BIOLOGY

CLASS

10

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If there is any objection with regard to the use of pictures and photographs in this book, please contact the publisher.

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Preface

Science is a way of finding out about the world by asking questions and trying to answer them by testing and observing. By devising experiments and looking at the results, students can get closer to the truth about how the world works. The Biological science is one of the important disciplines of the science that deals with the study of living things, their characteristics and the physiological processes, and their interactions in the world. It is undergoing rapid expansion; thus, topics such as biotechnology, cell biology, neuroscience, genetics, evolution and ecology are advancing rapidly.

The study of Biology involves making observations, formulating a hypothesis, and conducting scientific experiments in order to make meaning of the investigations.

This book is written based on the prescribed BCSE syllabus of the Royal Education Council, Bhutan.

Towards making the book user friendly, the book is designed with the following unique features:

- *contextualised to Bhutanese context with learning activities and examples.*
- *ample illustrations to substantiate the concepts.*
- *experiments and practical to facilitate learners construct their understanding of the world based on engagement with the real world.*
- *hands-on activities to develop skills and values and also to engage students authentically in exploring the concepts learnt.*
- *assessment questions at the end of chapters consist of good number of competency based test questions (CBT) critical in developing scientific ways of thinking.*
- *activity end questions include 2-3 direct questions related to activity and 1-2 indirect high level questions related to the application of the concepts.*
- *a summary at the end of every chapter is provided for easy skimming and revision.*
- *sample test paper at the end of the book with good number of competency based test questions.*
- *glossary at the end of the book is to help students reinforce their understanding of the scientific concepts.*
- *web links for further exploration related to the topic.*

Upon the meaningful engagement of students in the learning of Biology, the learning activities guided by the scientific concepts ensure students to realise the purpose of learning Biology. This study, thus, makes students scientifically literate with scientific cognitive skills and capabilities.

I would request all teachers and students to provide your valuable feedbacks, by which the book can be improved further.

Author

Syllabus

1. Cells

- *Describe the differences between the basic structures of a prokaryotic cell and a eukaryotic cell.*
- *Explain how substances enter and leave cells through the cell membrane by diffusion, osmosis and active transport.*
- *Explain division of cells by mitosis during growth, and by meiosis to produce gametes.*

2. Green plants

A. Nutrition

- *Explain that photosynthesis occurs in phases and explain each phase.*
- *Explain that the rate of photosynthesis by is affected by light intensity, carbon dioxide concentration or temperature.*
- *Explain the utilisation of the products of photosynthesis by plants.*

B. Hormones

- *Explain that plant hormones are used to control plant growth and development, including the plant hormones used commercially (rooting and grafting).*

C. Transport

- *Explain the importance of water in the support of plant tissues.*
- *Explain how minerals and food synthesised in the leaves are transported to other parts of the plants.*

3. Humans as organisms

A. Nutrition

- *Explain the role of enzymes, stomach acid and bile in the process of digestion.*

B. Circulation

- *Describe the composition and functions of blood.*
- *Explain the exchange of substances between capillaries and tissues.*

C. Respiration

- *Explain the processes of aerobic respiration and anaerobic respiration.*
- *Categorise respiration as aerobic respiration or anaerobic respiration, depending on the availability of oxygen.*
- *Explain how an 'oxygen debt' occurs in muscle during vigorous exercise.*

D. Nervous system

- *Describe the pathway taken by nervous impulses in response to a variety of stimuli, including the roles of receptors, sensory neurons and motor neurons.*
- *Explain the rapid responses to dangerous stimuli by the reflex arc and the relay neurone.*

E. Hormones

- *Explain the way in which hormonal control occurs including the effects of insulin, adrenalin and sex hormones.*
- *Describe some medical uses of hormones, including the treatment of diabetes and thyroid dysfunction.*

F. Homeostasis

- *Describe removal of waste products of body functions by the lungs and the kidneys.*
- *Explain regulation of the water content of the body by the kidneys.*

G. Reproduction

- *Explain the uses of hormones in controlling fertility (oral contraceptives inhibiting FSH production and giving FSH as a fertility drug).*

H. Health, disease and drugs

- *Describe the basic structure of and name examples of pathogens from the three types of micro-organisms (viruses, bacteria and fungi).*
- *Evaluate the protection by vaccination from contracting infectious disease.*

4. Variation, inheritance and evolution

A. Variation

- *Explain that sexual reproduction is a source of genetic variation, while asexual reproduction produces clones.*
- *Explain that mutation is a source of genetic variation and has a number of causes.*

B. Inheritance

- *Describe the mechanism of monohybrid inheritance where there are dominant and recessive alleles.*
- *Explain the mechanisms by which some diseases are inherited.*
- *Describe the structure of DNA and its functions.*

C. Evolution

- *Explain the two types of species.*
- *Discuss the mechanisms of speciation.*
- *Name the factors responsible for speciation.*

5. Living things in their environment

A. Ecosystem

- *Explain the components of ecosystem.*
- *Discuss the types of interactions.*
- *Explain a change in an ecosystem leads to competition.*

B. Biodiversity and sustainability

- *Explain biodiversity.*
- *Explain the biodiversity support services.*
- *Discuss the sustainability efforts in preserving biodiversity.*

Practical Works

- *Observe prepared slides of mitosis and meiosis.*
- *Experiment, investigate and demonstrate osmosis with potato cups or egg membranes.*
- *Demonstrate the effect of hypertonic and hypotonic solution on potato strips.*
- *Demonstrate the release of oxygen during photosynthesis.*
- *Demonstrate downward movement of food through phloem.*
- *Tests different food groups e.g. carbohydrates, fats and protein.*
- *Determine the influence of factors such as sunlight and water on photosynthesis.*
- *Carry out experiment on plant hormones i.e. rooting and grafting.*

Assessment

Assessment in science involves detailed process of measuring students' achievement in terms of knowledge, skills, and attitude. The progress of learning is inferred through analysis of information collected. The accuracy and objectivity of assessment determines its validity. The modality and components of assessment should be clearly conveyed to the students. The teacher's expectations should be made clear to students and appropriate learning outcomes should be set. The teachers can play an important role in the students' achievement by effectively monitoring their learning, and giving them constructive feedback on how they can improve, and provide the necessary scaffolding for the needy learners as identified through reliable assessment techniques and tools.

Purpose of Assessment

Assessment is used to:

- **inform and guide teaching and learning:** A good assessment plan helps to gather evidences of students' learning that inform teachers' instructional decisions. It provides teachers with information about the performance of students. In addition to helping teachers formulate the next teaching steps, a good classroom assessment plan provides a road map for students. Therefore, students should have access to the assessment so they can use it to inform and guide their learning.
- **help students set learning goals:** Students need frequent opportunities to reflect on what they have learnt and how their learning can be improved. Accordingly, students can set their goals. Generally, when students are actively involved in assessing their own next learning steps and creating goals to accomplish them, they make major advances in directing their learning.
- **assign report card grades:** Grades provide parents, employers, other schools, governments, post-secondary institutions and others with summary information about students' learning and performances.
- **motivate students:** Students are motivated and confident learners when they experience progress and achievement. The evidences gathered can usher poor performers to perform better through remedial measures.

The achievements and performances of the learners in Biology are assessed on the following three domains:

- **Scientific knowledge:** *Basic knowledge and understanding of cells and their structures and functions; multi-cellular organisms and physiology with their variations, adaptation and theories and evidences of evolution; ecological*

relationships and interdependence; implications of science and socio-economic development on the natural world.

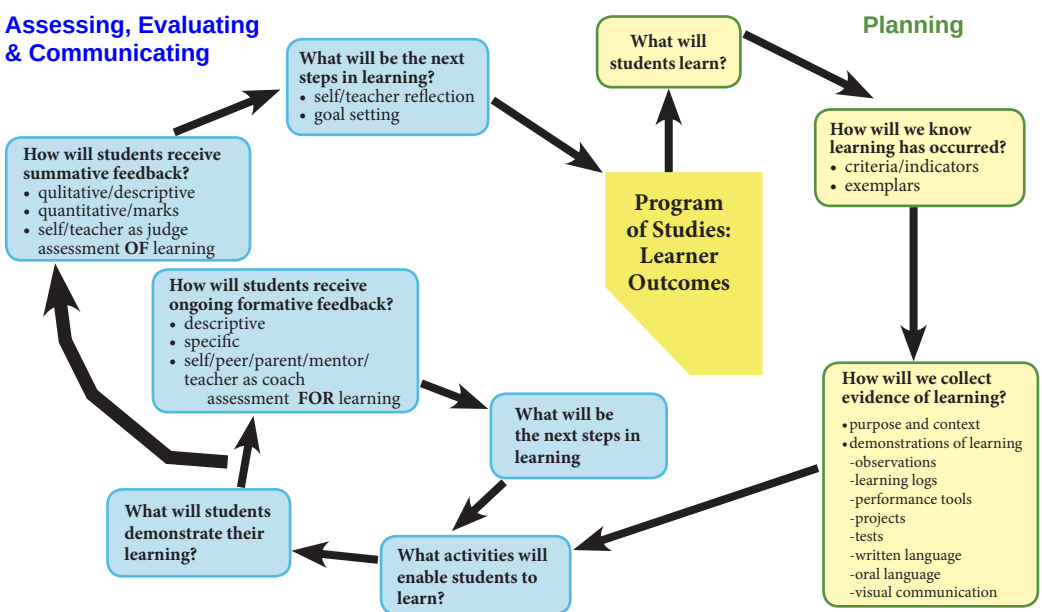
- **Working scientifically:** *Basic understanding of the nature of science, and how science works. Demonstration of logical and abstract thinking and comprehension of complex situations. Explore how technological advances are related to the scientific ideas underpinning them. Compare, contrast, synthesize, question and critique the different sources of information, and communicate their ideas clearly and precisely in a variety of ways, including the use of ICT.*
- **Scientific values and attitudes:** *Consider the power and limitations of science in addressing social, industrial, ethical and environmental issues, and how different groups in the community and beyond may have different views about the role of science. They make informed judgments on statements and debates that have a scientific basis and use their learning in science for planning positive action for the welfare of themselves, others in their community and the environment.*

The Assessment Process

Effective classroom assessment in Science:

- assesses specific outcomes in the program of studies.
- the intended outcomes and assessment criteria are shared with students prior to the assessment activity.

Assessing Students Learning in the Classroom



- assesses before, during and after instruction.
- employs a variety of assessment strategies to provide evidence of students' learning.
- provides frequent and descriptive feedback to students.
- ensures students can describe their progress and achievement, and articulate what comes next in their learning.
- informs teachers and provides insight that can be used to modify instruction.

Scheme of Assessment in Science

The following schemes of assessment are used to assess students' performance:

1. Continuous Formative Assessment (CFA)

Formative assessment is used to provide feedback to teachers and students, so that teaching and learning can be improved through the provision of regular feedback and remedial learning opportunities. It also enables teachers to understand what teaching methods and materials work best.

CFA facilitates teachers to diagnose the learning needs of learners and recognize the individual differences in learning. Through the constructive feedback, students are able to understand their strengths and weaknesses. It also empowers them to be self-reflective learners, who monitor and evaluate their own progress.

CFA should happen daily throughout the teaching-learning processes of the academic year. It is NOT graded, as it is only to give continuous feedbacks to the students.

2. Continuous Summative Assessment (CSA)

Continuous Summative Assessment is another form of continuous assessment (CA). It helps in determining the student's performance and the effectiveness of instructional decisions of teachers. The evidences from this assessment help students to improve learning, and mandate teachers to incorporate varied teaching strategies and resources to ensure quality teaching and learning in the science classes. This assessment also empowers students to be self-reflective learners, who monitor and evaluate their own progress.

In CSA, the students' performances and achievements are graded. This ensures active participations of learners in the teaching and learning processes.

1. Summative Assessment (SA)

Summative assessment (SA) is conducted at the end of the first term and at the end of the year to determine the level of learning outcomes achieved by students. The information gathered is used by teachers to grade students for promotion, and to report to parents and other stakeholders.

The identified techniques for SA are term examinations - first term and annual examinations. The questions for the term examinations should cover all the three domains of science learning objectives, using the principles of Bloom's taxonomy.

Assessment Matrix								
Types of assessment	CFA			CSA			SA	
Definition	It is a continuous process of assessing student's problems and learning needs and to identify the remedial measures to improve student's learning. It also enables teachers to understand what teaching methods and materials work best.			It is a continuous process of grading student's performances and achievements. Teachers provide feedbacks for improvement. It also enables teachers to understand what teaching methods and materials work best.			Assesses student's cumulative performances and achievements at the end of each term.	
Domains	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	SK, WS & SV	SK, WS & SV
Techniques	Quiz & debate,class presentation, homework, class work, immediate interaction with students.	Immediate interaction with students, class work, home work, experiments, exhibition, case studies	Observation of student's conduct, in group work, field trip, excursion, etc.	Home work and chapter end test.	Practical work	Project Work	Term exam	Term exam
Assessment Tools	Q&A, checklist and anecdotal records.	Checklist and anecdotal records.	Checklist and anecdotal records.	Rubrics (HW) and paper pencil test (Chapter end test).	Rubrics (Practical work)	Rubrics (Project work)	Paper pencil test	Paper pencil test
Frequency interval (when &how)	Checklists and anecdotal records must be maintained for each topic throughout the academic year.			HW-for every chapter, Chapter end test – for every chapter.	Practical work once in each term	Project Work –Once for the whole year but assessed two times (half yearly)	Once in a term.	Once in a year.
Format in Progress Report				SK	WS	SV	Mid-Term	Annual Exam
Weightings				T1= 2.5 T2= 2.5	T1= 5 T2= 5	T1= 2.5 T2= 2.5	T1=30	T2=50

Assessment Techniques and Tools

The following techniques and tools are used in assessing students' performance with objectivity.

1. Observation Check list

Observing students as they solve problems, model skills to others, think aloud during a sequence of activities, or interact with peers in different learning situations provides insight into student's learning and growth. The teacher finds out under what conditions success is most likely, what individual students do when they encounter difficulty, how interaction with others affects their learning and concentration, and what students need to learn next. Observations may be informal or highly structured, and incidental or scheduled over different a period in different learning contexts.

Observation checklists are tools that allow teachers to record information quickly about how students perform in relation to specific outcomes from the program of studies. Observation checklists, written in a yes/no format can be used to assist in observing student performance relative to specific criteria. They may be directed toward observations of an individual or group. These tools can also include spaces for brief comments, which provide additional information not captured in the checklist.

Tips for using Observation Checklists

i. *Determine specific outcomes to observe and assess.*

ii. *Decide what to look for. Write down criteria or evidence that indicates the student is demonstrating the outcome.*

iii. *Ensure students know and understand what the criteria are.*

iv. *Target your observation by selecting four to five students per lesson and one or two specific outcomes to observe. Date all observations.*

v. *Collect observations over a number of lessons during a reporting period and look for patterns of performance.*

vi. *Share observations with students, both individually and in a group. Make the observations specific and describe how this demonstrates or promotes thinking and learning.*

vii. *Use the information gathered from observation to enhance or modify future instruction.*

Sample Checklist

Name	Topic: Mitosis									Teacher's comments
	Scientific knowledge			Working scientifically			Scientific values			
	Explains all the phases of mitosis.	Lists down the significance of mitosis.	Draw the phases of mitosis.	Follows correct experimental procedures.	Handles equipment, apparatuses, and chemical safely.	Demonstrates ability to set up experiments.	Respects others ideas and views.	Shows curiosity to learn science.	Demonstrates concern for oneself and others.	
Dorji Om										
Jambay										

1. Anecdotal notes

Anecdotal notes are used to record specific observations of individual student **behaviours, skills, and attitudes** in relation to the outcomes of the science teaching and learning process. Such notes provide cumulative information on students' learning and direction for further instruction. Anecdotal notes are often written as ongoing observations during the lessons, but may also be written in response to a product or performance of the students. They are generally brief, objective, and focused on specific outcomes. The notes taken during or immediately following an activity are generally the most accurate. Anecdotal notes for a particular student can be periodically shared with the student, or be shared at the student's request.

The purpose of anecdotal notes is to:

- provide information regarding a student's development over a period of time.
- provide ongoing records about individual instructional needs.
- capture observations of significant behaviours that might otherwise be lost.

Tips for maintaining Anecdotal Notes

i. Keep a notebook or binder with a separate page for each student. Write the date and the student's name on each page of the notebook.

ii. Following the observations, notes are recorded on the page reserved for that student in the notebook.

iii. *The pages may be divided into three columns: Date, Observation and Action Plan.*

iv. *Keep notes brief and focused (usually no more than a few sentences or phrases).*

v. *Note the context and any comments or questions for follow-up.*

vi. *Keep comments objective. Make specific comments about student strengths, especially after several observations have been recorded and a pattern has been observed.*

2. Project work

Project work is one of the best ways to practice the application of scientific conceptual ideas and skills. The very purpose of including project work is to provide opportunity to explore and extend their scientific knowledge and skills beyond the classroom. Students learn to organize, plan and piece together many separate ideas and information into a coherent whole. Through project work, students learn various scientific techniques and skills, including data collection, analysis, experimentation, interpretation, evaluation and drawing conclusion; and it fosters positive attitude towards science and environment.

The science curriculum mandates students to carry out project work to help them to:

i. develop scientific skills of planning, designing and making scientific artefacts, carrying out investigations, observation, analysis, synthesis, interpretation, organization and recording of information.

ii. enhance deeper understanding of social and natural environment.

iii. develop student's ability to work in group and independently.

iv. provide opportunity to explore beyond the classroom in enhancing their scientific knowledge and skills, which will contribute towards the development of positive attitudes and values towards science and environment.

v. understand how science works and the nature of scientific knowledge.

vi. develop oral and written communication skills.

Teachers can facilitate students to carry out the project work by considering the following suggested guidelines.

- Allow students to select their own project ideas and topics.
- Encourage students to be scientifically creative and productive.
- Provide a clear set of guidelines for developing and completing projects.
- Help students to locate sources of information, including workers in science-related fields who might advise them about their projects.
- Allow students the option of presenting their finished projects to the class.

- Inform students about the general areas on which assessment may be made. For example, scientific content or concepts, originality of ideas, procedures, and the presentation.
- Advice students to contact their teacher for further assistance or consultations, for, students must be closely guided by the teacher starting from the selection of the topic, doing investigations, data collection, and analysis to writing report in a formal style.

Each student is assigned a Project Work for the academic year. The project work is assessed out of 28 marks, which should be converted out of 5 marks for the whole year. Students can share their project work findings, either in the form of class presentation or display.

At the end of the project work, every student must prepare a project work report, about 2000 to 2500 words, in the formal format, suggested in the following section. The product of the project work must be inclusive of write ups, illustrations, models, or collection of real objects.

Following are some of the useful steps that students may follow.

1. Select a topic for the science project

The first step in doing science project is selecting a topic or subject of your interest. Teachers guide students in identification and selection of the topic. The concerned teacher has to approve the topic prior to the commencement of the project work.

2. Gather background information

Gather information about your topic from books, magazine, Internet, people and companies. As you gather information, keep notes from where you got the information as reference list.

3. Write your hypothesis

Based on your gathered information, design a hypothesis, which is an educated guess in the form of a statement, about what types of things affect the system you are working with. Identifying variables is necessary before one can make a hypothesis. For example, The rate of osmosis depends on the concentration gradient between two solutions.. Develop a research question supported by a few questions to test your hypothesis. For example, How does concentration affect the rate of osmosis?. Sub-questions may include, How does the concentration gradients affect the osmosis? What happens to the rate of osmosis as the concentration gradient varies?

4. Identify variables

The hypothesis and the research questions should guide you to identify the variables. When you think you know what variables may be involved, think about ways to change one at a time. If you change more than one at a time, you will not know what variable is

causing your observation. Sometimes, variables are linked and work together to cause something. At first, try to choose variables that you think act independently of each other.

5. Design an experiment or observation method

Having made the hypothesis, design an experiment to test the hypothesis and devise the method of observation. Make a systematic list of what you will do or observe to answer each question. This list is known as experimental or observational procedure. For observations or an experiment to give answers, one must have a "control". A control is a neutral "reference point" for comparison that allows you to see what changing or dependent variable does by comparing it to not changing anything. Without a control, you cannot be sure what variable causes your observations.

6. Write a list of material

Make a list of materials useful to carry out your experiment or observations.

7. Write experiment results

Experiments are often done in series. A series of experiments can be done by changing one variable at a time. A series of experiments are made up of separate experimental "runs". During each run, you make a measurement of how much the variable affected the system under the study. For each run, a different amount of change in the variable is used. This produces a different degree or amount of responses in the system. You measure these responses and record data in a table form. The data from the experiments and observations are considered as a "raw data" since it has not been processed or interpreted yet. When raw data is processed mathematically, for example, it becomes result.

8. Write a summary of the results

Summarize what happened. This can be in the form of a table of processed numerical data, or graphs. It could also be a written statement of what occurred during experiments. It is from calculations using recorded data that tables and graphs are made. Studying tables and graphs, one can see trends or patterns that tell you how different variables cause to change the observations. Based on these trends, you can draw conclusions about the system under the study. These conclusions help to confirm or deny your original hypothesis. Often, mathematical equations can be made from graphs. These equations can help you to predict how a change will affect the system without the need to do additional experiments. Advanced levels of experimental science rely heavily on graphical and mathematical analysis of data. At this level, science becomes even more interesting and powerful.

9. Draw conclusions

Using the trends in your experimental data and your experimental observations, try to answer your original questions. Is your hypothesis correct? Now is the time to pull together what happened in the form of conclusion, and assess the experiments you did. Describe, how variables have affected the observations, and synthesize a general statement. For example, the pressure for the same fluid increases with the increase of depth!

10. Write a report on the project

Having completed all the steps of experiment and investigation with appropriate results and conclusion drawn, the last thing is to write a report. The report should start with an introduction on the topic related to your hypothesis, purpose of the study, literature review, methods used, findings, and conclude with conclusions. Do not forget to acknowledge the support provided by all individuals and organizations. Write a bibliography to show your references in any form. Such information includes the form of document, name of writer, publisher, and the year of publication.

The Format for Project Work write-up (report) should include the following aspects:

- The title of the project work.
- Acknowledgement: Show courtesy to thank the people and organizations for the help received.
- Table of content.
- Introduction: What is the topic about, and why was the topic chosen? hypothesis, research question.
- Background information: Scientific concepts, principles, laws and information on the topic.
- Methodology: Methods of data collection – sampling, tools used, etc; data sorting.
- Data analysis: Data tabulation, data processing, findings, etc. presented in a logical order with illustrations, photographs, and drawings where appropriate and necessary to support the findings.
- Conclusion: Reflection of the findings, learner's experiences and opinions regarding the project.
- Bibliography: List of the sources of the information.

The teacher uses the "Rubric for the Project Work" given below to assess the student's project work. Random viva voce is necessary to guide and support students' work during the course of project work.

Criteria for the Project Work

Name	Criteria						Bibliography (4)	Total scores (28)
	Problem and hypothesis (4)	Background research on the hypothesis (4)	Experimental design / materials / procedure (4)	Investigation (4)	Analysis (4)	Format and editing (4)		
Nima								
Dawa								

Rubrics for the Project Work

Criteria	Scoring				Total Score (28)
	4	3	2	1	
Problem and Hypothesis	• Problem is new, meaningful and well researched. • Hypothesis is clearly stated in the "IF...THEN" format.	• Problem is not new but meaningful. • Hypothesis is clearly stated.	• Problem is stated but neither new nor meaningful. • Hypothesis is not clearly stated.	• Problem is not stated and • Hypothesis is unclear.	
Background research on the hypothesis	• Research is thorough and specific. • All the ideas are clearly explained.	• Research is thorough but not specific. • Most ideas are explained.	• Research is not thorough and not specific. • Few ideas are explained.	• Research not thorough and • Ideas are not explained.	
Experimental design / materials / procedure	• Procedure is detailed and sequential. • All materials are listed. • Safety issues have been addressed.	• Procedure is detailed but not sequential. • Most materials are listed. • Safety issues have been addressed.	• Procedure is not detailed and not sequential. • Few materials are listed. • Few safety issues have been addressed.	• A few steps of procedure are listed. • Materials list is absent. • Safety issues are not addressed.	
Investigation	• Variables have been identified, controls are appropriate and explained. • Sample size is appropriate and explained. • Data collected from at least 4 sources.	• Variables have been identified and controls are appropriate but not explained. • Sample size is appropriate. • Data collected from at least 3 sources	• Variables have somewhat been identified, controls are somewhat known. • Sample size is not appropriate. • Data collected from at least 2 sources.	• Missing two or more of the variables or the controls. • Sample size is not considered. • Data collected from only 1 source.	

Criteria	Scoring				Total Score (28)
	4	3	2	1	
Analysis& conclusion	• Appropriate tool used for analysis. • Explanation is made for how or why the hypothesis was supported or rejected. • Conclusion is supported by the data. • Reflection is stated clearly.	• Appropriate tool used for analysis. • Conclusions are supported by the data. • Not enough explanation is made for how or why the hypothesis was supported or rejected. • Reflection is stated.	• No appropriate tool used for analysis. • Not enough explanation is made for how or why the hypothesis was supported or rejected. • Conclusion is not appropriate. • Reflection is not clear.	• No appropriate tool used for analysis. • Not enough explanation is made for acceptance and rejection of hypothesis. • Conclusion is absent. • Reflection is not stated.	
Format and editing	• Correct format followed throughout. • Report is free of errors in grammar, spelling or punctuation.	• Only one aspect of format is incorrectly done. • Report contains a few errors in grammar, spelling, and punctuation.	• Only two aspects of format are incorrectly done. • Report contains some errors in grammar, spelling, punctuation	• Three or more aspects of format are missing. • Report contains many errors in grammar, spelling, and punctuation.	
Bibliography	• Five or more references are cited in APA format and referenced throughout the paper and presentation.	• Three or four references are cited and referenced throughout the paper and presentation.	• One or two references are cited and referenced throughout the paper and presentation.	• No references made.	
				TOTAL SCORE	

1. Practical Work

Learning by doing is fundamental to science education. Practical work is one of the means that helps students to develop their understanding of science, appreciate that science is evidence driven and acquire hands-on skills that are essential to science learning and in their future lives. The practical work as defined by SCORE (2009a) is '*a "hands-on" learning experience which prompts thinking about the world in which we live*'. Therefore, the purposes of doing practical in science classes are to –

i. help students to gain or reinforce the understanding of scientific knowledge.
ii. develop students' understanding of the methods by which the scientific knowledge has been constructed.
iii. increase a student's competence to engage in scientific processes such as in manipulating and/or observing real objects and materials with due consideration for safety, reliability, etc.
iv. develop technical and scientific skills that improve science learning through understanding and application.
v. develop manipulative skills, knowledge of standard techniques, and the understanding of data handling.
vi. Inculcate excitement of discovery, consolidation of theory, and the general understanding of how science works.

Practical work is integral to the aspects of thinking and working scientifically in science, and must be built in as a full learning experience for students. Students are engaged in a range of practical activities to enable them to develop their understanding through interacting with apparatus, objects and observations.

The assessment of students' scientific skills and their understanding about the scientific processes through practical work is crucial in the process of science learning. To ensure the validity, assessment needs to sample a range of activities in different contexts; and reliability is ensured through the appropriate moderation procedures so that fairness in assessment is maintained.

The new science curriculum envisages that students are given the opportunity to undertake work in which they make their own decisions. They should be assessed on their ability to plan, observe, record, analyze, communicate and evaluate their works.

To ensure that the assessment in the practical is evidence-based and objective, rubrics is used. The rubrics are scored out of 16, which must be reduced to 5% each for the two terms.

