Q10 of that reaction at 30 °C

$$Q10 \text{ at } 30° C = \frac{\text{Rate of reaction at } (x+10)°C}{\text{Rate of reaction at } x°C} = \frac{\text{Rate at } (30+10)° C}{\text{Rate at } 30°C} = \frac{\text{Rateat } 40°C}{\text{Rateat } 30°C} = \frac{0.8}{0.4} = x\ 2$$

This means that the rate of the reaction doubles if the temperature is raised from 30°C to 40°C

Be aware that not all enzymes have an optimum temperature of 40°C. Some bacteria and algae living in hot springs (e.g. Amashyuza in Rubavu) are able to tolerate very high temperatures. Enzymes from such organisms are proving useful in various industrial applications.

ii. The pH

Most enzymes are effective only within a narrow pH range. The optimum pH is the pH at which the maximum rate of reaction occurs. Below or above the optimum pH the H^+ or OH^- ions react with functional groups of amino acids in the enzyme which loses its tertiary structure and become natured.

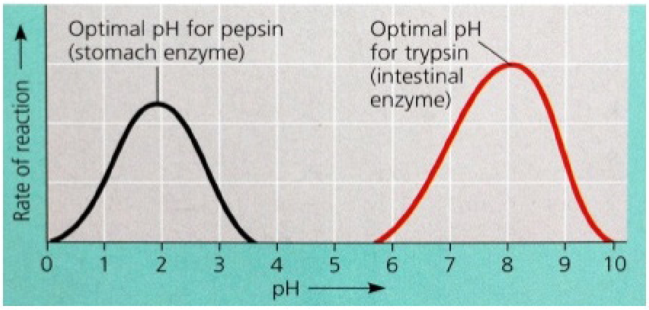


Figure 10.30: Optimum pH depends on nature of enzyme

Different enzymes have different pH optima (look in the table).

Table 10.5. Optimum pH of some digestive enzymes

Enzyme	Optimum pH
Pepsin and rennin	2.0
Salivary amylase	6.8
Trypsin	7.8
Lipase	9.0

Enzyme concentration

The rate of an enzyme-catalyzed reaction is directly proportional to the concentration of the enzyme if substrates are present in excess concentration and no other factors are limiting.

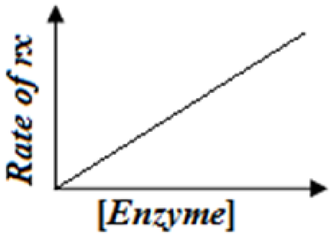


Figure 10.31: Effect on the rate of reaction

iii. Substrate concentration

At low substrate concentration, the rate of an enzyme reaction increases with increasing substrate concentration. The active site of an enzyme molecule can only bind with a certain number of substrate molecules at a given time. At high substrate concentration, there is saturation of active sites and the velocity of the reaction reaches the maximum rate.

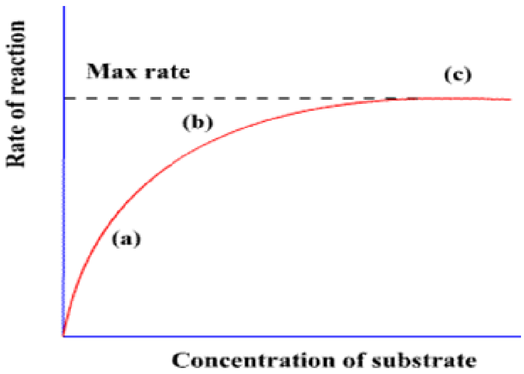


Figure 10.32: Effect of the concentration of substrate on the rate of reaction

iv. Inhibitors

The inhibitors are chemicals or substances that prevent the action of an enzyme. An inhibitor binds to an enzyme and then decreases or stops its activity. There are three types of inhibitors:

i. **Competitive inhibitors** are molecules that have the similar shape as the substrate. They are competing with the substrate to the active site of the enzyme e.g. O_2 compete with CO_2 for the site of RuBP-carboxylase.

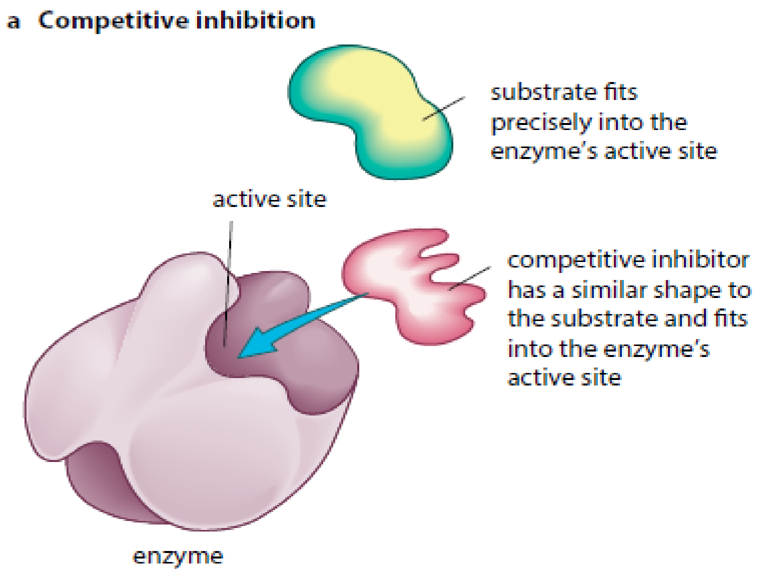


Figure 10.33: Competitive inhibition

ii. Non-competitive inhibitors are molecules that can be fixed to the other part of enzyme (not to the active site) so that they change the shape of active site, due to this the substrate cannot bind to the active sit of the enzyme.

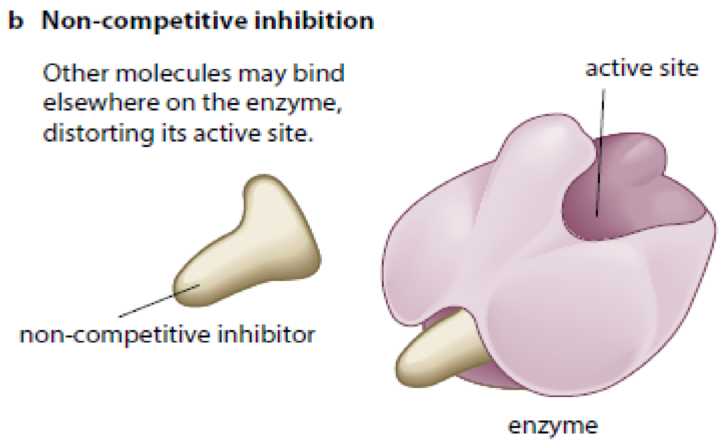


Figure 10.34: Non-competitive inhibition

iii. End product inhibitor Allosteric inhibitor or Allostery.

This is a chain enzymatic metabolic pathway where the final end product acts as an allosteric reversible inhibitor for the first, the second or the third step in the metabolic pathway. The shape of an allosteric enzyme is altered by the binding of the end product to an allosteric site. This decreases enzymatic activity. By acting as allosteric inhibitors of enzymes in an earlier metabolic pathway, the metabolites can help to regulate metabolism according to the needs of organisms. This is an example of negative feedback.

This often happen when few enzymes are working on a large number of substrate e.g. ATP is an end-product inhibitor of the enzyme PFK (Phosphofructokinase) in glycolysis during cell respiration. The end-product inhibitor leads to a negative feedback.

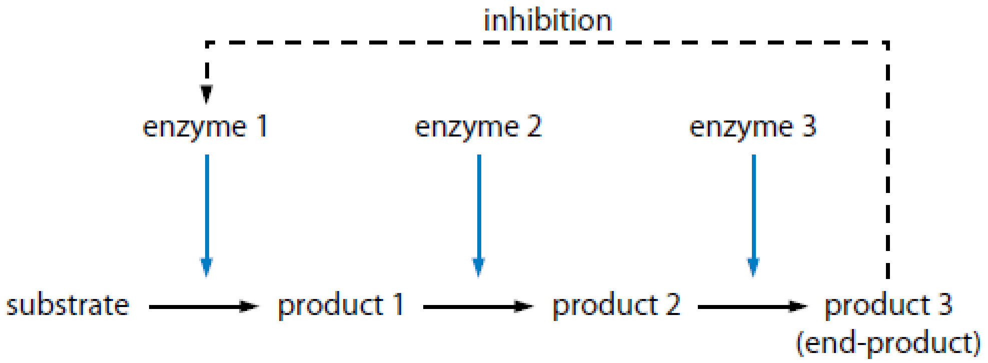


Figure10.35: Model of end – product inhibition.

The products of enzyme-catalysed reactions are often involved in the feedback control of those enzymes. Glucose-1-phosphate is the product formed from this enzyme-catalysed reaction. As its concentration increases, it increasingly inhibits the enzyme.

Note: Reversible and irreversible inhibition

Competitive inhibitor is reversible inhibitor as it binds temporarily to the active site. It can be overcome by increasing the relative concentration of the substrate. Some non-competitive inhibitors are reversible, that is, if the inhibitor binds temporarily and loosely to the allosteric site. Some inhibitors have very tightly, often, by forming covalent bonds with enzyme.

The nerve gas DIPF (DiIsopropylPhosphoFluoridate) is an irreversible inhibitor. It binds permanently with enzyme acetylcholisterase, altering its shape. The enzyme cannot bind with and break down its substrate acetylcholine (neurotransmitter). Acetylcholine molecules accumulate in the synaptic cleft. Nerve impulses cannot be stopped causing continuous muscle contraction. This leads to convulsions, paralysis and eventually death.

Many pesticides such as organophosphate pesticides act as irreversible enzyme inhibitors. Exposure to pesticides can produce harmful effects to the nervous and muscular systems of humans. Heavy metal ions such as Pb2+, Hg2+, Ag+, As+ and iodine-containing compounds which combine permanently with sulphydryl groups in the active site or other parts of the enzyme cause inactivation of enzyme. This usually disrupts disulphide bridges and cause denaturation of the enzyme.

d) Importance of enzymes in living organisms

Activity 10.2.d

Discuss and present your ideas about the need for different enzymes in living organisms.

Without enzymes, most of the biochemical reactions in living cells at body temperature would occur very slowly at not at all. Enzyme can only catalyze reactions in which the substrate shape fits that of its active site

There are thousands upon thousands of metabolic reactions that happen in the body that require enzymes to speed up their rate of reaction, or will never happen. Enzymes are very specific, so nearly each of these chemical reactions has its own enzyme to increase its rate of reaction. In addition, the organism has several areas that differ from one another by the pH. Therefore, the acid medium requires enzymes that work at low pH while other media are alkaline and therefore require enzymes that work at high pH. In addition to digestion, enzymes are known to catalyze about 4,000 other chemical reactions in your body. For example, enzymes are needed to copy genetic material before your cells divide.

Enzymes are also needed to generate energy molecules called ATP, move fluid and nutrients around the insides of cells and pump waste material out of cells. Most enzymes work best at normal body temperature -- about 98 degrees Fahrenheit -- and in an alkaline environment. As such, high fevers and over-acidity reduce the effectiveness of most enzymes. Some enzymes need co-factors or co-enzymes to work properly.

10.2.3. Mode of action of enzymes

Activity 10.2.3

There are two main hypotheses that explain the more of action of an enzyme on its substrate: the lock and key hypothesis and the induced-fit hypothesis. Carry out a research to find the relevance of each.

Enzymes do not change but substrates are converted to products. A substrate is a molecule upon which an enzyme acts. In the case of a single substrate, the substrate binds with the enzyme active site to form an enzyme-substrate complex. Thereafter the substrate is transformed into one or more products, which are then released from the active site. This process is summarized as follows:

$$E+S \rightarrow ES \rightarrow EP \rightarrow E+P$$

Whereby: E = enzyme, S = substrate(s), ES = Complex Enzyme-Substrate and P= product (s). There are two main hypotheses explaining the mechanism of enzyme action:

a) The lock and key hypothesis by Emil Fischer

In this hypothesis the substrate is the key and enzyme is the lock. In otherwise the active site is exactly complementary to the shape of the substrate.

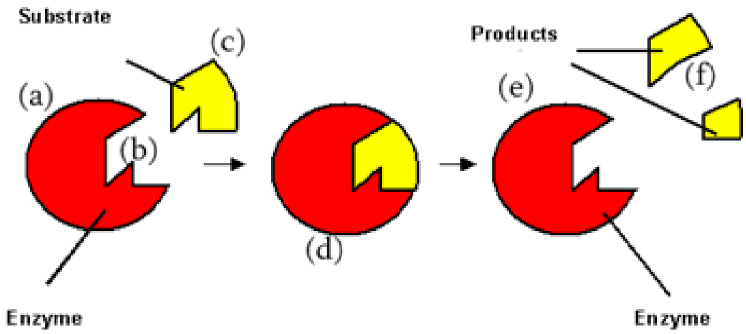


Figure 10.36: Lock and key hypothesis

b) The induced-fit hypothesis by Daniel Koshland

The induced-fit hypothesis is a modified version of the lock and key hypothesis and is more widely accepted hypothesis. In this hypothesis, the active site is flexible and is not exactly complementary to the shape of the substrate. An enzyme collides with the substrate molecule. The substrate binds to the active site. The bindings induce a slight change in the shape of the enzyme to enclose the substrate making the fit more precise. The active site now becomes fully complementary with the substrate as the substrate binds to the enzyme.

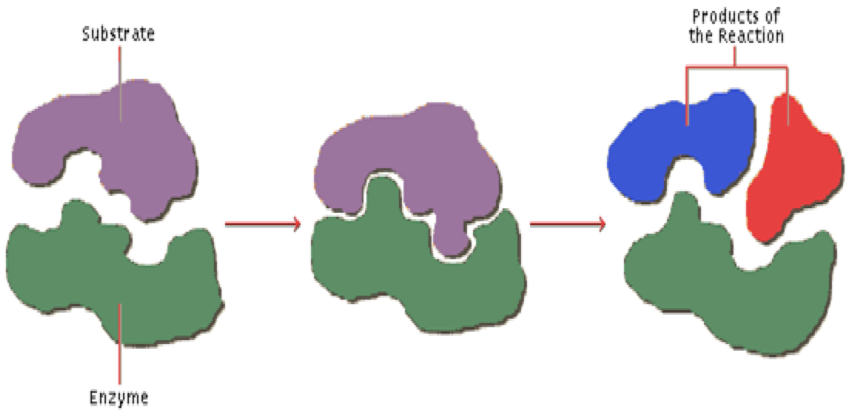


Figure 10.37: Induced fit hypothesis model

Note that the activity of a given enzyme in vitro (outside a living body) may not be necessarily the same in vivo (inside a living body).

Application activity 10.2

Fill the blank with appropriate terms: Enzymes are biological ____________________ produced by ___________________________ cells. Enzymes reduce the amount of ____________________ energy required for reactions to occur. They consist of globular ____________________ with _______________________ structure.

Answer the following questions:

a) What is the main role of enzymes?

b) What would happen if there are no enzymes in the cell? State any four properties of enzymes.

SKILLS LAB 8

Student-teachers will use the knowledge they acquired in this unit 10 by testing the components of the food and beverages in their food producing businesses. Here they will need the knowledge of food test techniques.

End unit assessment 10

1. Biological molecules are divided into:

a) Organic molecules and inorganic molecules

b) Carbohydrates and starch

c) Lipids, carbohydrates and water

d) Carbohydrates, food and potatoes

2. Write the formula of a monosaccharide with 3 atoms of carbon
3. Compare the structure of fat(triglycerides)and the phospholipids
4. Give two examples of how carbohydrates are used in the body.
5. The formula for a hexose is $C_6H_{12}O_6$ or $(CH_2O)6$. What would be the formula of?

   a) Triose

   b) Pentose

   c) Distinguish between:

   d) Alpha glucose and beta glucose

   e) Glycogen and cellulose

   f) Amylopectin and amylose

7. The drug can cleave the covalent bond between two sulfur atoms of non-adjacent amino acids. Which level of protein can be affected the most if the drug is mixed with primary, secondary, tertiary and quaternary structure of proteins.
8. State the property of water that allows each of the following to take place. In each case, explain its importance:

a) The cooling of skin during sweating

b) The transport of glucose and ions in a mammal

c) Much smaller temperature fluctuations in lakes and oceans than in terrestrial (land-based) habitats.

9. Construct the table that organize the following terms and label the columns and rows.

Phosphodiester linkages	Monosaccharide	polypeptides
Peptide bonds	Nucleotides	Triacylglycerol
Glycosidic linkages	Amino acids	Polynucleotides
Ester linkages	fatty acids	Polysaccharides

10. Explain what happen during protein denaturation?

11. Enzymes are biocatalysts.

a) What is the meaning of the following terms elated to enzyme activity?

ii. Catalyst

iii. Activation energy

iv. Lock and key

v. Q10

b) Why are there hundreds of different enzymes in a cell?

c) How do enzymes reduce the activation energy of a reaction?

12. Enzyme activity is related to a number of factors.

a) Explain why enzymes work faster at high temperatures

b) Describe what happens to the enzyme structure if the temperature is raised well above the optimum temperature.

c) How are enzymes affected by pH?

d) Why do different enzymes have a different optimum pH?

e) What is the difference between a reversible and irreversible enzyme inhibitor?

13. Some bacteria and algae can survive in the boiling waters of hot springs. Enzymes from these organisms are used in industrial processes. Why are these enzymes useful?

14. The following set data show the effect of temperature on the completion time of an enzyme reaction.

Temperature / ^0C	0.0	15	25	35	45	55	65
Rate of reaction / min-1	0.00	0.07	0.12	0.25	0.50	0.28	0.00

a) Plot the data on a graph

b) What is the optimum temperature of this reaction?

c) Describe the shape of the graph between 10 and 40^{0}C

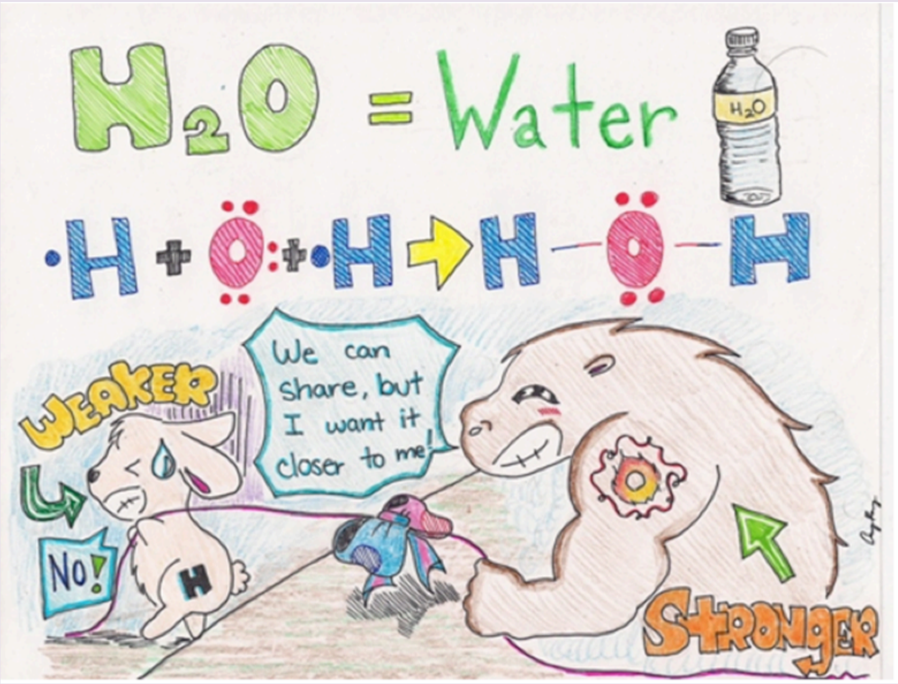
d) Calculate the rate of increase between 20 and 30^{0}C.

UNIT 11: COVALENT BONDS

Key unit competence

Demonstrate how the nature of the bonding is related to the properties of covalent compounds

Introductory Activity 11



As you can see from the picture above, Oxygen is the big buff creature with the tattoo of “O” on its arm. The little bunny represents a Hydrogen atom. The blue and red bow tied in the middle of the rope, pulled by the two creatures represent the shared pair of electrons, a single bond.

Because the Hydrogen atom is weaker, the shared pair of electrons will be pulled closer to the Oxygen atom.

1. Suggest the property used in Chemistry to describe the strength dedicated to oxygen, the stronger?
2. Suppose that the rope being pulled represents a single covalent bond, the electron contributed by hydrogen, the weaker will be transferred to oxygen the stronger?
3. If not, why?
4. Suppose again that we have two oxygens. They have the same strengths. What will happen to the pulled rope, or the shared pair of electrons?
5. Suggest a reason why, from the figure, one oxygen needed sharing with two hydrogens to form water.
6. Conclude about the possible types of covalent bonds.

11.1. Overlap of atomic orbitals to form covalent bonds

Activity 11.1

1. Modern research has shown that an electron moves around the nucleus in the three dimensional space. What are these dimensional spaces called?
2. What types of atomic orbital overlapping, what does this overlapping lead to?
3. Using dots or crosses, give the structure of N(z=7) and Br(z=13) showing only the electrons on the outermost shell.

Atoms have different ways of combination to achieve the stable octet electronic structure; two of those ways of combination led to the formation of ionic bond and metallic bond. But what happens where the two combining atoms need electrons to complete the octet structure and no one is willing to donate electrons? For example the combination of 2 hydrogen atoms or the combination of 2 chlorine atoms?

When this happens, the combining atoms share a pair of electrons where each atom brings or contributes one electron. In other words there is an **overlapping of two orbitals**, one orbital from one atom, each orbital containing one electron (see Fig.11.1): this bond is called "**Covalent bond".** The attraction between the bonding pair of electrons and the two nuclei holds the two atoms together. This theory of covalent bond is based on the concept that electrons are located around the atomic nucleus in orbitals. Then when two atoms approach each other to share electrons, their two orbitals, each containing one electron, overlap in the region between the two nuclei to form a pair of electrons. That pair of electrons is attracted by each nucleus and this force of attraction maintains the two atoms together; it is this force that is called chemical bond and in this case, it is qualified as "**covalent**".