Criteria for the Practical Work

Name	Criteria				Total scores (16)
	Scientific operation & report format (4)	Results & data representation (4)	Analysis & discussion (4)	Conclusions (4)	
Sonam					
Wangmo					

Rubrics for the Practical Work

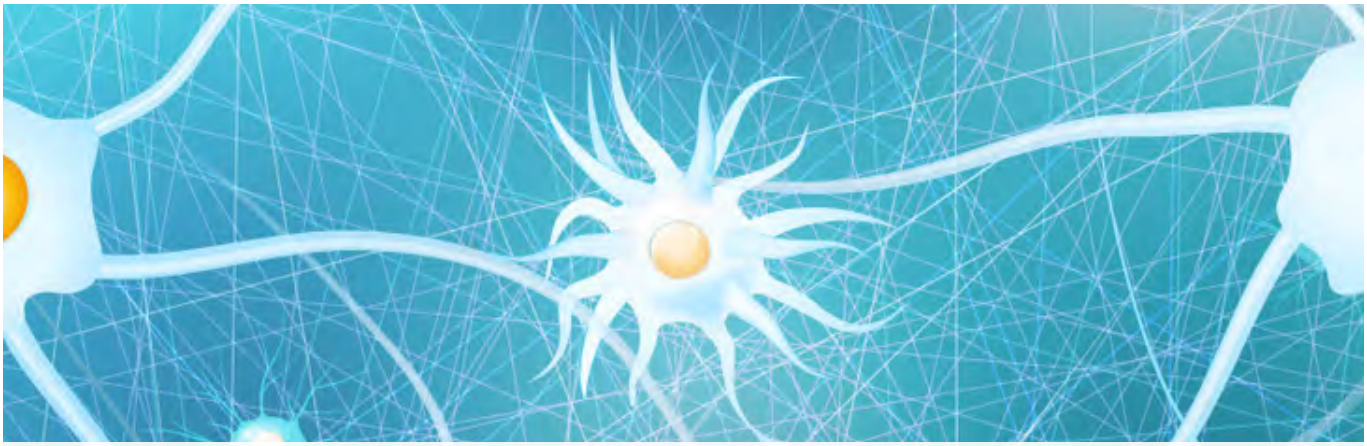
Criteria	Scoring				Total Score (16)
	4 (Very good)	3 (Good)	2 (Fair)	1 (Poor)	
Scientific operation	• Purpose is clear purposeful. • All the procedures are followed systematically. • Full attention is given to relevant safety for oneself and others.	• Purpose is clear purposeful. • All the procedures are followed but not done systematically. • Work is carried out with some attention to relevant safety procedures.	• Purpose is inaccurate, general or extraneous. • A few procedures are skipped. • Safety procedures were frequently ignored	• Purpose is vague or inaccurate. • Procedures are not followed • Safety procedures are ignored completely.	
Results & data representation	• Representation of the data/results in tables and graphs with correct units of measurement. • Transformations in the results/data are evident. • Graphs and tables are scaled correctly, with appropriate titles and labels.	• Representation of the data/results in tables and graphs with some error in units of measurement. • Transformations in some of the results/ data are evident. • Graphs and tables are scaled correctly with appropriate titles but no labels.	• Representation of the data/results in tables and graphs numerous error in units of measurement. • Transformations in most of the results/ data are not evident. • Graphs and tables are scaled correctly, but without appropriate titles and labels.	• Representation of the data/ results in tables and graphs are not relevant. • Transformations in the results/ data are not evident. • Some attempts are evident to produce graphs from the data/ results.	
Analysis & discussion	• All the tools used for analysis are appropriate. • A comprehensive discussion, containing a comparative analysis is evident. • The experimental findings are significant to the purpose of the experiment.	• Most of the tools used for analysis are appropriate. • A comprehensive discussion, containing some comparative analysis is evident. • The experimental findings do not have strong significance to the purpose of the experiment.	• Only a few tools are used for analysis. • A comprehensive discussion, containing a few comparative analysis is evident. • The experimental findings have weak significance to the purpose of the experiment.	• No appropriate tools are used for analysis. • Comprehensive discussion is absent. • The experimental findings have no significance to the purpose of the experiment.	
Conclusions	• Conclusions are drawn from the findings and are significant to objectives of the experiment. • Limitations of experiment are identified, and ways to improve are evident.	• Conclusions are drawn from the findings but less significant to objectives of the experiment. • Limitations of experiment are identified.	• Conclusions are not drawn from the findings and have no significance to objectives of the experiment. • Some limitations of experiment are identified.	• No valid conclusions drawn from the findings. • Limitations of experiment are not identified.	
				TOTAL SCORE	

Chapter-wise Weighting and Time allocation

Chapters	Chapter title	Maximum time required (mins)	Weighting (%)
Chapter 1	The Cell - The Unit of Life	280	10%
Chapter 2	Green plants	600	17%
Chapter 3	Human as Organisms	870	18%
Chapter 4	Response and Coordination in Human	450	14%
Chapter 5	Micro-organisms, Diseases and Drugs	400	12%
Chapter 6	Variation, Inheritance and Evolution	580	16%
Chapter 7	Living Things in Their Environment	420	13%
Total		3600	100.00%

The total time required to complete the topics is 3600 minutes or 90 periods of 45 minutes in a period.

Table of Contents



1 The Cell

The Unit of Life

All living organisms are made up of a single or multiple cells. Processes such as osmosis, diffusion and active transport help in the movement of substances in and out of the cell. Different forms of life continue due to the ability of cells to reproduce through cell division. Transmission and preservation of genetic information of an organism are possible due to cell division.

In single-celled organisms, cell division creates an entirely new organism. In multi-cellular organisms, cell division transforms a single cell into different groups of cells. In adult organisms, cell division replaces cells that die from natural causes, or those that are lost to changes in environment.

1. Types of Cell

Learning Objectives

On completion of this topic, you will be able to:

- describe the differences between the basic structures of a prokaryotic cell and a eukaryotic cell.
- observe the structural differences between the two types of cell under a microscope.

Our body is made up of millions of cells and they are the structural and functional **unit of life**. There are two basic types of cells based on the presence of membrane **bound organelles** and the **distribution of nuclear material** inside the cell. They are eukaryotic cell and prokaryotic cell.

a. Eukaryotic cell

In lower classes, you have studied the typical structure of a plant and an animal cell. They are examples of **eukaryotic cells**, which are complex and larger than the **prokaryotic cells**. The term eukaryote is derived from the Greek word- '*eukaryote*' meaning '*good nucleus*'. Eukaryotic cells can be easily distinguished because of the **presence of membrane-bound nucleus** and **organelles**, when observed under a microscope. The eukaryotes include all the **protists**, **plants**, a**nimals** and **fungi**. The structure of a eukaryotic cell is discussed below:

i. Structure of Eukaryotic Cell

You have already studied about eukaryotic cells in some details in class IX. You have learnt that a typical structure of eukaryotic cell consists of a **cell membrane**,

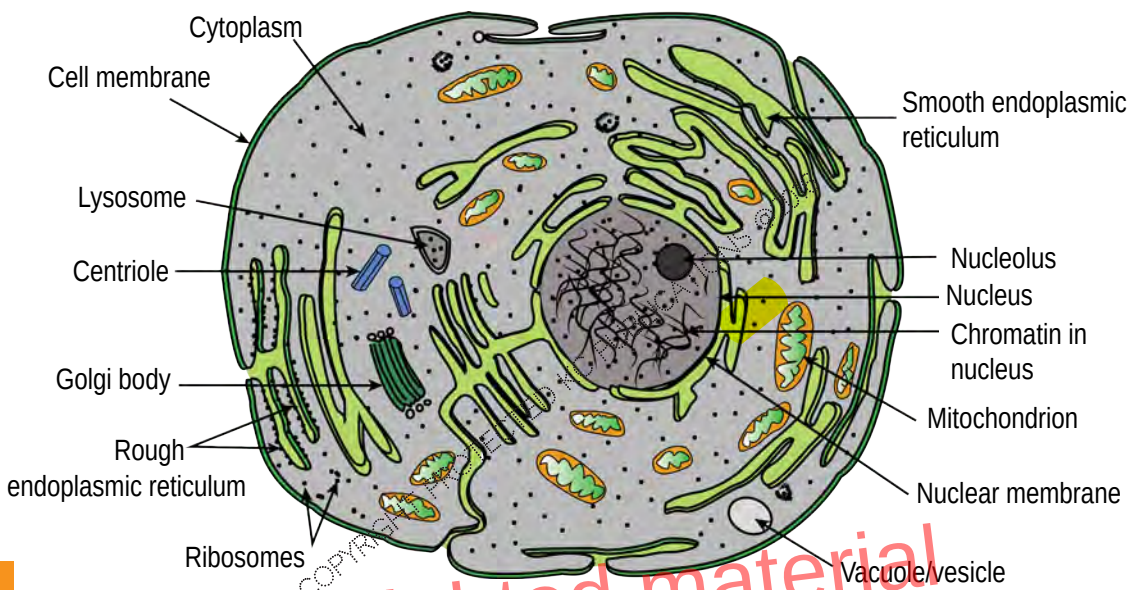


Figure 1.1: Structure of a eukaryotic cell

cytoplasm, membrane bound **cell organelles** and **nucleus**. Figure 1.1 shows the structure of a eukaryotic cell with its parts.

b. Prokaryotic cell

Prokaryotic cells are much **smaller** and **simpler** than eukaryotic cells. They are considered a **primitive type** of cells. The term prokaryote is derived from the Greek word '*prokaryote*' meaning '*before nucleus*'. These cells lack membrane bound organelles and their genetic materials are scattered in the cytoplasm. Prokaryotic cells are **unicellular organisms**. Though simple in structural organization, a prokaryotic cell shows very complex cellular activity. A prokaryotic cell generally consists of a **capsule**, **cell wall**, **plasma membrane**, **cytoplasm**, **nucleoid region**, **ribosome**, **plasmids**, **pili** and **flagella**. Figure 1.2 shows the structure of a typical prokaryotic cell.

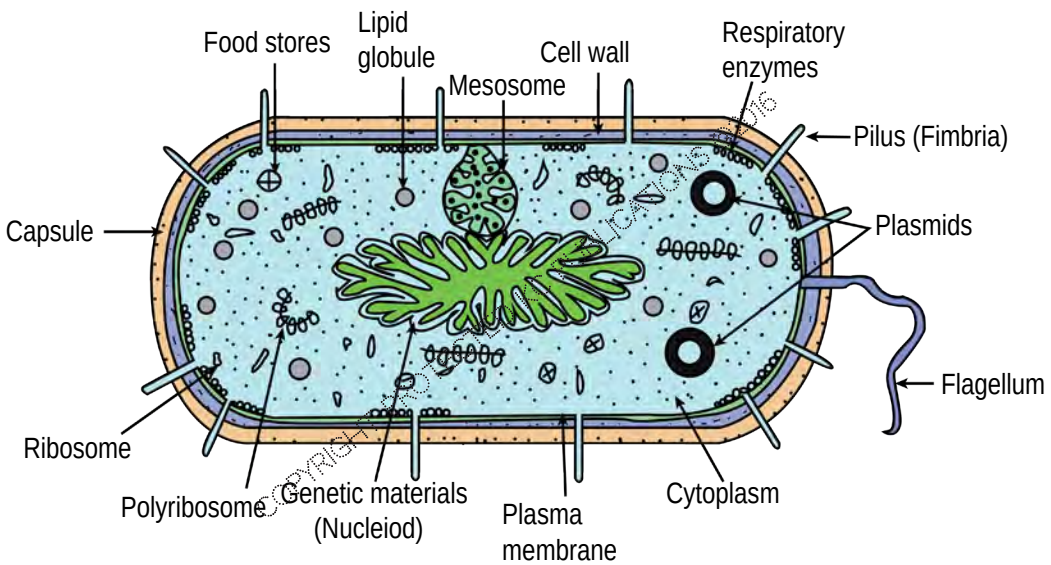
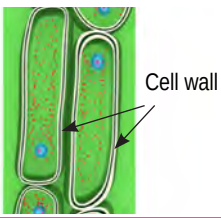
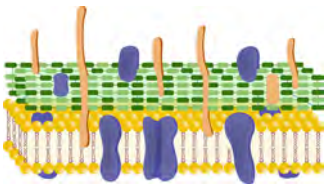
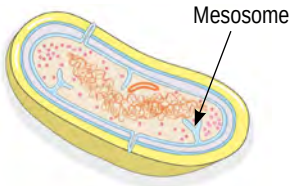
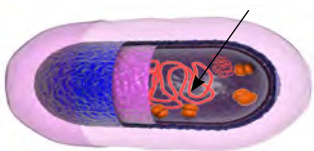


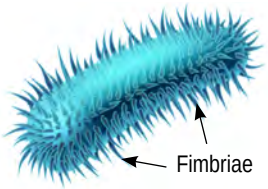
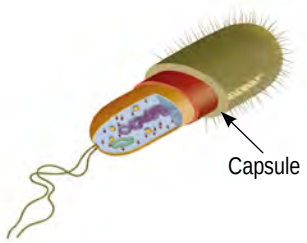
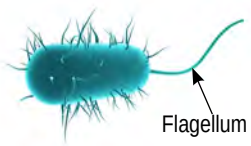
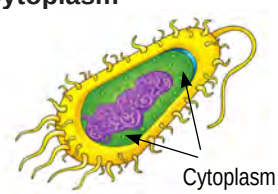
Figure 1.2: Structure of a prokaryotic cell

i. Parts of Prokaryotic Cell

A prokaryotic cell, such as **bacteria** and **blue green algae,** is a cell that does not have a true nucleus. The nuclear structure is called a nucleoid and contains most of the cell's genetic material. It is usually a *single circular molecule of DNA*. Plasmid is an *extra-chromosomal circular DNA* that helps to exchange DNA between the bacterial cells. The **cytoplasm** stores all the chemicals and components that sustain the life of a prokaryotic organism. The structure of a prokaryotic cell is discussed in Table 1.2.

Table 1.2 Parts of prokaryotic cell and their functions.

Part of cell	Descriptions
Cell wall 	• Semi-rigid casing made of **glycoprotein murein**, also called peptidoglycan. • Provides rigid **structural support** for the cell and gives shape. • Protects the cell from its external environment.
Cell membrane 	• A thin sheet made up of **phospholipids**, **proteins** and **carbohydrates**. • Provides a *selective barrier*, allowing certain substances and chemicals to move into and out of the cell.
Mesosome 	• It is the folding present inside the plasma membrane. • Plays a vital role in **cellular respirations**, **replication of DNA** during cell division. • Performs the role of **Golgi bodies** and **mitochondria**.
Ribosome 	• A tiny particle composed of **RNA** and **proteins**, which is the *site for protein synthesis*. • Helps in transferring the **genes**.
Plasmids 	• Small loops of DNA that helps to exchange DNA between bacterial cells. • Often contains genes which provides resistance to **antibiotics**, and is used in **genetic engineering**.
Nucleoid 	• Is the site, where the large DNA molecule is condensed into a small package. • **DNA** is the **code** that *directs all genetics and heredity of the cell*.

Pilus (Fimbria) 	• An elongated, **hollow protein appendage**, which is smaller to **flagellum**. • Helps bacteria to *fix to surfaces*. • Helps in **reproduction during conjugation**.
Capsule 	• Composed of a **thick polysaccharide** which covers the outside of the cell wall. • Serves as a **food reserve** and is important for sticking cells together. • *Prevents cell from dryness and protects from chemicals*. • Found only in some **gram +ve bacteria**.
Flagellum 	• A specialized appendage, which appears "*whip-like*". • Made of **proteins**. • Helps in **locomotion** *and mobility*.
Granule 	• Has *stored nutrients* such as **fats**, **phosphate**, or **glycogen** deposited in **dense crystals** or **particles** that can be tapped into when needed.
Cytoplasm 	• The functions for **bacterial cell growth**, **metabolism**, and **replication** are carried out inside the cytoplasm. It is a *gel-like matrix* composed of water, enzymes, nutrients, wastes, and gases and contains cell structures such as **ribosomes**, a **chromosome**, and **plasmids**.

c. Prokaryotic and eukaryotic cells

The structure of a **prokaryotic cell** is fundamentally similar to a **eukaryotic cell**. The main difference between the two types of cells is that the eukaryotic cells contain cellular organelles that are **membrane bound**, like the nucleus. Also, eukaryotic cells have other small membrane-enclosed structures like the mitochondria and chloroplasts, commonly known as organelles.

In prokaryotic cells, there is **no well-defined nucleus**. The genetic material is not

enveloped by a nuclear membrane. The cells do not have **membrane bound cellular organelles**. The **DNA**, genetic material of the cell, forms a **single large circle** that coils up on itself. Prokaryotic cells also contain **extra small circles of DNA**, known as plasmids. The difference between the prokaryotes and eukaryotes provides an important distinction among the groups of organisms.

Activity 1.1

Prokaryotic cell and eukaryotic cell

Materials required: permanent slide of a eukaryotic cell, micrograph of a prokaryotic cell, compound microscope

Procedure

Observe the given permanent microscope slides under the microscope and refer the micrograph.

Complete Table 1.3

Table 1.3 Spotting

Spotting	Diagram	Characteristics	Inference: Prokaryotes or Eukaryotes
Permanent slide			
Micrograph			

Questions

i. List the differences between the cell on permanent slide and micrograph.
ii. Draw the nucleus of the cell on permanent slide and micrograph and compare.
iii. Give two examples of organism that has cell structure similar to the cell on permanent slide.
iv. Which cell is more primitive? Why?
v. What type of cell makes your body muscle?

Brain Snack

- Eukaryotic cells are 10 times larger than prokaryotic cells, simply because they have a nucleus.

1.2 In and Out of Cells

Learning Objectives

On completion of this topic, you will be able to:

- explain the transport of substances through the cell membrane by diffusion, osmosis and active transport.
- relate the importance of transport processes to mankind.

All organisms and their cells need to maintain **homeostasis**. Homeostasis is the ability of an organism to maintain the **internal environment constant**. *How do cells keep a stable internal environment, when the environment around the cell is constantly changing*? You have learnt that water is the main component of all cells. Most part of the cytoplasm and cell sap is water. This water contains many dissolved substances which enter and leave the cells through the cell membrane. The **transport of materials in and out of the cell** is controlled by a cell membrane.

a. Cell membrane (plasma membrane)

Cell membrane is the outermost covering of an animal cell. In plant cell, it is found inside of the cell wall. Cell membrane separates the cell contents from the external environment. Every cell is bounded by a **thin**, **elastic** and **selectively permeable** cell membrane. It can be seen only under microscope.

i. Structure of cell membrane

The structure of cell membrane is complex. According to the Fluid Mosaic Model, the structure of cell membrane is composed of a thin layer of **lipid** and **protein**. It is about 7 to 10 mm thick. It has a remarkable structure that has properties of a solid and a liquid. Cell membrane forms a '*fluid sea*' in which **proteins**, **lipids** and **carbohydrates** are suspended or fixed at various points on its surface (Figure 1.3).

The '*fluid*' part is composed of **phospholipids** arranged in a **bilayer** called a phospholipid bilayer. Each phospholipid molecule has a ***hydrophilic head*** or *water-loving*, and a ***hydrophobic tail*** or *water-fearing*. The hydrophilic heads face the inside and outside of the cell, where **water is abundant**. The water-fearing, hydrophobic tails face each other in the **middle of the membrane**. The solid part, the '*mosaic*', is the variety of proteins, etc. embedded in the bilayer. The main function of lipids and proteins in cell membrane are:

1. Lipids provide flexibility to the membrane and allow the movement of lipids and protein molecules.
2. Proteins function as enzymes in **chemical reactions** or act as **receptors** for specific molecules or **transport materials** across the cell membrane.

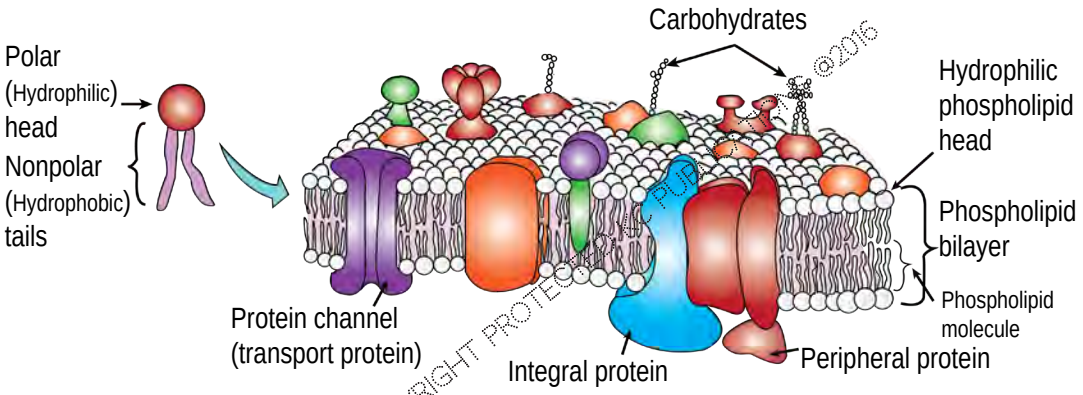


Figure 1.3: The structure of a cell membrane

The **main function** of cell membrane is to **selectively control** the entry and exit of substances in and out of the cell. Substances and water enter and leave cells by *three main processes*:

1. **Diffusion**
2. **Osmosis**
3. **Active transport**

b. Diffusion

The **movement of particles of a substance from an area of higher concentration to an area of lower concentration until they are equally concentrated** is called diffusion. Particles in liquids and gases have **kinetic energy** and move in all directions in **random motion**. In an area of higher concentration, some of the **particles collide** with one another and lose energy and slow down. While other particles, **tend to escape** from an area of higher concentration to an area of lower concentration. This results in a **concentration gradient** with particles diffusing from an area of higher concentration to an area of lower concentration.

There are two important points to remember in diffusion.

1. The **larger the size** of the particles, the **slower the** rate of diffusion.
2. The **greater** the difference in concentration, the **greater** is the rate of diffusion. This difference is known as concentration gradient.

Diffusion occurs in any substance in a **solution**, and in **gases**.

Activity 1.2

Demonstrating diffusion

Materials required: a beaker, iodine solution, water

Procedure

1. Fill the beaker with water.
2. Add a few drops of iodine solution. Observe.

Questions

i. Sketch the possible paths of iodine solution molecules inside the beaker.
ii. What change occurs to the colour of the water?
iii. What do you conclude from the experiment?
iv. Give one example each of where such process happens in animals and plants.
v. What is the importance of this process in plants and animals?

In order to carry out **photosynthesis**, a plant requires carbon dioxide. CO_2 diffuses into the leaves through the stomata. Similarly, **oxygen** produced in leaves diffuses out through the stomata. In an animal cell, the **glucose** and **oxygen** needed for respiration are carried through the blood. When the blood reaches cells, molecules of glucose and oxygen diffuse out of the blood into the cells.

c. Osmosis

Osmosis is a **special kind of diffusion** involving water molecules. Water molecules in pure water are **free to move randomly**, and thus diffuse into selectively permeable membranes. The cell membrane has **tiny pores**, which allow small molecules to pass through but not larger ones. The **diffusion of water molecules from a region of their higher concentration to a region of lower concentration through a selectively permeable membrane** is called *osmosis*. In the concentrated sugar solution, water molecules move much slower than water molecules of pure water, as they are associated with sugar molecules.

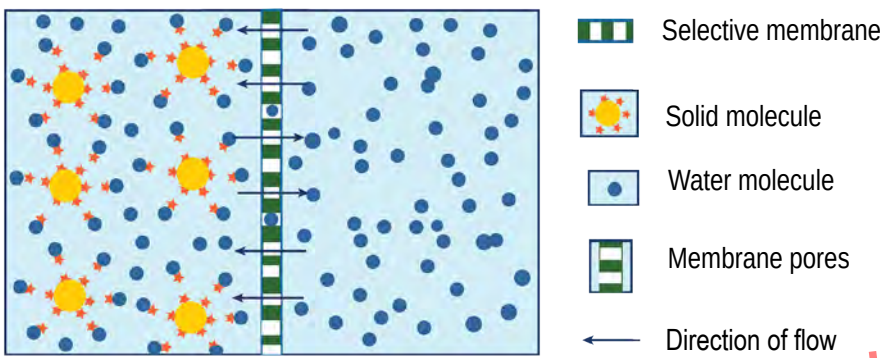


Figure 1.4: Movement of molecules in osmosis

Activity 1.3

Demonstrate osmosis using potato osmoscope

Materials required: potato, petri dish, pins, thread, sugar solution, water, and scalpel

Procedure

1. Peel off the skin of a large sized potato with a scalpel.
2. Cut off one end to make the base flat.
3. Make a cavity in the potato, almost up to the bottom.

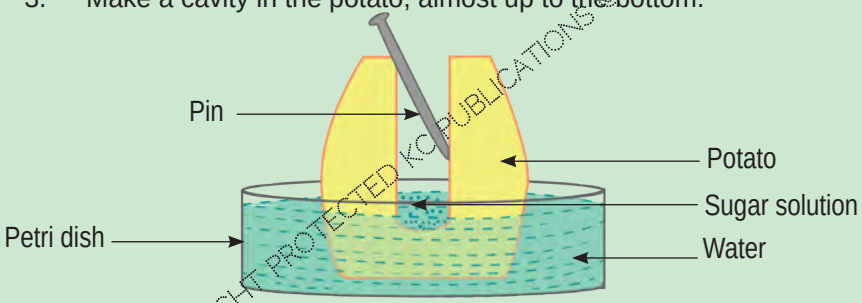


Figure 1.5: Potato osmoscope

4. Pour sugar solution into the cavity and mark the level by inserting a pin.
5. Place the potato in the petri dish containing water as shown in Figure 1.5.
6. Keep the experiment set up undisturbed and observe it after an hour.

Questions

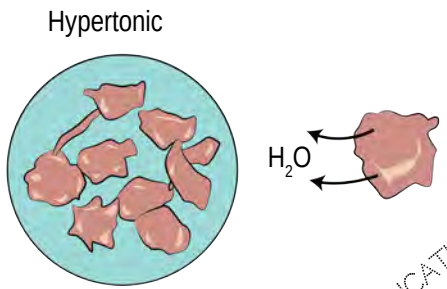
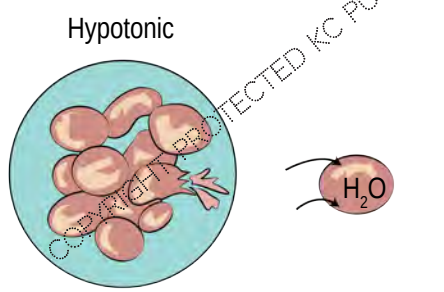
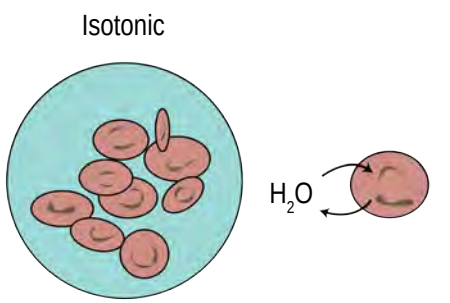
i. What happens to the level of sugar solution in the cavity? Give reasons.
ii. Predict what might happen to the level of water in the petri dish?
iii. Draw a labelled diagram of suitable control for your experiment.
iv. What will happen to the experimental result, if water in the petri dish is replaced with salt solution, more concentrated compared to the sugar concentration, in the osmoscope?
v. Which part of your experiment represents selectively permeable membrane?
vi. Write the conclusion for the experiment?

In **osmosis**, water molecules **move both ways** to even up the concentration. More water molecules move from pure water towards the higher concentrated solution because pure water has **more free water molecules**. **A measure of the tendency of free water molecules to diffuse to another area having less concentration of free water molecules** is referred as water potential. It is, abbreviated with the Greek letter **psi**(Ψ). The higher the concentration of free water molecules in a solution, the higher the water potential. It is measured in units of **megapascals** (MPa). The **highest water potential** is that of pure water at **0 MPa** (Ψ = 0 MPa).

In other words, water flows through a membrane from a solution of high water potential to a solution of low water potential.The pressure required to prevent the **net movement of pure water molecules** into a solution, so as to prevent the volume of the solution from increasing is called osmotic pressure.The addition of **solutes** lowers the water potential, and an increase in **pressure** will raise the water potential.

d. Tonicity

Tonicity is the relative concentration of solutions that determine the direction and extent of diffusion, commonly used when describing the response of cells immersed in an **external solution**. There are *three* classifications of tonicity based on the solution concentrations. They are hypertonic, hypotonic and isotonic.

Hypertonic (*hyper*: **high**; *tonic*: **tension**) is the condition, in which the solution has a **higher concentration of solutes outside the cell than inside the cell**. When a cell is immersed into a hypertonic solution, water flows out of the cell in order to balance the concentration of the solutes. This process of **movement of water out of the cell** is called exosmosis.	
Hypotonic *(hypo:* **lower***)* is the condition, in which solution has a **lower concentration of solutes outside the cell than inside the cell**. In order to balance the concentrations of solutes inside and outside the cell, water flows into the cell, and causes it to **burst**. This process of **movement of water into the cell** is called endosmosis.	
Isotonic *(iso:* **same***)* is the condition in which the solution **concentration of solutes outside the cell and inside the cell is same**. When a cell is placed in such solution, the cell neither **swells** nor **shrinks** because there is no concentration gradient for water to pass across the cell membrane. Water molecules diffuse through the plasma membrane in **both directions**. As the rate of water diffusion is the same in each direction, the cell neither gains nor loses water. There is no net osmosis.	

If a plant cell is placed in a hypertonic solution, water inside the cell is lost due to **exosmosis**. This causes the cytoplasm to **shrink** and become flaccid. If too much water leaves, the cell membrane pulls away from the cell wall. At this stage, the cell is said to be plasmolysed. On the other hand, if the same cell is put back into the **hypotonic solution**, the cell becomes **deplasmolysed** due to **endosmosis**. Water diffuses into the plant cell when placed in a hypotonic solution, and the cell contents expand. However, since plant cells are surrounded by a strong cell wall, they do not burst. Rather, the cell contents push against the cell wall, and the cell becomes turgid.

Animal cells also expand when placed in hypotonic solution. If this happens excessively, the cells burst because they do not have cell walls. If water leaves an animal cell by exosmosis, it shrinks and appears '*wrinkled*' and becomes crenated.

Osmosis in plants is significant in the following ways:

- It allows cells to take in enough water to become rigid and provide support.
- The cell-to-cell movement of water occurs throughout the plant body due to osmosis.
- Plant leaves become turgid and expand due to osmotic pressure.
- Osmosis helps growing points of root remain turgid and penetrate the soil particles.
- It regulates the opening and closing of the stomata.

Activity 1.4

Investigating effects of hypertonic and hypotonic solution on potato strips

Materials required: potato, measuring cylinder, petri dish, solutions S_1 and S_2 of different tonicity, ruler, filter paper, water, knife, stop watch.

Procedure

1. Pour 50 mL of solutions S_1 and S_2 into two separate petri dishes and label them accordingly.
2. Cut two strips from a potato, each strip measuring exactly 4 cm x 1 cm x 1 cm, see Figure 1.6.

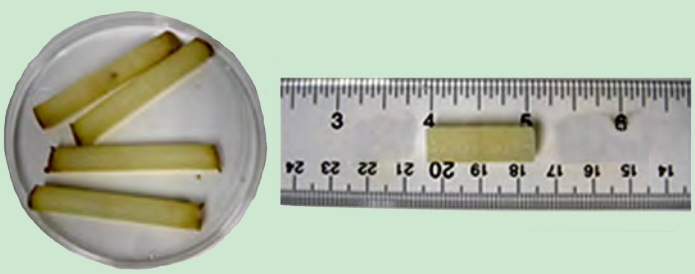


Figure 1.6: Potato strips

3. Place the strips on a moist filter paper to prevent them from drying.
4. Record the initial length of the two strips of potato, and fully immerse one strip each in the two solutions S_1 and S_2.
5. Cover the petri dishes to check evaporation of the solutions. Show the set-up to your teacher.
6. After an hour, remove the strips from the two solutions and dry them with filter papers.
7. Measure and record their lengths as against those recorded at the start. Copy and complete the table given below.

Experimental variables	Observations	
	Solution (S_1)	Solution (S_2)
Initial length of potato strip (cm)		
Final length of potato strip (cm)		
Change in length (cm) = Final length-Initial length		
% Change in length (cm) = (change in length ×100)/initial length		

Questions

i. Explain the changes that you have found in each strip.
ii. What does the % change in the length of strip indicate?
iii. From your observations, identify the nature of the solutions S_1 and S_2 with reference to the potato cell sap.
iv. Write a short report on your experiment.
v. What principle was being tested in the experiment?

e. Active transport

Transport of certain materials across the cell membrane requires **energy**. Active transport is the movement of particles from an area of low concentration to an area of high **against a concentration gradient**, using energy (**ATP**). In active transport, materials required by an organism or a cell need to move against a concentration gradient, and therefore, **require energy** (ATP), which must be supplied by the cell. Many essential substances are present at much higher concentrations inside cells than outside. For example, **concentration of nitrates is higher in root cell** than in the surrounding soil solution. Therefore, the plant cells utilise energy for active transport of nitrates across the cell membrane into the root cell against the concentration gradient. Similarly, **in animals**, essential food substances such as **simple sugars**, **amino acids**, **vitamins** and **minerals** are actively absorbed into the **villi** of small intestine during digestion of food.

1.3 Cell Division

Learning Objectives

On completion of this topic, you will be able to:

- explain division of cells by mitosis during growth.
- describe meiosis to produce gametes.

Reproduction of cells is essential to the development and function of all life. Every living cell today is said to have descended from a **single ancestral cells**. The reproduction of cell is carried out through the activity of **cell division**. This ability of cells allows organisms to **develop**, **grow**, **repair** and **live**. For example, a bacterial cell divides to produce two similar independent cells.

The cell, which undergoes division, is called **mother cell**, while the newly formed cells are called **daughter cells**. During cell division, the nucleus divides first followed by the cytoplasm. All the changes in nucleus and its division are termed as karyokinesis. The division of cytoplasm is known as cytokinesis.

There are *two types* of cell division: **mitosis** and **meiosis**.

a. Mitosis

In this type of cell division, **two daughter cells are produced** from a single mother cell. These daughter cells contain **identical sets of chromosomes**. For this reason, mitosis is also called as replicative division. Mitosis takes place when the organism grows and needs **repair** or **replacement**.

i. Stages of Mitosis

The **stages of mitosis** in plants and animals are similar, except in animal cells a **centrosome consisting of two centrioles** is present outside the nuclear membrane. The **centrosome** is absent in plant cells.

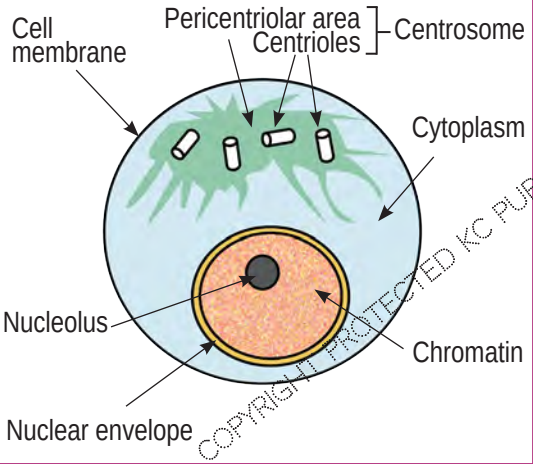
In mitosis cell division, the **same normal chromosome number** is maintained at each stages. Just before the division of the cell, it prepares for this change and doubles the quantity of DNA (the chromosome substance). This is interphase, apparently the resting phase, since **no change in chromosme** is visible externally, but actually it is quite active in synthesing the DNA.

Mitosis is a continuous process which takes place in *four* different stages- prophase, metaphase, anaphase and telophase. The details of each stage are discussed in Table 1.4.

Table 1.4 Mitosis in animal and plant cells.

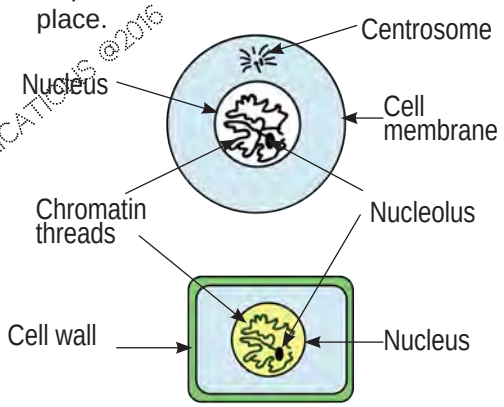
Interphase

- The cell enlarges in size and gathers proteins.
- It is the **resting stage** of the cell.



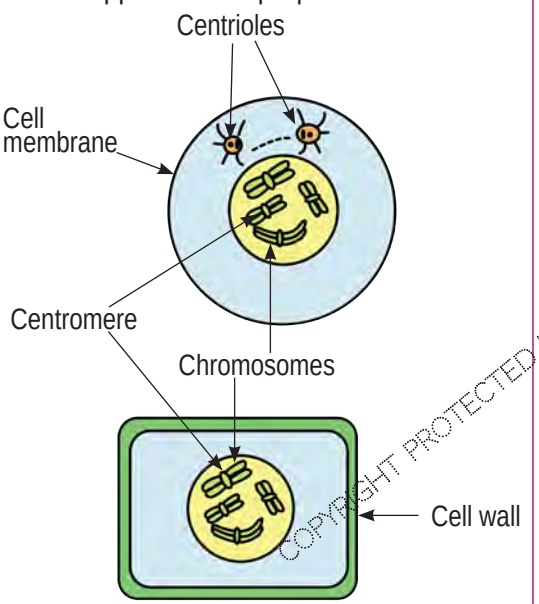
I. Prophase

- **Centrioles** start moving apart.
- Chromosomes occur in coiled network of **chromatin threads**.
- Replication of chromosomes takes place.



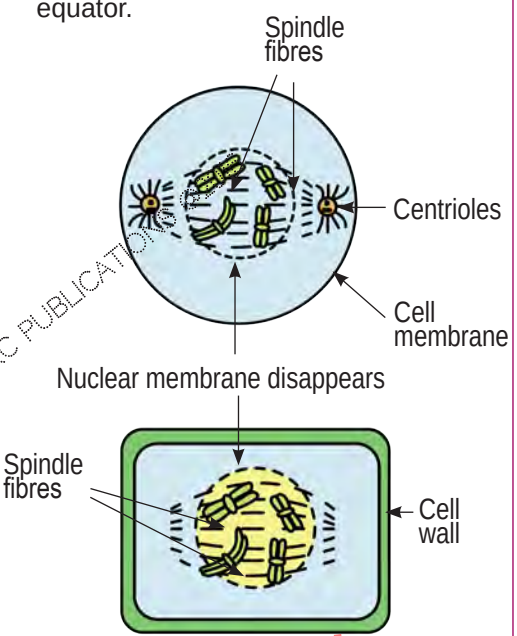
II. Early prophase

- **Centrioles** migrate to reach opposite poles.
- **Chromatin network** condenses to form chromosomes.
- **Nuclear membrane** and **nucleolus** disappear in late prophase.



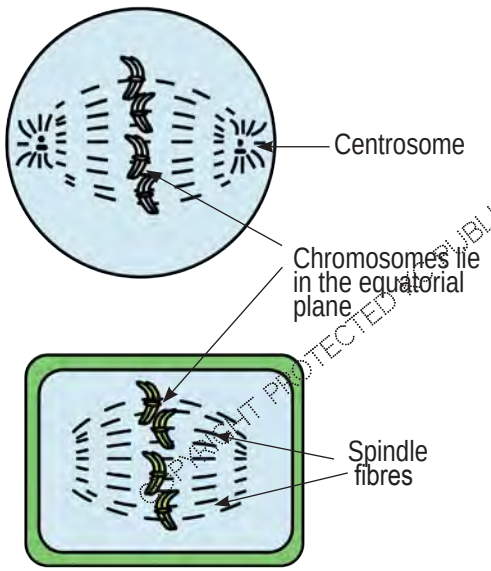
III. Late prophase

- **Spindle fibres** appear between the centrioles.
- Chromosomes split to form **sister chromatids**.
- **Chromosomes** move towards the equator.



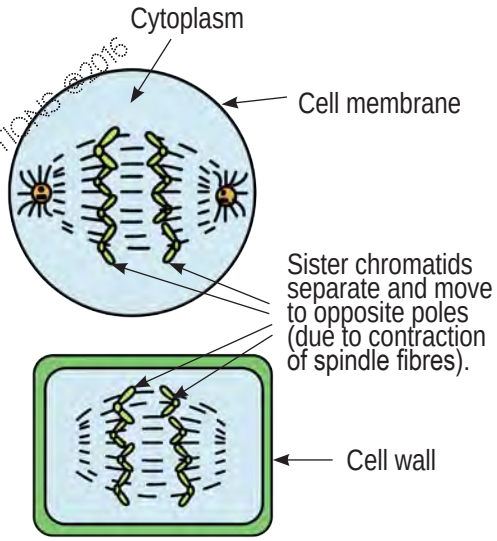
IV. Metaphase

- Each chromosome gets **attached to spindle fibre** at the **centromere**.
- All chromosome pairs lined up in the **equatorial plane**.



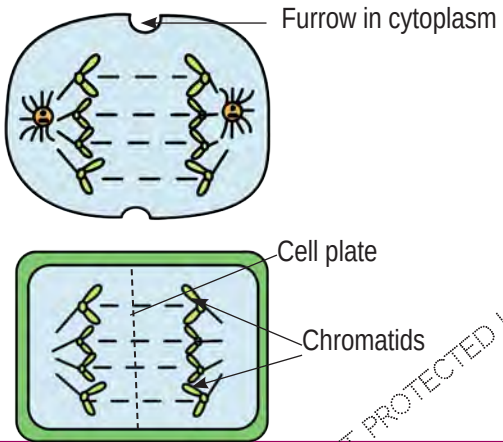
V. Anaphase

- The **centromeres** divide.
- The **two sister chromatids** move to each pole.
- A **furrow starts** in the cell membrane at the middle in animal cell.



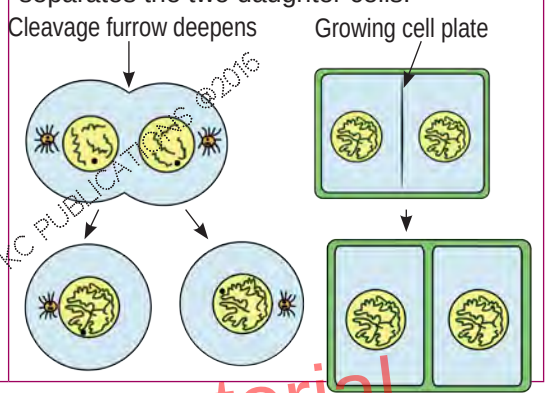
VI. Telophase

- **Chromosomes** reach the end of opposite poles.
- **Cell plate** is formed at the middle.
- **Cleavage furrow** starts deepening in the animal cell.
- **Nuclear membrane** is formed.
- **Nucleolus** reappears.



Division of the cytoplasm

Division of the cytoplasm, or **cytokinesis** is not a phase of mitosis. It is a separate process necessary for completing cell division. In **animal cells**, a cleavage furrow develops at the position of the metaphase plate, separating the nuclei. In **plant cells**, a new cell wall, known as the cell plate, forms at the midpoint of the cell. It extends outwards to the existing cell wall and separates the two daughter cells.



A cleavage furrow forms in the middle of the cell and the cell separates by a process called cytokinesis. **Two new identical cells called daughter cells are formed.**

ii. Significance of Mitosis

1. ***Growth***: The number of cells within an organism increases by mitosis, and this is the basis of **growth in multi-cellular organisms**. For example, the growth of a 3kg baby to a 20kg child is due to the increasing number of cells due to the process of mitosis.
2. ***Cell replacement***: Dead and worn out cells and tissues are continuously replaced with new cells by the process of mitosis.
3. ***Regeneration***: Some animals are able to regenerate whole parts of their body (e.g. arms in a starfish and tails in lizards) due to mitosis. Similarly, the healing process of a wound is also due to mitosis.
4. ***Genetic stability***: Each daughter cell produced by mitosis has a full set of chromosomes of parent cell. Therefore, no variation in genetic information arises by mitosis.
5. ***Asexual reproduction***: Mitosis helps many species to undergo asexual reproduction. As a result, the offspring have all the characteristics of their parents.

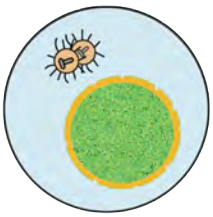
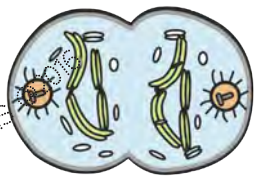
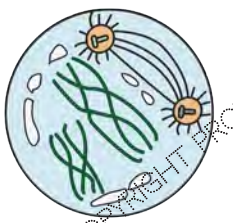
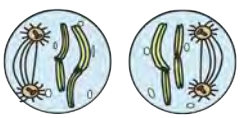
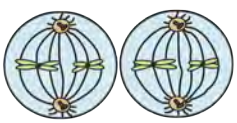
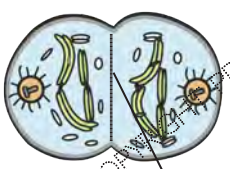
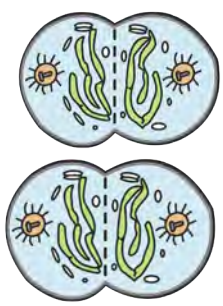
b. Meiosis

Meiosis is the type of cell division, which occurs in the **reproductive organs**. It occurs during the formation of **sperm** and **egg cells** in animals, and during **gamete formation** in plants. Meiosis resembles mitosis as it begins with the **interphase**. **Four daughter cells are formed** as a result of meiosis, each with **half the chromosome number of their parent cell**. Thus is a reduction division.

i. Stages of Meiosis

Meiosis comprises of two successive divisions Meiosis I and Meiosis II. **Meiosis II** is similar to mitosis, but **Meiosis I** is different in many important respects. The details of these two successive divisions are shown in Table 1.5.

Table 1.5 Meiosis in an animal cell

Meiosis I		Meiosis II	
Interphase I • **Chromatin** not visible. • **DNA & proteins** replicated.		**Interphase II** • **No DNA** replication. • **Chromosomes** remain visible.	
Prophase I • **Chromosomes** are visible. • **Homologous chromosomes** join together to form a chromatid **cross over**.		**Prophase II** • **Centrioles** replicate and move to the poles. • The chromosomes condense.	
Metaphase I • **Chromosomes** line up on equator.		**Metaphase II** • **Chromosomes** line up on equator.	
Anaphase I • **Chromosomes** separate (not chromatids-**centromere** doesn't split).		**Anaphase II** • **Centromeres** split. • **Chromatids** separate.	
Telophase I • **Nucleolus** forms. • **Cell** divides. • Formation of **two daughter cells**.		**Telophase II** • **Nucleolus** reappears. • The **spindle fibres** disintegrate. • Formation of **four daughter cells**.	

Four daughter cells have been produced from the original **single parent cell** with each cell now **containing half the number of chromosomes** (***haploid***) of the original parent cell.

In humans, there are **46 chromosomes** in the nucleus. These occur in **23 pairs** and are called homologous pairs. One chromosome from each homologous pair comes from the mother and is called the maternal chromosome, and the other comes from the father and is called the paternal chromosome.

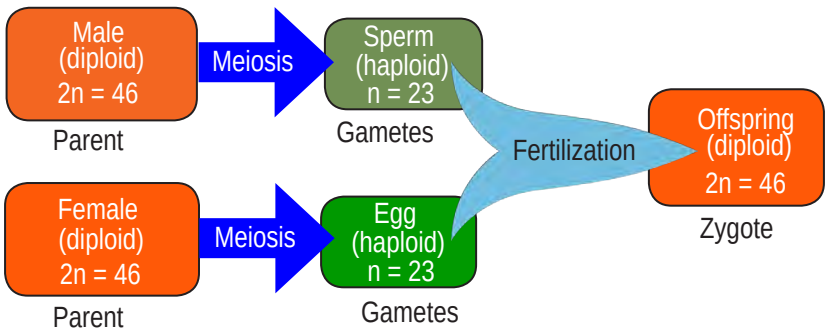


Figure 1.7: Offspring with 23 chromosome pairs

ii. Significance of Meiosis

1. ***Sexual reproduction***: In humans, meiosis produces sperm cells and egg cells, which only contain 23 chromosomes. During fertilization, the normal number of *46 chromosomes is restored.*
2. ***Genetic variation***: Meiosis allows for new combination of genes to occur in the gametes during sexual reproduction. This leads to *genetic variation* in the offspring.

Table 1.6 Comparison of Mitosis and Meiosis.

The stages	Mitosis	Meiosis	
		Meiosis I	Meiosis II
Prophase	**Chromosomes** become visible; **two chromatids** joined at the centromere; **nuclear membrane** breaks down; **nucleolus** disappears; and, **spindle fibres** are formed.	**Chromosomes** become visible; homologous chromosomes pair to form **bivalents**; **nucleolus** disappears; **spindle fibres** are formed.	**Chromosomes** reappear as **two chromatids** joined at the centromere; and **spindle fibres** are formed.
Metaphase	**Chromosomes** at equator of spindle, and **centromeres** attach to spindle fibres.	**Bivalents** at equator of spindle, and **centromeres** attach to spindle fibres.	**Chromosomes** at equator of spindle, and **centromeres** attach to spindle fibres.

The stages	Mitosis	Meiosis	
		Meiosis I	Meiosis II
Anaphase	**Centromeres** divide, and **chromatids** move to opposite poles.	**Chromosomes** (each of **two sister chromatids** joined at their centromeres) move to opposite poles.	**Centromeres** divide, and **chromatids** move to opposite poles.
Telophase	**Spindle fibres** break down, **nuclear membrane** reforms, and the **cytoplasm** divides.	**Spindle fibres** break down, **nuclear membrane** may reform, and the **cytoplasm** may or may not divide.	**Spindle fibres** break down, **nuclear membrane** reforms, and the **cytoplasm** divides.
The end results	**Two identical cells**, each with *diploid chromosome number*.	**Two non-identical nuclei**, each with *haploid chromosome number*.	**Four non-identical cells** each with the *haploid chromosome number*.
Functions	*Cellular reproduction, growth, repair and replacement of cells.*	*Sexual reproduction, production of gametes.*	

Activity 1.6

Spotting

Materials required: permanent slides of different stages of mitosis, micrograph of different stages of meiosis, compound microscope

Procedure

1. Observe each of the given permanent slides under a microscope and compare them to the micrographs of the different stages of meiosis.
2. Identify the cells which show the main stages of mitosis and meiosis using the positions and shapes of the chromosomes.
3. Observe the position of nucleus and centrioles of cells undergoing mitosis and meiosis.

Questions

i. Identify and name each stage.
ii. Write two points of identification for each stage.
iii. Draw a neatly labeled diagram of the observed stages of mitosis and meiosis.
iv. Write two differences between mitosis and meiosis.
v. Relate the regeneration of a broken lizard tail with cell division.

Lesson Summary

- All cells can be categorised into two types: prokaryotic cell and eukaryotic cell.
- Eukaryotic cell have true nucleus with nuclear envelope.
- Prokaryotic cells have genetic materials without the nuclear envelope.
- Cell-to-cell or within the cell transportation of materials take place by the process of diffusion, osmosis and active transport.
- The structure of cell membrane plays an essential role in all the cell processes. It is made up of phospholipid bilayer.
- Diffusion involves the movement of water molecules from higher concentration to lower concentration.
- Osmosis is a special kind of diffusion that happens between two solutions of different concentration separated by a semi-permeable membrane.
- Active transport requires ATP energy.
- A solution can be described as hypertonic, hypotonic and isotonic based on their tonicity.
- The two types of cell division are mitosis and meiosis.
- Mitosis takes place in the growing parts of an organism and it results in two diploid (2n) cells.
- The four phases of mitosis are prophase, metaphase, anaphase and telophase.
- Mitosis cell division helps in growth, cell replacement and regeneration in an organism. It also ensures genetic stability in an organism as a result of asexual reproduction.
- Meiosis is a type of cell division that creates genetic variation and reduces the chromosome number by half and produces sex cells, or gametes.
- Meiosis takes place in two phases: Meiosis I and Meiosis II.
- Four genetically unique haploid (n) cells are produced as a result of meiosis.

Weblink

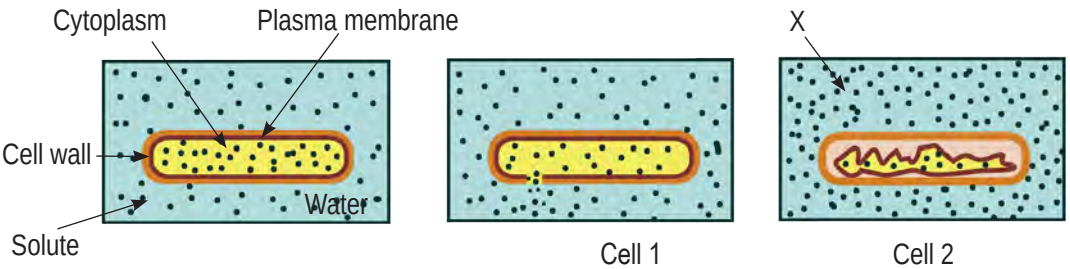
- http://www.nature.com/scitable/ebooks/essentials-of-cell-biology-14749010/118237871
- http://www.johnkyrk.com/
- http://www.brightstorm.com/science/biology
- http://vcell.ndsu.nodak.edu/animations/regulatedtranscription/index.htm
- http://www.learnerstv.com/animation/Free-biology-animations-page1.htm

Review Questions

A. Each question in this part is followed by four possible choices of answer. Choose the correct answer or the most suitable response.

1. In an onion root tip, the correct sequence of mitotic division is
   A. interphase-prophase-metaphase-telophase-anaphase.
   B. interphase-prophase-metaphase-anaphase-telophase.
   C. interphase-prophase-metaphase-anaphase-telophase-cytokinesis.
   D. prophase-metaphase-anaphase-telophase.

2. Base your answer to question Q2 & Q3 on the diagram below.



The type of solution most likely represented by 'X' is
   A. isotonic.
   B. hypertonic.
   C. hypotonic.
   D. saturated.

3. The arrows represent flow of water in and out of the cell. In Cell 2, the cytoplasm is pulled away from the cell wall and the cell is said to be plasmolysed. The same cell can be deplasmolysed by
   A. adding more solutes to solution 'X'.
   B. adding water to solution 'X'.
   C. placing it in pure water.
   D. placing it in saturated solution.

4. In a somatic cell of an animal, the centrioles begin to move to opposite points of the cell called poles. Some fibres appear between two daughter centrioles to form spindle fibres. Inside the nucleus, the nucleolus gradually disappears. The chromosomes start moving towards the 'equator' of the cell. This phase of cell division is
   A. prophase.
   B. prophase I.
   C. prophase II.
   D. metaphase I.

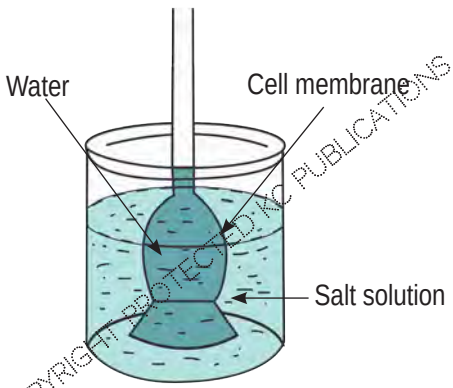
5. What will happen in the experimental diagram below?

   A. Water from the beaker will enter the thistle funnel.

   B. NaCl solutes will enter the thistle funnel from the beaker.

   C. Water from the thistle funnel will enter the beaker.

   D. NaCl solutes will not enter into the thistle funnel.



6. Salting of pork and pickles is a practical application of

   A. endosomosis.
   C. plasmolysis.

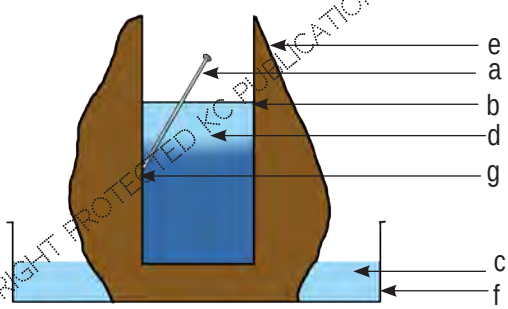
   B. exosmosis.
   D. deplaysmolysis.

7. Marine animals live in salt water, which is a hypertonic environment; there is more salt in water than in their cells. To prevent losing too much water from their bodies, animals intake large quantities of salt water and secrete salt bylipid molecule. This happens by a process called

   A. osmosis.
   C. active transport.

   B. diffusion.
   D. passive transport.

8. Choose the correct combination of label in the potato osmoscope below.



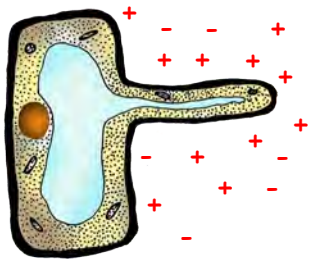
   A. a-alpin, b-final level, c- water, d-sugar solution, e-potato tuber, f-initial level, g-beaker.

   B. a-alpin, b-initial level, c-sugar solution, d-water, e-potato tuber, f-beaker, g-final level.

   C. a-alpin, b-final level, c-sugar solution, d-water, e-potato tuber, f-initial level, g-water level.

   D. a-alpin, b-final level, c-water , d-sugar solution, e-potato tuber, f-beaker, g-initial level.

9. The diagram on the right shows the concentration of nitrate ions in a root hair cell and in the surrounding soil water. The process in which nitrate ions are taken into the cell.



   A. Osmosis.
   B. Diffusion.
   C. Active transport.
   D. Passive transport.

10. Which statement is the difference between mitosis and meiosis?
   A. Gametes are formed by meiosis, while chick cell is formed by mitosis.
   B. Meiosis produces sperm cells, while mitosis forms ovum.
   C. Mitosis is for body growth, while meiosis is responsible for the repair of body cells.
   D. Genetic variation is due to mitosis, while meiosis does not affect genetic variation.

B. Fill in the blanks with the correct form of word(s).

1. During a certain phase of mitosis, a cell grows and the metabolic activity of the nucleus is intensified. The chromosome material is in the form of loosely coiled fine threads called……..
2. Complete the table.

Cell structure	Prokaryotic	Eukaryotic	
		Animal	Plant
Nucleus	.....	Present	.....
Membrane-bound cell organelles	.....	.....	Present

3. Processes in plants which require the movement of materials between the cells and surrounding environment of the plant. Two forms of such movements are ..... and .....
4. In animal, somatic cells divide by a process called mitosis. But meiosis division occurs in ..... cells.
5. A student puts cells of leaf inside a hypertonic solution for 5 minutes and observes it under the microscope. He notices that the cytoplasm has pulled away from the cell wall due to exosmosis. This stage of the cell is said to be .....

C. Name the following.

1. Just before cell division, the phase during which a cell prepares itself by doubling the quantity of DNA within the chromosome.
2. A type of cell that lacks both a true nucleus and other membrane-bounded cellular substructures.
3. Longer than cilia, but with the same basic construction as cilia that has functions in the cell movement.
4. The phenomenon by which the colour spreads throughout the entire water mass, when blue ink is put in a beaker.
5. The process in nerve cells, in which the sodium-potassium pump moves sodium out of the cell and potassium into the cell, both against their concentration gradients due to certain process.