Examples:

1. Formation of H_2 molecule by overlapping of two 1s orbitals of 2 hydrogen atoms*:*

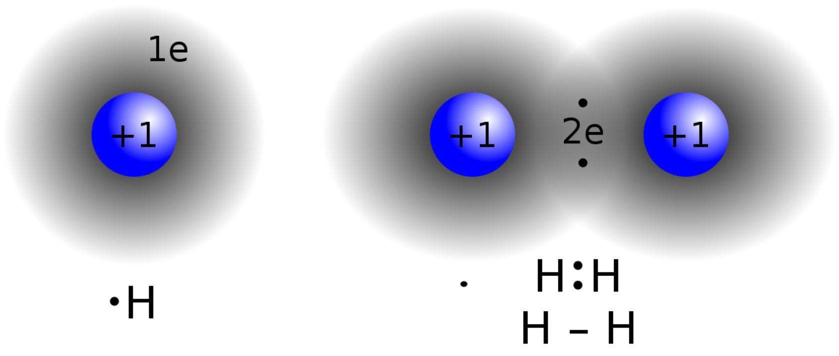


Figure 11.1: Formation of H_2 by s orbitals overlapping

(https://en.wikipedia.org/wiki/Covalent_bond)

2. (2) Formation of F_2 by overlapping of two p orbitals of 2 fluorine atoms:

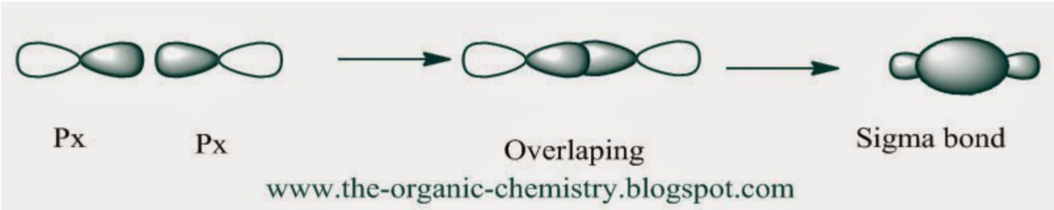


Figure 11.2: Formation of F_2 by overlapping of px orbitals

The two examples above have in common that the concentration of the bonding electrons are on the inter-atomic (inter-nuclei) axis; such bonds are called "**sigma bond**", represented by the symbol "σ".

As you can observe, p orbitals overlap head-to-head or axially, they form a σ bond.

1. Formation of O_2 molecule (O=O)

When O_2 forms, two orbitals in the same orientation, e.g. $p_{x,}$ overlap head-to-head to form a σ bond. The other orbitals, e.g. p_y, will overlap side-by-side or laterally:

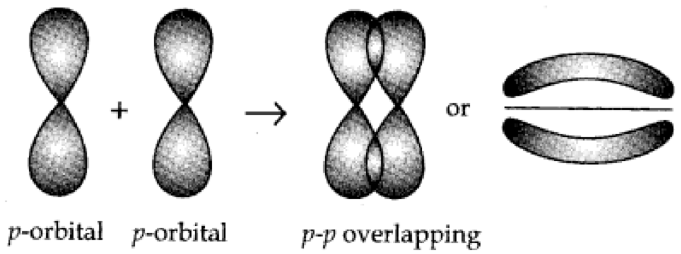


Figure 11.3: Side-by-side overlapping of p orbitals

As you notice, the density of bonding electrons is not on the inter-nuclei axis, it is rather located outside the axis but surrounding it. This kind of covalent bond is called " **Pi bond**", represented by the symbol "π". Hence the double bond O=O is made of two covelent bonds: a σ bond and a π bond.

Due to the position of their electrons density in relation with the two nuclei, σ bond participates in maintaining the two nuclei together more strongly than the π bond; that is why σ bond is stronger than π bond. In addition, π bond cannot exist alone, it exists only where there is a double or triple bond. Hence, in a double or triple bond, there is one σ bond and one or two π bonds respectively.

Application activity 11.1

1. Explain the formation of sigma(σ) and pi(π) bonds in:

a) N_2

b) Br_2

c) NH_3

2. Compare the stability of ethane CH_3- CH_3 and ethene CH_2=CH_2. Explain your answer.
3. How many sigma and pi bonds are found in the following molecules: CH_2=CH-CH=CH_2 and O_2?
4. Complete the table that follow by the missing data

Property	Covalent molecules	Ionic compounds
Formation		
Polarity		
Shape		
What is it?		
Melting point		
Occurs between		
Boiling point		
State at room temperature		
Examples		

11.2. Lewis structures using octet rule (dot and cross structures)

Activity 11.2

Using available resources, attempt the following:

1. Draw the diagrams indicating only the valence electrons of the following:

   Chlorine molecule (Cl), Carbon atom (C), Phosphorus atom (P), Nitrogen (N).

2. Draw the diagram to show how all electrons are shared in a molecule of
   i. NH_3 indicating all unshared electrons.
   ii. HCl (iii) N_2

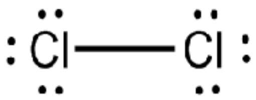
3. Identify the common feature possessed by the diagrams drawn above in 2.

Lewis structures *(also known as* **Dot and cross structures**, **Lewis dot diagrams**, **Lewis dot formulas**, **Lewis dot structures**, and **electron-dot structures**) are diagrams that show the bonding *between* atoms *of a* molecule *and the* lone pairs *of* electrons *that may exist in the molecule. A Lewis structure can be drawn for* **any covalently** *bonded molecule*, as well as **coordination compounds**.

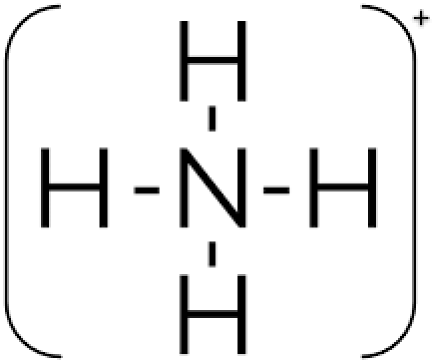
Lewis structures extend the concept of the electron dot diagram by adding lines between atoms to represent shared pairs *in a chemical bond.*

Lewis structures show each atom and its position in the structure of the molecule using its chemical symbol. Lines are drawn between atoms that are bonded to one another (**pairs of dots** can be used instead of lines). Excess electrons that form lone pairs are represented as pairs of dots, and are placed next to the atoms.

Examples: Lewis structure of Cl_2



Lewis structure of NH_4^+



How to draw Lewis Structures

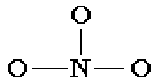
Let us use the **nitrate ion (NO_3^-)** as a typical example. An outline of how to determine the "best" Lewis structure for NO_3^- is given below:

1. Determine the***total number of valence electrons*** in a molecule.

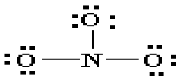
N	5
3 O	18
-ve	1
	24

2. Draw a ***skeleton for the molecule which connects all atoms using only single bonds***. In simple molecules, the atom *with the most available sites for bonding* is usually placed central. The number of bonding sites is determined by considering the number of valence electrons and the ability of an atom to expand its octet. As

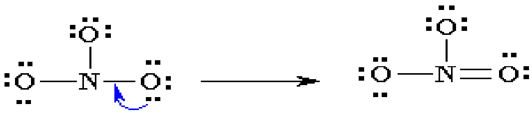
you become better, you will be able to recognize that certain groups of atoms prefer to bond together in a certain way!



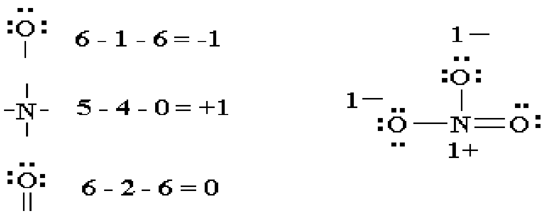
3. Of the 24 valence electrons in NO_3^-, 6 were required to make the skeleton. Consider the remaining 18 electrons and ***place them so as to fill the octets of as many atoms as possible*** (***start with the most electronegative atoms first then proceed to the more electropositive atoms)***.



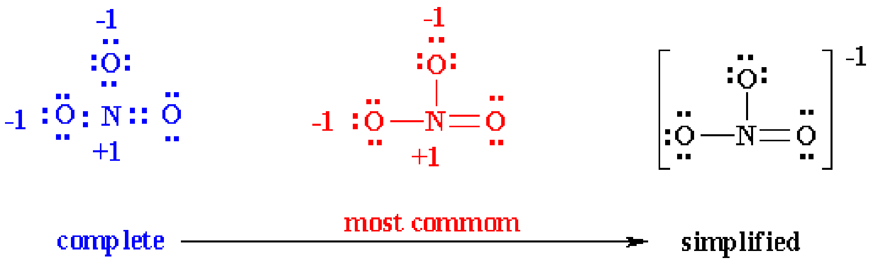
4. Are the ***octets of all the atoms filled***? If not then fill the remaining octets by making multiple bonds (***make a lone pair of electrons, located on a more electronegative atom, into a bonding pair of electrons that is shared with the atom that is electron deficient***).



5. Check that you have the ***lowest formal charges (F.C.)*** possible for all the atoms, without violating the octet rule; F.C. = (valence e^-) - (1/2 bonding e^-) - (lone electrons).



6. Thus the Lewis structure of NO_3^- ion can be written in the following ways:



Lewis structures of unusual compounds that do not obey Octet Rule

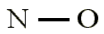
There are ***three general ways*** in which the octet rule breaks down:

- Molecules ***with an odd number of electrons***
- Molecules ***in which an atom has less than an octet***
- Molecules ***in which an atom has more than an octet***

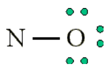
1. Odd number of electrons

Consider the example of the Lewis structure for the molecule nitrous oxide **(NO)**:

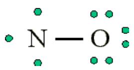
- Total electrons: 6 + 5 = 11
- Bonding structure:



- Octet on "outer" element:



- Remainder of electrons (11-8 = 3) on "central" atom:

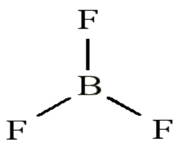


There are currently 5 valence electrons around the nitrogen. A double bond would place 7 around the nitrogen, and a triple bond would place 9 around the nitrogen. ***We appear unable to get an octet around each atom.***

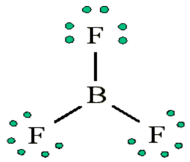
2. Less than an octet *(most often encountered with elements of Boron and Beryllium*)

Consider the example of the Lewis structure for boron trifluoride (BF_3):

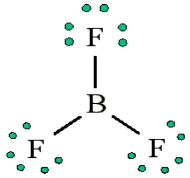
- Add electrons (3 x 7) + 3 = 24
- Draw connectivities



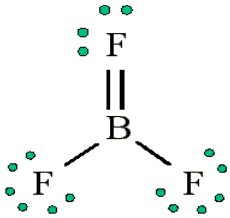
- Add octets to outer atoms:



- Add extra electrons (24 – 24 = 0) to central atom:



- Does central electron have octet? No, it has 6 electrons. Add a multiple bond (double bond) to see if central atom can achieve an octet:

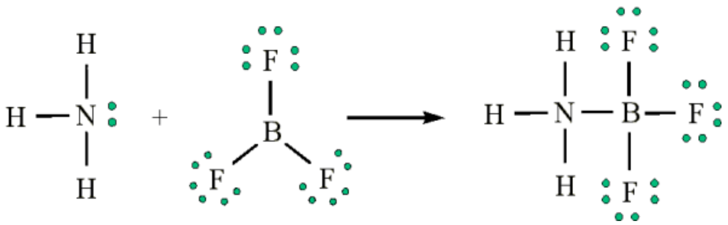


The central Boron now has an octet (there would be three resonance Lewis structures).

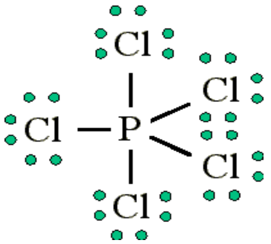
However, in this structure with a double bond the fluorine atom is sharing extra electrons with the boron.

The fluorine would have a '**+**' partial charge, and the boron a '-' partial charge, this is inconsistent with the electronegativities of fluorine and boron. Thus, ***the structure of BF_3, with single bonds, and 6 valence electrons around the central boron is the most likely structure.***

BF_3 reacts strongly with compounds which have an unshared (lone) pair of electrons which can be used to form a bond with the boron. Example: Reaction of BF_3 with ammonia.



3. More than an octet *(most common example of exceptions to the Octet Rule)* PCl_5 is a legitimate compound, whereas NCl_5 is not.

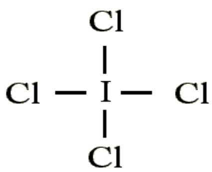


Expanded valence shells are observed only for elements in period 3 (i.e. n=3) and beyond.

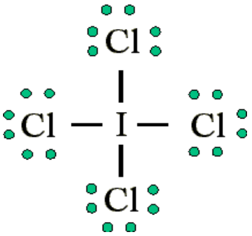
Size is also an important consideration: ***"The larger the central atom, the larger the number of electrons which can surround it"***. Expanded valence shells occur most often when the central atom is bonded to small electronegative atoms, such as **F**, **Cl** and **O**.

Example: Draw the Lewis structure for ICl_4^-

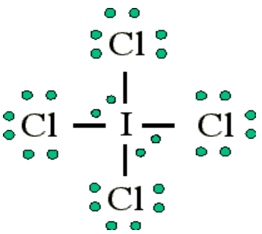
- Count up the valence electrons: 7 + (4 x 7) + 1 = 36 electrons
- Draw the connectivities:



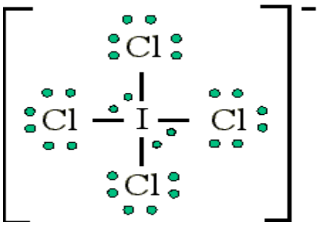
- Add octet of electrons to outer atoms:



- Add extra electrons (36-32=4) to central atom:



The ICl_4^- ion thus has 12 valence electrons around the central Iodine (in the 5*d* orbitals)



Other examples include: PCl_5 and SF_6

Application activity 11.2

1. Make a clear definition of the covalent bond.
2. For each of the following, write the electron –dot structures (Lewis structures) and choose one which violates the Octet Rule?

a) PCl_3

b) H_2S

c) CH_3Cl

d) C_2H_2

e) AsF_5

f) SO_4^{2-}

g) SF_6

h) HCl

11.3. Coordinate or dative covalent bond

Activity 11.3

Use your knowledge acquired from the previous lesson and draw the Lewis structure of ozone (O_3), NH_4^+, H_3O^+. One of the bonds in these molecules are special. Explain how they are formed.

A ***dative covalent bond***, or ***coordinate bond*** is a type of covalent bonding (i.e., electron sharing) where the shared electron pair(s) are completely provided by one of the participants in the union, and not by contributions from the two of them.

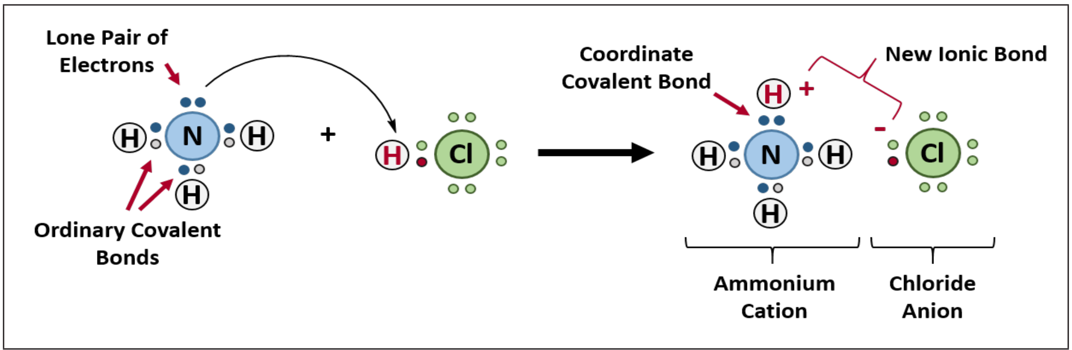
The contributors of these shared electrons are either ***neutral molecules*** which contain lone pair(s) of electrons on one of their atoms, or ***negatively charged groups*** (radicals) with free electrons to donate. Examples of these are: H_2O, NH_3 and CN^-.

Examples of coordinate bonding: In the reaction
between ammonia and hydrogen chloride a coordinate bond takes place forming solid ammonium chloride.

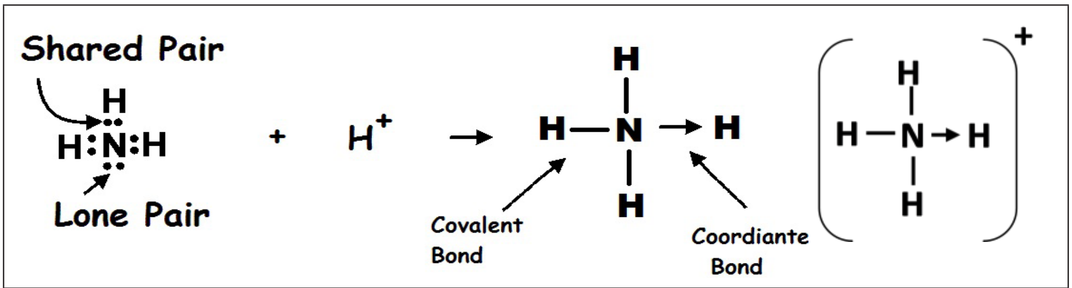
$NH_3 + HCl \rightarrow NH_4Cl$

In this reaction the hydrogen ion from the hydrogen chloride leaves its electrons and gets transferred to the lone pair of electrons on the ammonia molecule forming ammonium ions (NH_4^+). This is known as *a* ***coordinate bonding***.

Seeing that the hydrogen has left its electron, the chloride will therefore have a negative charge while the ammonium will have a positive charge. The diagram below shows the reaction:



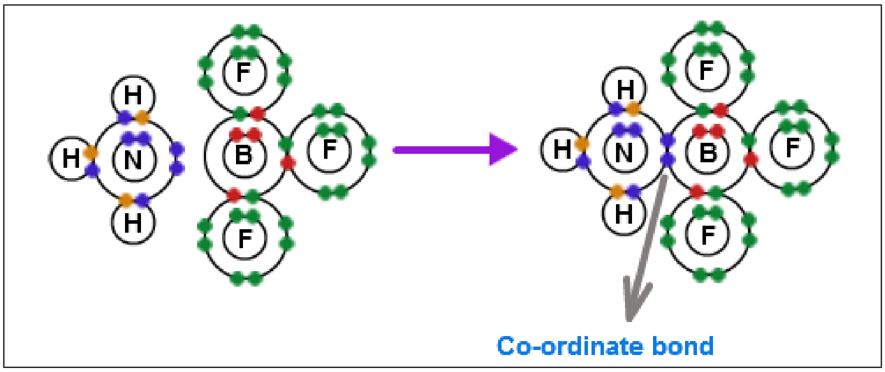
Note*:* The complete compound eventually formed comprises three types of bonding, i.e., ***covalent***, ***co-ordinate*** and ***electrovalent***. In NH_4Cl: Formation of NH_3 (covalency); formation of NH_4^+ (co-ordinate or dative bonding); and formation of NH_4Cl (electrovalency).



Dative covalent bonds are represented on drawings as an **"arrow"**, which usually points from the atom donating the lone pair to the atom accepting it.

Another example would be the ***reaction between ammonia and boron trifluoride***. Boron trifluoride is said to be ***electron deficient*** meaning it has 3 pairs of electrons at its bonding level but it is capable of having four pairs. In this reaction **the *ammonia is used to supply this extra lone pair*.**

A coordinate bond is formed where the lone pair from the nitrogen moves toward the boron. The end containing the nitrogen will therefore become more positive while the boron end will become more negative because it has received electrons.



Application activity 11.3

1. Give the difference and the similarity between a dative covalent bond and the normal covalent bond.
2. An aluminium chloride molecule reacts with a chloride ion to form the $AlCl_4^-$ ion.

a) Name the type of bond formed in this reaction.

b) Explain how this type of bond is formed in the $AlCl_4^-$ ion.

3. Co-ordinate bonding can be described as dative covalency.

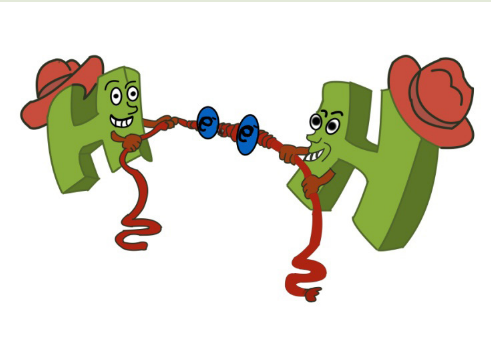
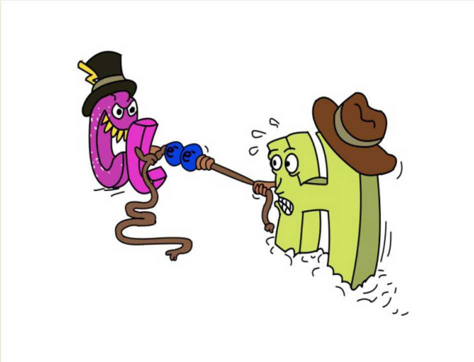
a) In this context, what is the meaning of each of the terms *covalency* and *dative?*

b) Write an equation for a reaction in which a co-ordinate bond is formed.

11.4. Polarity of the covalent bond

Activity 11.4

The following figures show two types of covalent bond, namely, polar and non-polar.

***Figure* A**	***Figure* B**
	

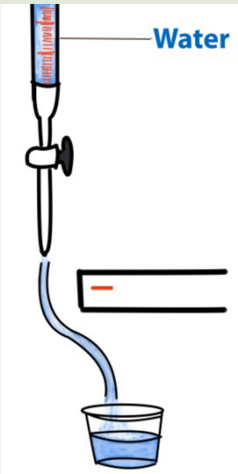
1. Covalent bond is formed between two atoms with similar or close ability to attract electrons towards themselves, and this is the reason why they share electrons without being transferred.

a) What is the name of the property used to compare that ability?

b) When the strengths of both atoms are equal, the covalent bond will be non-polar. Is figure **A** polar of non-polar?

c) Look at the figure **B**. The atom, in the zone with more electrons, will have a partial negative charge. In which zone will be more electrons?

2. Fill a burette with water. Open the tap and bring a charged ebonite rod close to the stream of water running from the jet. The water is deflected from its vertical path towards the charged rod as shown in the figure. Why is this?



A quantity termed ***'electronegativity'*** is used to determine the polarity of the covalent bond; whether a given bond will be ***non-polar covalent***, ***polar covalent***, or ***ionic***.

Electronegativity is defined ***as the ability of an atom in a particular molecule to attract electrons to itself (the greater the value, the greater the attractiveness for electrons).***

Fluorine is the *most* electronegative element (electronegativity = 4.0), the *least* electronegative is Caesium (electronegativity = 0.7).

The bond pair is equally shared in between two atoms when the electronegativity difference between them is zero or nearer to zero. In this case, neither of the atoms gets excess of electron density and hence carry no charge. This is called **non-polar covalent bond**.

However, when there is a considerable difference in the electronegativity, the bond pair is no longer shared equally between the atoms. It is shifted slightly towards the atom with higher electronegativity by creating partial negative charge (represented by δ^-) over it, whereas, the atom with less electronegativity gets partial positive charge (represented by δ^+). This type of bond is also referred to as **polar covalent bond.**

We can use the ***difference in electronegativity between two atoms*** to gauge the polarity of the bonding between them.

- In F_2 the electrons are ***shared equally*** between the atoms, the bond is ***non-polar covalent.***
- In HF the fluorine atom has greater electronegativity than the hydrogen atom. The ***sharing of electrons in HF is unequal***: the fluorine atom attracts electron density away from the hydrogen (the bond is thus a

polar covalent bond). The H-F bond can thus be represented as:

$$\overset{\delta+}{\mathrm{H}} - \overset{\delta-}{\mathrm{F}} \quad \text{or} \quad \overset{\longmapsto}{\mathrm{H - F}}$$

The 'δ^{+}' and 'δ^{-}' symbols indicate ***partial*** positive and ***negative charge*** respectively.