D. Match the items of column A with the most appropriate items of column B. Rewrite the correct matching pairs.

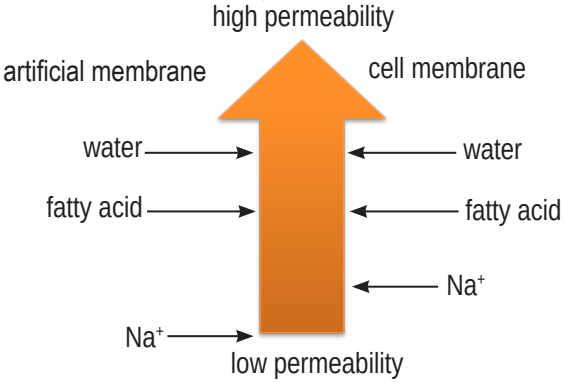
Column A	Column B
The homologous chromosome is pulled to opposite poles by spindle fibres.	Metaphase II
The centromeres divide and separate and the individual chromosomes are pulled to the opposite poles.	Telophase II
The phase of cell division during which the chromatid pairs line up in the centre of cells.	Prophase II
The spindle fibres disintegrate and a nuclear membrane forms around the chromosomes at each end and nucleoli reappears.	Anaphase I
Chromosomes reappear as two chromatids joined at the centromere, spindle fibres are formed.	Anaphase II

E. Give reasons.

1. When RBCs are placed in 0.3% NaCl, they burst.
2. If the cell membrane was completely permeable, the concentration inside the cell would be about the same as the outside.
3. Five potato cylinders, each measuring 40 mm were placed in a concentrated salt solution for 24 hours. When they were re-measured, their average length was 37 mm.
4. Mitosis cell division is also called replicative division.
5. Dry seeds when submerged in water soon swell up.

F. Answer the following questions.

1. An artificial membrane can be made which consists only of a lipid bilayer. The diagram below compares the permeability of such an artificial membrane with a cell membrane of an animal. Study and answer the questions that follow:

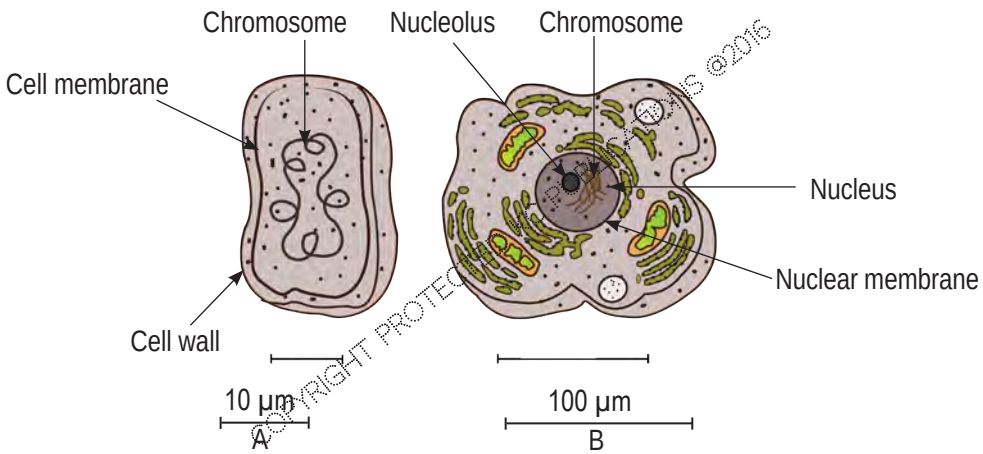


   i. Give reason why the permeability of both the membrane is same for fatty acid?

   ii. Why are sodium ions differentially permeable?

2. Imagine a yeast cell has first undergone one mitotic division and each daughter cell has undergone one meiotic division. Calculate the number of yeast cells produced.

3. Study the diagram below and answer the questions that follow:



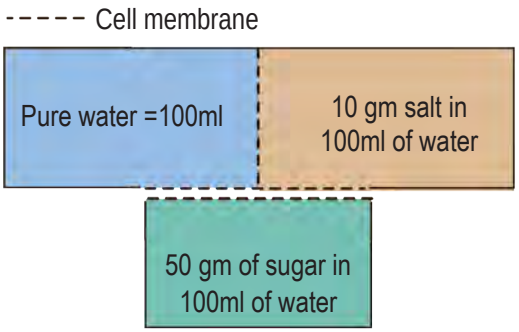
   i. Write two visible structural difference between cell A and cell B.

   ii. Describe the nature of chromosome in cell A and cell B.

   iii. Identify the type of cell for cell A and cell B. Support with one reason in each case.

   iv. How is cell A structurally similar to a plant cell?

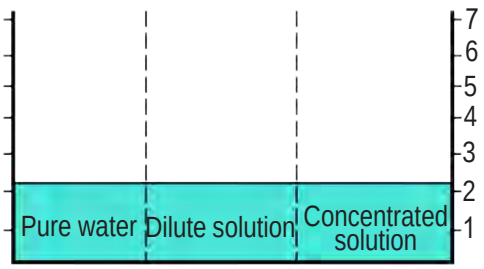
4. The diagram below shows three solutions of different concentration, separated by a selectively permeable membrane.



i. Copy the diagram and show by means of arrows, the direction of water movement between the solutions.

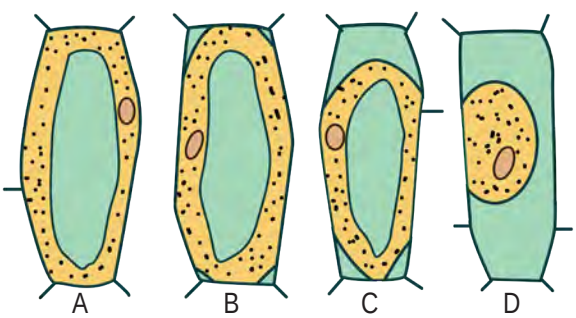
ii. Which solution has the highest water potential?

iii. The diagram below shows a vessel, which contains the above three solutions separated by a cell membrane. Draw a similar diagram to show the liquid levels after an hour or two.



iv. Name the phenomenon, by which cell gains water when placed in pure water.

5. The diagram below shows the different stages of plasmolysis in plant cell. Study and answer the questions that follow.



i. Identify and define the physiological process.

ii. Which stage is the initial stage? Support your answer.

iii. Which is the final stage? Support your answer.

6. A student conducted an experiment using the procedure below.

Cut a potato tuber into 2cm × 2cm × 2cm cubes of four. A cube each was placed in three different concentrations of salt solutions and one in distilled water. After 30 minutes, the length of potato cubes in each salt solution and distilled water were measured using a ruler. The results were tabulated below:

Length (cm)	Distilled water	NaCl in 100 mL of water		
		1 gm (1%)	10 gm (10%)	50 gm (50%)
Final length in (cm)	2.3 cm^3	2.1 cm^3	1.9 cm^3	1.7 cm^3

i. Identify the aim of the experiment.

ii. List down the materials required for the experiment.

iii. Predict the length of potato cube in 90% salt solution. Explain.

iv. Name the cell process in each case, when a potato cube was placed in distilled water and in the 10% salt solution.

v. Name two plant parts, where this process occurs.

2 GREEN PLANTS

All living organisms require continuous energy to carry out their different life activities. This energy directly or indirectly comes from the Sun. Light energy from the Sun is converted into chemical energy in series of chemical reactions in plants. These chemical reactions depend on several important factors. Food synthesized by the process of photosynthesis is translocated to different parts of the plants, and utilized for various life activities. Plants transport food, water and minerals through vascular tissues.

Growth and development is the essential characteristics of all living organisms. The growth and development of plants are regulated by plant hormones. These hormones are also used commercially in industries and agriculture.

2.1 Photosynthesis

Learning Objectives

On completion of this topic, you will be able to:

- explain the phases of photosynthesis.
- relate the rate of photosynthesis with factors such as light intensity, carbon dioxide concentration and temperature.
- explain the utilisation of the products of photosynthesis by plants.

The overall process of **photosynthesis** is the result of many chemical reactions. The chemical reactions that make up the process of photosynthesis are divided into two main phases: light reaction (**light-dependent reactions**) and dark reaction (**light-independent reactions**). Each phase occurs simultaneously in **chloroplast** during daylight, and they depend on each other.

a. Light Reaction

This reaction is also called light-dependent reaction because it **requires light**. It occurs in thylakoid membranes of the **grana** of the chloroplast.. A series of chemical reactions occur in quick succession, initiated by light and therefore, this phase is also known as photochemical phase. During the light reactions, sunlight **splits water molecule** to release oxygen and at the same time organic molecules such as **adenosine triphosphate** (**ATP**) and **nicotinamide adenine dinucleotide phosphate** (**NADPH**) are produced. These are initiated by pigments called chlorophylls.

Light reaction consists of *two main phases*:

1. ***Activation of chlorophyll***: When light strikes the reaction centres of chlorophyll, which are found in the chloroplasts, chlorophyll becomes activated with the absorption of light energy (photons).

2. ***Photolysis***: The absorbed light energy **splits water molecule** (H_2O) into **hydrogen** (H^+) and **oxygen** (O^{2-}) **ions**. Hydrogen combines with **NADP** to form $NADPH_2$.The O_2 gas is released into the air as a by-product.

$$H_2O \xrightarrow[(chlorophyll)]{(light\ energy)} 2H^+ + 2e^- + {}^1/_2O_2$$

In this phase of photosynthesis, there is a loss of energy along the **electron transport chain** to form the ATP from **ADP** (**adenosine diphosphate**). An electron transport chain (ETC) is a series of compounds that transfer electrons from **electron donors** to **electron acceptors**. Light energy is used to produce **ATP** and **NADPH** (nicotinamide adenine dinucleotide phosphate). Both ATP and and NADPH molecules are **energy-rich organic molecules**.

An equation for light reaction is

$$ADP + Pi\ (inorganic\ phosphate) \xrightarrow[chlorophyll]{light} ATP$$

$$2H_2O + 2NADP \xrightarrow[chlorophyll]{light} O_2 + 2NADPH_2$$

Activity 2.1

To investigate the release of oxygen during photosynthesis.

Design an experiment to investigate the release of oxygen during the photosynthesis using the following materials.

[funnel, test tube, beaker, water, water plant (hydrilla), glowing splinter]

Questions

i. Why should the level of water in the beaker be above the level of the stem of the inverted funnel?

ii. What is the use of the funnel in the experiment?

iii. Identify the gas produced, if any, in the test tube. Give one test to prove the gas you have identified.

iv. Write any two precautions for this experiment.

v. Draw a labelled diagram of an experimental set up.

vi. Explain your observations from the experiment.

vii. What can you conclude from the experiment?

viii. How would your experiment result change if kept in a dark room?

ix. Name any one of the water plants available in your locality that you can use instead of the hydrilla.

Brain Snack

- More than half (70%) of the world's oxygen is produced by phytoplankton photosynthesis in the world's oceans.
- Thirty percent (30%) of the world's oxygen is produced in the rainforest.
- Photosynthesis is the reason conifers and other pine trees grow in a cone shape. This shape allows more needles to be exposed to the sun, which enables the tree to grow taller.

b. Dark Reaction

Dark reaction uses the organic molecules, **ATP** and **$NADPH_2$**, produced in the light reaction. This reaction of photosynthesis **does not require light** and it is, therefore, called light-independent reaction. It occurs in the **stroma** of the chloroplast. This reaction involves a series of chemical reactions, each catalysed by different **enzymes**. During this reaction, molecules of **ATP provide** the energy for **sugar synthesis**, while the **NADPH provide** the **electrons** required for the reduction of carbon dioxide to **glucose** ($C_6H_{12}O_6$). The **carbon dioxide** (CO_2) present in the atmosphere gets combined with **hydrogen** (H) from water molecules to form glucose. **Six molecules** of CO_2 are used in the formation of a molecule of glucose.

The equation for the dark reaction is

(Pi = *inorganic phosphate*)

Dark reaction is also known as Calvin Cycle, and the entire Calvin Cycle takes place in the **absence of light**.

The light reaction and dark reaction of photosynthesis are summarized in Figure 2.1.

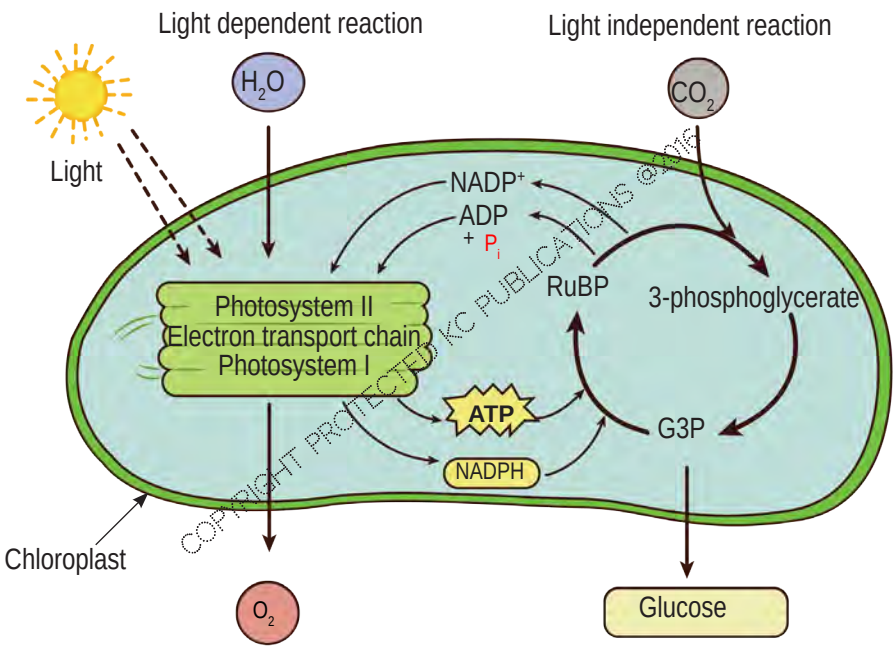


Figure 2.1: Light dependent reaction and light independent reaction

Difference between light dependent and light independent reactions.

Table 2.1 shows the differences between the two phases of photosynthesis.

Light dependent reaction	Light-independent reaction
• occurs in the thylakoid membrane of *grana*. • is largely a *photochemical change*, *requiring light*. • converts light energy to chemical energy in the form of *ATP* and *NADPH*$_2$	• occurs in the *stroma*. • is a series of *biochemical change*, each reaction catalysed by an *enzyme*. • converts carbon dioxide to compound such as *carbohydrates*.

c. Photosystems

All green plants contain **photosynthetic pigments** arranged in the centres called photosystems. They are made of several hundred chlorophyll molecules and accessory pigments such as **carotene** and **xanthophylls**. These photosystems trap light energy that initiate the **photochemical reactions** in photosynthesis. Light energy trapped is finally channelled to a **single chlorophyll molecule**, known as reaction centre. In the reaction centre, the energy of sunlight is converted into chemical energy. The different pigments of photosystem absorb light energy of **different wavelengths**, making the centre more efficient. Figure 2.2 shows the model of *photosystem*.

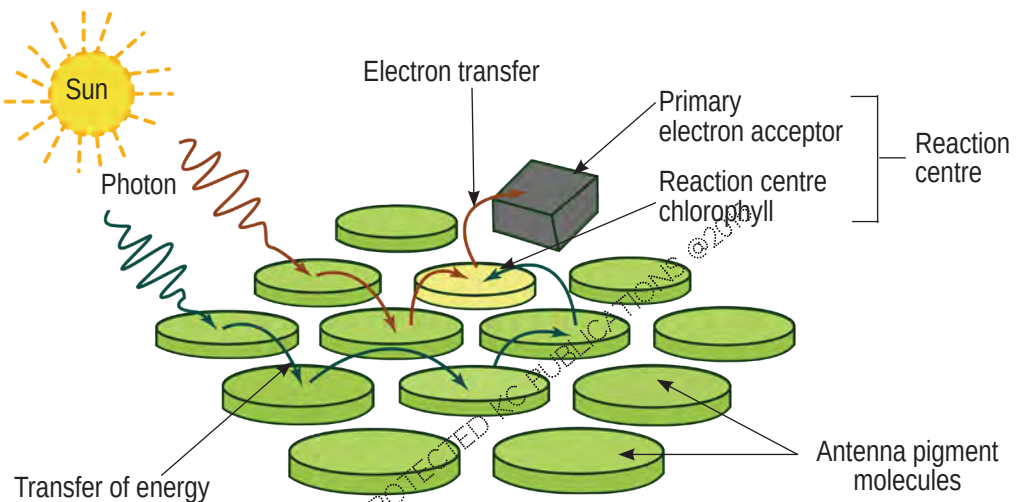


Figure 2.2: Model of photosystem

There are *two types* of photosystem present in the thylakoid membranes: **photosystem I** and **photosystem II**.

Photosystem I has a **reaction centre of chlorophyll**-a molecule, with maximum light absorption at **700 nm** wavelength. This reaction centre is also called P700.

Photosystem II has a **reaction centre of chlorophyll**-a molecule, with maximum light absorption at **680 nm** wavelength. This reaction centre is also called P680.

d. Factors affecting the rate of photosynthesis

There are several factors that affect the **rate of photosynthesis**. The rate of photosynthesis is the measurement of how fast photosynthesis takes place in a given time. It can be measured by the **amount of glucose produced** by a plant in a given time. By understanding the factors that affect the rate of photosynthesis, a scientist and farmer can alter the rate of photosynthesis in order to **increase the yield of a crop**. Following are some of the important factors that affect the rate of photosynthesis.

i. External factors

1. ***Light intensity***: The rate of photosynthesis increases with *increase* in the light intensity because as the plant absorbs more light energy, the more photosynthesis can occur. However, *very high intensity slows down* the rate of photosynthesis as it **bleaches the chlorophyll**. The rate of photosynthesis *increases linearly* with increasing light intensity from point A to B on the graph in Figure 2.3.

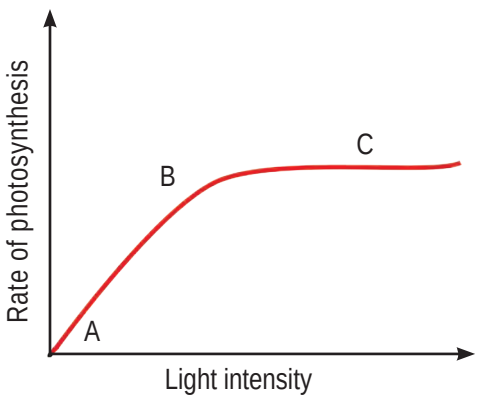


Figure 2.3: Effect of light intensity on the rate of photosynthesis

Gradually the rate falls and at a certain light intensity, the rate of photosynthesis *stays constant*, for example, from point B to C on the graph. At this point, a rise in light intensity has no effect on the rate of photosynthesis, because other factors such as **temperature** and **carbon dioxide become limiting**.

Many plants spread out their leaves in order to maximise the amount of light falling on them. However, too much light at high intensity can **damage chloroplasts**. Some woodland plants photosynthesize more efficiently in dim light and are so called shade plants.

2. ***Carbon dioxide concentration***: Carbon dioxide is used to make sugar in the photosynthesis reaction. An *increase in the concentration of carbon dioxide* results in an *increase in the rate of photosynthesis*. The rate of photosynthesis *increases*

linearly with increasing carbon dioxide concentration from point A to B on the graph in Figure 2.4.

Gradually, the rate falls and at a certain concentration of carbon dioxide, **the rate of photosynthesis remains constant**, from point B to C on the graph. Here, a rise in the carbon dioxide levels has no effect on the rate of photosynthesis as the other factors such as **light intensity become limiting**.

Many crops such as tomatoes and lettuce give higher yield, when grown in **greenhouses**. Farmers add carbon dioxide into the greenhouse to increase its concentration to *increase the crop yields*.

3. ***Temperature***: The rate of photosynthesis *increases with the increase in temperature*. The rate of photosynthesis increases until the temperature reaches the optimum temperature of **35^{0}C**, which is the **maximum** suitable temperature. However, **photosynthesis stops** when the temperature reaches 40°C. This is because high temperature **denatures the enzymes** involved in the chemical reactions of photosynthesis. Enzymes become **less effective**, when the temperature is lowered to around 0^0 C.

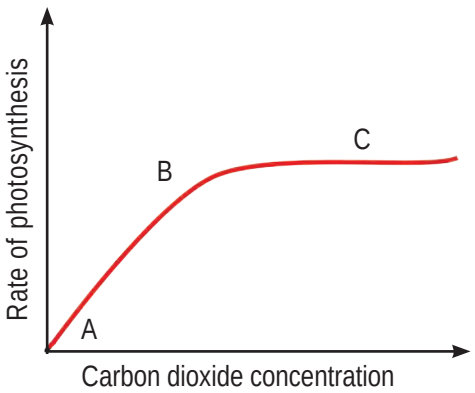


Figure 2.4 : Effect of CO_2 concentration on the rate of photosynthesis

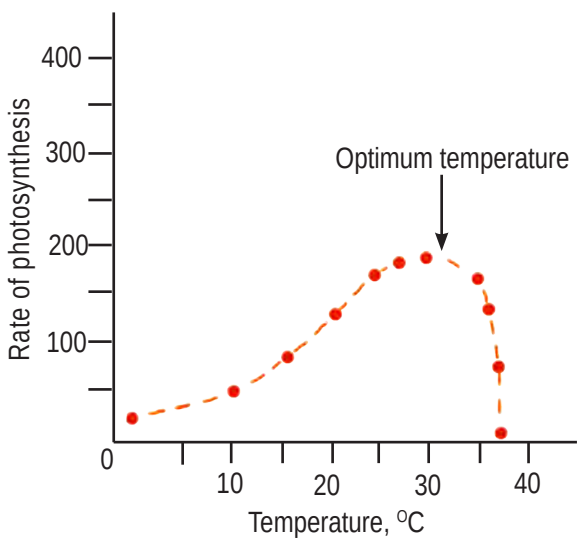


Figure 2.5: Effect of temperature on the rate of photosynthesis

The rate of photosynthesis *does not increase* with higher temperatures for all plants. Plants which grow in colder climates have an **optimum rate** of photosynthesis at **lower temperatures**. Therefore, the *optimum temperature of photosynthesis* is different for different types of plants.

4. ***Water content***: Water is an essential factor in photosynthesis in plants. Lack of water causes the *plant to wilt*, and thereby lose its ability to capture sunlight. It also limits the absorption of the right quantity of carbon dioxide. This happens because when the leaves are dry, they *close their stomata* to conserve water. This reduces the rate of photosynthesis.
5. ***Wavelength***: Photosynthesis depends upon the absorption of *light of different wavelengths* by pigments in the leaves of plants. Only **red** and **blue lights** are effective for photosynthesis. **Green light** is reflected or transmitted. Therefore, it does not play a role in photosynthesis. Light of wavelength longer than 700nm is not effective for photosynthesis in green plants. Experiments of **Engelmann** proved that *maximum photosynthesis occurs* in the red and blue parts of the light spectrum.
6. ***Oxygen concentration***: Photosynthesis does not take place in cells which lack oxygen. There are two reasons for this. First, the energy produced in **aerobic respiration** is necessary for photosynthesis. Second, oxygen is required for the *production and maintenance* of some substance essential for photosynthesis. High concentrations of oxygen **inhibit the rate of photosynthesis**. It promotes **photorespiration** in some plants instead of photosynthesis.
7. ***Pollution***: Pollution of the atmosphere with industrial gases produces **soot** that *blocks stomata and reduces the transparency of leaves*. Other pollutants are **ozone** and **sulphur dioxide**. Pollution of water affects the water plants. The capacity of water to dissolve gases like carbon dioxide and oxygen is greatly affected. Hence, the *effects of pollution are directly proportional to the rate of photosynthesis*.

ii. Internal factors

1. ***Chlorophyll content***: The role of chlorophyll in plants is to absorb light. Higher concentration of chlorophyll affects the rate of photosynthesis because more chlorophyll can absorb more light energy needed for the reactions. Deficiency of chlorophyll results in **chlorosis**, or **yellowing of leaves**.
2. ***Structure of leaf***: **Leaf anatomy** such as *thickness of cuticle and epidermis, size, position, number of stomata and its distribution, structure,* etc. affects the rate of photosynthesis. For example, more number of stomata facing the sunlight-increase the rate of photosynthesis and vice versa.
3. ***Protoplasm content***: Photosynthesis does not start immediately after the appearance of chlorophyll in very young leaves. It starts after some time. Similar thing happens when plants are transferred from dark to light. Thus some *internal factor is present in the protoplasm* of the cells. This is called the "**protoplasmic factor**". It is *enzymatic in nature*.
4. ***Age***: The rate of *photosynthesis is maximum* in adult leaves. It declines as the leaf gets old.

5. ***Hormones***: *Cytokinins*, *auxin* and *gibberellins* increase the rate of photosynthesis but the presence of *abscisic acid* reduces it.
6. ***Accumulation of end products of photosynthesis***: The accumulation of photosynthetic end products due to *slow translocation reduces the rate of photosynthesis*.

e. Blackman's law of limiting factors

In a process like photosynthesis, which is affected by more than one factor, its rate is limited by the factor which is **closest to its minimum value**. So at any point in time, if one of the *three factors* namely, **light intensity**, **carbon dioxide** and **temperature** is in low supply, this factor acts as the limiting factor. Only a change to the limiting factor increases or decreases the rate of photosynthesis. Changing the other two has no effect. Therefore, these three factors are called limiting factors. For example in Figure 2.6, when the temperature and CO_2 concentration are kept constant, the rate of photosynthesis increases with increase in light intensity and then remains constant. When the CO_2 concentration is increased, photosynthesis rate also increases to a maximum until it reaches at constant rate. If temperature is now increased, photosynthesis rate rises steadily.

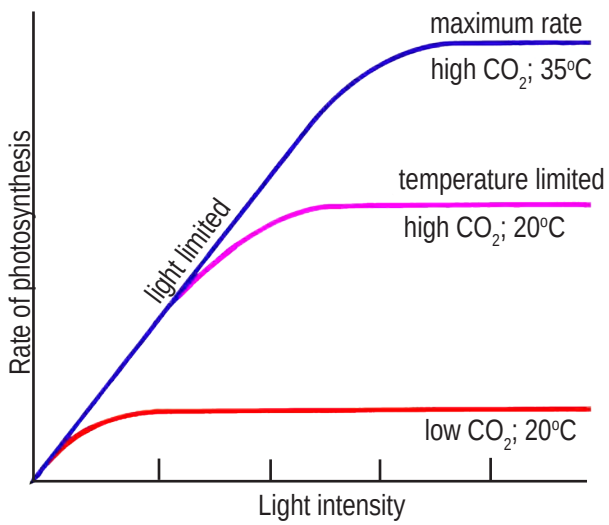


Figure 2.6: The graph showing the interaction of limiting factors

The law that explains the **interaction** of the limiting factors is called the Blackman's law of limiting factors. It states that "**when a process is conditioned to its rapidity by a number of factors, the rate of process is limited by the pace of the 'slowest factor' which presents a minimum concentration in relation to others.**"

f. Utilisation of photosynthesis products

The **end products** of photosynthesis are glucose, water and oxygen. Glucose, which is a simple sugar is used by plants for various **metabolic processes**. **Excess sugar** is *stored* in the plants in the form of insoluble starch. They are also used in synthesising **fats** and **proteins** in the plant body. **Water** may be reutilised in the subsequent **photosynthesis** processes. The **oxygen** produced may be used in the leaf cells for **respiration**, but the major portion of it diffuses out into the atmosphere through stomata. This oxygen molecule is essential for all living organisms.

Activity 2.2

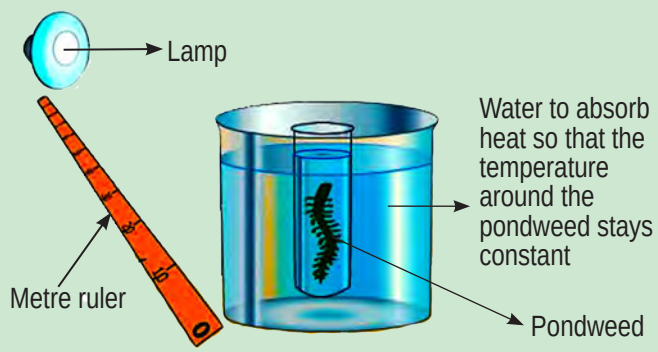
To investigate the effects of light on photosynthesis.

Materials required: bulb (100W), beaker, pondweed, water, metre ruler, thermometer, paperclip

Procedure

1. Take some pondweed and place them upside down in a test tube containing water. The pondweed are weighted down with a paperclip so that they remain in position.
2. Place the test tube with the pondweed in a beaker containing water. The large volume of water in the beaker maintains a constant temperature around the pondweed.
3. Provide light from a lamp. The light intensity is measured by the distance of the lamp from the pondweed.
4. Vary the distance of lamp in relation to the pondweed and count the number of bubbles produced per minute. Copy and complete Table 2.2.

Table 2.2



Distance between the pondweed and the light source (in metres)	Number of bubbles produced in 1 minute.
1.0	
0.8	
0.6	
0.4	
0.2	

Questions

i. What is the possible hypothesis for the experiment?

ii. Why is the test tube with weeds placed in the beaker of water?

iii. Draw a line graph to represent your results.

iv. How would the result vary, if 200W bulb is used?

v. What do you conclude from the experiment? Is your hypothesis true?

2.2 Transportation System in Plants

Learning Objectives

On completion of this topic, you will be able to:

- explain the transport of food from leaves to other parts of the plants.
- explain the absorption of minerals in plants.
- state the importance of water in support of plant tissues.

Multicellular organisms are made up of *tissues*, *organs* and *organ systems*. Such organisms need a transportation system to transport the required food materials. The *food materials*, *minerals*, and *water* are transported in plants through a **transportation system of vascular bundles**. Water, as a solvent plays an important role in the support of plant tissues.

a. Path of translocation of organic solutes

In lower classes, you have learnt that the **ascent of sap** takes place through xylem, while the **downward translocation** of the organic solutes takes place through phloem (Figure 2.9). Xylem and phloem are two important components of the **vascular bundle**.

i. Xylem

Xylem is a **complex tissue** that forms a part of the vascular bundle. It is mainly concerned with the **conduction of water and minerals** from the soil to the leaves. Xylems form a continuous channel through roots, stem and leaves of a plant. It consists of *four* different types of cells. *They are the following*:

i. tracheids are *narrow*, *hollow* and *long elongated* cells that transport water.

ii. vessel (tracheae) are *shorter* and *connected together into long tubes*. These cells have similar function to **tracheids**.

iii. xylem parenchyma are **living cells** with thin cell walls. These cells helps in *storage of reserve food and assist in conduction of water* through **tracheids** and **vessels**.

iv. xylem fibres are dead cells and are **tapering** at both the ends. They provide *strength* to the plant body.

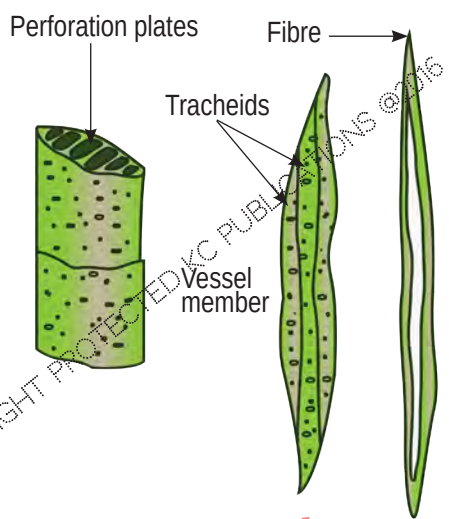


Figure 2.7: Xylem cells

ii. Phloem

Phloem is a **complex tissue** that conducts food in a plant. It is composed of *four* types of cells. *They are as follows*:

i. sieve element consists of **narrow** and **elongated** cells. They are **joined end to end** and , their walls are **perforated by sieve pores** forming a continuous channel that makes them more suitable for the transportation of food materials.

ii. companion cells are **small** with **thin cell walls** made up of *cellulose*. Each cell has a *nucleus*, and the *cytoplasm* has *rich mitochondria* and other cell organelles that are metabolically active. Companion cells are connected to **sieve tube** by plasmodesmata, a *bridge-like cytoplasmic connection* between the adjacent cells.

iii. phloem parenchyma is a **living cylindrical cell** with thin cell wall. It helps in the *storage of reserve food* and in *conduction* of food material.

iv. phloem fibres are **dead cells** that are **tapering at both the ends**. These cells provide mechanical support to plants. Examples of phloem fibres are *jute*, *coconut fibre*, *hemp* for making ropes, etc.

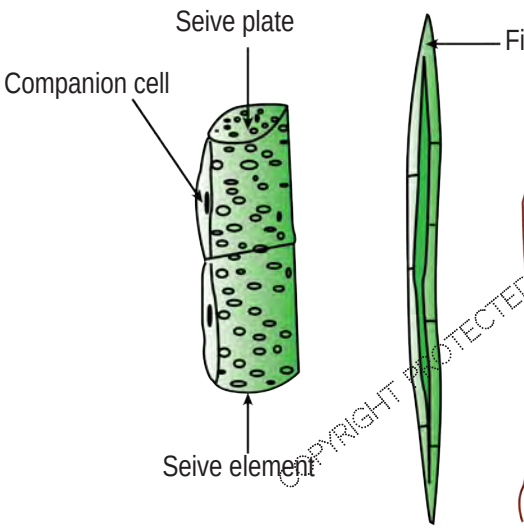


Figure 2.8: Types of cells in phloem

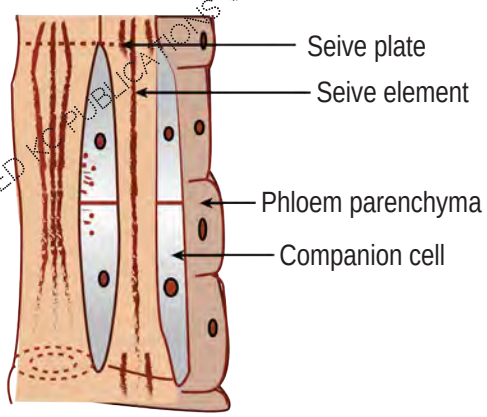


Figure 2.9: Phloem tissue

iii. Evidences of translocation of food

Many evidences show that the **translocation of food** takes place through the phloem. Some of these evidences are briefly discussed below:

i. When **sieve pores** are *blocked by plugging* with chemical compound like **callose**, translocation of food materials in plants stops.

ii. Large quantities of **organic solutes** are found in phloem sap during chemical analysis of the sap.

iii. The ***Ring experiment***, in which a *ring of bark* is removed including the phloem from the stem of the plant, **food materials accumulates** above the ring, since the translocation of materials is inhibited. Eventually, the *part below the ring dies*, while the *part of stem above swells and remains healthy* (Figure 2.10).

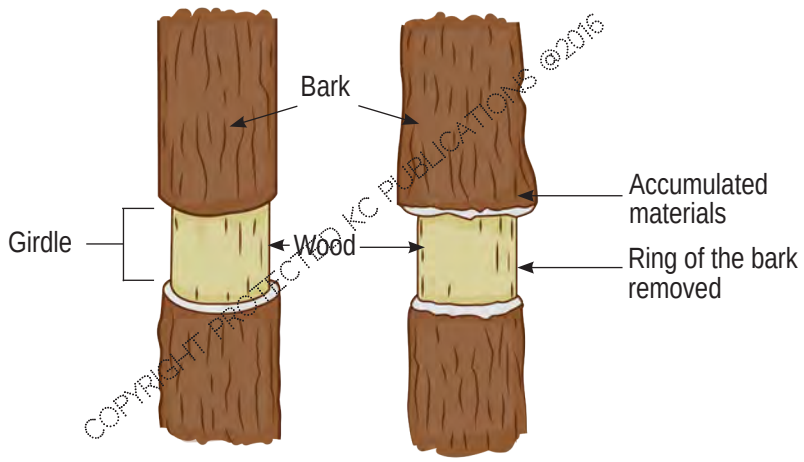


Figure 2.10: Ring experiment

iv. Most recently, the technique of ***radioactive tracing*** has indicated the translocation of food in phloem. In this technique, the **radioactive carbon** $^{14}CO_2$ was fed to green leaves in light, which made the sugar radioactive. The transportation of sugar was observed in the phloem of the plant.

b. Mechanism of translocation through phloem

Many different models have been proposed to explain the movement of sugar through the plants. One of the most accepted models of translocation of food in phloem includes ***pressure-flow mechanism or Munch's mass flow hypothesis***.

i. The pressure flow hypothesis

According to this mechanism, food is moved from sources to sinks. This mechanism is best explained with the help of **Munch mass-flow model** in Figure 2.11. It consists of *osmometer* to measure the osmotic pressure of the water. It is connected with membrane permeable only to water. One end of the membranous arm, 'A', is filled with a high concentration of solutes. It represents ***the source*** such as leaf of a plant. Other end, 'B', is filled with dilute concentration of solutes. It represents ***the sink*** such as respiring or storage regions of plants, e.g. *roots*. These two arms are connected by glass tube, which represents the *phloem*.

Water enters into the arm, 'A' by *osmosis,* because it has lower water potential than the water surrounding it. On the other hand, water leaves from arm 'B' because it is

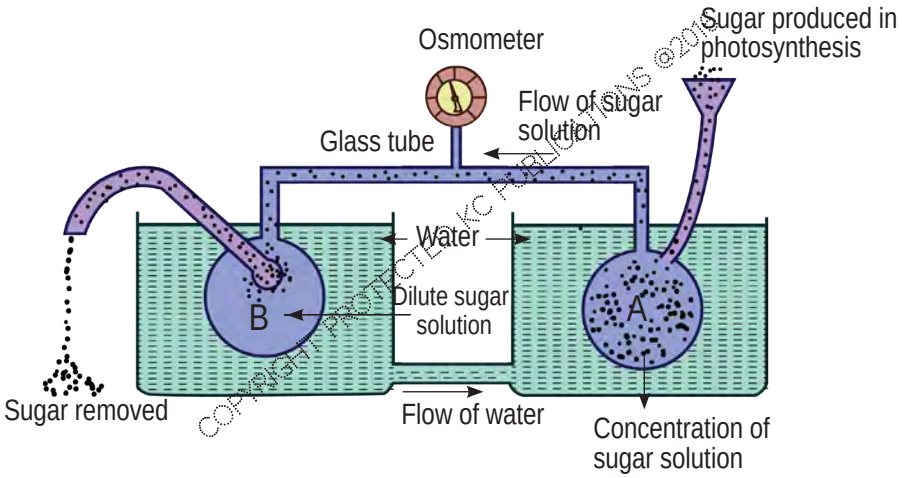


Figure 2.11: A model demonstrating the Munch mass flow hypothesis

forced out due to the *high turgor* pressure created in arm 'A'. The solutes are carried by *bulk flow* from 'A' to 'B' as the water flows into A. Eventually, this process stops when the pressure in the system is *equalized*. Using this *analogy*, **phloem transport** can be explained as; when the sucrose is loaded into **sieve element** by *active transport*, the *water potential* inside the sieve element decreases and water enters into it by *osmosis*. This process increases the *turgor pressure* of the **sieve cells** due to which it pushes the solutes to the *respiring plant cells* (***sink***) as the water moves in and out of the sieve elements. Removal of the **sucrose** at the sink increases the water potential causing water to move out of the sieve tube at the sink. This way, solutes move to sink cells while the water goes back to the **xylem**.

This model is supported by the following evidences:

i. When the contents of the *phloem sieve tubes are under marked pressure*, the *sieve tube sap exudes* as and when the phloem tissue is cut or damaged.
ii. Appropriate **gradients** in the concentration of sucrose between the *sink* and the *source* regions have been found in numerous plants.

***Drawbacks of the hypothesis*:**

i. Considering the amount of *food materials stored in the underground tuberous organs*, the rate of transport in sieve element is not sufficient to account for entire food transport.
ii. *Sieve elements are not continuous* as plasmodesmata and the sieve plates are a hindrance to mass flow.

c. Absorption of minerals

All organisms need **nutrition**. Green plants are **autotrophs** since they manufacture their own organic food from CO_2 and H_2O in the presence of sunlight. But they

require mineral salts in varying quantities for their healthy **growth** and **development**. Plants absorb the minerals from the soil and transport them to other parts of the plant. The **absorption**, **distribution** and the **use of minerals** by plants for their growth and development is called mineral nutrition.

i. The soil as the source of mineral nutrients

The mineral ions required by **terrestrial plants** are normally obtained from the soil. The mineral ions occur in various forms in the soil.

- ***Mineral ions in solution in soil water***: These are freely available to plants but can be also leached (washed away) from the soil by excess rainfall or by flooding.
- *Mineral ions adsorbed on the clay particles*: ***Clay particles*** are extremely small but collectively have large surface area to retain a reserve charged ions absorbed onto their surfaces. These ions are available to plants but not free to be leached away.
- ***Mineral ions in humus***: **Humus** is a black substance derived from decayed plants and animals remains. When it is decayed further, it releases the minerals.
- ***Mineral ions stored in the mineral skeleton***: The *mineral skeleton* of the soil is the long term store of essential ions in clay particles, sand, etc. These minerals are not available to plants but can be released by weathering processes.

d. Mineral nutrients uptake in plants

Mineral nutrients occur mainly in their **inorganic forms** of ions in the soil. Plants absorb mineral nutrients from the soil along with the upward conduction of water. Mineral salts are absorbed by three mechanisms namely, ion-exchange, mass flow and Donnan Equilibrium

i. Ion-exchange

The mechanism of absorption of mineral ions by ion exchange is explained further with the help of two theories. They are *contact exchange theory and carbonic exchange theory.*

1. **Contact exchange theory**. According to this theory, the ions absorbed on the surface of the root cells and clay particles are *not held tightly but oscillate* within the small volume of space called oscillation volume. If the roots and clay particles

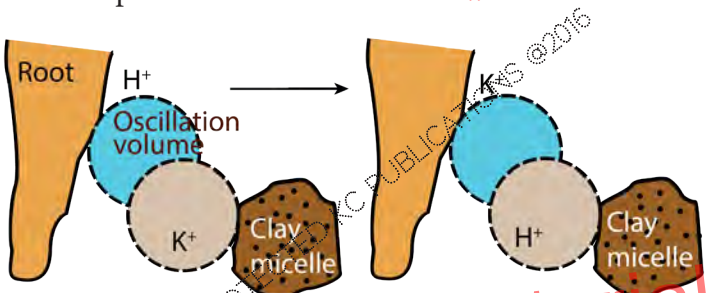


Figure 2.12 The contact exchange theory

are in close contact with each other, the *oscillation volume of two ions of the same charge overlap*, one is exchanged for the other (Figure 2.12). This is called contact exchange.

2. **Carbonic acid exchange theory**. According to this theory, the CO_2 released during *respiration of root cells* combine with water to form carbonic acid (H_2CO_3). Carbonic acid dissociates as H^+ ions and an anion HCO_3^- in the soil solution. These H^+ ions may be exchanged with cation adsorbed on **clay micelle**. The cations released from the clay micelle into the soil solution may be adsorbed on root cells in exchange for H^+ or as ion pairs with **bicarbonate** (Figure 2.13).

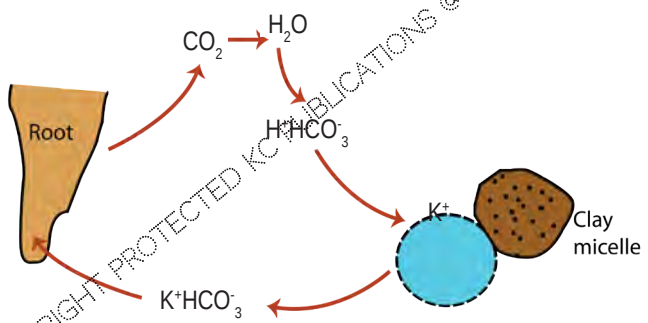


Figure 2.13: The carbonic exchange theory

ii. Mass flow

According to this ***hypothesis***, roots absorb a large quantity of ions along with the absorption of water due to **transpiration pull**. An increase in water flow in the plant due to transpiration pull also increases the total uptake of mineral ions. It occurs by **simple diffusion** without the expenditure of energy.

iii. Donnan equilibrium

Donnan equilibrium theory describes the **equilibrium that exists between two solutions separated by a selectively permeable membrane.** Due to the effect of the selective permeability of the membrane, an unusual presence of a different charged substances that are unable to pass through the membrane and thus creates an **uneven electrical charge** between the two sides of the membrane. As a result, the passage of some ions across the membrane is promoted and others are stopped. In a similar way, the root hair cells absorb certain mineral ions from the soil solution while stoping other ions.

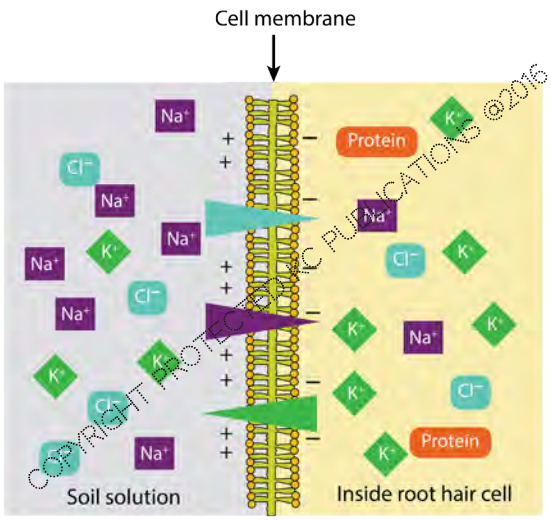


Figure 2.14: A model of ion exchange by Donnan's Equilibrium

2.3 Plant Hormones

Learning Objectives

On completion of this topic, you will be able to:

- explain that plant hormones are used to control plant growth and development.
- explain the commercial use of plant hormones.

Plants do not have **endocrine system** like that of animals for growth and development. Plants produce **chemical substances** within the cells which regulate their **growth**, **development** and **flowering** in plants. The internal regulators of growth and development are **genetic factors** and **growth regulators**. Genetic factors are *transmitted from one generation to another*, whereas, growth regulators are the *organic substances*, which are required for growth. These substances are called plant hormones or phytochromes. They are widely used for **commercial purposes** in industries and agriculture.

a. Types of plant hormones

Plant hormones are produced in any part of a plant and are transported to other parts, where it **influences a specific physiological process**. There are *five* main **plants hormones** or **phytochromes** that control the growth and development of plant, namely, auxins, gibberellins (GA), cytokinins, abscisic acid (ABA), and ethylene. **Ethylene** is the only gaseous hormone, whereas, **ABA** is a growth inhibitor. These hormones are required in smaller amount by plants which increases, decreases, or modifies the physiological process in plants.

The growth and development of plant body is **the sum total of the interaction** of different hormones present in the system. Figure 2.15 shows the types of plant hormones and their roles in the growth and the development of plant.

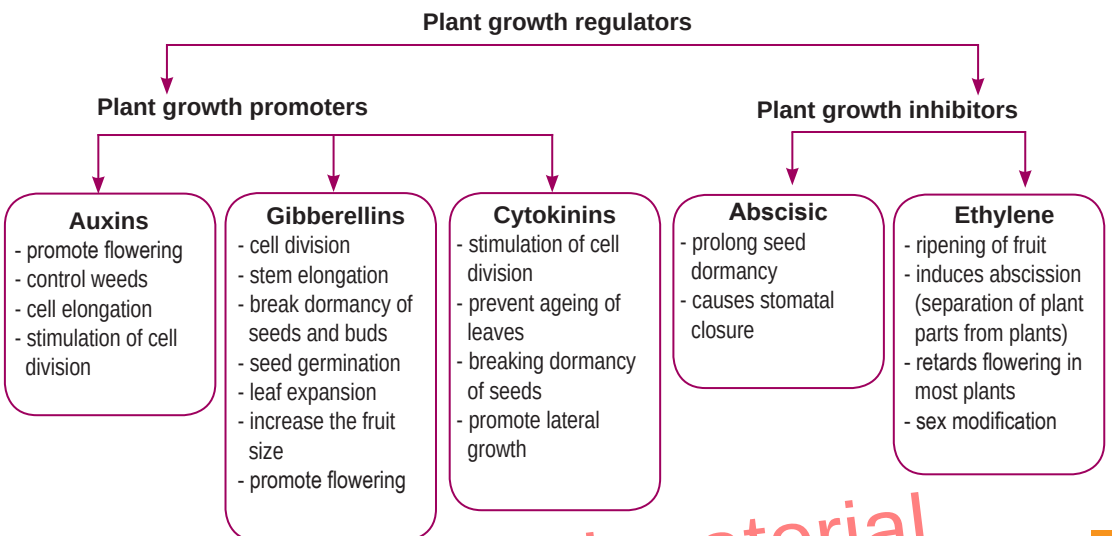


Figure 2.15: Plant growth regulators

b. The interaction of plant hormones

In plants, many features of development and response are **influenced by two or more plant growth hormones**. The control of the growth and development processes can rarely be due to a single plant growth substance. In most cases, plant growth substances interact to support each other's effects, and the process is known as synergism. For example, **gibberellins** and **auxins** (**IAA**) are **synergistic** in bud formation. However, plant growth substance may also oppose each other's effects, known as antagonism. For example, **IAA** and **cytokinin** are **antagonistic** to maintenance of apical dominance (i.e. IAA inhibits lateral bud growth and cytokinin promotes lateral bud growth). The interactions of plant growth hormones in plant growth and development are summarized in Table 2.3.

Table 2.3 Interaction of plant growth hormones

Process	Auxin (IAA)	Gibberellin (GA)	Cytokinin	Abscisic acid (ABA)	Ethylene
In stem					
Stem elongation (growth in length)	----------	promotes	promotes	inhibitory during physiological stress	
Bud formation	promotes slightly	promotes slightly	promotes	----------	----------
Apical dominance of terminal bud	inhibits lateral buds	enhance IAA action	promotes lateral bud	promotes bud dormancy	----------
In roots					
Root extension growth	promotes at very low concentration, inhibits at high conc.	----------	----------	----------	----------
Root initiation	promotes when applied to cuttings	inhibits	----------	----------	----------
In leaves					
Leaf growth	--------	promotes	promotes	-----	--------
Stomatal opening/ closing	------	-------	promotes opening	promotes closing	
Ageing (senescence) of leaves	delays	delays	delays	promotes	promotes

c. Commercial use of plant hormones

Plants hormones are used widely in commercial purposes in the following ways:

1. ***Hormones in rooting of cuttings***: The propagation of plants through stem cutting is common practice in **horticulture**, and in **plant breeding**. Exposure of stem to the IAA (indole acetic acid), enhances the initiations of roots that develop into new plant. **Artificial auxin** like α-naphthaline acetic acid (NAA) is effective in plant rooting and is less costly. With the use of hormone rooting powder, cut stems can develop roots and grow into **clones** of the parent plant.

Figure 2.16 Cutting dipped in rooting hormone powder

2. ***Parthenocarpic fruit development***: Plant hormone such as **IAA** is used to produce fruit grow without seeds. Un-pollinated flowers are treated with plant hormones, so that fruits without seeds are formed. If ovules are not fertilized, the seeds fail to develop and the young fruit falls off the plant. The development of fruit in the **absence of fertilized** ovules is referred to as parthenocarpic fruit.
3. ***Delay of pre-harvest fruit drop***: Fruit falls from the plant when an **abscission layer** is formed at the base of the fruit stalk; this is similar to leaf fall. Application of an *auxin delays abscission*. Many commercial plant growers often spray auxin on *apples*, *pears* and *oranges* to delay fruit fall.
4. ***Hormones as weedicides***: **Synthetic auxin** like 2, 4-dichlrophenoxyacetic acid is used as **weed-killer** or **herbicides**, which are not harmful to the surrounding plants or animals.
5. ***Storage***: Naphthalene acetic acid (NAA) is used to *prevent sprouting of potatoes, onion bulbs* and can be stored for a longer time by spraying auxins to the plants before harvest.
6. ***Flowering***: **NAA** is used to *induce flowering* in pineapple and litchi. Hormones are used to promote the ripening of fruit or induce flowering when required.
7. ***Delayed ripening***: In some fruits, ripening can be delayed due to Gibberellin (GA), e.g. citrus. This is useful in storing fruits.
8. ***Sprouting***: *Rhizomes*, *corms* and other *storage organs* can be made to sprout early by exposing them to **ethylene**.
9. ***Increase yield***: GA is used with grapes and tomatoes to **elongate clusters** and to increase the number and size of the fruits.
10. ***Ripening of fruits***: Fruits such as *bananas picked unripe* for the safe transport, are induced to ripen by exposure to ethylene gas.

Plant hormones such as **gibberellins** (**GA**) and **abscisic acid** (**ABA**) are used in Renewable Natural Resources Research and Development Centres of Bhutan for the purposes stated below.

1. GA for **breaking seed dormancy** and to **extend the shelf life** of citrus fruit in post harvest management. It is also used for research purposes in citrus fruit **colour development** and **rind thickness** and
2. ABA for **rooting purposes** in plant **propagation**.

Activity 2.3

Investigate root initiation in bean cutting using plant hormone.

Materials required: α-naphthaline acetic acid (NAA), spring balance, bean stem cuttings, water, soil, container

Procedure

1. Take one bean cutting and treat with only water.
2. Take another bean cutting and apply 5 mg of NAA.
3. Take third bean cutting and treat with 20 mg of NAA.
4. Take fourth bean cutting and treat with 50 mg of NAA.
5. Keep record for all the observations for about two weeks.

Questions

i. Write the aim of the experiment.
ii. State the possible hypothesis for the experiment.
iii. Draw a line graph showing the relationship between number of roots initiation and the concentration of NAA.
iv. Mention any precaution needed for this experiment.
v. What conclusion can you draw from the experiment?
vi. Where can you apply the knowledge gained from the experiment?
vii. Write a short report about your investigation.

Lesson Summary

- The net reaction in the photosynthesis of carbon dioxide and water, together with energy from the sun produce glucose and oxygen.
- Photosynthesis occurs in two phases: light dependent reaction and light independent reaction.
- During the light dependent reactions of photosynthesis, solar energy is converted into the chemical energy of ATP and NADPH, and it releases oxygen.
- During light independent reaction, also known as Calvin cycle, the chemical energy of ATP and NADPH is used to convert carbon dioxide into glucose.
- Photosystem is of two types: photosystem I and photosystem II.
- The three main factors that affect the rate of photosynthesis are light, temperature and carbon dioxide. These three factors are called the limiting factors.
- Pressure-flow hypothesis explains the mechanism of translocation of the organic food materials in plants through the phloem.
- The mechanism of adsorption of mineral ions by ion exchange is explained with the help of two theories, contact exchange theory and carbonic exchange theory.
- Mass flow hypothesis and Donnan Equilibrium explain the mechanism of adsorption of mineral ions in plants.
- In plants, the internal regulators of growth and development are genetic factors and growth regulators.
- The five plant hormones are auxin, gibberellins, cytokinin, abscisic acid ethylene. These hormones have been used commercially for different purposes purposes by farmers and horticulturists.

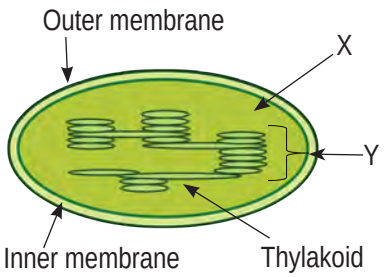
Weblink

- http://www.johnkyrk.com/
- http://www.brightstorm.com/science/biology/cell-functions-and-processes/
- http://vcell.ndsu.nodak.edu/animations/photosystemII/index.htm
- http://www.learnerstv.com/animation/animation.php?ani=166&cat=biology
- https://highered.mheducation.com/sites/9834092339/student_view0/chapter38/animation_-_phloem_loading.html
- http://www.kscience.co.uk/animations/auxin.swf

Revision Questions

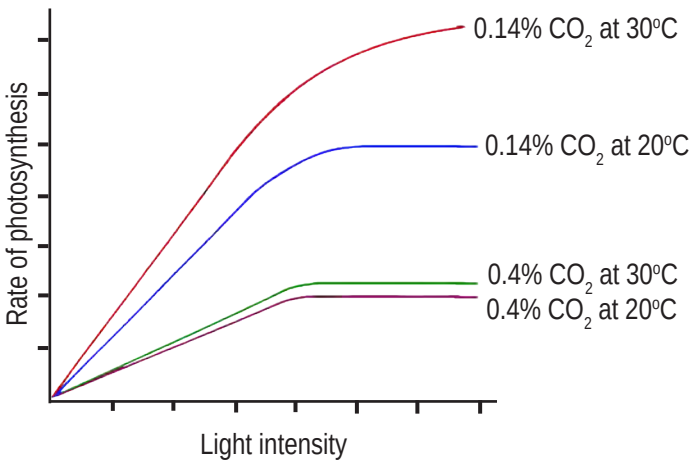
A. Each question in this part is followed by four possible choices of answers. Choose the correct or the most suitable response.

1. The diagram below is a cell organelle in a plant cell where photosynthesis occurs. A special structure labelled 'X' is the site for



   A. light-independent reaction.
   B. light dependent reaction.
   C. stomatal transpiration.
   D. cellular respiration.
   E.

2. The graph on the right shows the effect of light intensity on the rate of photosynthesis. After careful analysis, a student interpreted the graph, more precisely, as



   A. increase in light intensity results in increase in rate of photosynthesis.
   B. increase in concentration of CO_2 results in increase in rate of photosynthesis.
   C. increase in temperature results in increase in rate of photosynthesis.
   D. factors such as light intensity, carbon dioxide concentration and temperature serve as a limiting factors to each other.

3. The principal pathway of organic materials transportation in mango tree is
   A. leave cell ⟶ companion cell ⟶ sieve cell ⟶ root hair cell.
   B. leave cell ⟶ sieve cell ⟶ companion cell ⟶ root hair cell.
   C. leave cell ⟶ phloem parenchyma ⟶ companion cell ⟶ sieve cell ⟶ root hair cell.
   D. leave cell ⟶ phloem parenchyma ⟶ sieve cell ⟶ root hair cell.

4. The theory of translocation of organic food material through phloem is acceptable

because of evidence(s) from

A. Ring experiment.
C. Mass flow.
B. Carbon dating.
D. Both A and B.

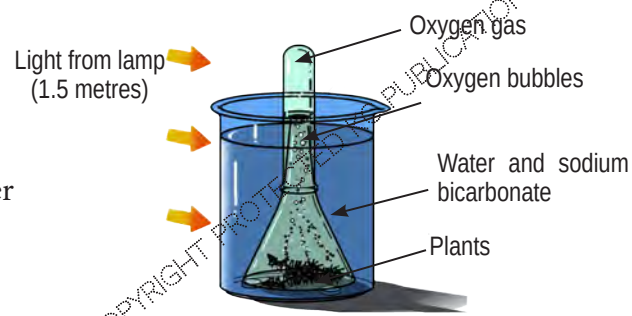
5. Find out the correct option from the given statements between soil and root cells of plants.

i. Anions and cations are located on the surface of the cell wall through root hair cells absorption.
ii. The soil solutions also contain ions.
iii. Carrier molecules are involved in ion exchange and energy consumed is from ATP.
iv. Such ionic exchange occurs even against their concentration gradient.