The arrow indicates the "pull" of electrons off the hydrogen and towards the ***more electronegative*** atom, fluorine.

- In **LiF** the *much greater relative* electronegativity of the fluorine atom completely strips the electron from the lithium and the result is an *ionic bond* (no sharing of the electron).

Note: ***The following is the general thumb rule for predicting the type of bond based upon electronegativity differences:***

– If the electronegativities are equal (i.e. if the electronegativity difference is 0), the bond is ***non-polar covalent.***

– If the difference in electronegativities between the two atoms is greater than 0, but less than 2.0, the bond is ***polar covalent.***

– If the difference in electronegativities between the two atoms is 2.0, or greater, the bond is ***ionic.***

Using the examples used above, we can predict the type of bond as follows:

Substance	**F_2**	**HF**	**LiF**
Electronegativity Difference	4.0 - 4.0 = 0	4.0 - 2.1 = 1.9	4.0 - 1.0 = 3.0
According to the Rule: **Type of Bond**	ΔE=0 Non-polar covalent	0<ΔE<2.0 Polar covalent	ΔE2.0 Ionic (non-covalent)

Note: A non-polar molecule ***is one in which the electrons are distributed more symmetrically and thus does not have an abundance of charges at the opposite sides***. The ***charges all cancel out each other***. Examples of non-polar molecules include diatomic molecules, CH_4, CO_2, C_2H_4, cyclohexene, CCl_4, etc.

Application activity 11.4

1. a)Predict whether the following bonds in compounds are polar, non polar or ionic.

   i. $BeCl_2$ (ii) BF_3 (iii) CH_4 (iv) PCl_3 (v) H_2S (vi) $SnCl_2$

   ii. CO_2 (viii) SO_2 (ix) SO_3 (x) SF_6 (xi) PCl_5 (xii) Cl_2

   c) Explain how the nature of the bonds (polar, non polar or ionic) affect the physical properties of the different compounds Explain. Use specific examples.

   d) Hydrogen chloride and ammonia are very soluble in water but methane is not. Explain.

2. Draw Lewis structure of PCl_5, $BeCl_2$ and BF_3 and show polarity of each bond

11.5. Physical properties of covalent compounds: simple molecular structure

Activity 11.5

1. Carbon dioxide (CO_2), Bromine (Br_2) and SiO_2 molecules are all covalent substances.

   a) Give the physical states of these substances at room temperature.

   b) Arrange the molecules above in decreasing order of melting and boiling points knowing their physical states at room temperature.

   c) Suggest any reason for the differences in the melting points.

2. Do research and be able to explain physical properties of simple molecular compounds

Substances composed of relatively small covalently bonded structures are called ***Simple Molecular Structures***. These contain only a few atoms held together by strong covalent bonds and can be further categorised into two types: ***Individual*** (which are usually gases like carbon dioxide) and ***molecular*** (which are usually solids like iodine).

The Physical Properties

4. **Low melting and boiling points**

   Simple Molecular Structures tend to have low melting and boiling points since the forces between molecules are quite weak. Little energy is required to separate the molecules.

5. **Poor electrical conductivity**

There are no charged particles (ions or electrons) delocalized throughout the molecular crystal lattice to conduct electricity. They cannot conduct electricity in either the solid or molten state.

6. **Solubility**

Polar compounds are soluble in water (polar) while non-polar compounds are soluble in nonpolar solvents (oil, hexane…). This means that substances with the same type of polarity will be soluble in one another. Moreover, compounds with differing polarities will be insoluble in one another`

Example:

Hydrogen chloride HCl, Ethanol CH_2CH_2OH are soluble in water because there are all polar but they are not soluble in organic solvents which are nonpolar like hexane and heptane.

Application activity 11.5

1. Explain why:

a) Simple molecules have low melting points;

b) Simple molecules have poor conductivity of electricity;

2. Which compounds are soluble or insoluble in water?

SKILLS LAB 11

1. Using adequate materials construct any three models of molecules of your choice. These models show shells and all electrons. Electrons which form covalent bonds are highlighted. Molecules to be made: HCl, CO_2, H_2, CH_4, C_2H_2, NH_3, BF_3.
2. Plants contain many chemicals. To extract them from plants for further studies many solvents such as water, acetone, and hexane are used. Based on the physical properties especially solubilty do research and find solvents that should be used to extract some substances which are found in different plants of your environment. Solvents to be used are: water, hexane and cetone.

End unit assessment 11

1. Complete the table below by yes or no

Substance	Soluble in water	Insoluble in water
Nitrogen N_2		
Formic acid HCOOH		
Methane CH_4		
Octane C_8H_{18}		
Acetone $CH_3CO\ CH_3$		

2. Choose the best answer. The correct dot formulation for ***nitrogen trichloride*** has:

a) 3 N-Cl bonds and 10 lone pairs of electrons.

b) 3 N=Cl bonds and 6 lone pairs of electrons.

c) 1 N-Cl bond, 2 N=Cl bonds and 7 lone pairs of electrons.

d) 2 N-Cl bonds, 1 N=Cl bond and 8 lone pairs of electrons.

e) 3 N-Cl bonds and 9 lone pairs of electrons.

3. Explain why the boiling point of water is much bigger than that of methane while their masses are not very different.

4.Choose the correct answer. A (pi) bond is the result of the

a) Overlap of two s orbitals.

b) Overlap of an s and a p orbital.

c) Overlap of two p orbitals along their axes.

d) Sidewise overlap of two s orbitals.

5. Show different poles δ- and δ+ in the following molecules between O, N, Cl and other atoms bonded to them.

a) H_3C-Cl b) H_3C-O-H c) C_2H_5-NH_2

6. Write the structural formula of propane and propene and compare their reactivity on the type of bonds in their respective molecules .

7. The equation below shows the reaction between boron trifluoride and a fluoride ion. $BF_3 + F^- \rightarrow BF_4^-$

In terms of the electrons involved, explain how the bond between the BF_3 molecule and the F^- ion is formed. Name the type of bond formed in this reaction.

8. The table below shows the electronegativity values of some elements.

	Fluorine	Chlorine	Bromine	Iodine	Carbon	Hydrogen
Electronegativity	4.0	3.0	2.8	2.5	2.5	2.1

a) Define the term *electronegativity*.

b) Write the formula of hydrogen chloride, hydrogen iodide, hydrogen fluoride and hydrogen bromide and range them from the most polar to the least one

9.Draw Lewis structures showing electrons in the outermost shell of each atom in the following compounds: a) H_2O_2, b) HCN, c) C_2H_2, d)SF_6, e) Al_2S_3

Atomic numbers: H(z=1), O (z= 8), C (z=6), N(z= 7), S (z=16), F (z= 9), Al (z= 13)

10. How many sigma and pi electrons are contained in the following molecule?

$H_2C = CH- CH_3$

UNIT 12: IONIC AND METALLIC BONDS

Key unit competence

Describe how properties of ionic compounds and metals are related to the nature of their bonding.

Introductory Activity

Consider the following figure **12.1** below.

Figure12.1

The figure shows materials commonly used at home. If you reflect back around your house/home you will see hundreds of objects made from different kinds of materials.

a) Observe the objects (in picture) and classify them according to the materials they are made of.

b) Have you ever wondered why the manufacturers choose the material they did for each item?

c) Why are frying saucepans made of metals and dishes, cups and plates often made of glass and ceramic?

d) Could dishes be made of metal? And saucepans made of ceramic and glass?

Of the total number of individual chemically pure substances known, several million are compounds, formed when two or more elements are chemically bonded together and less than 100 are elements. Only six of these elements consist of free, unbounded atoms at room temperature. These are the noble gases. All other elements exist as individual or giant molecules, or metallic lattices, in which atoms are chemically bonded to each other.

12.1. Explanations of why atoms of elements form bonds

Activity 12.1

Consider Chlorine (Cl, Z = 17) and Argon (Ar, 18) atoms of the elements of Period 3 in the Periodic Table.

a) Which of these atoms is more reactive?

b) Suggest the reasons for your answer in (**a)** in terms of the electronegativity and electronic structure.

c) Choose, between Chlorine and Argon, which one has lower energy potential.

The atoms of most elements form chemical bonds because the atoms become more stable when bonded together. Electric forces attract neighbouring atoms to each other, making them stick together.

In atoms, electrons are arranged into complex layers called shells. For most atoms, the outermost shell is incomplete, and the atom shares electrons with other atoms to fill the shell.

The type of chemical bond maximizes the stability of the atoms that form it.

An ionic bond, where one atom essentially donates an electron to another, forms when one atom becomes stable by losing its outer electrons and the other atoms become stable (usually by filling its valence shell) by gaining the electrons. Covalent bonds form when sharing atoms results in the highest stability.

Other types of bonds https://www.thoughtco.com/types-of-chemical-bonds-603984besides ionic and covalent chemical bonds exist, too.

Atoms with incomplete shells are said to have high potential energy; atoms whose outer shells are full have low potential energy. In nature, objects with high potential energy "seek" a lower energy, becoming more stable as a result. Atoms form chemical bonds to achieve lower potential energy.

Application activity 12.1

Explain why atoms of elements form bonds in terms of stability and potential energy.

12.2. Gain of stability by losing and gaining electrons

Activity 12.2

The figure below shows how the atoms may gain stability by losing and gaining electrons.

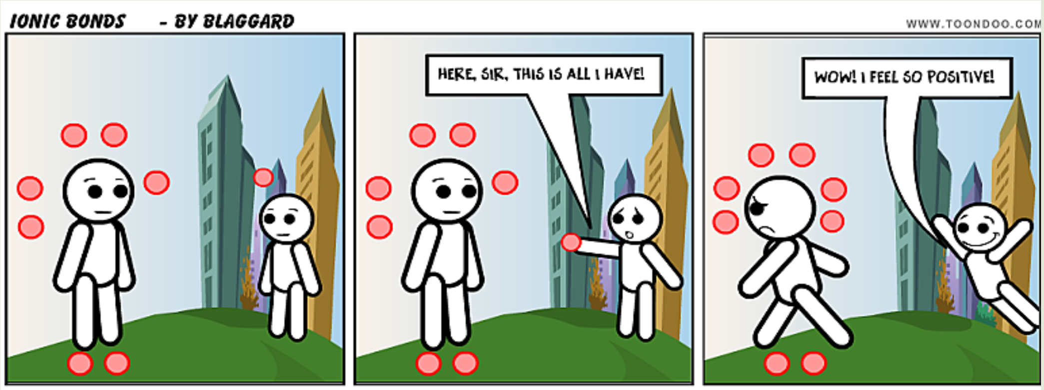


Figure 12.3.: Gaining stability in atom by losing and gaining electrons

1. Analyse the figure and explain how the two atoms were unstable and how they became stable.
2. Use the terms "Little" and "Big" for the atoms shown in the figure and answer the following questions.

a) Is atom "Little" metal or non-metal? Explain.

b) Suggest, with reasons, the group to which those atoms belong.

c) Finally, atom "Little" is feeling good and so positive! Why?

d) State and describe clearly the group on the periodic table that contains elements that have the same atomic structures as the species obtained when atom "Big" has received the electron from atom "Little".

Like people always relate and connect to others depending on their values, interests and goals so do **unstable atoms**. They combine together to achieve **stability**. We know that ***noble gases are the most stable elements in the periodic table***. They have a filled outer electron energy level.

When an atom ***loses, gains***, or ***shares*** electrons through bonding to achieve a filled outer electron energy level, the **resulting compound is often more stable than individual separate atoms.**

- Neutral sodium has one valence electron. When it loses this electron to chlorine, the resulting Na^+ cation has an outermost electron energy level that contains eight electrons. It is isoelectronic (same electronic configuration) with the noble gas neon.
- On the other hand, chlorine has an outer electron energy level that contains seven electrons. When chlorine gains sodium's electron, it becomes an anion that is isoelectronic with the noble gas argon.

It is easiest to apply the "**Octet Rule**" to predict whether two atoms will form bonds and how many bonds they will form. Most ***atoms need 8 electrons to complete their outer shell***. So, an atom that has 2 outer electrons will often form a chemical bond with an atom that lacks two electrons to be "complete". The octet rule states that elements gain or lose electrons to attain an electron configuration of the nearest noble gas. Octet comes from Latin language meaning "eight".

Note that the ***"Duet Rule"*** is also applied. The noble gas *HELIUM* has two electrons (a doublet) in its outer shell, which is very stable. Hydrogen only needs one additional electron to attain this stable configuration, while lithium needs to lose one.

Low atomic weight elements (the first twenty elements) are most likely to adhere to the Octet Rule. For example,

- A **sodium** atom has ***one lone electron*** in its outer shell.
- A **chlorine** atom, in contrast, is ***short one electron*** to fill its outer shell.
- Sodium ***readily donates (loses) its outer electron*** (forming the Na^+ ion, since it then has one more proton than it has electrons), while chlorine ***readily accepts (gains) a donated electrons*** (making the

Cl^- ion, since chlorine is stable when it has one more electron than it has protons).

- Sodium and chlorine ***form an ionic bond with each other***, to form table salt or sodium chloride.

Application activity 12.2

1) State the following Rule?
   a. Octet Rule
   b. Duet Rule

2) Answer to the following questions
   a. Does sodium need to gain electron than chlorine? (Yes or No)
   b. Explain the target of sodium when it is seeking to lose electron and chlorine to gain electron.

3) Which of the following is stable? Explain why?

   i. Na^+ iii. Cl

   ii. Na iv. Cl^-

12.3. Ionic bonding

Activity 12.3

In the Ordinary Level, you learnt that there exist three main types of chemical bonding namely, covalent, ionic and metallic.

a) Recall the definition of the ionic bond.

b) The bond formed between sodium and chlorine atoms to form the table salt is an ionic bond. Using experiments performed in daily life and performing the non-performed ones, state the properties of a table salt and use it to generalize the properties of ionic compounds basing on the criteria given in parentheses (Appearance/physical state, Solubility in water and in organic solvent, Temperature required to melt, Electrical conductivity of solid and aqueous solution).

An ionic bond is a chemical bond formed between two ions with opposite charges. Ionic bonds form when one atom gives up one or more electrons to another atom. These bonds can form between a pair of atoms or between molecules and are the type of bond found in salts.

12.3.1. Ionic bond formation

Once the oppositely charged ions formed when electrons are transferred from one atom to another, they ***are attracted by their positive and negative charges*** (by electrostatic forces) and form an ionic compound. Ionic bonds are also formed when there is a large electronegativity difference between two atoms. This difference causes an unequal sharing of electrons such that ***one atom completely loses one or more electrons and the other atom gains one or more electrons.*** For example, in the creation of an ionic bond between a metal atom, sodium (electronegativity = 0.93) and a non-metal, fluorine (electronegativity = 3.98).

Let us take a look of how sodium and fluorine bond to form sodium fluoride:

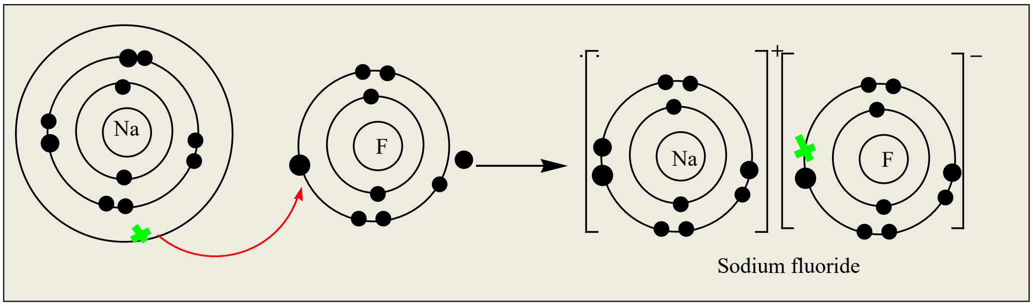


Figure 12.4.: Formation of NaF

The *curved arrow* between sodium and fluorine atoms represents the transfer of an electron from a sodium atom to a fluorine atom to form oppositely charged ions. These two ions ***are strongly attracted to each other because of their opposite charges***. A bond is now formed and the resulting compound is called **Sodium fluoride.**

Another example of ionic bonding formation is the ***formation of magnesium oxide***.

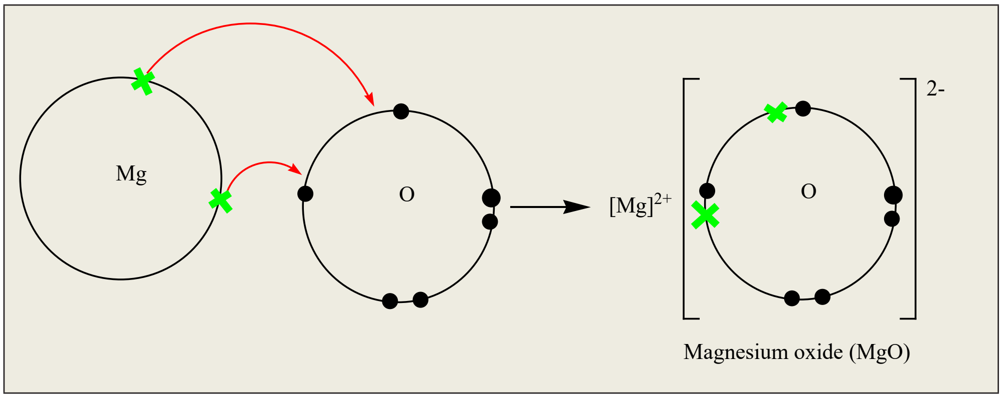


Figure 12.5: Formation of MgO

12.3.2. Properties of ionic compounds

Here are the properties shared by the **ionic compounds**. Notice that the properties of ionic compounds relate to ***how strongly the positive and negative ions attract each other*** in an ionic bond.

1. **They have high melting points and high boiling points**

In an ionic lattice, there are ***many strong electrostatic attractions between oppositely charged ions.*** We therefore expect that ionic solids will have high melting points. On melting although the regular lattice is broken down, there will still be significant attractions between the ions in the liquid. This should result in high boiling points also.

The factors which affect the melting point of an ionic compound are:

- The ***charge on the ions***: «*The greater the charge, the greater the electrostatic attraction, the stronger the ionic bond, the higher the melting point*». For example, Melting Point of **NaCl** is **801 °C** and that of **MgO** is **2,800 °C**.
- The ***size of the ions***: «*Smaller ions can pack closer together than larger ions so the electrostatic attraction is greater, the ionic bond is stronger, the melting point is higher*». For example, Melting Point of **NaF** is **992 °C** and that of **CsF** is **2,800 °C**.

2. **Most ionic compounds are soluble in water**

This is because *the electrostatic forces of the polar water molecules are stronger than the electrostatic forces keeping the ions together*. When an ionic compound like NaCl is added to water, water molecules attract the positive and negative salt ions. Water molecules surround each ion and move the ions apart from each other. The separated ions dissolve in water. There are several exceptions, however, where the electrostatic forces between the ions in an ionic compound are strong enough that the water molecules cannot separate them. Despite these few limitations, water›s ability to dissolve ionic compounds is one of the major reasons it is so vital to life on Earth. Ionic compounds are generally insoluble in non-polar solvents like kerosene.

3. **They are hard and brittle**

Ionic crystals are hard because ***the positive and negative ions are strongly attracted to each other and difficult to separate,*** however, ionic solids ***are brittle***. When a stress is applied to the ionic lattice, the layers shift slightly. The layers are arranged so that each cation is surrounded by anions in the lattice. If the layers shift then ions of the same charge will be brought closer together. Ions of the same charge will repel each other, so the lattice structure breaks down into smaller pieces.

4. They conduct electricity when molten or dissolved in water

In order for a substance to conduct electricity, it ***must contain mobile particles capable of carrying charge***.

- **Solid** ionic compounds ***do not conduct electricity*** because the ions (charged particles) ***are locked into a rigid lattice or array***. The ions cannot move out of the lattice, so the solid cannot conduct electricity.
- When is **molten**, the ions ***are free to move*** out of the lattice structure.

– Cations (positive ions) *move towards the negative electrode* (cathode): $M^+ + e^- \rightarrow M$

– Anions (negative ions) *move towards the positive electrode* (anode): $X^- \rightarrow X + e^-$

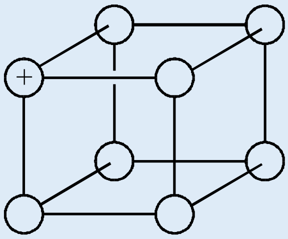
- When is **dissolved in water** to form an aqueous solution, the ions are released from the lattice structure and ***are free to move*** so the solution conducts electricity just like the molten (liquid) ionic compound.

5. They form crystals

Ionic compounds form *crystal lattices* rather than *amorphous solids*. Although molecular compounds form crystals, they frequently take other forms but molecular crystals typically are softer than ionic crystals. At an atomic level, an ***ionic crystal is a regular structure, with the cation and anion alternating with each other and forming a three-dimensional structure based largely on the smaller ion evenly filling in the gaps between the larger ion.***

Application activity 12.3

1. The diagram below represents a part of the structure of sodium chloride. The ionic charge is shown on the centre of only one of the ions.



a) On the diagram, mark the charges on the four negative ions.

b) What change occurs to the motion of the ions in sodium chloride when it is heated from room temperature to a temperature below its melting point?

c) Sodium chloride can be formed by reacting sodium with chlorine. A chloride ion has one more electron than a chlorine atom. In the formation of sodium chloride, from where does this electron come?

2. Draw diagrams to illustrate the formation of ionic compounds in the following substances:

a) Magnesium chloride

b) Sodium peroxide

c) Iron (III) chloride

d) Sodium sulphide

3. Solid sodium chloride and solid magnesium oxide are both held together by ionic (electrovalent) bonds.

a) Using s, p, d and f notation, write down the symbol for and the electronic configuration of **(i)** a sodium ion; **(ii)** a chloride ion; **(iii)** a magnesium ion; **(iv)** an oxide ion.

b) Explain what holds sodium and chloride ions together in the solid crystal

c) Sodium chloride melts at 1074 K; magnesium oxide melts at 3125 K. Both have identical structures. Why is there such a difference in their melting points?

12.4. Metallic bonding

Activity 12.4

1. Give three examples of substances which are malleable, ductile, good conductor of heat and electricity, and having a characteristic luster. Here you can use a dictionary or other searching tools to find the meaning for any unfamiliar word.

2. Suggest another property, apart from those given, of the substances you have given in **1**.

3. Choose from the examples given in **1**, one which is most common and well known.

a) This substance is seen to be composed by atoms of one element. Which one?

b) Use a labelled drawing to show the internal structure of that kind of substance.

A metallic bond ***is a type of chemical bond formed between positively charged atoms in which the free electrons are shared among a lattice of cations.*** In contrast, covalent and ionic bonds form between two discrete (separate) atoms.

Metallic bonding is the main type of chemical bonds that forms between metal atoms (pure metals and alloys and some metalloids). A metal *is* ***a lattice of positive metal "ions" in a "sea" of delocalised electrons*****.**

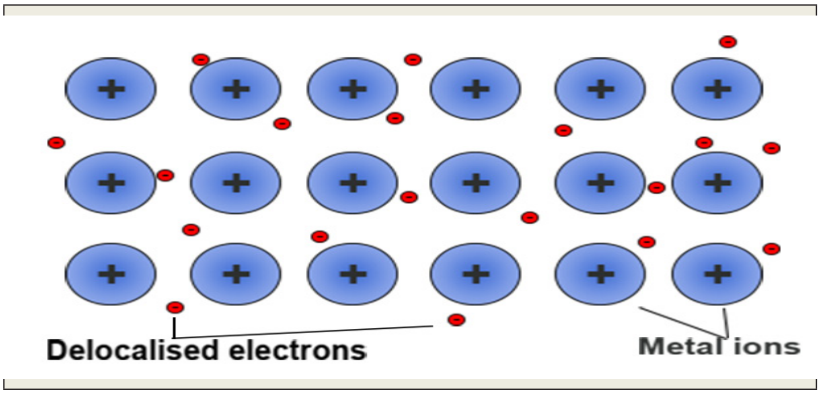


Figure 12.6:Electron Sea Model of Metallic bonding

12.4.1. Formation of metallic bond

The outer energy levels of metal atoms (the ***s*** and ***p*** orbitals) overlap. At least one of the valence electrons participating in a metallic bond is not shared with a neighbour atom, nor is it lost to form an ion. Instead, the electrons form what may be termed an «**electron sea**" in which valence electrons are free to move from one atom to another. Metallic bonding refers ***to the interaction between the delocalised electrons and the metal nuclei.***

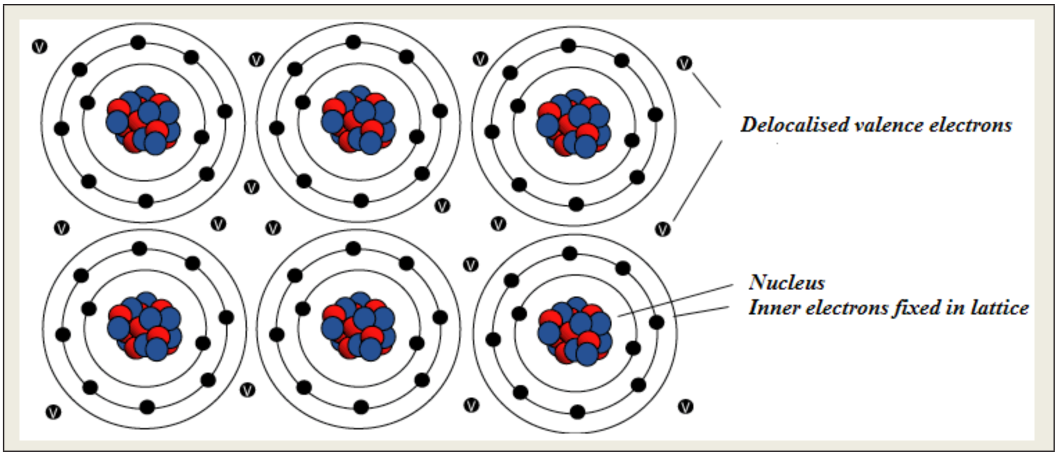


Figure 12.7.: Interaction between the delocalised electrons and the metal nuclei

The ***electron sea model*** is an oversimplification of metallic bonding.

Calculations based on electronic band structure or density functions are more accurate. Metallic bonding may be seen as a consequence of a material having many more delocalized energy states than it has delocalized electrons (electron deficiency), so localized unpaired electrons may become delocalized and mobile. The electrons can change energy states and move throughout a lattice in any direction.

Bonding can also take the form of metallic cluster formation, in which delocalized electrons flow around localized cores. Bond formation depends heavily on conditions. For example, hydrogen is a metal under high pressure! As pressure is reduced, bonding changes from metallic to non-polar covalent.

12.4.2. Physical properties of metals

Because electrons are delocalized around positively charged nuclei, metallic bonding explains many properties of metals. The three main factors that affect the strength of a metallic bond are:

- ***Number of protons/ Strength of nuclear attraction*****:** The more protons the stronger the force of attraction between the positive ions and the delocalized electrons
- ***Number of delocalized electrons per atom*****:** The more delocalized electrons the stronger the force of attraction between the positive ions and the delocalized electrons
- ***Size of atom*****:** The smaller the atom, the stronger the force of attraction between the positive ions and the delocalized electrons and vice-versa, the larger the atom, the weaker the force of attraction between the positive ions and the delocalised electrons.

The main physical properties of metallic metals are given below.

1. Electrical Conductivity

Most metals are ***excellent electrical conductors*** because the ***electrons in the electron sea are free to move and carry charge.*** For example, electric wires in our homes are made of aluminium and copper. They are good conductor of electricity. Electricity flows most easily through gold, silver, copper and aluminium. Gold and silver are used for fine electrical contacts in computers.

2. Thermal Conductivity

Metals conduct heatbecause the ***free electrons are able to transfer energy away from the heat source*** and also because ***vibrations of atoms (phonons) move through a solid metal as a wave***. Cooking utensils and water boilers are also made of iron, copper and aluminium, because they are good conductors of heat.

3. Ductility

Metals ***tend to be ductile or able to be drawn into thin wires*** because ***local bonds between atoms can be easily broken and also reformed.*** Single atoms or entire sheets of them can slide past each other and reform bonds. Wires are mainly made from copper, aluminium, iron and magnesium.

4. Malleability

Metals ***are often malleable or capable of being molded or pounded into a shape***, again because ***bonds between atoms readily break and reform***. This ability to bend or be shaped without breaking occurs because ***the electrons simply slide over each other instead of separating***. The binding force between metals is non-directional, so drawing or shaping a metal is less likely to fracture it. ***Electrons in a crystal may be replaced by others***. Gold and Silver metals are the most malleable metals. They can be hammered into very fine sheets. Thin aluminium foils are widely used for safe wrapping of medicines, chocolates and food material.

5. Metallic Luster

Metals ***tend to be shiny or display metallic luster***. They are opaque once a certain minimum thickness is achieved. The ***electron sea reflects photons off the smooth surface*** therefore there is an upper frequency limit to the light that can be reflected. Silver is a very good reflector. It reflects about 90% of the light falling on it. All modern mirrors contain a thin coating of metals. Due to their shiny appearance they can be used in jewellery and decorations.

Application activity 12.4

1. Magnesium has a higher melting and boiling point than sodium. This can be explained in terms of the electronic structures, the packing, and the atomic radii of the two elements.
   a) Explain why each of these three things causes the magnesium melting and boiling points to be higher.
   b) Explain why metals are good conductors of electricity.
   c) Explain why metals are also good conductors of heat.

1. Magnesium has a higher melting and boiling point than sodium. This can be explained in terms of the electronic structures, the packing, and the atomic radii of the two elements.
   a) Explain why each of these three things causes the magnesium melting and boiling points to be higher.
   b) Explain why metals are good conductors of electricity.

c) Explain why metals are also good conductors of heat.

2. Pure metals are usually malleable and ductile.

a) Explain what those two words mean.

b) If a metal is subjected to a small stress, it will return to its original shape when the stress is removed. However, when it is subjected to a larger stress, it may change shape permanently. Explain, with the help of simple diagrams why there is a different result depending on the size of the stress.

c) When a piece of metal is worked by a blacksmith, it is heated to a high temperature in a furnace to make it easier to shape. After working it with a hammer, it needs to be re-heated because it becomes too difficult to work. Explain what is going on in terms of the structure of the metal.

d) Why is brass harder than either of its component metals, copper and zinc?

SKILLS LAB 12

The figure below shows the electric conductivity of distilled water (A), solid table salt (B) and a solution of a table salt (C) respectively.

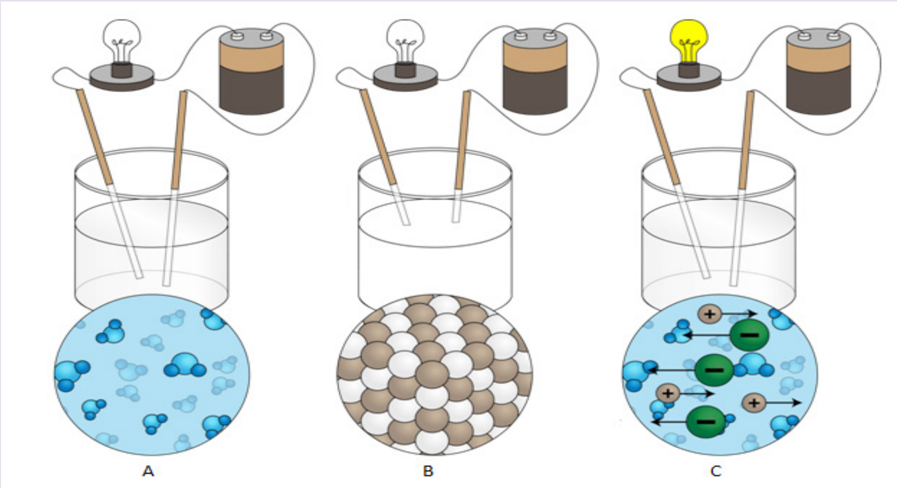


Figure 12.8.: Investigation of the electric conductivity

a) Use the diagrams **A**, **B** and **C** to explain the observations from the set up.

i. No light is given out by bulb in A

ii. No light is given out by bulb in B

iii. Light is given out in C

b) Suppose that you have a 30 cm bar made of table salt. Suggest the change, if there is any, that can occur and deduce the property related, when this salt bar is:

i. Dropped from a table of 1 m high to the floor

ii. Immersed in water found in a water bath.

c) Dry heated to 100 °C

End unit assessment 12

1. State whether the following statement is *True* or *False*. Justify your answer. “Sodium Chloride has a higher melting point than Magnesium Oxide”.
2. Why are ionic compounds brittle?
3. Why do ionic compounds have high melting points?
4. What happens when an electric current is passed through a solution of an ionic compound?
5. This question is about metallic bonding.

a) Describe the bonding that is present in metals.

b) Explain how the bonding and structure lead to the typical metallic properties of electrical conductivity and malleability.

c) Suggest a reason why aluminium is a better conductor of electricity than magnesium.

6. Silver and sodium chloride melt at similar temperatures. Give two physical properties of silver which are different from those of sodium chloride and, in each case, give one reason why the property of silver is different from that of sodium chloride.
7. This question is about calcium oxide (CaO).

a) Describe the nature and strength of the bonding in solid calcium oxide.

b) Use the kinetic theory to describe the changes that take place as calcium oxide is heated from 25°C to a temperature above its melting point.

c) State two properties of calcium oxide that depend on its bonding.

UNIT 13: THIN LENSES

Key unit competence

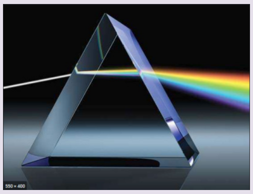
Explain the properties of lenses and image formation by lenses

Introductory Activity 13

Observe these images below and answer the following questions


A


B


C


D

a) Through your observation, Name A,B,C and D and identify where they can be used in our daily life activities

b) What is the effect of light on A, B, C and D?

c) Analyze the phenomenon in figure C thereafter write your observation in your notebook

d) How the images are formed on the above figures? Explain your reason

13.1. Types and characteristics of lenses

Activity 13.1

1. Look closely at the lenses and answer these questions in your notebook:

a) How are the lenses shaped? Explain your answer

b) How are the lenses different?

c) Classify these lenses according to your observation thereafter explain the conditions used to classify them.

A **lens** is an optical device with perfect or approximate axial symmetry which transmits and refractslight, by converging or diverging the beam. Most lenses are spherical lenses: their two surfaces are parts of the surfaces of spheres. Lenses are classified by the curvature of the two optical surfaces.

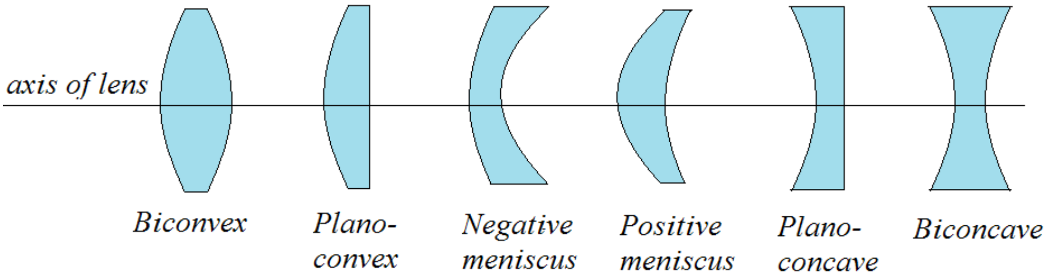


Figure 13.1: Classification of lenses

A lens is a piece of glass with one or two curved surfaces. The lens which is thicker at the centre than at the edges is called a convex lens while the one which is thinner at its centre is known as a concave lens. The curved surface of the lens is called a meniscus. The lens in the human eye is thicker in the centre, and therefore it is a convex lens.

The light rays from the ray box change the direction after passing through the lens. They are therefore refracted by the lens. Hence, lenses form images of objects by refracting light.

You can see that the rays from the convex lens are getting closer and closer to a point. The rays are thus converging, and hence a convex lens is called a converging lens. You can also see that the refracted rays from the concave lens are spreading out. This kind of lens is called diverging lens. When light passes through a lens, refraction occurs at the two lens surfaces.

Using Snell's law and geometry, you can predict the paths of rays passing through lenses. To simplify such problems, assume that all refraction occurs on a plane, called the principal plane that passes through the center of the lens. This approximation, called the thin lens model, applies to all the lenses.

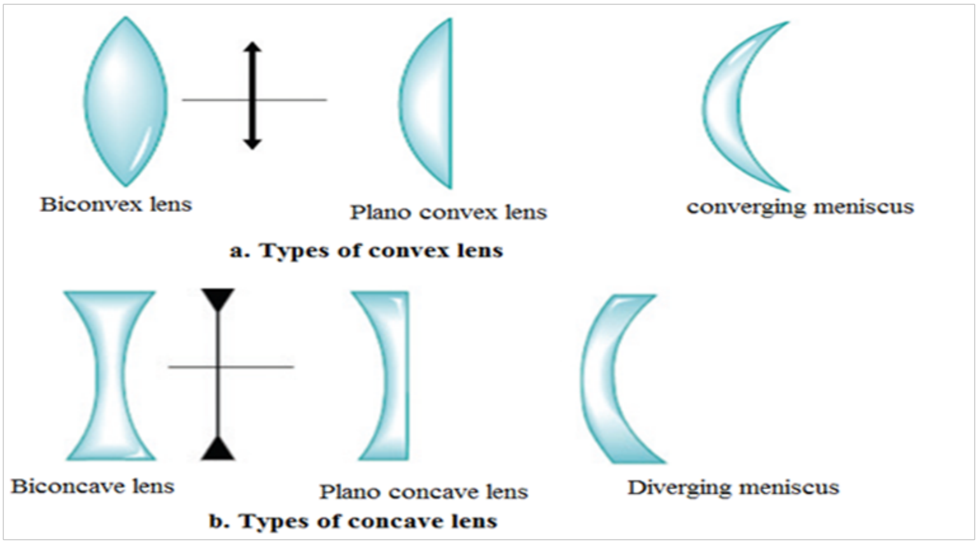


Figure 13.2 Types of lenses

Application activity 13.1

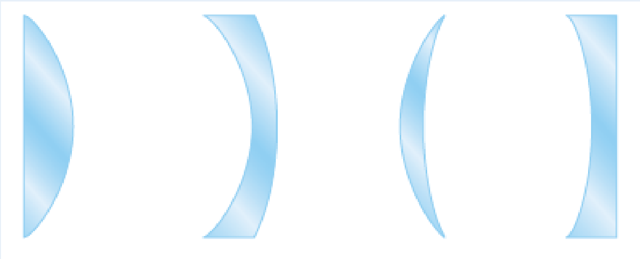
1. The cross sections of four different thin lenses are shown in **Figure below.**

a) Which of these lenses, if any, are convex, or converging lenses?

b) Which of these lenses, if any, are concave, or diverging lenses?

c) Why do you make such decision at **a** and**b**?

d) Where did you see these types of lenses in everyday life?



2. Make a deep research on where this types of lenses are used in our daily life activities

13.2. Refraction of light through lenses.

Activity 13.2

i. Hold a hand lens about 2 m from the window. Look through the lens. (CAUTION: Do not look at the sun).

   What do you see?

ii. Move the lens farther away from your eye.

   What changes do you notice?

iii. Now, hold the lens between the window and a white sheet of paper, but closer to paper.

iv. Slowly move the lens away from the paper towards the window. Keep watching the paper.

What do you see? What happens as you move the paper?

Do you see that an inverted image of trees outside is formed on the paper? How do you think the image is formed?

Lenses can be thought of as a series of tiny refracting prisms, each of which refracts light to produce an image. These prisms are near each other (truncated) and when they act together, they produce a bright image focused at a point.

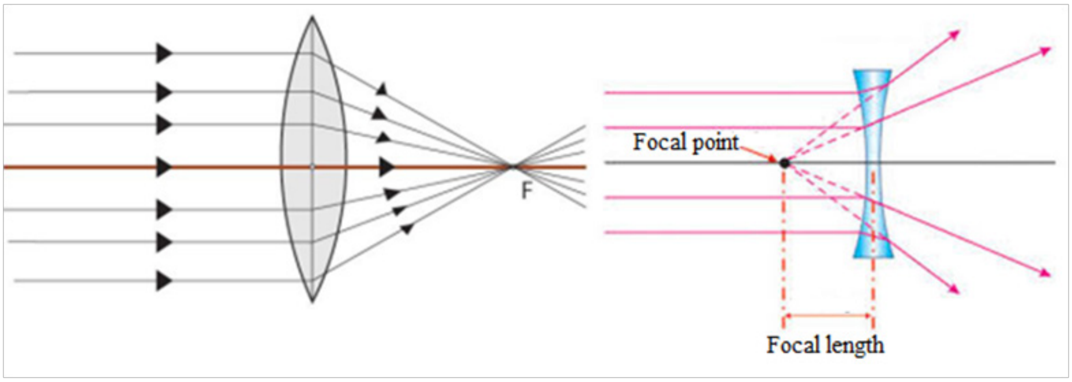


Figure13.3: Action of converging and diverging lenses

Each section of a lens acts as a tiny glass prism. The refracting angles of these prisms decrease from the edges to its centre. As a result, light is deviated more at the edges than at the centre of the lens.

The refracting angles of the truncated prisms in a converging lens point to the edges and so bring the parallel rays to a focus.

The truncated prisms of the diverging lens point the opposite way to those of the converging lens, and so a divergent beam is obtained when parallel rays are refracted by this lens because the deviation of the light is in the opposite direction.

The middle part of the lens acts like a rectangular piece of glass and a ray incident to it strikes it normally, and thus passes without deviation.

13.2.1 Ray diagrams and properties of images formed by lenses

Notice that an image cannot be seen on the screen irrespective of the position of the object.

The nature of the image formed by a convex lens depends on the position of the object along the principal axis of the lens.

The principal focus of a lens plays an important part in the formation of an image by a lens since parallel rays from the object converge to it, and thus, we consider points F and 2F when describing the nature of the images formed by the lens.

These images can be larger or smaller than the object or same size as the object. When an image is larger than the object, we say that it is magnified and when it is smaller, we say that it is diminished.

Images which can be formed on the screen are Real images. Because light rays pass through these images, real images can be formed on the screen. All real images formed by the convex lens are inverted.

To determine an image point, we need to consider only the three rays indicated if Fig.13.4, which uses an arrow (on the left) as the object, and a converging lens forming an image to the right. These rays, emanating from a single point on the object, are drawn as if the lens were infinitely thin, and we show only a single sharp bend at the centre line of the lens instead of refraction at each surface. These three rays are drawn as follows:

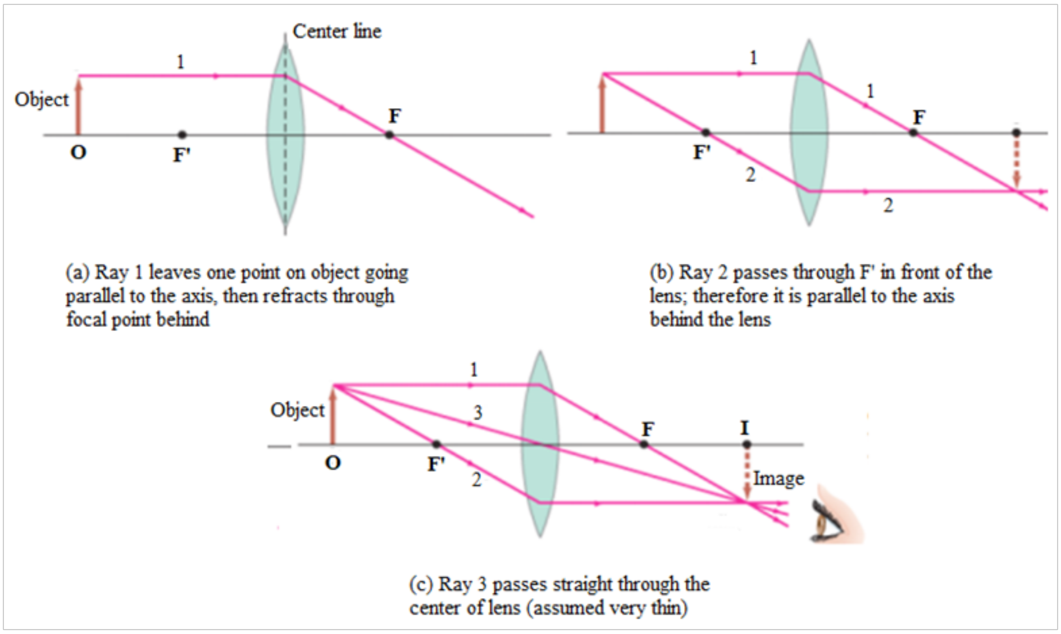
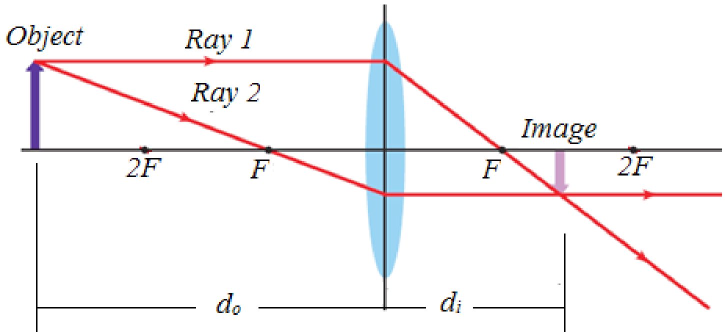


Figure 13.4: Ray tracing for convex lens

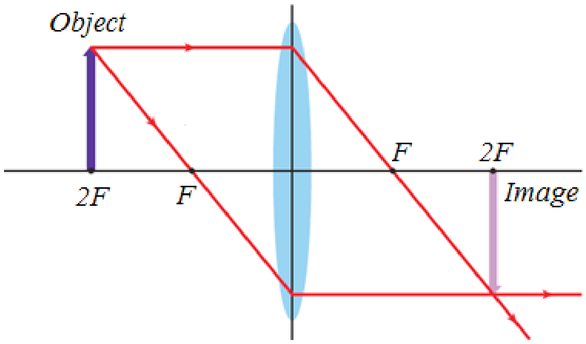
The point where these three rays cross is the image point for that object point. Actually, any two of these rays will suffice to locate the image point, but drawing the third ray can serve as a check.