A. iii & iv.
C. i, ii and iv.
B. i, ii & iii.
D. ii, iii and iv.

6. The diagram below shows a student's experiment with elodea, a common aquatic plant. What change in the experiment is most likely to increase the volume of accumulation of oxygen gas at the top of the tube?

A. Use fewer plants.
B. Replace the beaker with a larger container.
C. Move the light source closer to the beaker.
D. Reduce the amount of water.



7. Which of the following statements is the most accurate?

A. Food can travel up the stem in the phloem.
B. Food can travel down the stem in the phloem.
C. Food can travel up or down the stem in the phloem.
D. Food can travel up or down the stem in the xylem.

8. Which is not the function of auxin in plants?

A. Promote flowering.
C. Ripening of fruits.
B. Controls weeds.
D. Cell elongation.

9. Which chlorophyll molecule is found in photosystem II?

A. P670 C. P700

B. P680 D. P720

10. Mark the odd one out.

A. Temperature. C. Age of leaf.

B. Chlorophyll content. D. Structure of leaf.

B. Fill in the blanks with the correct form of word(s).

1. A student conducted an experiment to find out the effects of plant hormone on stem elongation. She concluded that both gibberellins and cytokinin promotes stem elongation. This kind of interactions between the substances that support each other's effects is called ……..
2. During photolysis, the light energy splits water molecule into ….....……. an ……. ……. ions.
3. Complete the following equation which summarizes the process of photosynthesis.

…..CO… + 6 …… ⟶ C…… + 6 ….

4. A farmer in order to the increase the shelf life of his vegetables and cut flowers, needs to spray …….
5. A gardener cuts hedges around her house only at the top to promote ……..... growth.

C. Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.

Column A	Column B
Dark reaction	xylem
Light reaction	photosystem
Translocation of organic solutes	thylakoids
Transportation of minerals and nutrients	stroma
Reaction centre of chlorophyll-a	phloem

D. Name the following.

1. The theory of mineral element absorption that believes that ions are absorbed when ions overlap its oscillation volume.
2. A gas hormone responsible to ripe the unripe tomato.

3. The absorption, distribution and metabolism of various mineral elements in plants.
4. A single chlorophyll molecule in chloroplast, where the photons are channelized and trapped.
5. The form of substance, by which an apple tree transports its organic food materials within its body parts.

E. Give reasons.

1. Ethylene lamp is used in fleshy fruits.
2. Light intensity, carbon dioxide concentration and temperature are limiting factors.
3. NAA is sprayed on storage organs like rhizome, potato, corms and onion bulbs.
4. Water in the xylem and translocation of food is related with each other.

F. Copy and complete the following paragraph. Select the most appropriate words from the list below.

A green plant can make all the substances it needs. It builds up carbohydrates by the process of ……. In this process, it combines …….. ……from the ……... with ……. ….. from the …… to form …… The ……. needed for this process comes from ……..,which is absorbed by the ……. in the …….. of leaf cells. The waste product of the process is……

[soil, energy, oxygen, glucose, chloroplasts, mineral salts, cells, photosynthesis, air, respiration, sunlight, water, nitrogen, chlorophyll, carbon dioxide].

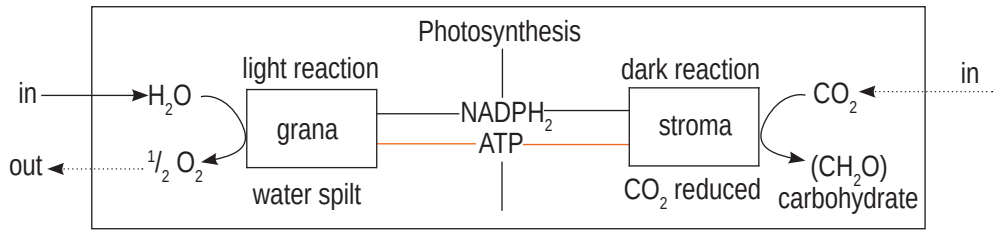
G. Answer the following questions.

1. Design an experiment to test the hypothesis that a volatile substance emitted by ripe tomatoes, helps to ripe the unripe tomatoes without contact.
2. Outline how plants absorb minerals from soil.
3. As a farmer how would you prevent leaf fall and fruit drop in plants?
4. What is hydroponics? What are its uses for farmers?
5. Suppose you have a potted rose plant in your house, how would you demonstrate downward translocation of food in it? Support your answers with aim, materials required, procedure, observation, result and diagrams.
6. Using the Table 2.3.
   i. Give two examples of plant hormones that are synergistic to each other.
   ii. Give two examples of plant hormones that are antagonistic to each other.
   iii. List two inhibitory functions of auxins.

iv. If you remove the apical bud from the shoot and apply either IAA, cytokinin or ABA to the cut surface, what would happen in each case after a few days.

7. Outline the fate of the glucose produced from photosynthesis.

8. The diagram below shows a summary of photosynthesis. Study and answer the questions that follow:



i. Explain how water splits.

ii. How are above two phases of photosynthesis related?

iii. What does the outer bigger box represent?

iv. Where does the oxygen released by photosynthesis come from?

v. If ATP and NADPH are the end products of the light reactions. What are their uses in dark reaction?

vi. What gas will be taken in and given out by a green plant in dark and in sunlight?

vii. Which carbohydrate is the main storage substance?

9. A student sets up an experiment in the laboratory as below. Study and answer the questions that follow. 'Y' is the substance produced as a result of dissolving sodium bicarbonate ($NaHCO_3$) in water.

i. Identify the environmental factors X, Y and Z that would affect the experiment.

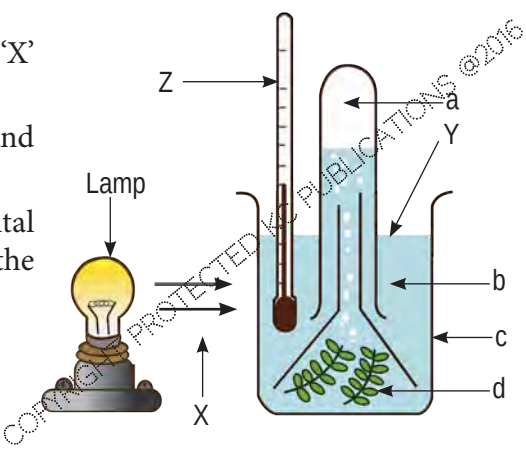
ii. Name the parts a, b, c and d.

iii. How would environmental factor 'X' affect the formation of 'a'.

iv. Draw the relationship between X, Y and Z.

v. If the mercury level of environmental factor 'Z' is 45^0 C, how would it affect the leaves of part'd'.

vi. Criticise the set up of the experiment.



3 HUMAN AS ORGANISMS

All organisms are made up of several complex organ systems. The human being is made up of organ systems that work in coordination to support all the life functions of the body. Each organ system is made up of organs that work together to function as an organ system. In this chapter, you will study more about the four human organ systems; digestive system, circulatory system, excretory system and respiratory system. Each of this system carries out major functions of the body such as digestion, circulation of blood, excretion and respiration respectively.

3.1 Digestion

Learning Objectives

On completion of this topic, you will be able to:

- explain the role of enzymes, stomach acid and bile in the process of digestion.
- illustrate the chemical reactions of digestion by using word equations.

Digestion is a process that features the breakdown of large and **complex food molecules** into **simple** and **smaller molecules**, so that they are easily absorbed by body cells. In the human **digestive system**, digestion of food involves **mechanical digestion** and **chemical digestion**. Mechanical digestion involves the physical breakdown of large particles of food into smaller forms. It begins with the chewing of food by the teeth and continues through the muscular mixing of food by the stomach and intestines. Bile produced by the liver is also used to mechanically break fats into smaller globules. Along with the mechanical digestion of food, chemical digestion also occurs that further breaks down the more complex molecules into smaller molecules that are easier to absorb.

a. Chemical digestion

Chemical digestion involves several enzymes and occurs in a series of steps. It begins in the mouth with **salivary amylase** in saliva, which splits the *complex carbohydrates into simple carbohydrates*. The enzymes and acid in the **stomach** continue chemical digestion, but the bulk of chemical digestion takes place in the **small intestine**. The enzymes that help in the chemical digestion are called digestive enzymes. They are found in the digestive tracts of humans. They help to break down complex molecules like **proteins**, **carbohydrates** and **fats** into their smaller units for easy absorption by the body.

In the human digestive system, the main sites of chemical digestion are the **mouth**, **stomach** and the **small intestine**.

i. Mouth

In the mouth cavity, **salivary glands** secrete a group of enzymes and substances that help in digestion. The salivary glands secrete saliva, which mixes with the chewed food. Saliva has *two* functions:

1. Saliva contains the enzyme amylase, which is a carbohydrase and breaks down starch into sugar. This enzyme is also referred to as ptyalin.
2. Saliva also contains mucus, which moistens and lubricates the food and helps to pass down the **oesophagus** easily.

Lingual lipase is an enzyme produced by the salivary glands that helps breakdown

lipids in the mouth. Another enzyme called lysozyme helps to kill harmful germs present in the food during digestion in the mouth. *Digestion of carbohydrates and lipids* are initiated in the mouth.

ii. Stomach

The **stomach** plays a major role in digestion, mixing and crushing the food. The bolus formed in the mouth enters the stomach. The **muscular wall** of the stomach churns the food and mixes it well with the secretions. After 2 to 3 hours of churning the food, the mixture is a **thick pulpy mass** called chyme.

The enzymes that are secreted in the stomach are called gastric enzymes. The stomach cells secrete **gastric juice** which mixes with the food. The gastric juice contains a protease enzyme called pepsin, which breaks down proteins into **amino acids**. The juice also contains hydrochloric acid. The acid in the juices kills germs present in the food.

The stomach secretes the following **enzymes**, **hormones** and **acid** that help in the chemical digestion.

1. Pepsin is the main gastric enzyme. It is produced by the stomach cells called '***chief cells***' in its inactive form **pepsinogen**, which is a zymogen. Pepsinogen is then activated by the **hydrochloric acid** into its active form, **pepsin**. Pepsin works best in an acidic environment of **pH 2**.

   Pepsinogen (inactive) $\xrightarrow{HCl}$ **Pepsin** (active)

   Pepsin breaks down the protein in the food into smaller particles, such as **peptones**, **peptide** and **amino acids**.

   Protein $\xrightarrow{pepsin}$ **Peptides** + **Amino acids**

   Protein digestion first starts in the stomach.
2. Gastric acid, which in lay man's term is called '***stomach acid***', is produced by the cells of the stomach called parietal cells. It is composed of **hydrochloric acid** (HCl), **potassium chloride** (KCl) and **sodium chloride** (NaCl). **HCl** mainly activates inactive protein enzymes and destroys any bacteria or virus that remains in the food.
3. Gastrin is an important hormone produced by the stomach cells. This hormone enters the bloodstream and eventually returns to the stomach, where it stimulates **parietal cells** to produce HCl.
4. Gastric lipase is an **acidic lipase** secreted by the gastric chief cells in the stomach. It has an optimum pH of **3-6**. It breaks about 30% of the fats into **fatty acids** and **glycerol**.

iii. Small intestine

The **partially digested food** (*chyme*) leaves the stomach through the **pyloric sphincter** and enters the small intestine. In the small intestine *three* important juices are added to the chyme.

1. Bile juice: It is a complex fluid containing *water, electrolytes and bile acids, cholesterol, phospholipids and bilirubin* that flows into the small intestine. The liver produces **bile**, which is stored in the gall bladder and enters the small intestine through the bile duct. Bile has two important functions:
   i. Bile *neutralises* the acidity of the chyme in the duodenum. This provides the best pH for the enzymes in the small intestine to work on the food.
   ii. Bile *emulsifies or breaks down* large molecules of fat into smaller fat molecules, such as *fatty acids* and *glycerol*, which increases the surface area of fats for the enzyme lipase to work on.
2. Pancreatic juice: The pancreas secretes a very strong digestive juice known as pancreatic juice, which is capable of digesting lipids, carbohydrates, proteins and nucleic acids. The pancreatic juice contains *carbohydrases*, *proteases* and *lipases*. Pancreatic juice contains the following digestive enzymes:
   i. Trypsinogen is an **inactive form** of enzyme. It is activated through the duodenal enzyme enterokinase into its active form trypsin. Once activated, it breaks down proteins into amino acids.

Trypsinogen —enterokinase→ **Trypsin**
(inactive) *(active)*

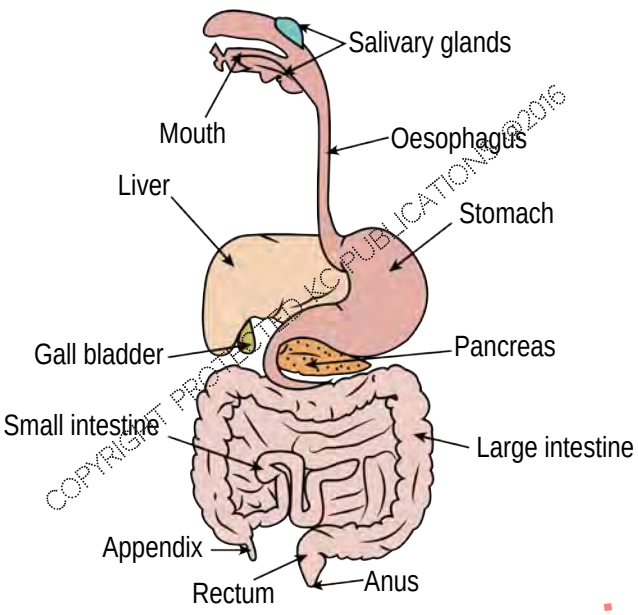


Figure 3.1: The human digestive organs

ii. Chymotrypsinogen is also an **inactive form** of enzyme. It is activated by ***enterokinase***. Once activated, it breaks down proteins into amino acids.

iii. Pancreatic lipase **emulsifies** fats into fatty acids and glycerol.

iv. Nucleases breaks down the nucleic acids (DNA and RNA) into *nucleotides* and *nucleosides*.

v. Pancreatic amylase breaks down the remaining starch and glycogen into sugar. Humans lack an enzyme **cellulase** to digest cellulose.

3. Intestinal juice: The glands in the wall of the small intestine produce intestinal juice. The lining of the small intestine produces numerous enzymes, whose function is to further break down the chyme into absorbable particles. Ileum is the site of complete digestion of carbohydrates, proteins and fats. Some of these enzymes include:

i. Erepsin or peptidase converts proteins into peptones and amino acids.

$$\textbf{Protein} \xrightarrow{\text{erepsin}} \textbf{Peptides} + \textbf{Peptones} + \textbf{Amino acid}$$

ii. Maltase converts maltose into glucose.

$$\textbf{Maltose} \xrightarrow{\text{maltase}} \textbf{Glucose}$$

iii. Lactase converts lactose into glucose and galactose.

$$\textbf{Lactose} \xrightarrow{\text{lactase}} \textbf{Glucose} + \textbf{Galactose}$$

iv. Sucrase converts sucrose into glucose and fructose.

$$\textbf{Sucrose} \xrightarrow{\text{sucrase}} \textbf{Glucose} + \textbf{Fructose}$$

v. Lipase emulsifies the remaining fats into fatty acids and glycerol.

$$\textbf{Fats} \xrightarrow{\text{lipase}} \textbf{Fatty acids} + \textbf{Glycerol}$$

iv. Large intestine

Excess water and **salts** are absorbed by the mucous lining of the large intestine. The undigested residue is converted into semi-solid faeces. The faeces is stored in the **rectum** until it is excreted through the anal canal.The final function of the digestive system is the *excretion of waste* by the process known as egestion or defecation. **Defecation** removes indigestible substances from the body, so that they do not accumulate inside the gut.

b. Absorption of food

The **end products** of *carbohydrate*, fat and *protein digestion* are *glucose*, *glycerol*, *fatty acids, amino acids* and *vitamins*. Once food has been reduced to its simplest form, it is ready for the body to absorb. **Absorption** begins in the stomach with simple molecules like water and alcohol being absorbed directly into the bloodstream. Most

absorption takes place **in the walls of the small intestine**, which are densely folded to maximize the surface area in contact with digested food. The end products like fatty acids and glycerol enter the lymph present in the lymph vessel or lacteals. For efficient absorption, the small intestine has the following adaptations.

i. It is very **long** and is lined with **tiny finger like projections** called villi. There are millions of villi which provide a massive surface area to maximise the rate of absorption. Each villus in turn is covered with even smaller microvilli.

ii. The villi have very **thin walls** and a good blood supply, so that the digested food can be easily absorbed into the blood.

iii. It has **lacteal** or **lymph vessel** in each villus for absorption of fat.

The large intestine is also involved in the absorption of **water** and **vitamins** before faeces leave the body.

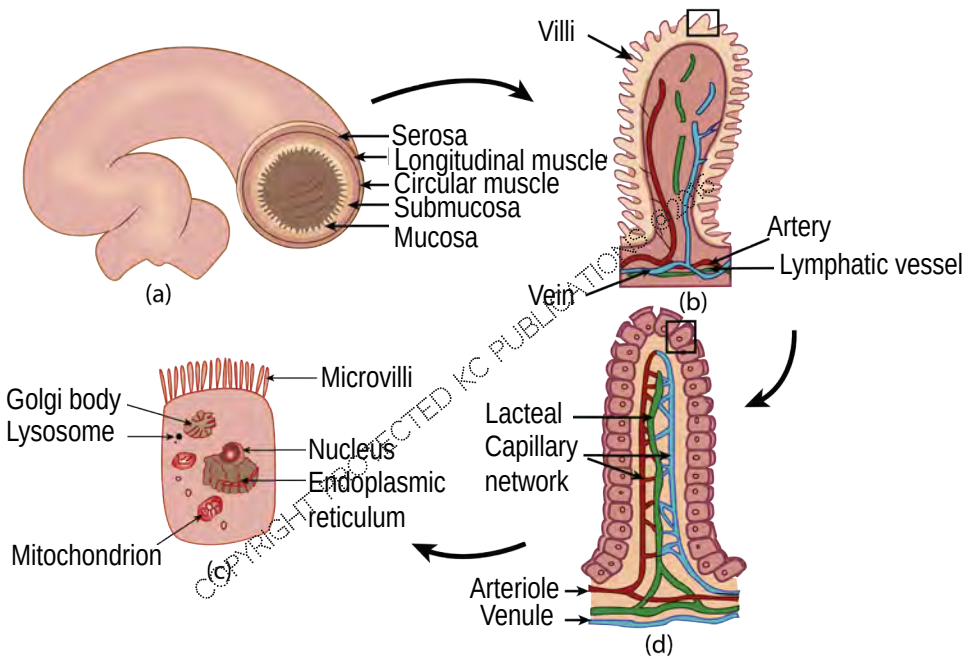


Figure 3.2: Intestinal villus

c. Assimilation of food

The food absorbed by the walls of the small intestine is distributed to different parts of the body by the blood.

i. Glucose is used by cells for respiration to release energy. *Excess amount of glucose* is converted into **glycogen** in liver and is stored in muscle cells and liver cells.

ii. Amino acids are used for the synthesis of proteins in the **construction of various cell organelles.**

iii. Fatty acids and glycerol are converted into **fats** in body cells.

Activity 3.1

Laboratory tests to identify different food groups

Materials required: test tubes, test tube rack, test tube holder, Bunsen burner, match box, spatula, 1% starch solution, iodine solution, Biuret reagent, Sudan III, protein solution, oil, water, etc.

Procedure

Conduct the test for different food groups as per the procedure provided in Table 3.2. Copy and complete the table.

Food groups	Procedure	Observation	Inference
Test for starch	*Iodine test* i. Add 2mL of iodine solution to the 1% starch solution in a test tube. ii. Heat the above solution after making observation in step i.		
Test for lipids	Add 2mL of oil to 2mL of water in a test tube. Add few drops of Sudan III and shake it.		
Test for proteins	*Biuret test* Add 2mL of protein solution (which is an extract of pulses, or egg albumin or milk) and 2mL of Biuret reagent.		

Questions

i. Name any two plant tissues that can be used to demonstrate the presence of protein.
ii. Identify one confirmatory test for the protein.
iii. Write any two precautions that you will take while conducting the test for starch.
iv. Explain the significance of this experiment in our daily life.
v. Design another method to test for the presence of lipids in food.

3.2 Blood and Circulation

Learning Objectives

On completion of this topic, you will be able to:

- describe the composition of blood.
- explain the exchange of substances between capillaries and tissues.

The human **circulatory system** consists of the circulatory medium and a system of tubes. The circulatory medium comprises of blood, lymph and tissue fluid which carry food, oxygen and other substances. A system of tubes comprises of arteries, veins, lymph vessels and capillaries which transport the body fluids. The heart pumps the blood through the blood vessels. The function of circulatory system is to *transport oxygen* and *nutrients* to different body cells. It also removes carbon dioxide and other waste products from the body.

a. Blood and its composition

Blood is a fluid connective tissue. It helps in the **transportation** of oxygen, carbon dioxide, nutrients, hormones, etc. Blood plays an important role in the maintenance and regulation of **pH** and **body temperature**. It also protects our body from pathogens and foreign substances. The average adult body has approximately about 5 to 6 litres of blood.

The blood is composed of about 55% plasma and 45% cellular components. **Plasma** is composed of *water*, *plasma protein*, and other solutes such as *food substances*, *ions*, *hormones*, *vitamins* and *dissolved gases*. Cellular components include red blood cell, white blood cell and platelets.

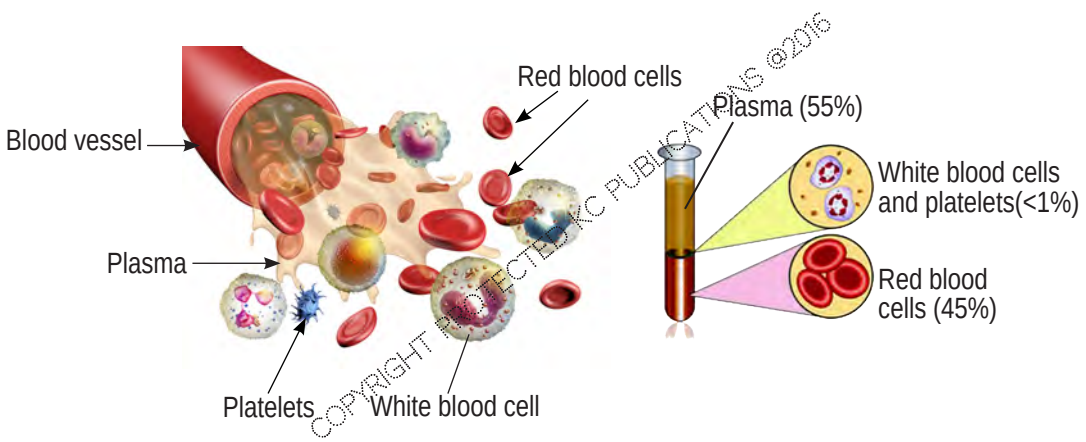


Figure 3.3: Composition of blood

i. Plasma

It is the **yellow liquid part** of the blood, in which red and white blood cells as well as platelets are suspended. The **plasma** consists of:

Water: *90%*

Plasma protein *(7%)*: *albumin* (most numerous), *globulins*, *fibrinogens*, *prothrombin*

Organic materials: *glucose*, *amino acids*, *fats, urea*

Inorganic materials: *sodium chloride*, *sodium bicarbonate*, *ions*

Others: *hormones*, *blood gases* and others.

The plasma from which the **protein fibrinogen** has been removed is called serum.

Functions of blood plasma

1. Plasma helps in the *transportation of hormones*, *vitamins*, *minerals*, and *drugs.*
2. Plasma proteins participate in CO_2 *transport* in blood.
3. Most blood *clotting factors* are plasma proteins.
4. Plasma proteins contribute to about 15% of the *buffer activity* of blood.
5. It contributes in the *regulation of arterial blood pressure* due to presence of water and plasma proteins.

ii. Cellular components

The cellular components of the blood are of *three* types, which are visible under the microscope. They are red blood cells, white blood cells and platelets.

1. Red blood cells (RBCs)

Red blood cells are **biconcave disc shaped** cells, which lack nucleus and other organelles. Red blood cell is also called as erythrocyte. These cells contain a pigment called haemoglobin, which helps to transport oxygen and carbon dioxide in blood. The diameter of red blood cells ranges from about 7 to 8 microns. The main function of RBCs is the *transportation of respiratory gases.* The RBC constitutes about 60% of the blood volume. The average life span of each RBC cell is about **120 days**, and is destroyed in the **spleen**.

Figure 3.4: Structure of red blood cells

The main function of RBCs is :

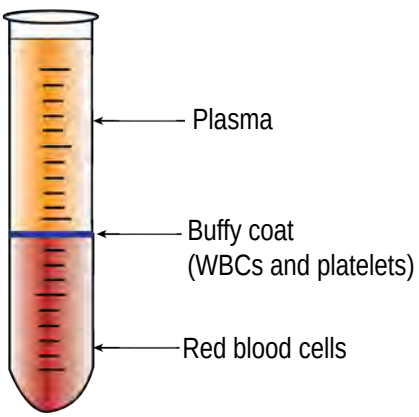
i. transportation of oxygen from the lungs to tissues, and carbon dioxide from tissues to the lungs.

Production of red blood cells

Red blood cells are produced in the **bone marrow** of the bones. The production of red blood cells is controlled by a hormone called erythropoietin. Red blood cells have **no nucleus** and can easily change shape, which helps them to fit through the various blood vessels in the body.

A **normal blood count of RBC** ranges from 4.5 to 5.5 per mL in adult human. If the blood count of RBC is less than the normal value, then it is due to some deficiency like low level of oxygen in blood cells, deficiency in iron, vitamin B_{12}, blood loss and other infections.

Hematocrit = % of RBCs



The percentage of red blood cells volume to the total blood volume is called hematocrit. It is calculated by dividing the red blood cells volume by total blood volume and multiplied by 100. The normal average is about 46% in male, and 42% in female. An increase in hematocrit is called polycythemia, while a decrease in hematocrit is called anemia.

$$\text{Hematocrit} = \frac{\text{total RBC volume}}{\text{total blood volume}} \times 100$$

2. White blood cells (WBCs)

The name **white blood cell** is due to its white colour. They are produced in the **bone marrow of the bones and lymph nodes**. White blood cells are irregular in shape with a nucleus. They are the part of the immune system that destroys infectious agents called pathogens. White blood cells are also known as leukocytes. These blood cells have the ability to move in and out of blood vessels, and can respond to chemicals released by damaged tissues. They are much **lesser in number** compared to red blood cells.

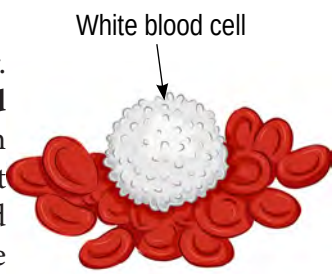
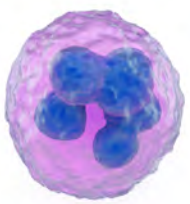
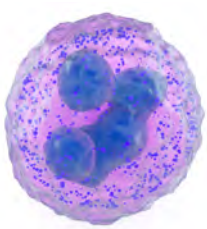


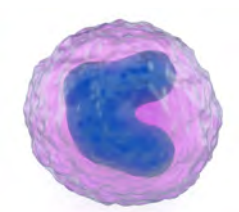
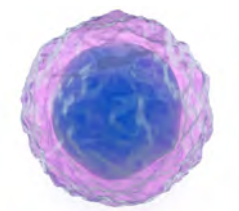
Figure 3.5: Structure of white blood cell

The size of WBC ranges from 10 to 12 microns. It survives for about *12 hours* to *12 days*. The WBC count varies between male and female. They are of two main types; granulocytes and agranulocytes.

Granulocytes are further divided into neutrophils, eosinophils and basophils. **Agrunulocytes** are of two types lymphocytes and monocytes. Their details are given in Table 3.1.

Table 3.1 Types of white blood cells.

Two main types of WBCs	Appearance	Identifying characteristics	Function
A. Granulocytes 1. Cytoplasm contains granules that absorb dyes and gives granular appearance. 2. Nucleus usually constricted into lobes.	1. *Neutrophils*(62%) 	1. Nucleus is 3 to 5 lobed. 2. Cytoplasm has very fine granules. 3. Stain with **neutral dyes**.	1. Helps in the destruction of bacteria by **phagocytosis**.
	2. *Eosinophils*(2.3%) 	1. Nucleus 2 lobed. 2. Stain dark red with **eosin**.	1. **Engulf bacteria**. 2. Responsible for controlling mechanisms associated with allergy and asthma.
	3. *Basophils* (.04%) 	1. Nucleus large three lobed. 2. Cytoplasm contain large granules. 3. Cells look purple in colour, when stained with **Leishman's stain**.	1. Releases chemical **histamine** during **inflammatory reactions**. 2. Protects our body from several **allergic** symptoms.

Two main types of WBCs	Appearance	Identifying characteristics	Function
B. Agranulocytes 1. Cytoplasm contains granules but does not absorb dyes and gives nongranular appearance.	1. *Lymphocytes* (30%) 	1. Cell contains a large bilobed nucleus. 2. The nucleus is generally of half -moon shaped or kidney shaped and it occupies 3 to 8 percent of WBCs.	Protect against the **blood borne pathogens** and they move quickly to the sites of infections in the tissues.
	2. *Monocytes* (5.3%) 	Their size ranges from 12 to 20 micrometers.	**Produce antibodies** to attack and destroy virus and bacteria.