13.2.2 Graphical construction of images by Converging lens

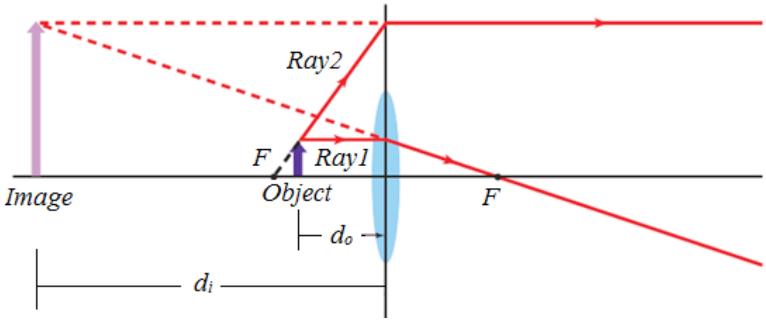
If the lens is biconvex or plano-convex, a collimated parallel or diverging beam of light travelling through the lens will be converged to a spot behind the lens. In this case, the lens is called a converging lens.



When an object is placed at a distance greater than the focal length from the lens, the image is real and inverted on the other side of the lens. When an object is placed at a distance equal to twice the focal length from the lens, the image is the same size as the object and inverted.



A convex lens forms a virtual image that is upright and larger compared to the object when the object is located between the lens and the focal point.



13.2.3 Graphical construction of images by diverging lens

If the lens is biconcave or plano-concave, a beam of light travelling to the lens axis and passing through the lens will be diverged.

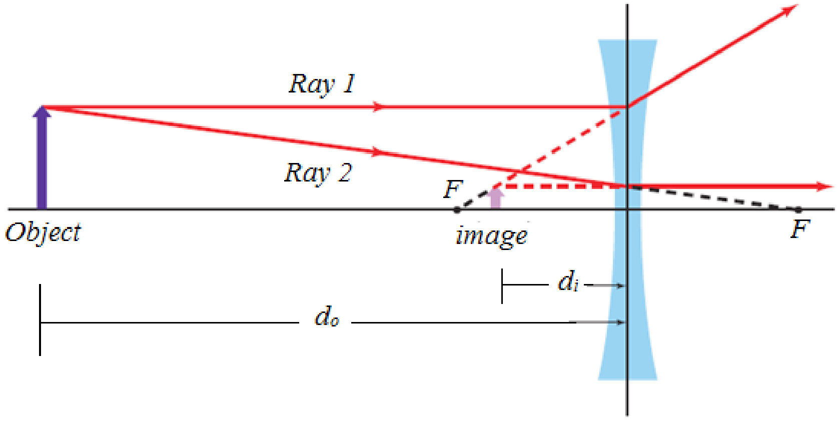


Figure 13.5: Finding image by ray tracing for a diverging lens

Concave lenses produce only virtual images that are upright and smaller compared to their objects.

When an object is between F and the lens, there is no image formed on the screen. The image formed is not real and is only seen by removing the screen and placing an eye in its position. We say that it is a virtual image. For a virtual image, rays appear to come from its position.

Unlike for a convex lens where the nature of the image depends on the position of the object, a concave lens gives only an upright, small, virtual image, and is situated between the principal focus and the lens for all positions of the object.

Application activity 13.2

1. Design an experiment to study images formed by convex lenses of various focal lengths. How does the focal length affect the position and size of the image produced?
2. An object of length 5 cm is placed at a distance 25 cm in front of a lens of focal length 10 cm.Use a ray diagram to construct the image of this object and state its properties if the lens is :

a) Converging;

b) Diverging.

13.3. Thin lens equations and determination of focal length

Activity 13.3

Task 1:

i. Place a converging lens on a table while facing a window.

ii. Place a white screen behind the lens. Move the screen to and fro (forwards and backwards) until a sharp image of a distant object is seen on the screen.

iii. Discuss and write down the observation in your notebook.

iv. Measure the distance from the lens to the screen. What is this distance called?

Task 1:

i. Place a converging lens on a table while facing a window.

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iii. Discuss and write down the observation in your notebook.

iv. Measure the distance from the lens to the screen. What is this distance called?

Task 2:

i. Draw a ray diagram to determine the nature and position of the image of an object placed 10cm from a diverging lens of focal length 15cm.

ii. Using the above information, find the nature and position of the image using a lens formula. (Assign ***f*** a negative sign during your substitution).

iii. What is the location of the image?

13.3.1 Convex lens

We now derive an equation that relates the image distance to the object distance and focal length of a thin lens. This equation will make the determination of image position quicker and more accurate than doing ray tracing. Let be the object distance, the distance of the object from the center of the lens, and the distance of the image from the center of the lens. And let and refer to the heights of object and image. Consider two rays shown in Figure below for a converging lens, assumed to be very thin.

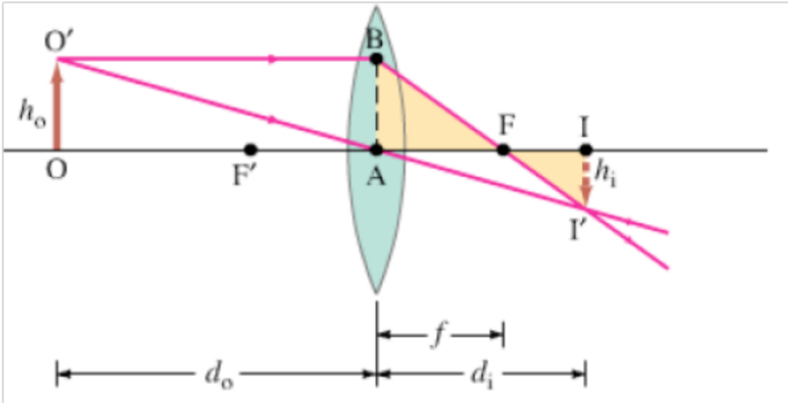


Figure 13.6: Deriving the lens equation for a converging lens

The right triangles FI'I and FBA are similar because angle AFB equals angle IFI'; so

$$\frac{h_i}{h_0} = \frac{d_i - f}{f}$$

Since length $AB = h_0$. Triangles OAO' and IAI' are similar as well. Therefore,

$$\frac{h_i}{h_0} = \frac{d_i}{d_0}$$

We equate the right sides of these equations (the left sides are the same), and divide d_i by to obtain

$$\frac{1}{f} - \frac{1}{d_i} = \frac{1}{d_0}$$

Or
$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$$

This is called the **thin lens equation.** It relates the image distance d_i to the object distance d_0 and focal length . It is the most useful equation in geometric optics. If the object is at infinity, then $\frac{1}{d_0} = 0$, so $d_i = f$. Thus the focal length is the image distance for an object at infinity, as mentioned earlier.

13.3.2 Concave lens

We can derive the Lens equation for diverging lens using the following figure.

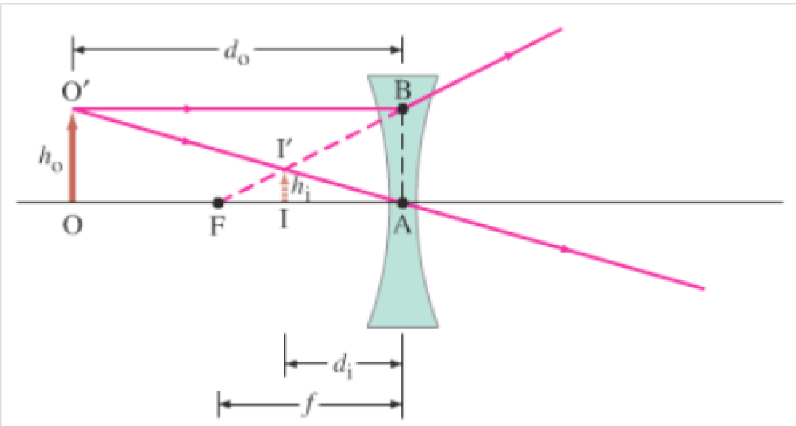


Figure 13.7:Deriving the lens equation for a diverging lens.

Triangles IAI' and OAO' are similar; and triangles IFI' and AFB are similar. Thus (noting that length $AB = h_0$)

$$\frac{h_i}{h_0} = \frac{d_i}{d_0} \quad \text{and} \quad \frac{h_i}{h_0} = \frac{f - d_i}{f}$$

When we equate the right sides of these two equations and simply, we obtain

$$-\frac{1}{f} = \frac{1}{d_0} - \frac{1}{d_i}$$

This equation becomes the same as that of convex lens if we make f and d_i negative. That is, we take f to be negative for a diverging lens and d_i negative when the image is on the same side of the lens as light comes from.

Thus

$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i}$$

Will be valid for both converging and diverging lenses, and for all situations, if we use the following **sign conventions:**

1. The focal length is positive for converging lenses and negative for diverging lenses.
2. The object distance is positive if the object is on the side of the lens from which light is coming; otherwise, it is negative.
3. The image distance is positive if the image is on the opposite side from where light is coming; if it is on the same side, it is negative. Equivalently, the image distance is positive for real image and negative for a virtual image.
4. The height of the image, is positive if the image is upright, and negative if the image is inverted relative to the object. (is always taken as positive).

13.3.3 Magnification

The **magnification,** m, of a lens is defined as the ratio of the image height to object height. From the above figures and the sign conventions, we have

$$m = \frac{h_i}{h_0} = -\frac{d_i}{d_0}$$

for an upright image the magnification is positive, and for an inverted image the magnification is negative.

13.3.4 The power of lenses

Whenever a ray of light passes through a lens it bends except when it passes through the optical centre. The degree of convergence or divergence of a lens is expressed as power. A lens of short focal length deviates the rays more while a lens of large focal length deviates the rays less. Thus the power of a lens is defined as the reciprocal of its focal length.

Power of a lens $P = \frac{1}{f}$

The unit of power is dioptre (D) $1D = 1m^{-1}$

From sign convention 1, it follows that the power of converging lens, in diopters, is positive, whereas the power of a diverging lens is negative. A converging lens is sometimes referred to as positive lens, and a diverging lens as a negative lens.

In case the lenses are combined

$$P = P_1 + P_2 + ...$$

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + ...$$

or

$$F = \frac{f_1 f_2 ...}{f_1 + f_1 + ...}$$

Example 13.3

An object is placed 32.0 cm from a convex lens that has a focal length of 8.0 cm.

a) Where is the image?

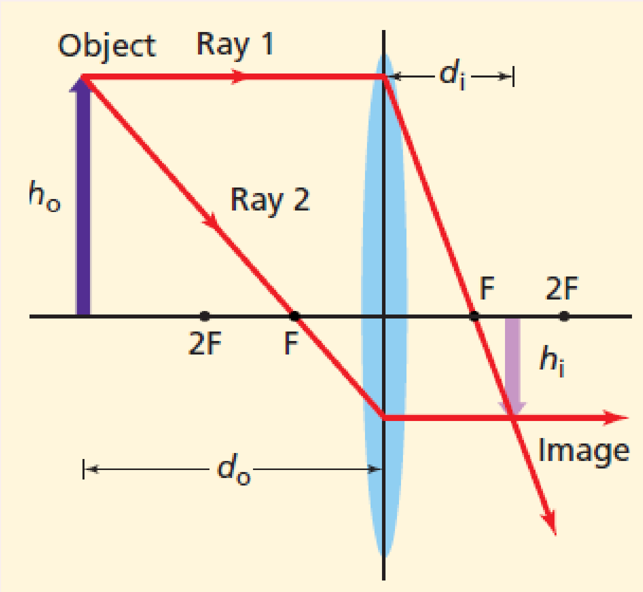
b) If the object is 3.0 cm high, how tall is the image?

c) What is the orientation of the image?

Solution

1. Analyse and sketch the problem

- Sketch the situation, locating the object and the lens.
- Draw the two principal rays



Known

$$d_0 = 32.0\,cm$$
$$h_0 = 3.0\,cm$$
$$f = 8.0\,cm$$

Unknown:

$$d_i = ?$$
$$h_i = ?$$

2. Solve for the unknown

a) Use the thin lens equation to determine d_i

$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_i} \rightarrow d_i = \frac{fd_0}{d_0 - f}$$

$$d_i = \frac{(8.0cm)(32.0cm)}{(32.0cm) - (8.0cm)} = 11\,cm$$

11 cm away from the lens on the side opposite the object.

b) Use the magnification equation and solve for image height.

$$m = \frac{h_i}{h_0} = -\frac{d_i}{d_0}$$

$$h_i = \frac{-d_i h_0}{d_0} = \frac{-(11cm)(3.0cm)}{32.0cm} = -1.0\,cm\ (1.0\,cm\ tall)$$

c) The negative sign in part b means that the image is inverted.

13.3.5 Lens maker formula

The following assumptions are made for the derivation:

- The lens is thin, so that distances measured from the poles of its surfaces can be taken as equal to the distances from the optical centre of the lens.
- The aperture of the lens is small.
- Object point is considered.
- Incident and refracted rays make small angles.

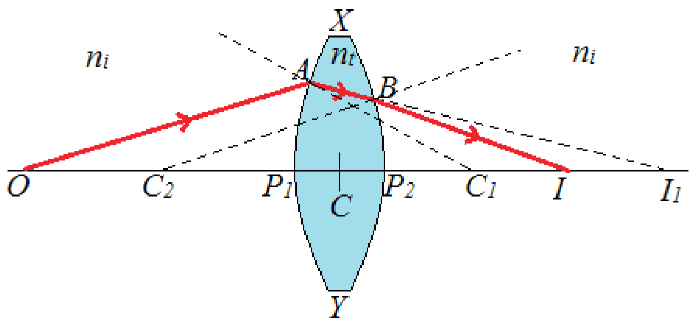


Figure 13.8: Derivation of lens maker formula.

Consider a convex lens of absolute refractive index n_t to be placed in a rarer medium of absolute refractive index n_i.

Considering the refraction of a point object on the surface XP_1Y, the image is formed at I_1 who is at a distance of P_1I_1.

$CI_1 = P_1I_1$ (as the lens is thin)

$CC_1 = P_1C_1 = R_1$

$CO = P_1O$

The refracted ray from A suffers a second refraction on the surface XP_2Y and emerges along BI. Therefore I is the final real image of O. Here the object distance is

$$d_o = CO \approx CI_1 \approx R_1$$

It follows from the refraction due to convex spherical surface XP_1Y

$$\frac{n_i}{-d_o} + \frac{n_t}{CI_1} = \frac{n_t - n_i}{R_1}$$

Let $CI \approx P_2I = d_i$ be the final image distance. Let R_2 be radius of curvature of second surface of the lens.

$$d_i = CI \approx CI_1 \approx R_2$$

It follows from refraction due to concave spherical surface from denser to rarer medium that

$$\frac{-n_t}{CI_1} + \frac{n_i}{d_i} = \frac{n_t - n_r}{R_2} = \frac{n_t - n_i}{-R_2}$$

Adding

$$\frac{n_i}{-d_o} + \frac{n_i}{d_i} = (n_t - n_i)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{d_i} - \frac{1}{d_o} = \frac{(n_r - n_i)}{n_i}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

From equations $\frac{n_r}{n_i} = n$ and $\frac{1}{f} = \frac{1}{d_i} - \frac{1}{d_o}$

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

This equation gives the lens maker's formula

Note:

- The lens maker's formula indicates that a convex lens can behave like a diverging one if $n_i > n_t$ i.e., if the lens is placed in a medium whose index is greater than the index of lens. Similarly a concave lens can be made convergent.
- The lens maker's formula can be derived for a concave lens in the same way.

Sign convention states that real is positive while virtual is negative. This should be put under consideration when one is using the lens formula to solve problems.

Application activity 13.3

1. Compute the composition and focal length of the converging lens which will project the image lamp, magnified 4 times, upon a screen 10.0 m from the lamp.
2. A lens has a convex surface of radius 20 cm and a concave surface of radius 40 cm and is made of glass of refractive index 1.54. Compute the focal length of the lens, and state whether it is a converging or a diverging lens.

13.4. Defects and correction of lenses

Activity 13.4

i. Place a white sheet of paper on a horizontal ground.
ii. Hold a glass ruler above the paper so as to focus rays from the sun on to the paper.
iii. Observe carefully the image formed on the sheet of paper.
iv. Repeat the above with the convex lens. What have you observed?
v. Use internet to search for Defects and correction of lenses

Aberration

A lens made of a uniform glass with spherical surface cannot form a perfect image. The spherical aberration is prominent image defect for a point source on the optical axis of such a lens. It arises because all rays through the lens are not focused to a common point.

The dependence of index of refraction of wavelength also causes the focal length, and thereby the image position, to depend on the color of the light. All simple lenses suffer from such chromatic aberration.

There are several different types of aberration which can cause the image to be an imperfect replica of the object(Spherical aberration, chromatic aberration, coma, field curvature, barrel, pincushion distortion, astigmatism, etc).

Notice that the image has coloured patches. This defect where by an image formed has coloured patches is called chromatic aberration. There are two kinds of defects; spherical aberration and chromatic aberration.

13.4.1 Spherical aberration

This arises in lenses of larger aperture when a wide beam of light incident on the lens, not all rays is brought to one focus.

As a result, the image of the object becomes distorted. The defect is due to the fact that the focal length of the lens for rays far from the principal axis are less than for rays closer to a property of a spherical surface and as a result, they converge to a point closer to the lens.

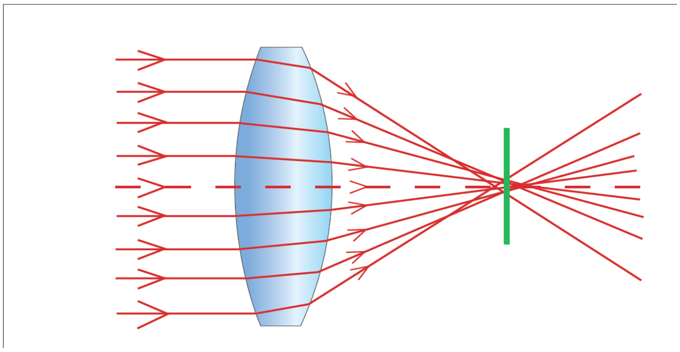


Figure13.9: Spherical aberration

This defect can be minimized (reduced) by surrounding the lens with an aperture disc having a hole in the middle so that rays fall on the lens at a point closer to its principal axis. However, this reduces the brightness of the image since it reduces the amount of light energy passing through the lens.

13.4.2 Chromatic aberration

Chromatic aberration is caused by the dispersion of the lens material. Since, from the lens formulae, f is dependent upon n, it follows that different colours of light will be focused to different positions.

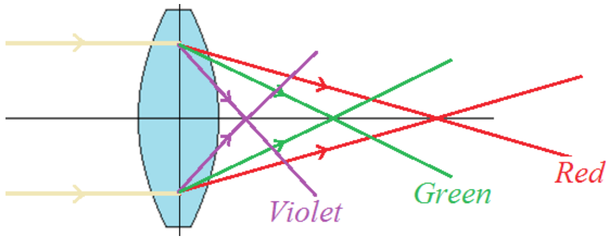


Figure13.10: Chromatic aberration

Chromatic aberration can be minimised by using **an achromatic doublet (or achromat)** in which two materials with differing dispersion are bonded together to form a single lens.

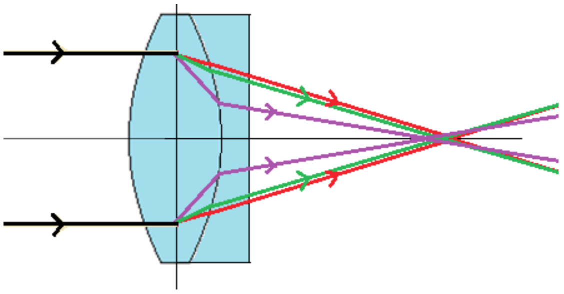


Figure13.11: Correction of chromatic aberration

Application activity 13.4

i. How spherical and chromatic aberration can be reduced?

ii. If a plano-convex lens is used as objective lens in a telescope, how is its convex surface faced to minimize spherical aberration? Explain

13.5. Refraction through prisms

13.5.1. Terms associated with refraction through prism

Activity 13.5

Problem

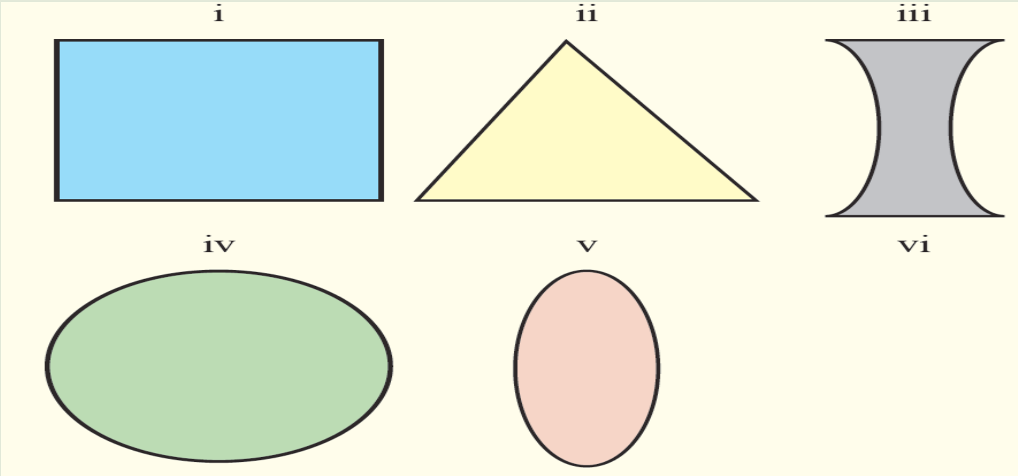
Have you ever heard of a prism?

How does it look like?

Procedures

a) Consider the shapes of the glasses provided below. Observe them clearly and identify the shape of a prism.

Explain your reasoning.



b) With the help of a teacher, touch, observe and identify the real shape of the prism.

c) Examine the features of the one selected as a prism.

In optics, a prism is transparent material like glass or plastic that refracts light. At least two of the flat surfaces must have an angle less than 90° between them. The exact angle between the surfaces depends on the application

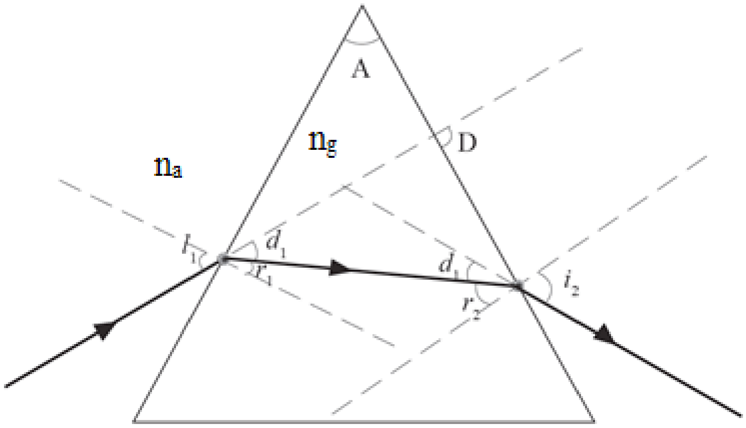


Figure 13.12: refraction through a prism

From the figure 13.12, the following terms are used in refraction through prism.

Angle A: This is called refracting angle or angle of the prism. It is the angle between the inclined surfaces of the prism.

Angle *i*: This is the angle of incidence on the first face of the prism.

Angle r_1: This is the angle of refraction on the first face of the prism.

Angle r_2: This is the angle of refraction on the second face of the prism.

Angle I_2: This is the angle of emergence from second face of the prism. Sometimes this is denoted by letter e.

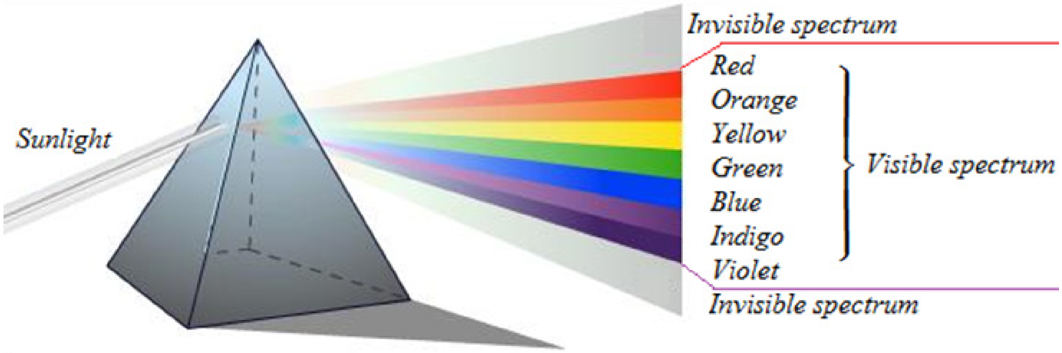
Angle D: this is the angle of deviation of rays through a prism.

n_a: is a refractive index in air.

n_g: is a refractive index in glass

13.5.2 Dispersion of light by a prism

Dispersion of light is the separation of a beam of light into its constituent colours. This takes place when a light beam passes through a dispersive medium. A beam of white light incident on a prism splits into its constituent colours to form "a visible spectrum"consisted of colours **violet, indigo, blue, green, yellow, orange and red.**



When a polychromatic light is incident on the first surface of the prism, each constituent colour gets refracted through a different angle. When these colours are incident on the second surface of the prism they are again refracted further.

Application activity 13.5

1. i. Place a prism in the centre of a piece of paper so that its refracting surface is directly facing the windows in order to receive light from the sun.
   ii. Place a white screen on the far side of the prism so that the refracted rays hit it.
   iii. Observe what is formed on the screen.
   iv. In brief, write in your notebook the observation.
2. Do a research to find other terms associated to the refraction light through prism.

13.6 Deviation by a prism and determination of refractive index

Activity 13.6

1. Have you ever heard of the word deviation? List down in your notebook at least two ways in which light can be deviated.
2. You are provided with a glass prism of refracting angle 60°, four optical pins, a white sheet of paper, a soft board and fixing pins.

i. Place a prism on a white sheet of paper and mark its outline ABC.

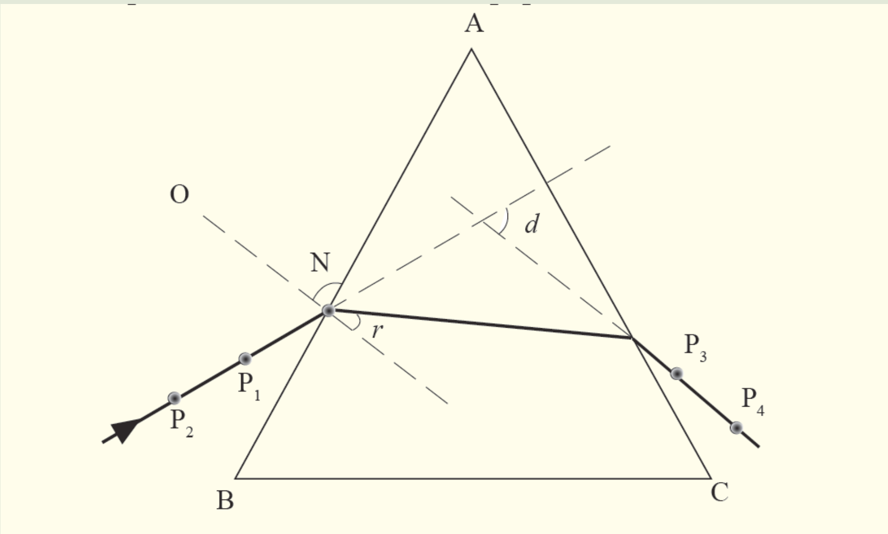


Figure 5.8: Diagram related to activity

ii. Remove the prism and draw a normal line ON to face AB and draw a line making an angle of 10° to ON to represent the incident ray.

iii. Place back the prism in its outline and fix pins P_1 and P_2 along the line.

iv. While looking through the other face AC of the prism, fix pins P_3 and P_4 so that they appear in line with images of P_1 and P_2.

v. Remove the prism and draw a line through P_3 and P_4 on to face AC of the prism.

vi. Measure the angle of deviation d.

vii. What is your observation on the direction of incident ray after refraction?

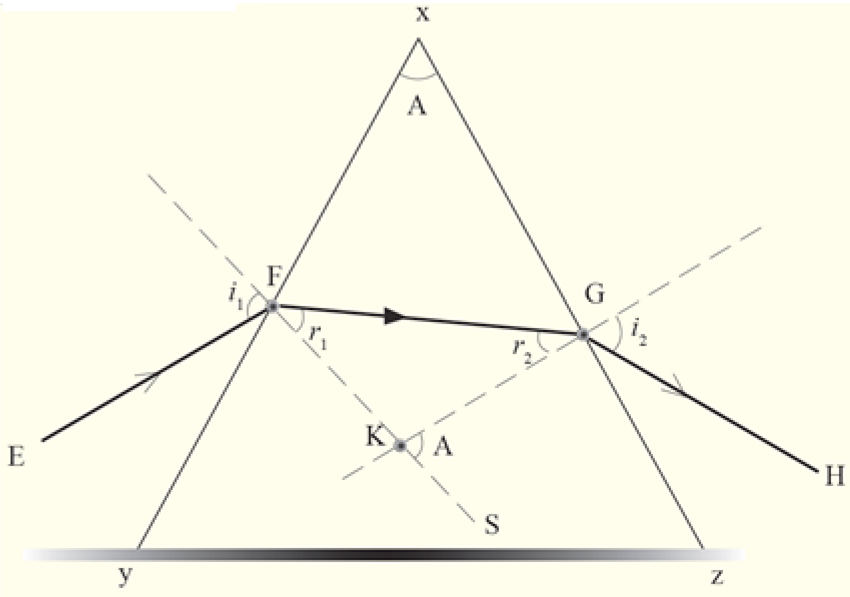


Figure13.13: Refraction through prism

In the figure13.13, E F is a ray incident on the refracting surface YX of the prism XY Z from air and then to air from surface XZ of the prism. KF and KG are normal at the points of incidence and emergence of the ray respectively.

Now, from the geometry of quadrilateral XFKG,

$< X FK + < X GK = 180^{O}$ and

$A + <F K G = 180^{O}$ …………………….(1)

But since FKS is a straight line,

$\Delta FKG + \Delta GKS = 180^{O}$…………….(2)

Comparing equation (1) and (2), it means that, ΔGKS = A.

Using ΔKFG, ΔGKS is an opposite exterior angle of r_1 and r_2

Thus, $r_1 + r_2$ = ΔGKS.

Hence, $r_1 + r_2 = A$

Note that given $i1$, r_1 and i_2, r_2 as angles of incidence and refraction at F and G as shown and n is the prism refractive index, and then Snells law holds.

That is; Sin i_1 = n sin r_1, and

Sin $i_2 = n$ sin r_2

The position and shape of the third side of the prism does not affect the refraction under consideration and so is shown as an irregular in figure.

Example

A ray of light falls from air to a prism of refracting angle 60° at an angle of 30°. Calculate the angle of emergence on the second face of the prism (Take refractive index of the material of glass, n_g = 1.5).

Solution

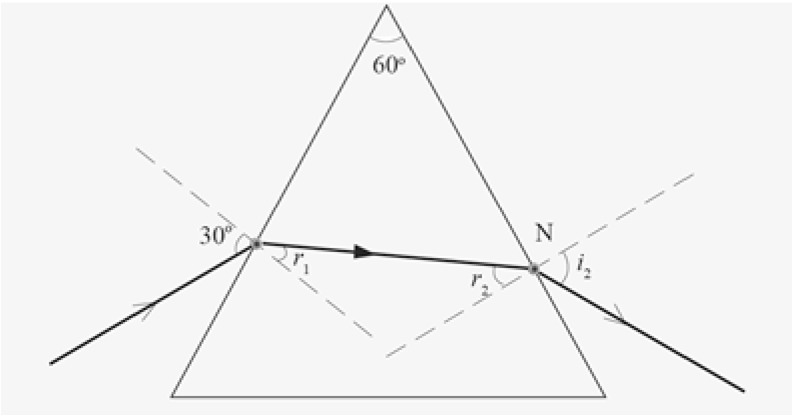


Figure 13.14: Ray through a prism

Using Snell's law,

$$n \sin i = constant$$

Thus

$$n_a \sin i_1 = n_g \sin r_1$$
$$1 \sin 30^0 = 1.5 \sin r_1$$

Therefore

$$\sin r_1 = \frac{0.5}{1.5} \rightarrow r_1 = \sin^{-1}\frac{0.5}{1.5} = 19.5^0$$

But $r_1 + r_2 = A$

It follows that

$$r_2 = 60^0 - 19.5^0 = 40.5^0$$

Now, on the second face,

$$n_g \, sin\, r_2 = n_a \; sin\, i_2$$

$$1.5 \sin 40.5^0 = sin\, i_2$$

So,

$$i_2 = \sin^{-1}(0.974) = 77^0$$

Hence the angle of emergence equals 77^0

1. Deviation of light by a glass prism

Light can be deviated by reflection and refraction. Since a prism refracts light, it therefore changes its direction.

A prism deviates light on both faces. These deviations do not cancel out as in a parallel sided block where the emergent ray, although displaced, is parallel to the incident ray surface. The total deviation of a ray due to refraction at both faces of the prism is the sum of the deviation of the ray due to refraction at the first surface and its deviation at the second face.

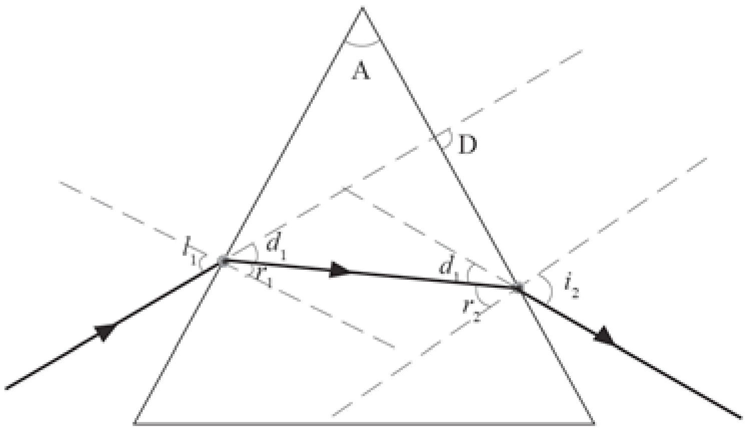


Figure 13.15: Diagram related to activity

Let d_1 and d_2 be angles of deviation at the first and second faces of the prism respectively.

Total deviation $D = d_1 + d_2$

Angle of deviation at the first face, $d_1 = i_1 - r_1$ and the angle of deviation at the second face,

$d_2 = i_2 - r_2$

Thus

$$D = d_1 + d_2 = i_1 - r_1 + i_2 - r_2 = (i_1 + i_2) - (r_1 + r_2)$$

But $r_1 + r_2 = A$

Therefore

$$D = (i_1 + i_2) - A$$

N.B: The deviation D for a small angle prism is $D = A(n-1)$

The expression $D = A(n-1)$ shows that for a given angle A, all rays entering a small angle prism at small angles of incidence suffer the same deviation.

2. Angle of minimum deviation

From the variation figure below, there is one angle of incidence which gives a minimum deviation. The experiment shows that this minimum deviation occurs when the angle of emergence is exactly equal to the angle of incidence and the two internal angles of refraction are equal.

At this value, a ray passes symmetrically through the prism and the ray inside the prism is perpendicular to the directing plane.

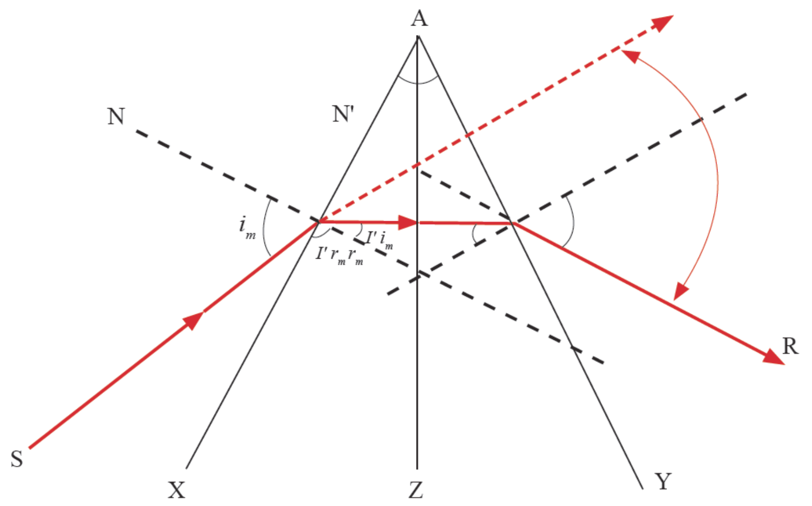


Figure 13.16: Minimum deviation

Since the angle of emergence i_2 = angle of incidence i_1, it follows that

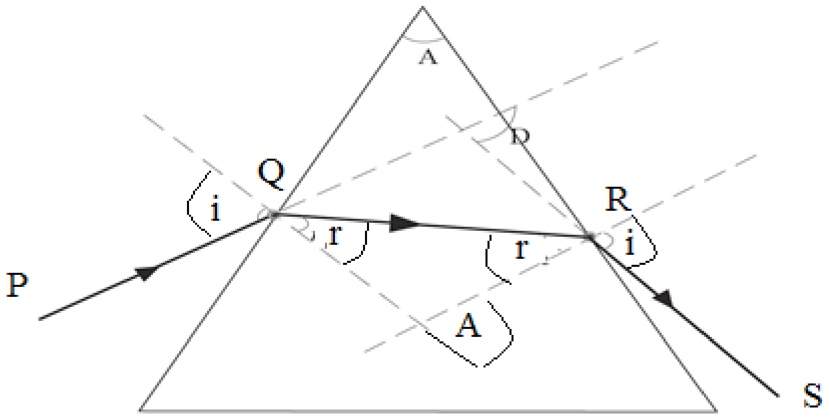
$$i_1 = i_2 = i \text{ and } r_1 = r_2 = r$$

From deviation

$$D = (i_1 + i_2) - A$$
$$D_{\min} = i + i - A$$
$$D_{\min} = 2i - A$$

3. Determination of refractive index *n* of a material of the prism

A very convenient formula for refractive index, n, can be obtained in the minimum deviation case. The ray PQRS then passes symmetrically through the prism, and the angles made with the normal in the air and in the glass at Q, R respectively are equal. Suppose the angles are denoted by as shown. Then



$$(i-r)+(i-r)=D_{\min}$$

And $r+r=A$ (The refracting angle); so,

$$r=\frac{A}{2}$$

Substituting for we get:

$$2i=A+D_{\min}$$

$$i=\frac{A+D_{\min}}{2}$$

$$n=\frac{\sin i}{\sin r}=\frac{\sin\left(\frac{A+D_{\min}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Example

A glass prism of refracting angle 60o has a refractive index of 1.5. Calculate the angle of minimum deviation for a parallel beam of light passing through it.

Solution:

$$n = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A + D_{\min}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$1.5 = \frac{\sin\left(\frac{D_{\min} + 60}{2}\right)}{\sin\left(\frac{60}{2}\right)}$$

Thus,

It follows that

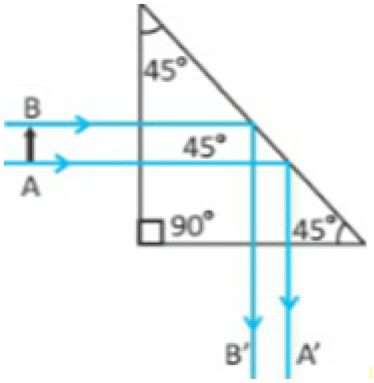
$$D_{\min} = 2\sin^{-1}(0.75) - 60^0 = 97.2^0 - 60^0 = 37.2^0$$

Hence,

$$D_{\min} = 37.2^0$$

4. Applications of total internal reflection of light by a prism

Many optical instruments use right -angled prisms to reflect a beam of light through 90° or 180° (By total internal reflection) such as cameras, binoculars, periscope and telescope. One of the angles of right angled prism is 90°.



When a ray of light strikes a face of prism perpendicular, it enters the prim without deviation and strikes the hypotenuse at an angle of 45°. Since the angle of incidence 45° is greater than critical angle of the glass which is 42°, the light is totally reflected by the prism through an angle of 90°. Two such prisms are used in periscope. The light is totally reflected by the prism by an angle of 180°. Two such prisms are used in binoculars.

Application activity 13.6

1. A ray of light is refracted through a 60 degree prism of ordinary glass making an incident of 35 degree with the normal i.e incident ray =35°.What will the angle of emergent ray and the angle of deviation measure?
2. **What are the conditions for minimum deviation when a ray of light passes through a prism?**
3. Find the reflective index of the material of prism, if a thin prism of angle A is equal to 6 degree, produces a deviation is equal to 3 degree.
4. Show that the deviation produced by a small angled prism is independent with angle of incidence.

SKILLS LAB 13

DETERMINATION OF THE FOCAL LENGTH OF A LENS

Apparatus required:

1 torch bulb fitted in a bulb holder

1 switch

3 Torch cells

2 Cell holders

Connecting wires about 50cm long.

Wire gauze

Converging lens, of focal length 15cm.

Lens holder,

White screen

Metter rule.

Retort stand with its holding accessories.

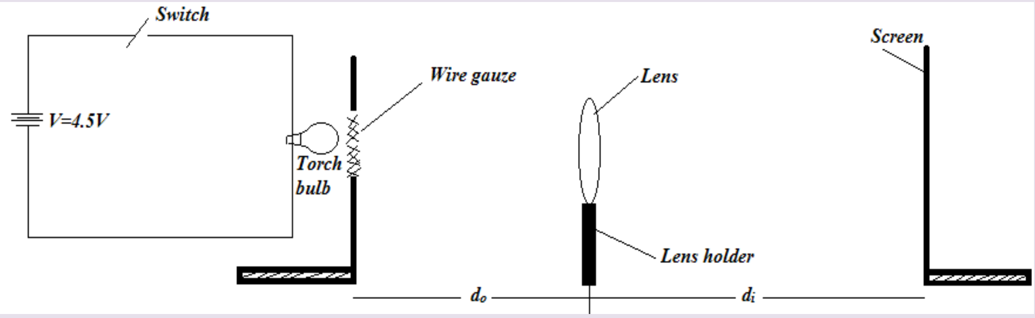
Instructions:

In this experiment you will determine the focal length of the converging lens provided.

a) Mount the on lens the holder and place it facing a window

b) Place the screen behind the lens and adjust the screen until a clear image of a distant object is obtained

c) Measure and record the distance, *x*, between the lens and the screen.



d) Arrange the bulb, the wire gauze, lens and the screen as shown in figure.

e) Adjust the lens so that d_o equals $4.5x$.

f) Close the switch and move the screen until a clear image is formed on the screen.

g) Arrange the bulb, the wire gauze, lens and the screen as shown in figure.

h) Adjust the lens so that d_o equals $4.5x$.

i) Close the switch and move the screen until a clear image is formed on the screen.

j) Measure and record the distance d_i.

k) Repeat the procedures e) to g) above, for d_o equal to $4.0x$, $2.5x$, and $2.0x$.

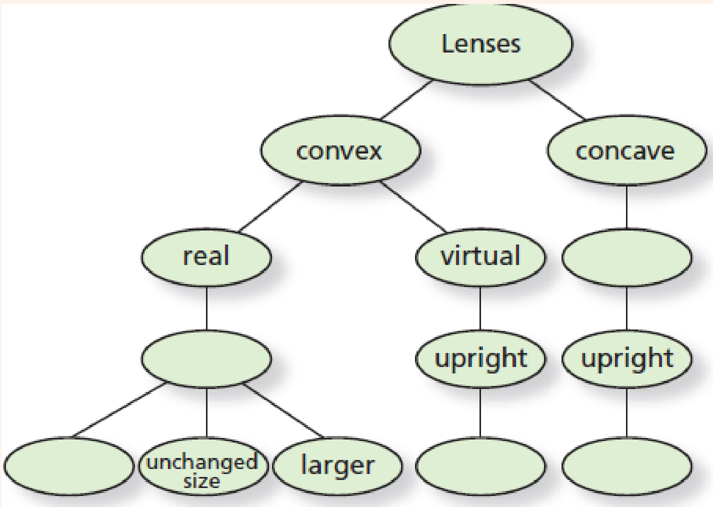
l) Record your results in a suitable table including the values of $d_o d_i$ and $d_o + d_i$.

m) Plot a graph of $d_o d_i$ (along the vertical axis) against $d_o + d_i$ (along the horizontal axis).

n) Find the slope

End unit assessment 13

1. Complete the following concept map using the following terms: *inverted, larger, smaller, and virtual.*



2. Explain the lens defects and their corrections.
3. A sharp image is located 78.0mm behind a 65.0mm-focal-length converging lens. Find the object distance (a) using a ray diagram, (b) by calculation.
4. An object is placed 10cm from a lens of 15m of focal length. Determine the image position.
5. An object of 2cm is placed at 50 cm from a diverging lens of focal length 10cm. Determine its image height and location.
6. An object located 32.0 cm in front of a lens forms an image on a screen 8.00 cm behind the lens.

   (a) Find the focal length of the lens.

   (b) Determine the magnification.

   (c) Is the lens converging or diverging?,

   (d) Determine the power of this lens.

UNIT 14: ASEXUAL AND SEXUAL REPRODUCTION IN PLANTS

Key unit competence

Describe modes of reproduction in plants and apply various methods of asexual and Sexual reproduction as means of increasing crop yield.