Functions of white blood cells

i. They destroy and digest virus and bacteria by engulfing them in a process known as phagocytosis.

ii. They play vital role in controlling the level of **red blood cells** (**RBCs**) in blood.

iii. They produce **antibodies** which help to attack and destroy virus and bacteria.

Production of white blood cells

White blood cells are mostly produced in bone marrow. A few of them are produced in **lymph nodes** and **spleen**. The productions of white blood cells are more during the time of injury and infections. A normal blood count of WBC ranges between 6,000 to 9,000 per cubic mL of blood. The overproduction of white blood cells may also be caused due to **inflammatory disease** like - *anemia*, *leukemia*, and it can also be due to tissue damage. The lesser count of WBC from the normal value can be due to *bone marrow deficiency* and *exposure to radiations*.

3. Blood platelets (Thrombocytes)

They are **small**, **oval** or **round structures**, **non-nucleated**, floating in the blood plasma. They are normally 2 to 3 microns in diameter and have the lifespan of about *3* to *5 days*. The total count of platelets is about 2,00,000 to 3,00,000 per mL of blood. **Platelets** are small fragments of giant cells called megakaryocytes in the red bone

marrow. Their production is controlled by a hormone called thrombopoietin.

Platelets play vital role in **blood clotting**. At the site of injury, they disintegrate and release a chemical substance known as ***thrombokinase***, which initiates the process of clotting.

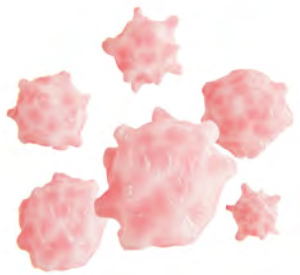


Figure 3.6: Structure of blood platelets

Brain Snack

- The human body is estimated to have 60,000 miles of blood vessels. The only part of your body that has no blood supply is the cornea in the eye. It gets its oxygen directly from air.
- A lobsters blood is colourless but when exposed to oxygen it turns blue.

b. Clotting of blood

When there is a cut in the blood vessel, **blood oozes out** but stops after 2 to 3 minutes. This is due to a phenomenon called blood clotting. Clotting is rapid, preventing serious blood loss by providing a **scab** to the **injured blood vessel**. Platelets normally remain inactive in the blood until they reach the damaged tissue. Once activated, platelets change into a **spiny ball shape** and become very **sticky** and stick on to the damaged tissues. Platelets also begin sticking together to form a platelet plug to minimize the bleeding.

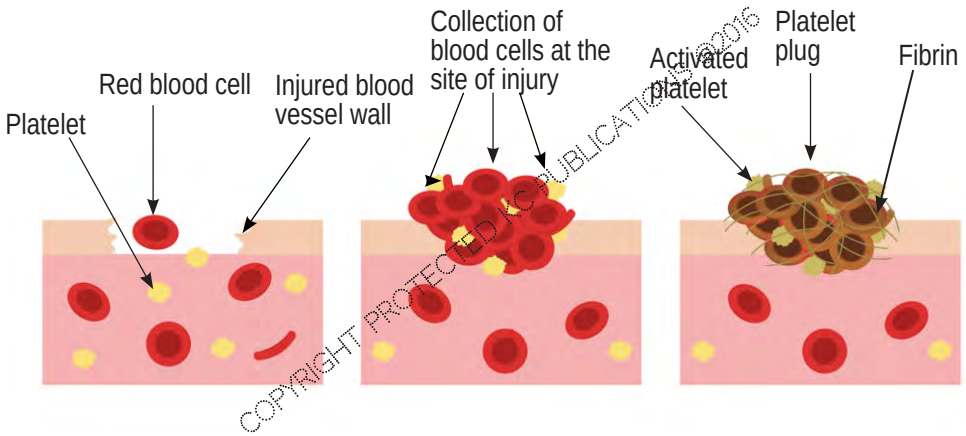


Figure 3.7: Blood clotting

Under *normal conditions*, clotting can be prevented by a substance called heparin present in blood plasma. A condition in which blood fails to clot is known as haemophilia. Any injury to a person suffering from haemophilia can lead to excessive bleeding, which can be fatal.

The process of blood clotting is complex and involves three major steps.

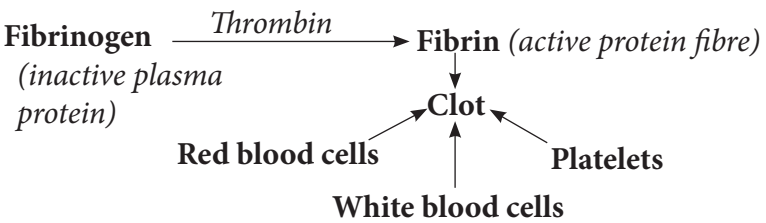
1. The **platelets** collected at the damaged site, release a substance called prothromboplastin. This substance in the presence of **calcium ions** form thromboplastin.

Prothromboplastin (*from platelets*) $\xrightarrow[Ca^{++}]{}$ **Thromboplastin**

2. **Thromboplastin** with calcium ions and **vitamin K** convert plasma protein prothrombin to an enzyme thrombin at the damaged site.

Prothromin $\xrightarrow[Ca^{++}]{\textit{Thromboplastin}}$ **Thrombin**

3. **Thrombin** then converts fibrinogen into insoluble short length fibrin fibres. These fibres stick to one another and form a **mesh**. The mesh traps blood cells such as **RBCs**, **WBCs** and **platelets** and results in a clot.



After the formation of blood clot, it is further strengthened by a process called clot retraction. In this process, the platelets in the clot contract, pulling the fibrin strands to which they are attached resulting in a strong and **tight sealed patch**. This prevents the loss of blood and the entry of **bacteria** and other **pathogens**. Eventually, the **inflammation sites regain** normal conditions.

Activity 3.2

Examining blood cells under the microscope

Materials required: microscope, slide, sterilized needle, spirit, cotton, Leishman stain, distilled water

Procedure

1. Take two clean slides.
2. Clean the skin of the fingertip and prick it with the sterilized needle.
3. Wipe off the first blood, which oozes out with the cotton.
4. Gently squeeze the fingertip and take a drop of blood near the right end of one slide.
5. Immediately place the second glass slide held at an angle of 60° over the first slide close to the drop of blood and smear the blood drop gently on the slide. A fine layer of blood will be formed on the first slide as blood smear.
6. Allow the blood smear to dry and stain with a few drops of Leishman stain. After two minutes, add a few drops of distilled water.

7. Allow the mixture to remain for another two minutes. Drain out the excess mixture and rinse with tap water.
8. Once the slide is dried, examine under the microscope.

Precaution

Never share needles with others.

Questions

i. Draw the blood cells as observed under the microscope.
ii. Write any two precautions for the experiment.
iii. Write one identifying feature for each type of blood cells you observe under the microscope.
iv. What is the function of Leishman stain?
v. What is the scientific importance of this experiment?

c. Blood groups and blood transfusion

The **human blood group** was first discovered by Karl Landsteiner in 1901. His work helped to determine blood groups and thus helped in the **safe transfusion of blood**. He was awarded the ***Nobel Prize*** in medicine in 1930 for his discovery. Human blood groups are classified based on **ABO system** and the **Rhesus factor**.

According to the ***ABO system***, blood groups are classified into four major blood groups, which are determined by the presence or absence of *two antigens*: **A** and **B**. Antigens are the protein on the surface of a *RBC membrane*. The proteins produced by **lymphocytes** in response to the presence of antigens is called antibody. The main role of the antibody is to attack **foreign antigens**, which results in blood clumping or agglutination.

The *four kinds* of blood groups are **A**, **B**, **AB** and **O** (*null*). Summary of each type is given in the Table 3.2

Table 3.2 Blood group chart

Blood Group	Antigen A	Antigen B	Antibody A	Antibody B	Donate blood to	Receive blood from
A	Present	-	-	Present	**A** and **AB**	**A** and **O**
B	-	Present	Present	-	**B** and **AB**	**B** and **O**
AB (*Universal recipient*)	Present	Present	-	-	**AB**	**AB**, **A**, **B** and **O**
O (*Universal donor*)	-	-	Present	Present	**O**, **A**, **B** and **AB**	**O**

i. The Rhesus (Rh) factor

A substance called '**Rh factor**' is found on the surface of RBCs of most people. One who has this '*Rh factor*' is called Rh^+. One who lacks it is called Rh^-. A person with **Rh^- blood** does not have **Rh** antibodies naturally in the blood plasma. But a person with **Rh^-** can develop **Rh** antibodies in blood plasma if one receives blood from a person with **Rh^+** blood, whose **Rh factor** can trigger the production of **Rh** antibodies. The two blood grouping systems combine to describe the following eight different blood groups in humans.

Blood group **A** = **A** *positive* **A^{+ve}**, *and* **A** *negative* **A^{-ve}**.

Blood group **B** = **B** *positive* **B^{+ve}** *and* **B** *negative* **B^{-ve}**.

Blood group **AB** = **AB** *positive* **AB^{+ve}**, *and* **AB** *negative* **AB^{-ve}**.

Blood group **O** = **O** *positive* **O^{+ve}**, *and* **O** *negative* **O^{-ve}**.

ii. Blood transfusion

Blood transfusion is a procedure in which blood is given to a patient through an **intravenous line** in one of the blood vessels. **Blood transfusions** are done to replace blood lost during **surgery** or due to **serious injury**. A blood transfusion is also done when a person's body cannot produce enough blood because of an illness.

A person with **blood group A** can donate blood to another person with **blood group A** or **AB**. Similarly, a person with **blood group B** can donate blood to another person with **blood group B** or **AB**. A person with **blood group AB** can donate blood to **AB blood group** only. A person with **blood group O** can donate blood to **A**, **B**, **AB** and **O**. Therefore, people with **blood group O** are called universal donors, as they can give blood to any blood type. People with **blood group AB** are, on the other hand called universal recipients, as they can receive blood from any blood type.

In case of **Rh positive** and **Rh negative blood group**, generally, **Rh^+** person can receive blood from any other blood type but a person with **Rh^-** person can receive blood from **Rh^-** persons only.

d. Exchange of substances between capillaries and tissue

There are different types of blood vessels in the human circulatory system. These are the **network of tubes** that transport the blood around the body. Arteries carry blood away from the heart and veins carry blood back to the heart. When an artery reaches an organ it branches out into capillaries. It is in the capillaries, where substances such as oxygen, food and carbon dioxide are exchanged between the blood and the organ cells by diffusion. **Capillary walls contain small pores** through which certain substances move in and out of the blood vessels.

The blood is retained inside the blood vessels, but the fluid derived from the plasma escapes through the walls of capillaries. This fluid that bathes the cells is called tissue fluid. **Tissue fluid** has a composition similar to that of blood plasma, but lacks **proteins**. Its fluid contains *oxygen*, *glucose*, *amino acids*, *fatty acids*, *hormones* and *inorganic ions*. These are the composition of blood required by cells of the body. In addition, tissue fluid collects **carbon dioxide** and other **excretory substances**.

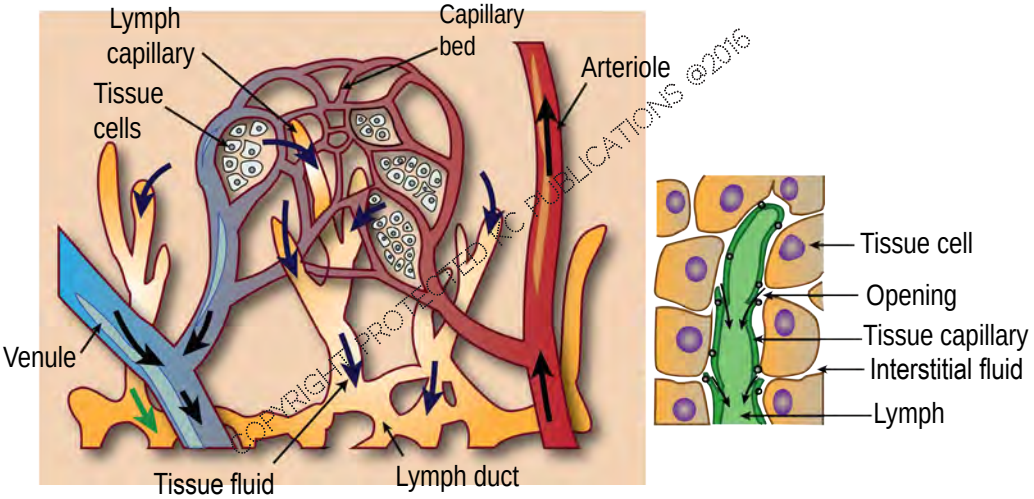


Figure 3.8: A capillay network and lymph capilllary

Fluid exchange is controlled by blood pressure within the capillary vessel and osmotic pressure of the blood within the vessel. The osmotic pressure is produced by high concentrations of **salts** and **plasma proteins** in the blood. The pressure exerted by fluids, such as blood and tissue fluid, against the walls of the capillaries is called hydrostatic pressure. The source of the hydrostatic blood pressure is the pumping action of the heart.

e. Lymphatic system

Lymphatic system or immune system is part of **circulatory system**. It consists of many network of vessels called lymph vessel that run throughout our body. These small lymph vessels join to form larger vessels called lymphatics, which provide an **accessory route** so that fluids can flow from the tissue spaces into the blood. They carry proteins and large particles away from the tissue spaces, which cannot be absorbed directly into the blood capillary. Before reaching the blood circulation, lymph passes through one or more lymph nodes, where suspended solids are removed by cells of **lymph nodes**. During the exchange of material, there is always slightly more filtration of fluid into the tissue spaces than is re-absorbed. About 90% of the fluid that has filtered out is re-absorbed; the other 10% flows into lymph vessels as **lymph**. *Accumulation of excess fluids* in a body causes swelling of the body and the condition is called oedema.

3.3 Excretion

Learning Objectives

On completion of this topic, you will be able to:

- describe removal of waste products of the body by lungs and kidneys.
- explain the regulation of water content of the body by kidneys.

Our body performs numerous functions in order to keep the organ systems running. It also produces wastes. These wastes are **toxic chemicals** if left to accumulate inside the body. The wastes can seriously harm or even kill the cells. This process of removing wastes and excess water from the body is called excretion. It is one of the important ways for the body to **maintain homeostasis**. Although kidneys are the main organs of excretion, several other organs also excrete wastes. They include the **large intestine**, **liver**, **skin**, and **lungs**. All of these organs along with the kidneys constitute the excretory system.

The **human excretory system** functions to remove waste from the human body. This system consists of specialized structures and capillary networks that assist in the excretory process.

a. Urinary system

Urinary system plays an important role in the excretion of nitrogenous waste in the form of urine from our body. It consists of many accessory parts that assist in the process of excretion. The functions of these accessory parts are discussed in Table 3.1.

Table 3.1 Parts and functions of urinary system

Renal artery	The renal artery enters the kidney at the notch on the concave side called the **hilus renalis**. As it is a branch from the aorta, it brings oxygenated blood into the kidneys.
Renal vein	The renal vein drains away deoxygenated blood, which is free of toxic substances into the **inferior vena cava**.
Ureter	The ureter, a tube, runs from each kidney downwards into the lower part of the abdomen connecting each kidney to the **urinary bladder**. Its function is to transport the urine from the **kidneys** to the urinary bladder.
Urinary bladder	This is a large *muscular storage sac* that collects urine from both the kidneys through the **ureters**. The mouth of the bladder is guarded by a tight ring of muscle called the **sphincter**, which regulates the opening or closing of the bladder.
Urethra	This is a short muscular tube that carries urine at intervals from the urinary bladder to the outside. The base of the **urethra** is also guarded by a **sphincter**, which keeps the urethra closed except, while passing urine.

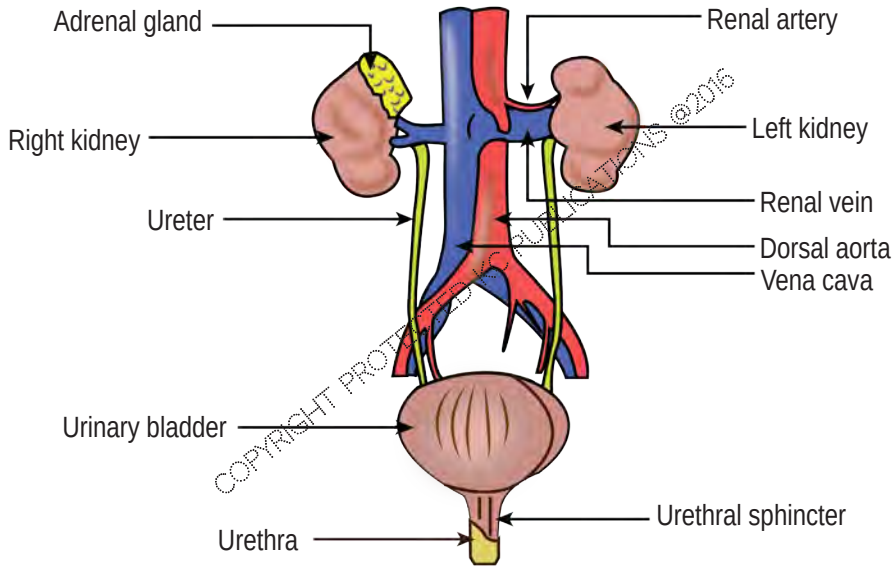


Figure 3.9: Parts of the urinary system

b. The human kidney

The kidneys are **reddish brown**, **bean-shaped organs** situated in the abdominal cavity, one on either side of the **vertebral column** in the lumbar region of the body. The right kidney is slightly lower than the left, as the right side of the abdominal cavity is occupied by the liver. Each kidney is the size of a *clenched fist* and is about 10 cm long, 6 cm wide and 4 cm thick. A thin, tough, fibrous whitish capsule envelops each kidney. The outer surface of the kidney is convex, while the inner surface is concave. Blood enters the kidneys through renal arteries and leaves through the renal veins. The human kidneys are the principal excretory organs through which the **nitrogenous metabolic wastes** are eliminated in the form of urine.

i. Internal structure of kidney

A *longitudinal section* of the kidney shows two distinct regions: an **outer cortex** and an **inner medulla**. The cortex is a pale red coloured layer and contains the **malpighian capsule**, the **proximal** and **distal** parts of the *renal tubule*. The medulla forms the inner dark red zone and contains the **Henle's loop** and the **collecting tubules** in the form of **renal pyramids**. The conical pyramids project into the renal pelvis. This is a large funnel-shaped region behind the **renal medulla**. Urine flows into the **renal pelvis** through minute openings at the *tips or papillae of the pyramids*. The urine that is collected is passed down to the **ureters** and into the **bladder**. Each kidney consists of a large number of *microscopic filtering units* called nephrons.

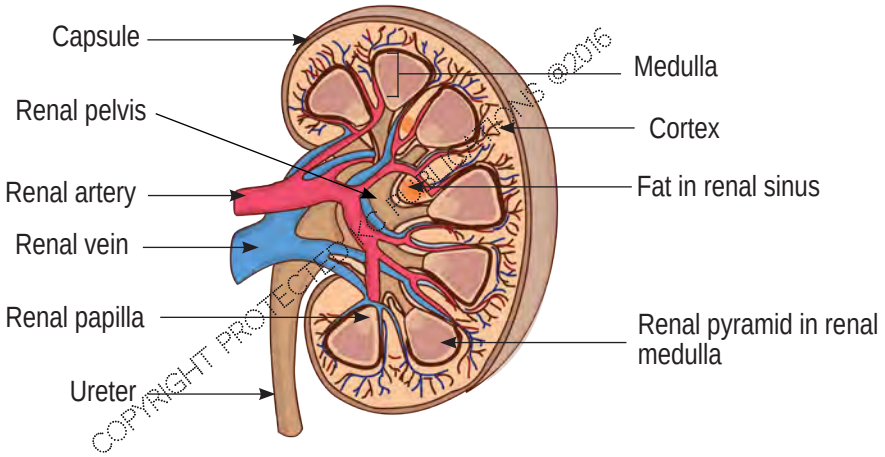


Figure 3.10: A longitudinal section of the kidney

ii. The kidney tubule or nephron

The *functional and structural unit* of the kidney is the kidney tubule or nephron. It is a minute tubule about 3 cm long. The nephron is differentiated into six *distinct* regions, each with a specific function. The nephron begins with a cup-shaped **Bowman's capsule** that surrounds a network of blood capillaries called the glomerulus. The glomerulus is formed by the **afferent arteriole** (incoming) and the **efferent arteriole** (outgoing).

The glomerulus and Bowman's capsule form the **first region of the nephron**, and it is known as the Malpighian capsule. This region leads into the remaining part of the tubule. The proximal convoluted tubule (**PCT**) is the region behind the Bowman's capsule. The proximal convoluted tubule consists of a coiled tube that descends as descending limb of Henle and ascends to form the ascending limb of Henle. The **loop of Henle** continuous as distal convoluted tubule, which is another coiled and twisted tubule that continues to form the collecting duct.

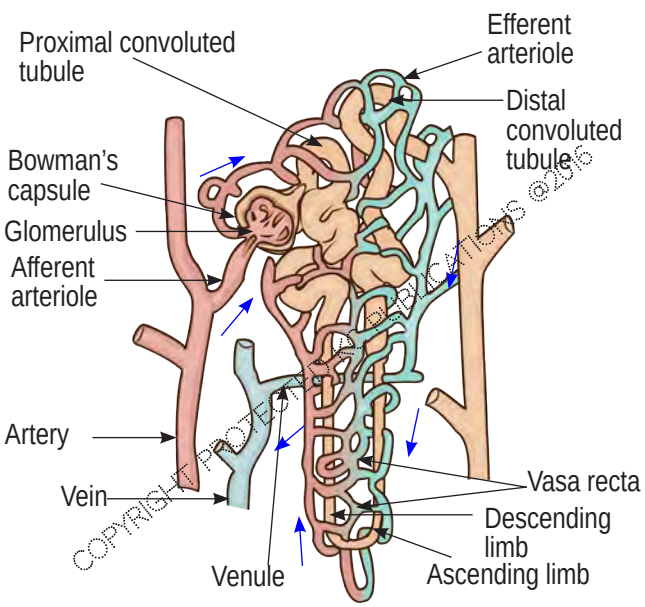


Figure 3.11: The structure of a nephron

Several collecting ducts fuse to form large collecting ducts, which pass downwards from the cortex to the medulla region. These larger ducts are called ***ducts of Bellini*** that open into the renal pelvis, draining out the urine collected from the nephrons.

iii. Blood supply to the kidney tubule

The *blood supply to the nephron* begins from an afferent arteriole serving the glomerulus. From the glomerulus, blood is carried by efferent arteriole which then breaks up into two other systems of capillaries. One is a capillary network serving the proximal and distal convoluted tubules and the other is a single straight capillary running beside the limbs of the **loop of Henle**. These two capillary structures are called vasa recta (Figure 3.11).

Activity 3.3

Human excretory system

Materials required: charts/models of L.S of kidney of a man and charts/model of nephron.

Procedure

1. Observe and examine the L.S of kidney and nephron.
2. Identify the cortex and medulla and examine the distribution of nephrons and parts of a nephron.
3. Draw a labelled diagram of the observed structures.

Questions

i. Differentiate between cortex and medulla based on the distribution of nephron and parts of the nephron.

ii. Describe the structure of nephron. If the nephron is a straight structure, how would it affect the urine formation?

iii. How does the osmotic pressure contribute in the excretion process?

Brain Snack

- The kidney only represents less than 1% of body mass but it, receives about 25% of all blood flow. In a day, it filters 1800 litres of blood, which is 400 times the blood volume. It gets more blood flow than the brain or the heart.
- The human kidney contains more than 1.2 million nephrons. If you were to uncoil and untwist all the nephrons in a single kidney, they would span over 8 Km.

c. Urine formation

The formation of urine takes place in nephron through the following processes.

i. Ultrafiltration

The blood enters the **glomerulus** under high pressure compared to pressure in other capillaries. This high pressure is because of the efferent arteriole (outgoing) being narrower than that of the afferent arteriole (incoming). Therefore, many contents in blood are forced to pass through the capillary walls with high pressure into the lumen of **Bowman's capsule** by the process known as ultrafiltration. Water, glucose, vitamins, amino acids, uric acid, ammonia, salts and ions all make up the glomerular filtrate. About 180L of **glomerular filtrate** is produced each day. The blood that remains in the glomerulus after the ultrafiltration is thicker as it contains blood proteins and other bigger molecules like **proteins**.

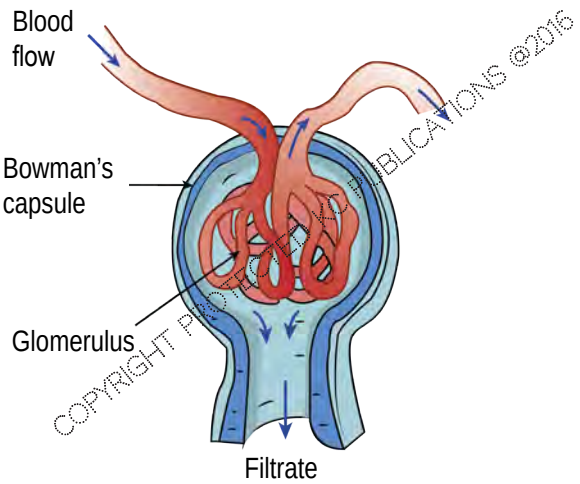


Figure 3.12: Site of ultrafiltration

ii. Selective re-absorption

Those components of filtrates in the kidney tubules that are useful for the body are being **re-absorbed** across the cells of tubule walls by **active transport**. The re-absorbed substances include **glucose**, **amino acid**, as well as other compounds that help to maintain water and salt composition of the body fluids. The re-absorption process varies in different parts depending on which *transporter molecules* are involved. Movement of water across the tubule walls occurs passively by **osmosis** as each section of the tubule is **permeable** to different nutrients or wastes.

iii. Tubular secretion

Other substances not required by the body are added to the filtrate by **active transport** from the cells of the tubule walls. Such substances include **toxins** due to medication, **hydrogen ions**, **potassium ions**, etc. The remaining constituent after tubular re-absorption and secretion in the collecting duct is the urine. It is a watery solution of waste products containing **salts**, **organic compounds**, and two important nitrogen compounds: ***uric acid*** and ***urea***. Uric acid results from nucleic acid decomposition, and urea results from amino acid breakdown in the liver. Both of these nitrogen products can be **poisonous** to the body and must be removed in the form of urine.

Micturition

Urine formed by the kidneys is **temporarily stored** in the bladder, and release of urine from urinary bladder through **urethra** is called micturition. It takes place by contraction of the bladder wall and relaxation of the **sphincter muscle**. This sphincter and the process of urination are normally under conscious control. On an average, the urine output in a healthy person is 1 to1.8 litres per day.

d. Composition of urine

The volume and composition of urine vary widely from day to day even in a healthy person depending on several factors. *For example*, urine output increases with increase in fluid intake, or changes depending on the food consumed, or due to physical activity. However, normal human urine consists of about 95% of **water** and 5% **solid wastes** dissolved in it. The urine is **yellow** due to the presence of a pigment called urochrome formed by the break down of **haemoglobin** of the red blood corpuscles.

The **pH** of urine is generally about 6, which is *slightly acidic*. The odour of urine is **pungent** due to **ammonia** formed by bacterial decomposition. This is because bacteria convert urea to ammonia. The nitrogenous wastes found in urine are **urea**, **ammonia**, **uric acid** and **creatinine**. **Salts** like *sodium chloride, traces of mineral ions like sulphates, chlorides, phosphates, sodium, calcium, magnesium, iodine, vitamins, oxalic acid, alcohol, hormones and enzymes* are also present. **Glucose** and **proteins** are normally absent. Their levels go up in the case of diseases like **diabetes mellitus** or **kidney failure**.

The composition of a sample of urine is often tested in hospital because **urine of abnormal composition** is an easy indicator of disease or malfunction of many of the body systems. *For example*, when glucose appears in the urine, it may be a symptom of diabetes.

e. Osmoregulation

In humans, **kidney tubule regulates** the contents of salts and water in the body cells. The mechanism by which the correct balance of water and solutes in the body is maintained is known as osmoregulation. It occurs by regulation of the water and salt concentration of the blood. The **descending loop of Henle** allows the re-absorption of water, while the **ascending loop** allows for passive and active transport of salts.

The **re-absorption** of the remaining water in the distal convoluted tubule is dependent on the presence of the hormone vasopressin or anti-diuretic hormone (ADH). In the presence of this hormone, the **water permeability of the tubule wall** is enhanced, and thus more water will be re-absorbed by an active process. Some individuals suffer from a condition in which they secrete very low levels of **ADH**. The result is excessive urination and a disease called diabetes insipidus.

Aldosterone is another hormone secreted into the distal convoluted tubule that helps in the re-absorption of more **sodium** (Na^+) and secretion of more **potassium** (K^+). In addition, **hydrogen ions** (H^+) and **ammonium ions** are also secreted.

The **collecting duct** is normally impermeable to water, but in the presence of **vasopressin**, it becomes permeable. The liquid that flows out of the collecting duct into the renal pelvis is the **final filtrate**, or **urine**.

Drinking enough water, directly or through food helps in the proper functioning of kidneys. **In hotter days, we drink plenty of water** but we urinate fewer times and the urine passed is generally more concentrated. It is because in hot days, we lose a considerable amount of water from our body in the form of sweats. As a result, kidneys have to reabsorb more amount of water from the nephron, making urine more concentrated.