Introductory Activity

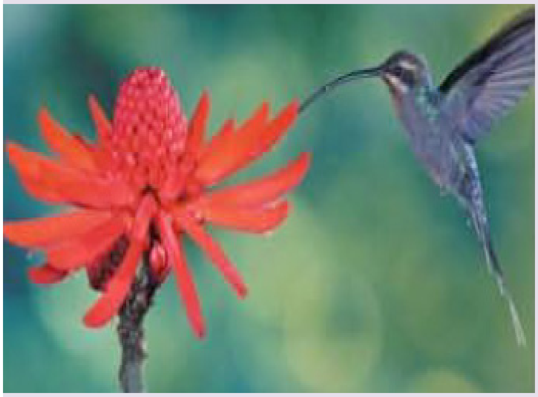
Task 1

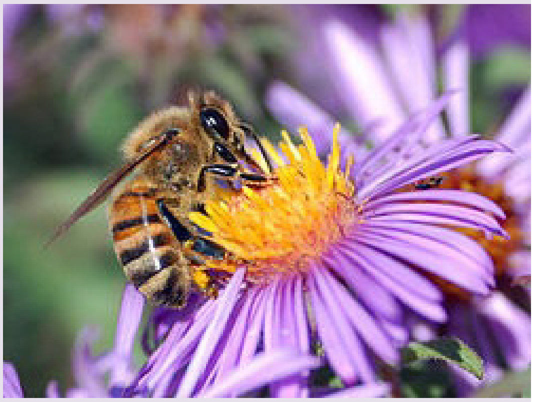
The kingdom Plantae comprises about 260,000 known species including flowering and non-flowering plants. All plants have a general organization which includes vegetative and reproductive organs. Plants reproduce through different ways: Use the books and other source of information to:

1. Write on how lower organisms such unicellular plant and another like cassava, sugar cane and apple reproduce.
2. Describe the techniques used by people to grow Irish potatoes, cassava and bananas.
3. Describe each of the following methods of asexual reproduction: fragmentation, budding and spore formation.

Task 2

1. Observe the following pictures and suggest what is going on.
2. How are the pictures below related to reproduction in flowering plants





14.1 Application of artificial propagation in growing improved varieties of plants

Activity 14.1. a

Using addition resources to your textbook available in your school such as the books from the school library and search further information from the internet. Discuss on application of artificial propagation in growing improved varieties of plants.

Artificial vegetative propagation is the deliberate production of new plants from parts of old plants by humans. This can be done by following three methods:Cutting, layering, and grafting.

Artificial vegetative propagation is usually used in agriculture for the propagation (or reproduction) of those plants which produce either very few seeds or do not produce viable seeds. Some examples of such plants which are reproduced by artificial vegetative propagation methods are: Banana, Pineapple, Orange, Grape, Rose, etc.

Vegetative propagation of particular cultivars that have desirable characteristics is very common practice. Reasons for preferring vegetative rather than sexual means of reproduction vary, but commonly include greater ease and speed of propagation of certain plants, such as many perennial root crops and vines. Another major attraction is that the resulting plant amounts to a clone of the parent plant and accordingly is of a more predictable quality than most seedlings. However, as can be seen in many variegated plants, this does not always apply, because many plants actually are chimeras and cuttings might reflect the attributes of only one or some of the parent cell lines.

Man-made methods of vegetative reproduction are usually enhancements of natural processes, but they range from rooting cuttings to grafting and artificial propagation by laboratory tissue culture. In horticulture, a “cutting” is a piece that has been cut off from a mother plant and then caused to grow into a whole plant. A popular use of grafting is to produce fruit trees, sometimes with more than one variety of the same fruit species growing from the same stem. Rootstocks for fruit trees are either seedlings or propagated by layering.

Figure 14.1: Mass propagation of eucalyptus seedlings

The following are methods of vegetative artificial propagation

Activity 14.1. b

Demonstration of asexual reproduction in plants by cuttings

Requirements

Growth medium or moist soil, sweet potatoes vines, elephant grass, sugarcane or cassava stems, secateurs/sharp knife and rooting hormone.

Procedure

1. Collect clean and healthy stems from cassava, sugarcane or potato plants.
2. Using a secateurs/sharp knife, cut the stem of either cassava, sugarcane or sweet potato stems into suitable sizes.
3. Place them in either suitable medium of growth or apply rooting hormone if available or plant them in moist soil in the school garden.
4. Leave the set up for about 13 days, and then observe the development of roots and leaves at nodes.

Draw and record what you will observe after 13 days on the development of roots and leaves at nodes.

a) Cutting

This is simple procedure in which part of the plant is removed by cutting and placed in a suitable medium for grow. The part of the plant which is removed by cutting it from the parent plant is called a 'cutting'. In this method one-year-old stem of root is cut from a distance of 20 to 30 cm. and is buried in the moist soil in natural position. After sometime, roots develop from this cutting and it grows into a new plant. This method is commonly used in rose and sugar cane. Care is taken that nodes which were lower in parent plant (morphologically) are put in the soil, while the morphologically higher nodes are kept up. Adventitious roots are given off at the lower nodes.

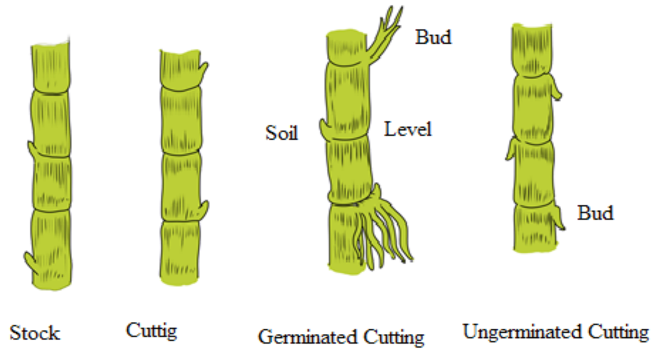


Figure 14.2.cutting technique

b) Layering

This method of vegetative propagation is used in those plants whose soft branches occur near the ground such as jasmine plant. In this method, a branch of the plant which is near to the ground is pulled towards the ground and a part of this branch is covered with moist soil leaving the tip of this branch above the ground. After sometime, roots develop from that part of the branch which was buried in the soil. This branch is then cut of along with the roots from the parent plant and develops into a new plant. This method of asexual reproduction is also used in the production of plants such as Bougainvillea, jasmine, guava, strawberries, lemon, China rose etc.

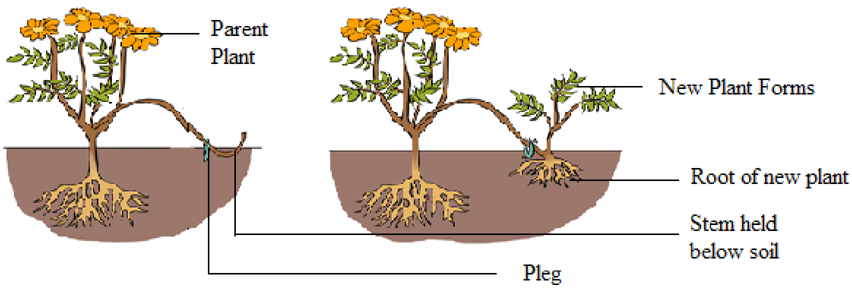


Figure 14.3: Vegetative propagation by layering.

c) Grafting

In this method of vegetative propagation the stems of two different plants are joined together so as to produce a new plant containing the characters of both plants. Out of the two plants one plant has a strong root system while the other has a better flower or fruit yield. The plant of which the root system is taken is called **‘stock’**, while the other plant of which the shoot is selected is known as **‘scion’** or **‘graft’**. These two stems i.e. the stock and the scion are fitted together by making slanting cuts in them and bound tightly with a piece of cloth and is covered with a polythene sheet.

While joining the scion with the stock care should be taken that the diameter of the stock and scion chosen for grafting should be equal. Scion gets the mineral and water from the soil through the stock and develops branches and produce fruits. This method of propagation is used in mango, apple, banana, pear, grape, pineapple and peach.

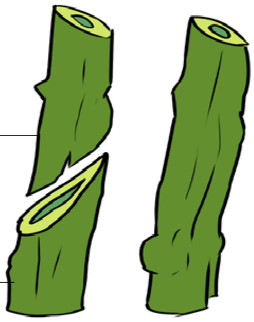


Figure 14.4: Vegetative propagation by grafting.

Vegetative and artificial reproduction in flowering plants

The reproductive part of the plant is a flower. The union of male and female gametes to form a zygote is called fertilization. The transfer of pollen grains from the anther to the stigma of the same flower or the different flower is called pollination. In nature, plants reproduce asexually in a variety of ways. The vegetative reproductive parts in flowering plant are stem, branches, and leaves and they have the following characteristics:

Characteristics of Stem:

Stem develops from the plumule of embryo, Stem is generally the ascending; part of the plant axis, It bears a terminal bud for growth in length, The stem is differentiated into nodes and internodes, the stem nodes possess dissimilar appendages called leaves, The young stem is green and capable of performing photosynthesis, In the mature state it bears flowers and fruits, Leaves and stem branches develop exogenously, Stem exposes leaves, flowers and fruits to their most suitable position in the aerial environment for optimum function, Hair, if present, is commonly multicellular and Stems are usually positively phototropic, negatively geotropic and negatively hydrotropic.

Characteristics of Leaf

- It is dissimilar lateral flattened outgrowth of the stem,
- The leaf is exogenous in origin
- It is borne on the stem in the region of a node,
- An axillary bud is often present in the axil of the leaf.

- Leaf has limited growth. An apical bud or a regular growing point is absent,
- The leaf base may possess two lateral outgrowths called stipules,
- A leaf is differentiated into three parts: leaf base, petiole and lamina.
- The lamina possesses prominent vascular strands called veins,
- It is green and specialized to perform photosynthesis,
- Leaf bears abundant stomata for exchange of gases and it is the major seat of transpiration.

Characteristics of branches

A *branch* or tree *branch* is a woody structural member connected to but not part of the central trunk of a tree. Large *branches* are known as boughs and small *branches* are known as twigs. Due to a broad range of species of trees, *branches* and twigs can be found in many different shapes and sizes.

Application activity 14.1

1. Write on the methods of artificial vegetative propagation.
2. Cassava produces flowers, fruits and seeds. Why people prefer to grow cassava by cutting rather than germination of seed?
3. Describe the characteristics of vegetative reproductive parts in a flowering plant
4. Explain the application of artificial propagation in growing improved varieties of plants.

14.2. Sexual reproduction in plants

Activity 14.2

Collect different forms of flowers from the school compound or around the school, such as hibiscus, morning glory, sweet potato, or maize flower (use any type of flower in your community not necessarily the ones mentioned here)

1. Observe and describe the structures of collected flowers.
2. How do collected flowers differ externally?
3. Cut one of the flowers into two halves, draw and label one half of flower.

14.2.1. Types, structure and functions of flowers

a) Types of flowers

1. **According to absence of some reproductive parts of the flower, we can distinguish:**

   a) **Unisexual flower:** is a flower that consists of one type of reproductive organ. This can be: **staminate:** unisexual male (with androecium only), or **carpellate:** unisexual female (with gynoecium only). E.g. flower of papaya.

   b) **Bisexual or hermaphrodite flower:** a flower with the two reproductive organs. It contains both male and female reproductive organs (androecium and gynoecium). E.g. flowers of beans.

   Dioecious plants are plants that have male flowers and female flowers on separate plants (e.g. papaya/pawpaw) while **monoecious** plants are plants that have both male and female flowers on the same plant (e.g. maize).

2. **According to the position of ovary in the point of insertion of calyx, corolla and stamen, we can distinguish:**

   a) **A flower with inferior ovary:** it is when the ovary is located below the point of insertion of calyx, corolla and stamens.

   b) **A flower with superior ovary:** it is when the ovary is located over the point of insertion of calyx, corolla and stamens.

   c) **The semi-infer or semi-super flower:** when ovary is neither infer nor super but in the middle of receptacle which is hollowed.

   - When sepals are joined together, the flowers are called **gamosepal,** and where are not joined together, the flower is called **dialysepal.**
   - When petals are joined together, the flowers are called **gamopetal,** and when are not joined together, the flower is called **dialypetal.** When they are absent, the flower is called **apetal.**

3. **According to the shape and symmetry of the flower, we can distinguish:**

   i. **Zygomorphic or irregular flower:** a flower with a bilateral symmetry. The flower cannot be divided into two similar halves. E.g. flowers of beans, cassia.

   ii. **Actinomorphic or regular flower:** a flower with a radial symmetry. The flower can be divided into two or more planes to produce similar halves. E.g. flowers of coffee, orange.

3. **Dichogany: it is when male and female organs of the flower mature at different times. We can distinguish:**

- **Protandry:** when stamens mature before pistil.
- **Protogyny:** when pistil matures before stamen.

4. **Inflorescence is when two or more flowers borne on a common stalk.**

a) Structure of a typical complete flower

A flower is a reproductive organ of a plant, which produces **fruits** and **seeds**.

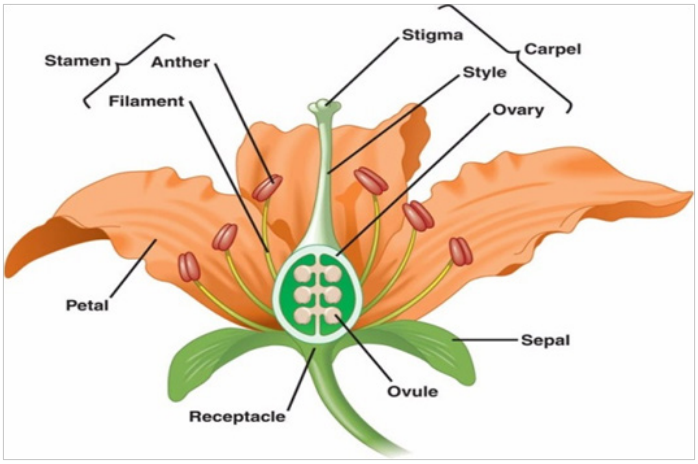


Figure 14.5: Diagram of a complete flower.

A typical hermaphrodite or bisexual flower contains the following parts:

- **Pedicel:** it is the stalk which attaches the flower on the main floral axis.
- **Receptacle:** it is the swollen part at the end of the stalk where other parts of the flower are attached.
- **The calyx:** it is the set of **sepals,** generally having green colour. They protect the internal parts of the flower. In some plants, the sepals are coloured and are called **petaloids.**
- **The corolla:** it is the set of **petals,** with different colours and nectar glands that produce sugary substances which participate in attraction of pollinating agents. In some plants, the petals are green and are called **sepaloids.** Both calyx and corolla are collectively called **perianth.** They are called floral envelope or accessory organs as they do not participate directly in reproduction, or in formation of fruits and seeds, they all insure the protection of internal parts of the flower.
- **Androecium:** is the male reproductive organs of the flower. It consists of many **stamens.** A stamen consists of: the **filament** which supports

anther, and **anther** which contains the pollen grains or male gametes.

- **Gynoecium/pistil:** is the female reproductive organ. It consists of many carpels, and each carpel is made of: stigma (plural: stigmata), style and ovary with ovules.

  a) The stigma: receive pollen grains from anther during pollination.

  b) Style: supports the stigma in a good position to receive pollen grains.

  c) Ovary: a sac where ovules are produced. Ovules become seeds after fertilisation.

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Gynoecium/pistil: is the female reproductive organ.

It consists of many carpels, and each carpel is made of: stigma (plural: stigmata), style and ovary with ovules.

- **The stigma:** receive pollen grains from anther during pollination.
- **Style:** maintains the stigma in a good position to receive pollen grains.
- **Ovary:** a sac where ovules are produced. Ovules become seeds after fertilisation.

Application activity 14.2.1

1. What are the male and female structures of a flower?
2. How might be an advantage for a plant to have many flowers together in a single structure?
3. Where does the female gametophyte develop?
4. Describe the flower and how it is involved in reproduction.

14.2.2. Pollination and double fertilisation in flowering plants and events in a flower after fertilisation

Activity 14.2.2

Use library resources to identify different pollinating agents and describe the process of double fertilization in flowering plants.

1. **Pollination**

Pollination is transfer of pollen grains from anther to the stigma.

a) **Types of pollination:** there are two types of pollination such as: self-pollination and cross-pollination.

i. **Self-pollination:** it is the transfer of pollen grains from anther to the stigma of the same flower, or of different flowers but of the same plants. It involves one plant. E.g. flowers of maize and beans.

ii. **Cross-pollination:** it is the transfer of pollen grains from anther to the stigma of the flower of another plants. It involves two plants. E.g. flowers of pawpaw.

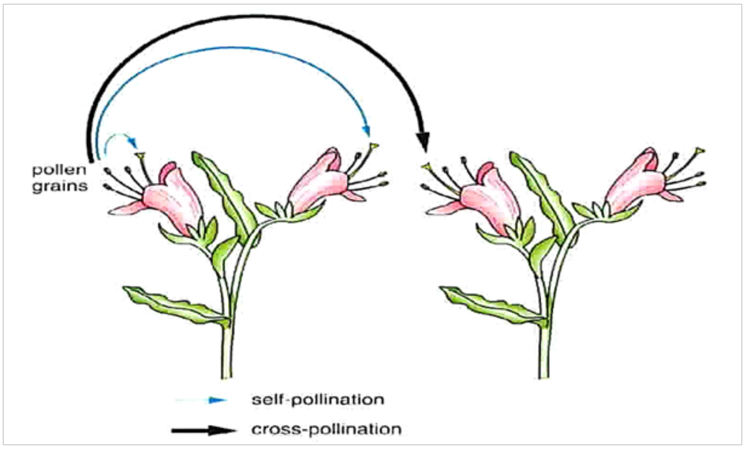


Figure 14.6: self and cross-pollination

b) Main Pollinating agents

Flower structure is closely related with the way they are pollinated. This means that flowers are adapted to specific agents or mode of pollination. ***The common agents of pollination are: insects (entomophily), wind (anemophily), water (hydrophily), humans (anthropophily), and birds (ornithophily).***

Characteristics of insect-pollinated flowers: (entomophilous flowers):

- Flowers produce the nectar to attract pollinators.
- Flowers have large brightly coloured corolla to attract pollinators.
- Production of scents to attract pollinators.
- The surface of the stigma should be sticky to hold pollen grains.
- Pollen grains are **sticky**and rough enough to remain on the surface of stigma.

Characteristics of wind-pollinated flowers: (enemophilous flowers)

- The flowers have large stigma to hold pollen grains.
- The surface of the stigma should be sticky to hold pollen grains.
- Pollen grains are rough enough to remain on the surface of stigma.
- The flowers are or are not brightly-colored.
- They have or do not have scent.
- They do or do not secrete nectar.
- They produce large quantities of pollen grains, as much of them never reach the stigmas.

2. Double fertilization and events after fertilization in flowering plants

Double fertilization is a complex fertilization mechanism of flowering plants (angiosperms). This process involves the joining of a female gametophyte (megagametophyte, also called the embryo sac) with two male gametes (sperm).

a) Development of pollen grains and plant ovules.

i. Development of pollen grains

The pollen grains are produced in the anthers while the ovules are produced in the ovary.

Pollen grains

Each anther has four pollen sacs which contain many diploid microspore mother cells that undergo meiosis to form four microspores each. At first, the four microspores remain together as tetrads. The nucleus of each microspore then divides by mitosis, forming a generative nucleus and a tube or vegetative nucleus. At this point, the content of the pollen grain may be considered as the male gametophyte. A two-layered wall forms around each pollen grain. The outer wall, the exine is thick and sculptured. The inner wall, the intine is thin and smooth. There are many pores or apertures in the wall through which a pollen tube may emerge.

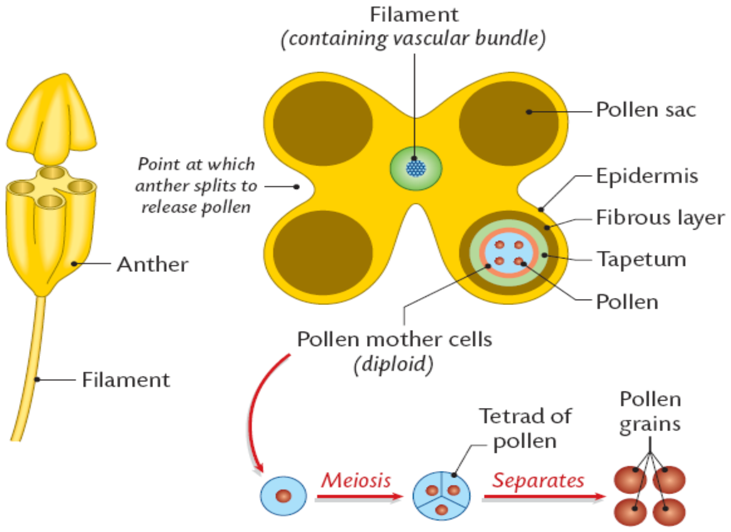


Figure 14.7: Development of pollen grains

ii. Development of Plant ovule

Each ovule is attached to the ovary wall by a short stalk called funicle.

The main tissue in the ovule is the nucellus which is enclosed and protected by the integuments.

At one end of the ovule, there is a small pore called micropyle. A single diploid megaspore mother cell in the nucellus undergoes meiosis, producing four megaspores. Three of the four megaspores degenerate, while the remaining cell, called the embryo sac, grows to many times its original size. The nucleus of the embryo sac divides mitotically three times, resulting in eight haploid nuclei which are arranged in groups of four nuclei at the two poles. At this point, the contents of the embryo sac may be regarded at the female gametophyte.

One nucleus from each pole migrates to the centre of the embryo sac. These two nuclei are called polar nuclei, and they fuse to form a single diploid nucleus. Meanwhile, cell walls form around the remaining six nuclei and they form the synergids, antipodals and the egg (ovum). Only the egg functions as the female gamete.

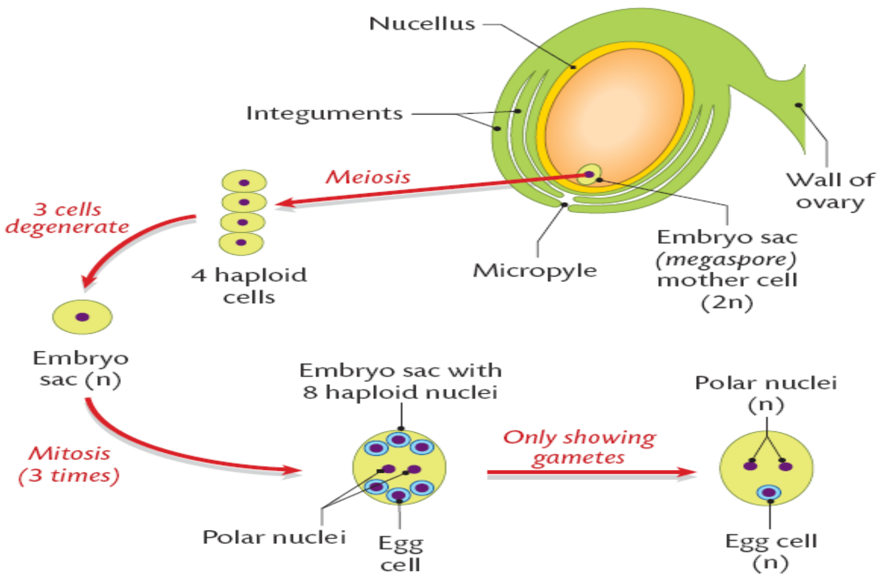


Figure 14.8: Development of plant female gamete

In summary, the pollen grain: contains two haploid nuclei: one called generative nucleus, and **the other** the tube nucleus.

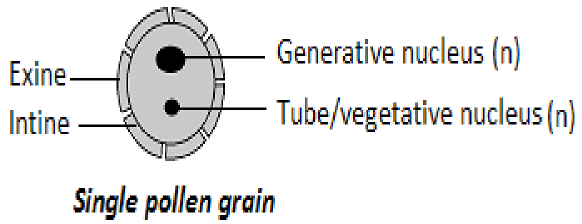


Figure 14.9: a pollen grain

On the other hand, the ovule or embryonic sac contains eight nuclei:

- Three antipodal nuclei/cells at one end
- Two polar nuclei/cells in the middle of ovule
- Two synergids (non-functional nuclei)
- One big egg cell.

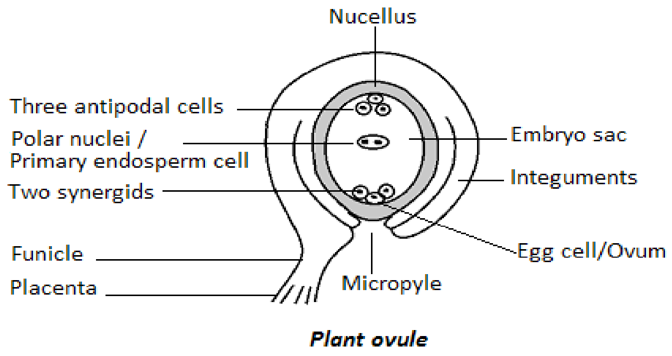
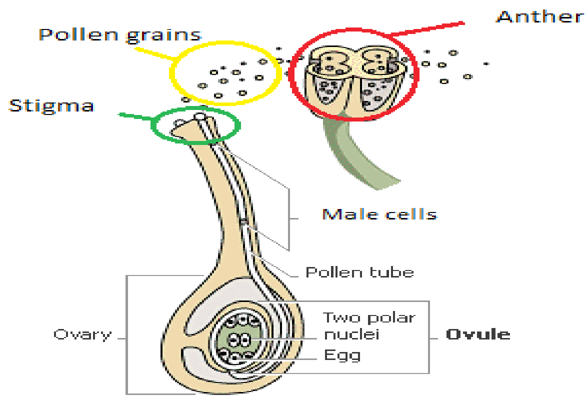


Figure 14.10: structure of plant ovule

The process of double fertilization: It begins when a pollen grain adheres to the stigma of the carpel, the female reproductive structure of a flower. The pollen grain then takes in moisture and begins to germinate, forming a pollen tube that extends down toward the ovary through the style.

The growth of the pollen tube is controlled by **the pollen tube nucleus.** In the pollen tube, the generative nucleus divides mitotically into two haploid nuclei which are the **male gamete nuclei**. These follow behind the tube nucleus as the pollen tube grows down the style towards the ovule. The tip of the pollen tube then enters the ovary and penetrates through the micropyle opening, releasing the two sperms in the megagametophyte or ovule.

The tube nucleus degenerates, leaving a clear passage for the entry of male nuclei. ***One nucleus fertilizes the egg*** cell to form a **diploid zygote (2N),** which will grow into a new plant embryo**;** the ***other fuses with polar nuclei*** to form a **triploid nucleus (3N)**, which will grow into a food-rich tissue known as **endosperm,** which nourishes the seedling as it grows.



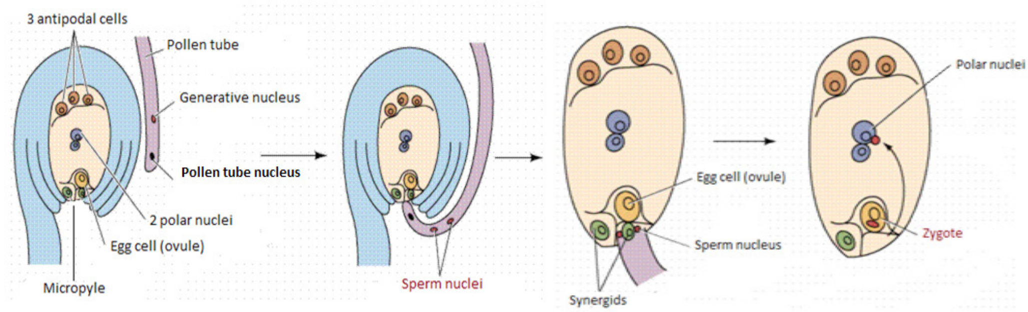


Figure 14.11: the process of double fertilization.

This process is described as **double fertilisation** and is typical of angiosperms. If there is more than one ovule in the ovary, each must be fertilised by separate pollen grain and hence the fruit will have many seeds genetically different from each other.

3. Events in a flower after fertilization

After fertilisation, the calyx, corolla, stamens and style may wither gradually and **fall off**, but in some flowers the calyx may persist. The ovule forms the **seed**, the two integuments of the ovule will form the **seed coat**, and the ovary will develop into **fruit**, with the ovary wall forming the **pericarp (fruit wall).** The diploid zygote undergoes cell division to form the **embryo**, the triploid primary endosperm nucleus develops into **endosperm**, a store used by the developing embryo. This persists in endospermic seeds of monocotyledons. The micropyle persists as a **small hole** in the seed coat through which water is absorbed during germination.

Table 14.2: Floral parts and their fate after fertilization

Floral Part	Fate after fertilization
(a) sepals, petals & stamens	All wither and drop off
(b) ovary i) ovary wall ii) ovules iii) integuments iv) fertilized egg	• Becomes the fruit • fruit wall • seeds • seed coat (testa) • embryo

Application activity 14. 2.2

1. Are angiosperms typically wind or animal pollinated? How does this process occur?
2. What is meant by the term endosperm?
3. How are brightly coloured petals advantageous to the plant?
4. What do you understand by the term double fertilization?
5. What happens to the antipodal cells and synergids cells after fertilization?

14.2.3 Structures and types of fruits and seeds

Activity 14. 2.3

Observe slides containing micrographs of different fruits and seeds. According to their characteristics:

a) Differentiate fruits.

b) Draw and show a structure of seed as seen on microscope

Below are some examples of fruits:

Figure 14.12: Different fruits

A fruit is a structure formed from the ovary of a flower, usually after the ovules have been fertilized. In nature, a fruit is normally produced only after fertilization of ovules has taken place, but in many plants, largely cultivated varieties such as seedless citrus fruits, grapes, bananas, and cucumbers, fruit matures without fertilization, a process known as **parthenocarpy**. Ovules within fertilized ovaries develop to produce seeds. In unfertilized varieties, seeds fail to develop, and the ovules remain with their original size.

A fruit consists of two main parts; **pericarp** (fruit wall) and the **seed**. The pericarp has three layers: **epicarp** or exocarp (outermost), **mesocarpe** (middle) and **endocarp** (inner).

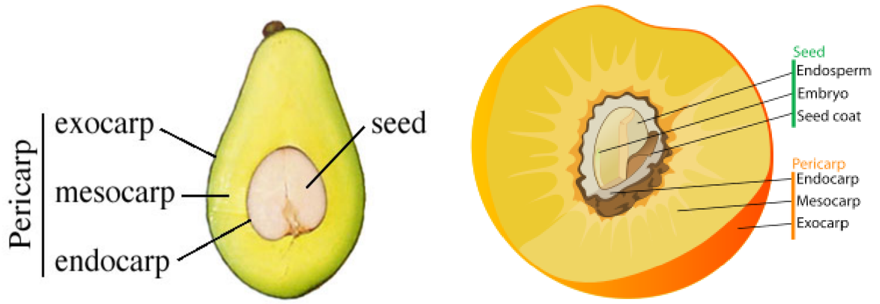


Figure 14. 13: Structure of a fruit

The fruit can have a dry pericarp or fleshy pericarp. The fruits with fleshy pericarp include: berry and drupe. **Drupe** is a fleshy fruit with only one seed, E. g. avocado.

Figure 14.14: Structure of a drupe

Berry is a fleshy fruit having many seeds inside of it. E.g. tomatoes, orange, and pawpaw.

Figure 14.15: Structure of berry

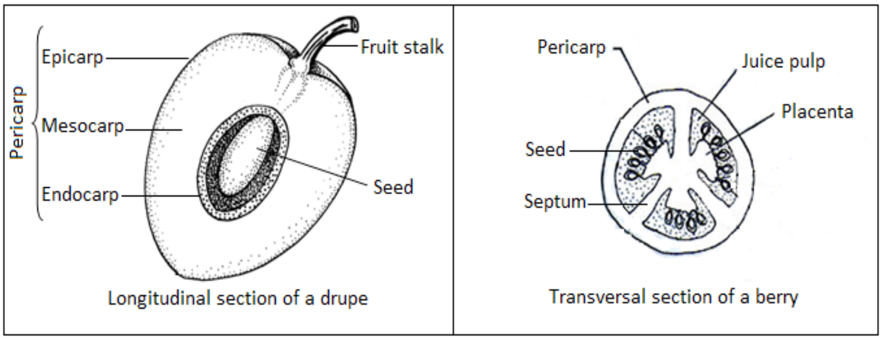


Figure 14.16: structures of drupe and berry

The fruits with dry pericarp include **indehiscent fruit** or **dehiscent fruit**. Indehiscent fruits do not open. Seeds remain inside of the fruits. E.g. fruits of coconuts. Dehiscent fruits open and release seeds. These include: dehiscent fruits with one carpel, and those with many carpels. Dehiscent fruits with one carpel include; those which open along one side, e.g. follicle; and those which open along both sides, e.g. legume (beans). Fruits of eucalyptus are exam of dehiscent fruits with many carpels.

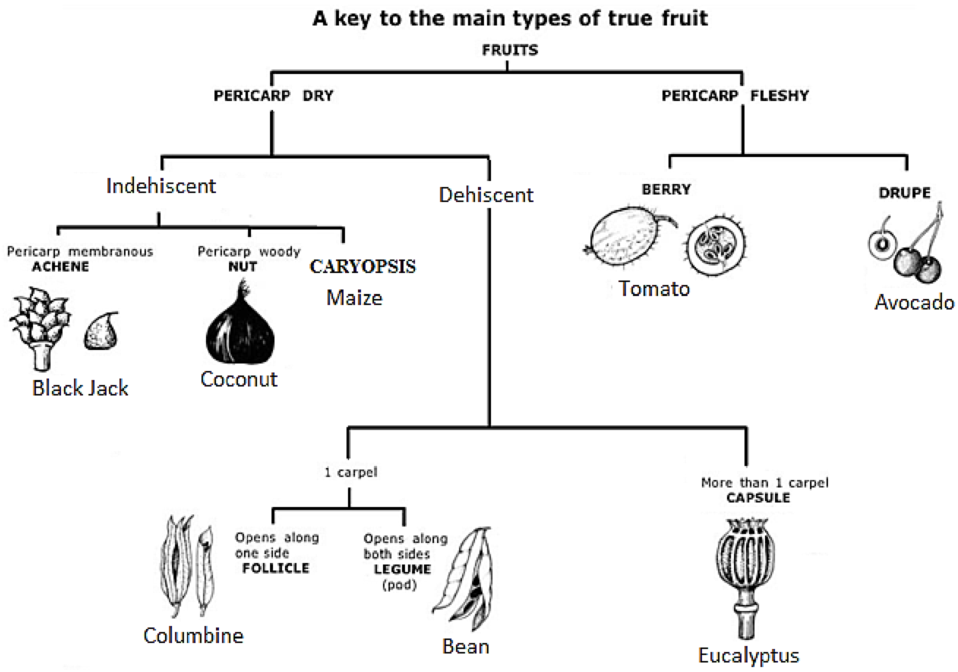


Figure 14.17: Types of fruits

The major function of a fruit is the protection of developing seeds. In many plants, the fruit also aids in seed distribution (dispersal).

Food value

Fruits are eaten raw or cooked, dried, canned, or preserved. Carbohydrates, including starches and sugars, constitute the principal nutritional material. Citrus fruits, tomatoes, and strawberries are primary sources of **vitamin C**, and most fruits contain considerable quantities of **vitamin A** and **vitamin B**. In general, fruits contain little protein or fat. Exceptions are avocados, nuts, and olives, which contain large quantities of fat, and grains and legumes, which contain considerable protein.

A seed is an embryonicplant enclosed in a protective outer covering. The formation of the seed is part of the process of reproduction in seed plants, the spermatophytes, including the gymnosperm and angiosperm plants. Seeds are the product of the ripened ovule, after fertilization by pollen and some growth within the mother plant. The embryo is developed from the zygote and the seed coat from the integuments of the ovule.

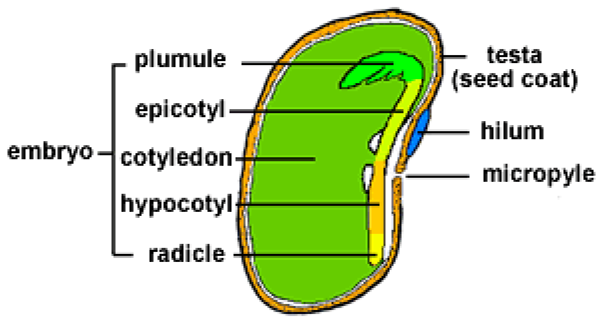


Figure 14.18: structure of a seed

The main components of the seed:

A seed is made up of a **seed coat** (**testa**), one or two **cotyledons** and an **embryonic axis**. The embryonic axis is made up of a plumule, an epicotyl, a hypocotyl and a radical. A seed which has one seed-leaf is described as monocotyledonous, and one which has two, as dicotyledonous. Maize is **monocotyledonous** seed while bean is a **dicotyledonous** seed.

- The **cotyledons**, the seed leaves, attached to the embryonic axis. There may be one (Monocotyledons), or two (Dicotyledons). The cotyledons are also the source of nutrients in the non-endospermic Dicotyledons, in this case they replace the endosperm, and are thick and leathery. In endospermic seeds the cotyledons are thin and papery.
- The **epicotyl**, the embryonic axis above the point of attachment of the cotyledon(s).
- The **plumule**, the tip of the epicotyl, and has a feathery appearance due to the presence of young leaf primordia at the apex, and will become the shoot upon germination.

- The **hypocotyl**, the embryonic axis below the point of attachment of the cotyledon(s), connecting the epicotyl and the radicle, being the stem-root transition zone.
- The **radicle**, the basal tip of the hypocotyl, grows into the primary root.

Monocotyledonous plants have two additional structures in the form of sheaths. The plumule is covered with a **coleoptile** that forms the first leaf while the radicle is covered with a **coleorhiza** that connects to the primary root and adventitiousroots form from the sides. Here the hypocotyl is a rudimentary axis between radicle and plumule.

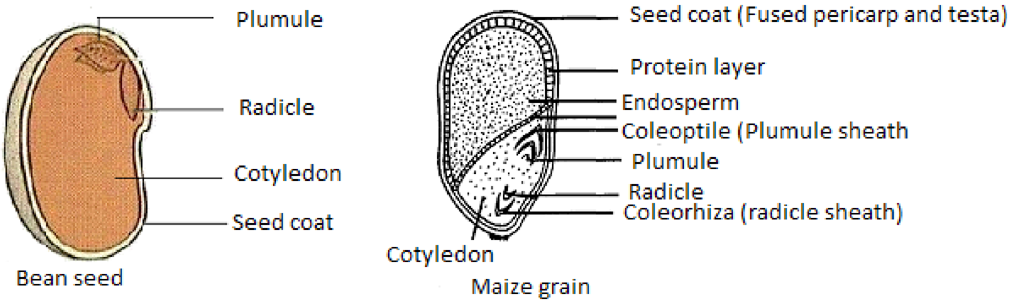


Figure 14.19: structure of dicotyledonous and monocotyledonous seeds

Application activity 14.2.3

1. Describe the structure of a drupe
2. Differentiate between a drupe and a berry
3. What would happen to the fruit if ovules in the flower did not develop?
4. Compare the typical structure of seeds that are dispersed by animals to those dispersed by wind and water.

14.2.4. Fruits and seeds dispersal with their adaptations

Activity 14.2.4

Use library resources like books, internet and search to find answers for the following questions:

1. Suggest ways of fruits and seeds dispersal.
2. Explain adaptation of fruits dispersed by animals.

Dispersal of fruits and seeds is the scattering of fruits and seeds from their mother plants. They are four methods of seeds and fruits dispersal such as:

1. Dispersal by **Wind**
2. Dispersal by **Water**
3. Dispersal by **Animals** and
4. **Mechanical** Dispersal.

Seeds disperses by wind or water are typically **lightweight**, allowing them to be carried in air or to float on the surface of water. The wind carries also small seeds that have wing-like structure. Seeds dispersed by animals are typically contained in sweet, nutritious flesh fruits. They can be carried externally on their feet, fur, feathers, or beaks. Those seeds with hooks or sticky substances rely on the chance that they will attach themselves to a passing animal. Other seeds are eaten by animals and passed out in the faeces.

With mechanical Dispersal: all dehiscent fruits scatter the seeds when they burst. This dehiscence is accompanied by the expression of great force in many fruits so that seeds are jerked a considerable distance away from the mother plant. Such fruits are called explosive fruits.

These seeds will germinate where the faeces will be deposited. The dispersal of seeds is important for the survival of the plant species because:

- It minimises overcrowding of plants growing around the parent plant that could then result in too much competition for nutrients and light;
- It allows the plant species to colonise new habitats which can offer suitable conditions.

Application activity 14.2.4

1. Why is it adaptive for some seeds to remain dormant before they germinate?
2. The seeds of a bishop pine germinate only after they have undergone a forest fire. Evaluate the significance of this structural adaptation.
3. Evaluate the importance of seed dispersal.

SKILLS LAB

After studies, and completion of this unit 14, student-teachers will use the acquired knowledge to increase the crop productivity using different modes of vegetative and artificial propagation. They will also improve the quality of fruit plants by using for example grafting method.

End unit assessment 14

PART A

A) Multiple choice questions: choose the best answers.

1. In cutting method of vegetative propagation, cuttings are mainly taken from

a) Leaves of parent plant

b) Roots or stems of parent plant

c) Shoots of parent plant

d) Buds of parent plant

2. Artificial methods of vegetative propagation includes

a) Cloning

b) Grafting

c) Cuttings

d) Both b and c

3. Example of plant in which vegetative propagation is occurred by leaves is called

a) Cannabis

b) Chrysanthemum

c) Bryophyllum

d) Brassica

4. Which of the following is NOT an advantage of asexual reproduction?

a) Rapid reproduction.

b) High genetic diversity.

c) No need for a mate.

d) Low resource investment in offspring.

B) Questions with short and long answers

1. Name the plants which are grown by grafting method.
2. What do you understand by grafting?
3. How will you show that vegetative propagation takes place in potatoes?
4. Explain the method by which the sugarcane and rose are grown.
5. Give the names the different methods of artificial vegetative reproduction.
6. Explain the term vegetative reproduction and give one example of plant which reproduces by using this type of asexual reproduction.

PART B

1. Answer by true or false

a) Seeds that are dispersed by animals are not contained in a flesh-sweet tissue.

b) During pollination, pollen grains move from stigma to anther.

2. Chose the letter that best answers the question or complete the statement.

a) Which of the following is not part of a flower?

i. Stamens

ii. Petals

iii. Carpels

iv. Stem

v. Sepals.

b) Which flower structure that includes all the others listed below?

i. Stigma
ii. Carpel
iii. Ovary
iv. Style
v. Ovule

c) The thickened ovary wall of a plant may join with other parts of the flower stem to become the

i. Cotyledon
ii. Fruit
iii. Endosperm
iv. Seed

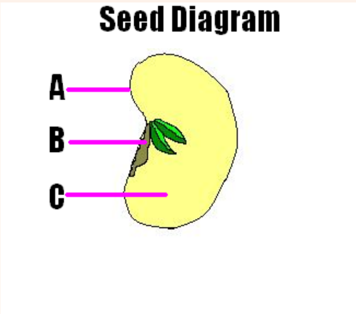
d) In angiosperms the structures that produce the male gametophyte are called the

i. Pollen tubes
ii. Stigma
iii. Anthers
iv. Sepals

e) In angiosperms, the mature seed is surrounded by a

i. Flower
ii. Fruit
iii. Cotyledon
iv. Cone

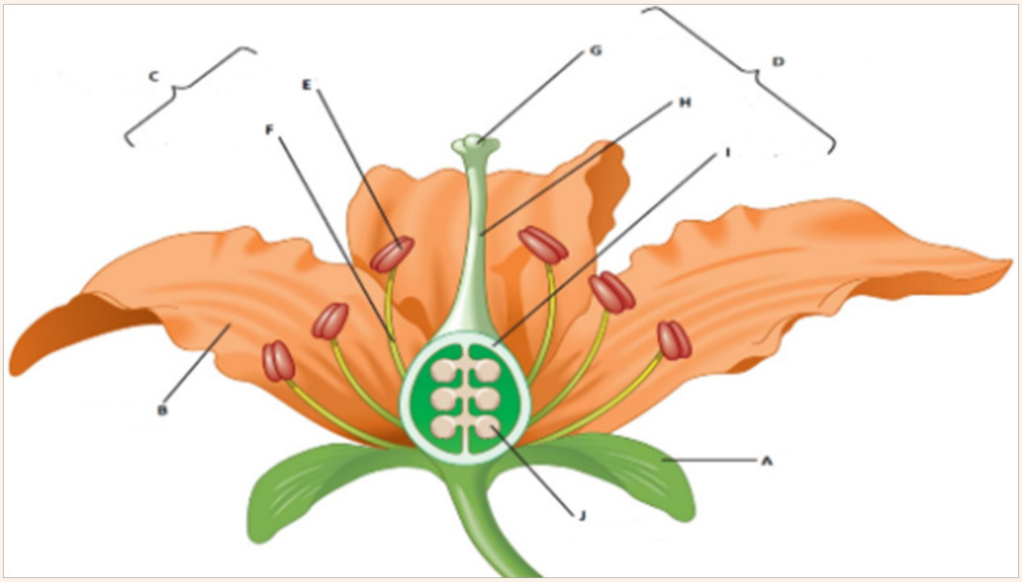
3. Which are more likely to be dispersed by animals- the seeds of angiosperms or the spores of a fern? Explain your reasoning.
4. Pollination is a process that occurs only in seed plants. What process in seedless plants is analogous to pollination?
5. Propose a hypothesis to explain why angiosperms have become the dominant type of plant on the earth.
6. Study the structure of the seed bellow



a) Name the parts labelled by: A, B and C

b) What is the importance of the part C for a growing seedling?

7. Many flowers have bright patterns of coloration that directly surround the reproductive structures. Evaluate the importance of those bright-coloured patterns to plants.
8. What is the function of endosperm?
9. Some plants form flowers that produce stamens but no carpels. Could fruit form on one of these flowers? Explain your answer.
10. Distinguish between pollination and fertilization.
11. Give names of letters from A to J, and explain the function of the parts represented by: B, G, and E.



12. Explain why the relationship between bees and flowers is described as mutually beneficial.
13. What is the main advantage of cross-pollination?
14. Why are the stamens of wind-pollinated plants and insect-pollinated plants different?
15. Differentiate wind-pollinated flowers from insect-pollinated flowers.
16. Give one example of a plant that uses each of the following dispersal mechanism:

a) An explosive device which works by being inflated with water.

b) A winged seed lifted by air currents

c) A buoyant seed carried by sea currents

d) A gluey substance which sticks the seed to an animal.

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