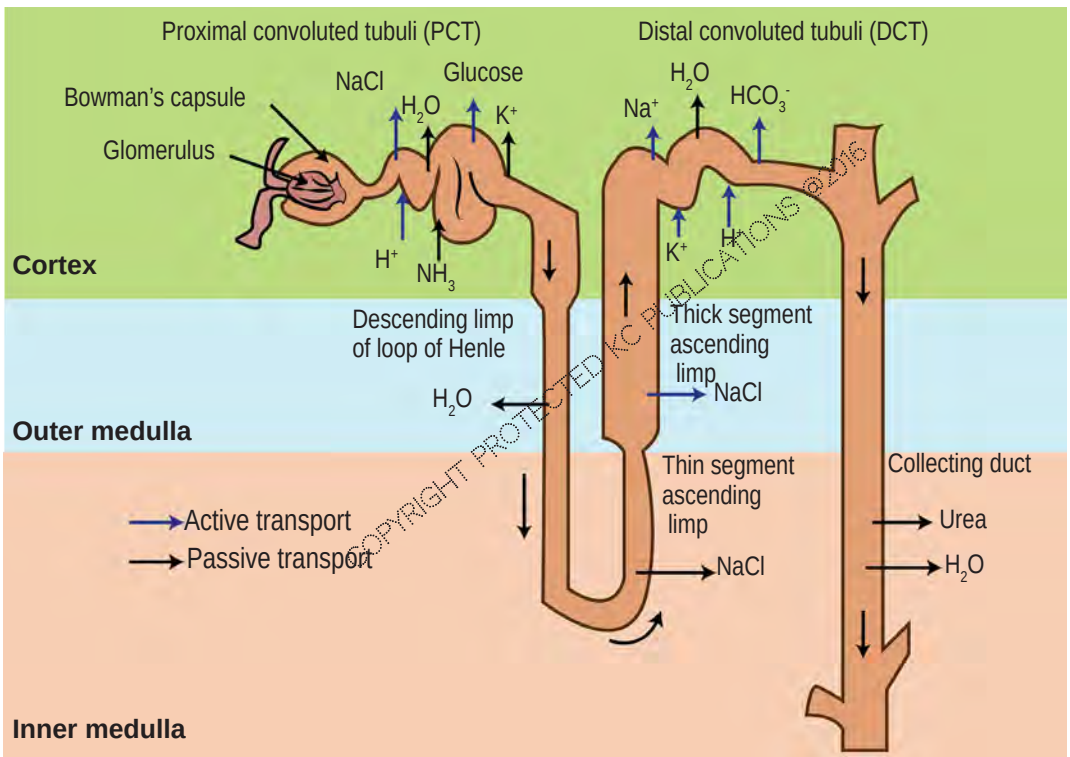


Figure 3.13: Tubular re-absorption and secretion

f. Kidney disease and Haemodialysis

Kidney function can fail suddenly in the case of injury or overdose, or it can decline gradually as a result of diabetes or high blood pressure. A person can live a normal, healthy life with just one kidney. Diseases that threaten the health and functioning of the kidneys include **kidney stones**, **infections**, and **diabetes**.

1. Kidney stones are mineral crystals formed in urine inside the kidney. They may

be extremely painful if the kidney stones block the ureter. They must be removed from the kidney for easy excretion of urine.

2. Bacterial infections of the urinary tract, especially the bladder, are very common. Bladder infections can be treated with **antibiotics**. If untreated, they may lead to kidney damage.
3. Uncontrolled diabetes may damage capillaries of nephrons. As a result, kidneys lose their ability to filter blood. This is called kidney failure. Kidney failure can be treated by a **kidney transplant** and **haemodialysis**. Haemodialysis is a medical procedure in which the blood of the patient is filtered through a machine called haemodialyser (Figure 3.14).

The machine works by drawing the patient's blood through tubing into a bath of purifying liquid, then returning it to the body. The tubing is made of **semipermeable membrane**. When exposed to such a membrane, particles in solution always move from **higher concentration to one with lower concentration**. So, in dialysis, the toxic waste particles in the blood cross the membrane into the dilute water, the larger particles, such as red blood cells, are too big to pass through the membrane pores.

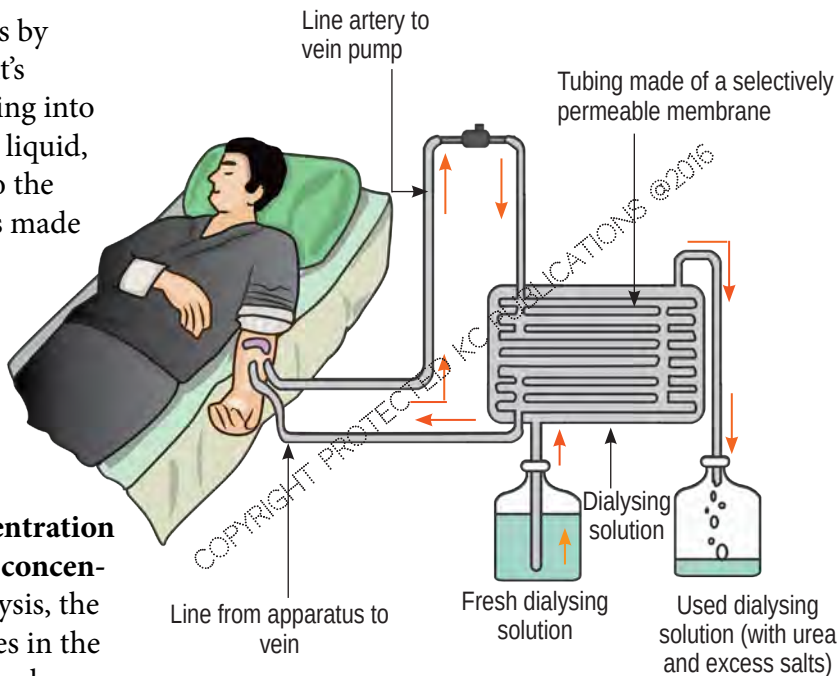


Figure 3.14: Haemodialysis procedure

g. Accessory excretory organs

1. Lungs: **Carbon dioxide** is a waste product formed due to **oxidation of food** in releasing energy, and carried to the lungs by the blood. **During expiration**, this carbon dioxide along with a small quantity of water vapour is expelled out of the lungs.
2. Skin: The skin of **aquatic animals** is permeable and excretory wastes are removed by diffusion. However, in **terrestrial animals**, skin is less permeable and excretory

products pass out only through ducts and pores. **Human skin** has two kinds of glands that perform the function of excretion.

i. Sweat glands are long tubular glands, coiled at their ends, located in the dermis of the skin, embedded in the subcutaneous tissue. They produce a watery fluid called **sweat** which consists of about 98% water and 2% solid residue. The *organic waste* includes **urea**, **uric acid**, **creatinine**, **volatile fatty acids**, and the *inorganic waste* includes **sodium chloride**, **potassium chloride** and **glucose**.

ii. Sebaceous glands are microscopic exocrine glands in the skin that secrete an oily or waxy matter, called sebum. It lubricates and makes the skin and hair of mammals waterproof. **Excretory substances** like **waxes, sterols**, **fatty acids** and traces of other **hydrocarbons** are eliminated along with the sebum.

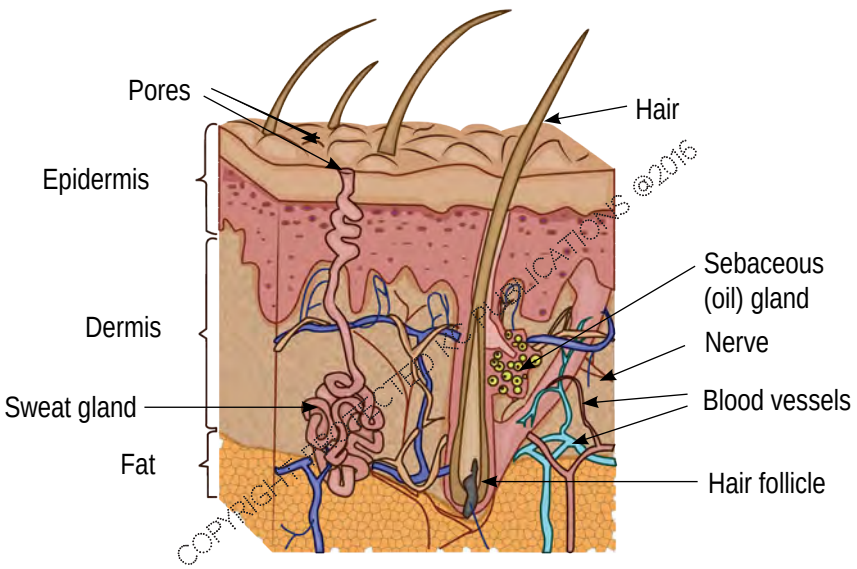


Figure 3.15: Vertical section of the skin

3. Liver: **Bile pigments** (*biliverdin* and *bilirubin*) are produced as a result of the **breakdown of haemoglobin** in the worn out red blood cells in the liver. It is then excreted with the bile into the duodenum and removed along with the faeces. Liver also excretes **cholesterol**, various inactivated products of **steroid hormones** and harmful products like **alcohol**, **nicotine** and several **drugs**.

3.4 Respiration

Learning Objectives

On completion of this topic, you will be able to:

- categorise respiration as aerobic respiration or anaerobic respiration.
- explain the processes of aerobic respiration and anaerobic respiration.
- explain how an 'oxygen debt' occurs in muscle during vigorous exercise.

All organisms **require energy** to sustain life. Plants trap energy from sunlight through the process of **photosynthesis** and store in the chemical bonds of carbohydrate molecules. We need energy to function and this energy is obtained from the food we eat through **chemical reactions** that are enzyme controlled. In **cellular respiration**, organisms control the release of energy from organic molecules and use this energy for activities to sustain life.

a. Cellular respiration

You have already studied that **cellular respiration** involves the breaking down of glucose into carbon dioxide and water. It occurs in a series of metabolic reactions and processes, which take place in the cells of organisms. The process of cellular respiration involves the **conversion of biochemical energy from glucose into adenosine triphosphate** (ATP). **ATP** is a high energy molecule, which is used by cells. Living organisms are capable of carrying out reactions in a controlled manner, so that energy is released in the right quantity at the right time. Therefore, organisms are able to use the energy to carry out activities such as **reproduction**, **movement**, and **growth**.

Cellular respiration takes place both in **eukaryotic** and **prokaryotic cells**. Cellular respiration can be aerobic respiration or anaerobic respiration. **Aerobic respiration** takes place only in the presence of oxygen, whereas an **anaerobic respiration** does not require oxygen. During cellular respiration, glucose undergoes a series of enzyme-catalysed oxidation reactions.

i. Mechanism of aerobic respiration

In aerobic respiration **adenosine triphosphate** (**ATP**) is produced by the cells due to the oxidation of organic compound (glucose). ATP is a rich energy molecule that produces large amounts of energy. Aerobic respiration includes *three major phases*: **glycolysis**, **Krebs cycle** and **electron-transport pathway**.

1. Glycolysis

The first process of cellular respiration is ***glycolysis***, which literally means '*sugar splitting*'. This step takes place in the cytoplasm of the cell. During glycolysis, single molecule of glucose is split and ultimately converted into two molecule of *pyruvic acid*.

The process of glycolysis involves series of reactions as outlined in Figure 3.16. Each **small circle in the diagram represents one carbon atom**. *The summary of the major steps involved here are*:

i. The **six-carbon atom** (glucose) is broken down to two-molecules of **three-carbon sugar phosphates** with the expenditure of two molecules of **ATP**.

ii. The **three-carbon phosphate molecules** are then oxidized to 3C compound called pyruvic acid by the removal of hydrogen, producing reduced NAD (**nicotinamide adenine dinucleotide**). Both ATP and NADP (nicotinamide adenine dinucleotide phosphate) molecules are energy-rich and are used in other cell reactions.

iii. **Two molecules of ATP** are produced at the end of glycolysis.

iv. The pyruvic acid is passed on to the second process known as the ***Krebs cycle***.

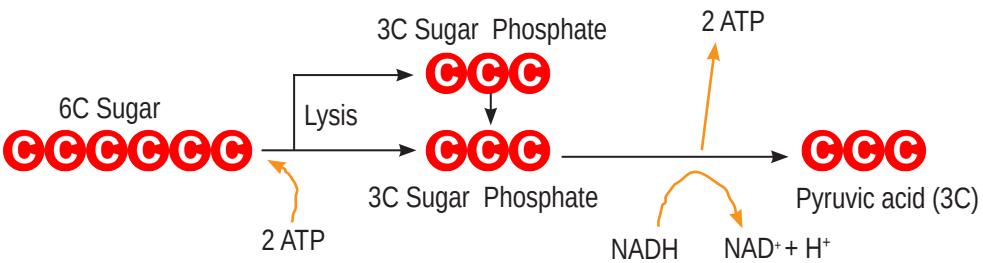


Figure 3.16: A summary of glycolysis

2. The Krebs cycle

The reaction of this cycle is discovered by Sir Hans Krebs in 1937. It occurs in the **mitochondria** of a cell in **the presence of oxygen**. This cycle *begins with pyruvic acid* from the glycolysis. Before the Krebs cycle begins, pyruvic acid is split apart and combined with an enzyme known as coenzyme A (CoA). The Krebs cycle is also known as citric acid cycle because of production of **citric acid** in the process. The summary of the ***Krebs cycle*** is represented in Figure 3.17.

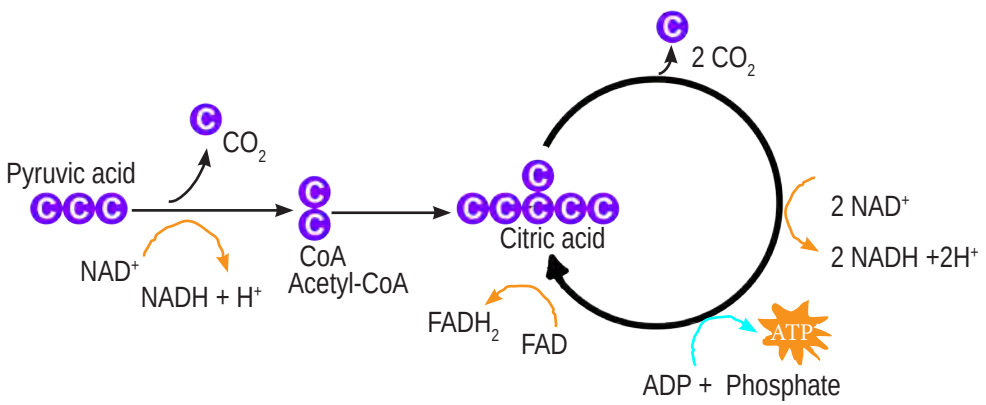


Figure 3.17: A summary of Krebs cycle

After the formation of citric acid, it goes through a series of reactions that release energy. Carbon dioxide is also released as **waste product** of these reactions.

In the final step of the ***Krebs cycle***, citric acid is regenerated in a series of reactions, which is available to repeat the cycle. At a certain point in time, **two molecules of carbon dioxide** are given off and a pair of hydrogen is removed by which a molecule of **ATP is formed**. The original glucose molecule is broken down completely. All **six of its carbon atoms** are combined with **oxygen** to form *carbon dioxide*. The energy is stored in ATP, NADH and $FADH_2$. $FADH_2$ is an **energy-carrying compound**.

3. Electron-transport pathway

The electron transport pathway is where most of the energy is released in cellular respiration. In this process, cell converts **$FADH_2$** and **NADH** to **ATP**. This involves a series of electron carriers in the **mitochondrial membrane**. Through these reactions, high energy electrons are passed to oxygen, which creates gradient to produce ATP.

ii. Mechanism of anaerobic respiration

Anaerobic respiration is the process that starts *like aerobic respiration* and stops half way through, because oxygen is not available to finish the respiration process. In tissues, in the absence of oxygen, ***glycolysis*** (see Figure 3.16) can take place initially but the ***Krebs cycle*** (see Figure 3.17) is *blocked*. Hence, **pyruvic acid** is converted by certain specialised cells into other compounds in a process called fermentation.

The two common fermentation processes are alcoholic fermentation and lactic acid fermentation, which take place in **anaerobic conditions**.

Alcohol fermentation	This process occurs in higher plant cells and yeast in **absence of oxygen**. The *byproduct of alcoholic fermentation* is **ethyl alcohol** also known as **ethanol**. In this process, a molecule of glucose undergoes **glycolysis** to yield two molecules of **pyruvic acid**, **2 NADH** and **2 ATP** with the help of the enzyme *pyruvate decarboxylase*. This enzyme is not found in humans.
Lactic acid fermentation	In lactic acid fermentation, the **three-carbon pyruvic acid** is rearranged into *three-carbon molecule* **lactic acid**. The energy rich compound, **NADH** is oxidized to **NAD^+**, which is then available for use in glycolysis, while the pyruvic acid is reduced to lactic acid. The byproduct of this process is lactic acid, which causes the **muscle fatigue**.

Activity 3.4

Library or internet research

Visit your school library or IT room where you have access to internet and collect information on alcohol fermentation and lactic acid fermentation. Work in pairs or in a group.

Questions

i. How are alcohol fermentation and lactic acid fermentation similar?
ii. Name the compound responsible for giving bread its mysterious smell.
iii. Name the gas responsible for the bubbly appearence in alcoholic drinks.
iv. Explain the importance of alcohol fermentation in the production of bread's light, fluppy texture.
v. What are applications of alcohol fermentation?

b. Oxygen debt

Our **muscles** need oxygen and glucose to **respire aerobically** and produce the energy they require; these substances are carried to the muscle through the blood. However, during **vigorous exercise**, our body muscles will not get sufficient oxygen for respiration. Therefore, it relies on anaerobic processes for the first couple of minutes. This type of respiration is not as efficient as **aerobic** and only a small amount of energy is released. This is because **glucose is partially broken down** and a poisonous chemical, lactic acid is produced. If lactic acid builds up in the body, it stops the muscles from working and causes muscle fatigue. To remove lactic acid from the body, oxygen is needed and this amount of oxygen required to break down the lactic acid is referred to as oxygen debt.

The **liver** converts the **lactic acid back to pyruvic acid and to glucose**. The glucose then enters the blood and returns to the muscles to be used for energy. When all the lactic acid has been broken down, the breathing rate and heart beat returns to normal.

Lesson Summary

- HCl activates pepsinogen into pepsin. It also helps to kill germs.
- Gastric juice, pancreatic juice and intestinal juice contain enzymes that help in the digestion of food.
- Bile helps in emulsification of fats.
- Blood is composed of about 55% plasma and 45% cellular components.
- Red blood cells, white blood cells and platelets make up the cellular components of blood.
- The two main types of WBCs are granulocytes and agranulocytes.
- Blood transfusion is a procedure in which blood is given to a patient through an intravenous line in one of the blood vessels.
- Capillary is site for the exchange of substances between blood and organ cells.
- Lymphatic system carries the larger molecules away from the tissue fluids to the blood.
- The kidneys filter blood and form urine.
- Urine formation takes place in a distinct mechanism of ultrafiltration, selective re-absorption and tubular secretion.
- Each kidney has more than a million nephrons, which are the structural and functional units of the kidney.
- The kidneys maintain homeostasis by controlling the amount of water, ions, and other substances in the blood.
- Lungs, skin and liver are accessory excretory organs.
- Aerobic respiration takes place in three major stages: glycolysis, Krebs cycle and electron-transport pathway.
- Alcoholic fermentation and lactic acid fermentation are two common processes of anaerobic respiration.
- The extra amount of oxygen required to break down the lactic acid after an anaerobic respiration is called oxygen debt.

Weblink

- http://sciencelearn.org.nz/Contexts/Digestion-Chemistry/Science-Ideas-and-Concepts/The-human-digestive-system
- https://www.youtube.com/watch?v=igZdLN7nw6k
- http://www.myvmc.com/anatomy/blood-function-and-composition/

Review Questions

A. Each question in this part is followed by four possible choices of answer. Choose the correct or the most suitable response.

1. A woman has undergone a surgery for removal of gall bladder. While being discharged from the hospital, if you were a doctor, what advice would you give her?

   A. Take a diet with less protein.
   B. Take less sugary fruits.
   C. Take less quantity of liquids.
   D. Take food that contains less fats.

2. A student investigated different types of white blood cells in the laboratory. Cell 'X' stains dark red and was found to contain two lobed nucleus. Cell 'Y' appeared purple in colour, when stained with Leishman's stain. Large granules are also seen in the cytoplasm under a microscope. The third cell, 'Z' was observed to be multinucleated. Its cytoplasm is filled with very fine granules. In the above investigation, the cell 'X, 'Y' and 'Z' can be identified as

   A. monocyte, lymphocyte and basophil respectively.
   B. basophil, eosinophil and monocyte respectively.
   C. lymphocyte, neutrophil and eosinophil respectively.
   D. eosinophil, basophil and neutrophil respectively.

3. The correct flow of blood in kidney is

   A. renal artery ⟶ afferent arteriole ⟶ glomerulus ⟶ efferent arteriole ⟶ vasa recta ⟶ venule ⟶ renal vein.
   B. renal vein ⟶ venule ⟶ glomerulus ⟶ efferent arteriole ⟶ vasa recta ⟶ afferent arteriole ⟶ renal artery.
   C. renal artery ⟶ afferent arteriole ⟶ glomerulus ⟶ vasa recta ⟶ efferent arteriole ⟶ venule ⟶ renal vein.
   D. afferent arteriole ⟶ renal artery ⟶ glomerulus ⟶ efferent arteriole vasa recta ⟶ venule ⟶ renal vein.

4. Under low oxygen conditions, production of lactic acid in the body can lead to

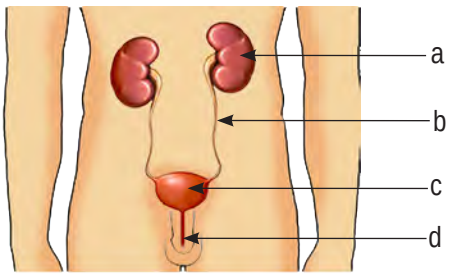
   A. the shut down of glycolysis.
   B. muscle soreness and fatigue.
   C. the production of more carbon dioxide.
   D. the production of more adenosine triphosphate.

5. When you visit a hospital, a doctor records your pulse rate by pressing your wrist

exactly on

A. lymph vessel.
C. vein.
B. artery.
D. capillary.

6. The given diagram shows the human urinary system. The parts marked a, b, c & d is



A. a-kidney, b-urethra, c-urinary bladder, d-ureter.
B. a-kidney, b-urinary bladder, c-sphincter, d-urethra.
C. a-kidney, b-ureter, c-urinary bladder, d-urethra.
D. a-kidney, b-urinary bladder, c-urethra, d-collecting duct.

7. It is assumed that alcohol is absorbed in the stomach. Which of the following pieces of evidence would best support this assumption?
   A. No enzymes for digesting alcohol are found in the small intestine.
   B. Chemists can show that the alcohol molecule is small.
   C. Alcohol can be shown to appear in the blood circulation soon after it is drunk.
   D. Some people feel intoxicated very soon after drinking alcohol.

8. A physiologist wants to find out the rate of filtration in the glomeruli of the kidneys. The best experimental design would be to inject a substance which
   A. cannot pass through the glomerular capillaries.
   B. can pass through the glomerular capillaries but is totally reabsorbed in the renal tubules
   C. can pass through the glomerular capillaries and is partially reabsorbed in the renal tubules .
   D. can pass through the glomerular capillaries and is not reabsorbed in the renal tubules.

9. The need for excretion in living organisms is more precisely to
   A. remove the substances in excess.
   B. remove the waste products of metabolism.
   C. remove the toxic substances that is harmful to the body.
   D. remove the unwanted substances from the body.

10. A food sample is taken in a test tube and a few drops of iodine were added to it. The solution turned blue black. This suggests that the food sample contains

A. fat. C. vitamins.

B. protein. D. vitamins.

B. Fill in the blanks with the correct form of word(s).

1. Chemical digestion of carbohydrates begins in the mouth and chemical digestion of proteins begins in the …….
2. Ascending limb of Henle's loop is……to water whereas the descending limb is …… to it.
3. Either ethyl alcohol or lactic acid is produced as a result of……...
4. Arteries and veins are two of the three main types of blood vessel. The third type of blood vessel which is much smaller is called……
5. Re-absorption of Na^+ from distal parts of the tubules is facilitated by hormone ……....

C. Name the following.

1. Blood plasma contains the same constituents as the constituents in dialysis fluid. One constituent is missing in dialysis fluid.
2. A hormone that helps in water elimination, making the urine hypotonic to the body fluids.
3. The intermediate products of anaerobic respiration in an active muscle, which is associated with oxygen debt.
4. Part of circulatory system, where the exchange of nutrition takes place between the tissue fluids and the body cells.
5. Glands responsible for oily skin in human.

D. Name the following.

1. If a person has taken in large amount of proteins in his diet, he/she is likely to secrete more amounts of amino acids.
2. Protein-free fluid is filtered from blood plasma into the Bowman's capsule.
3. Alcohol inhibits the secretion of ADH by the pituitary. That is why, when it is drunk to excess, the person urinates too much.
4. The starting molecule for Krebs cycle is glucose.
5. Human beings excrete mainly urea with the urine.

E. Write one function of the following.

1. Villi 2. Lacteals 3. Capillaries
4. Collecting duct 5. Plasma

F. Match the items of column A with the most appropriate items of column B. Rewrite the correct matching pairs.

Column A	Column B
Breaks down of small polypeptides into amino acids.	salivary amylase
Breaks down of fats into glycerol, fatty acids, or glycerides.	pepsin
Begins to break down of proteins into small polypeptides	pancreatic amylase
Begins to break down of starch into smaller polysaccharides or the disaccharide maltose.	lipase
Continues to break down of starch and smaller polysaccharides into disaccharides.	aminopeptidase

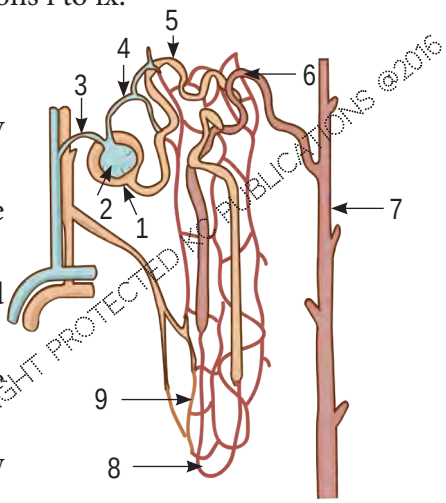
G. Give reasons.

1. There is little digestion of starch in the stomach.
2. Strenuous exercise leads to muscle cramp.
3. Red blood cells are enucleated.
4. Workers in deep mines usually suffer from dehydration.
5. If you exercise on a hot day, you are likely to lose a lot of water in sweat. For the next several hours, you may notice that you do not pass urine as often as one normally does, and that urine is also darker than usual.

H. Answer the following questions.

1. Name three components that are present in the urine of a healthy person.
2. A drop of blood from a blood donor is mixed with serum from a group A person and serum from a group B person. The donor's red cells clumped in the A serum but not in the B serum. What is the donor's blood group?
3. Write the symptoms and causes of diabetes mellitus.
4. Tabulate the differences and similarities between artery, vein and capillary.
5. In what ways does lactic fermentation differ from an alcoholic fermentation.
6. Milk provides proteins, carbohydrates and fats. Describe briefly each of these nutrient is chemically digested inside different parts of the digestive system.
7. Draw up a table to show the change in composition of the blood as it passes through the
   i. lungs ii. intestine iii. kidneys
8. What is the difference between gas exchange and the cellular respiration?
9. Explain the mechanism of blood clotting in your words.

10. Study the figure below and answer the questions i to ix.



i. Identify the part of an organ.

ii. Write the names of parts numbered 1 to 7.

iii. Where is the structure labelled 1 precisely located in the kidney?

iv. Where does filtration take place in the nephron?

v. Give two features of the nephron that aid filtration.

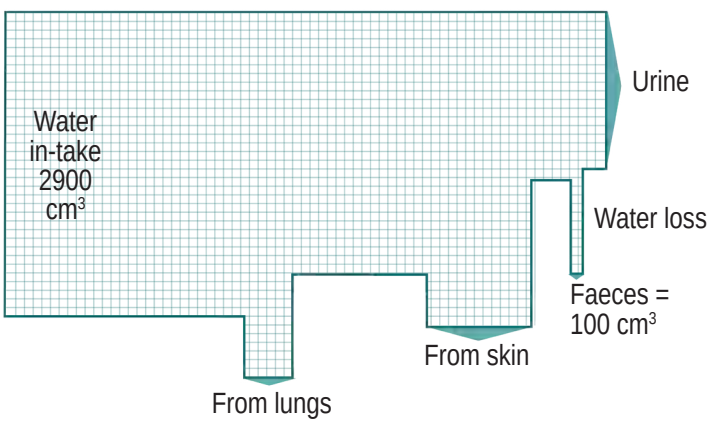
vi. Where does reabsorption occur in the kidney?

vii. If a person has a damaged loop of Henle, how will it affect the re-absorption of water?

viii. Suggest two situations which may result in the drop of water content of the blood.

ix. Name the hormone associated with changing the permeability of the structure labelled 6.

10. The diagram below shows the amount of water loss by an adult in one day. The widths of the arrows show how much water is lost in each way.



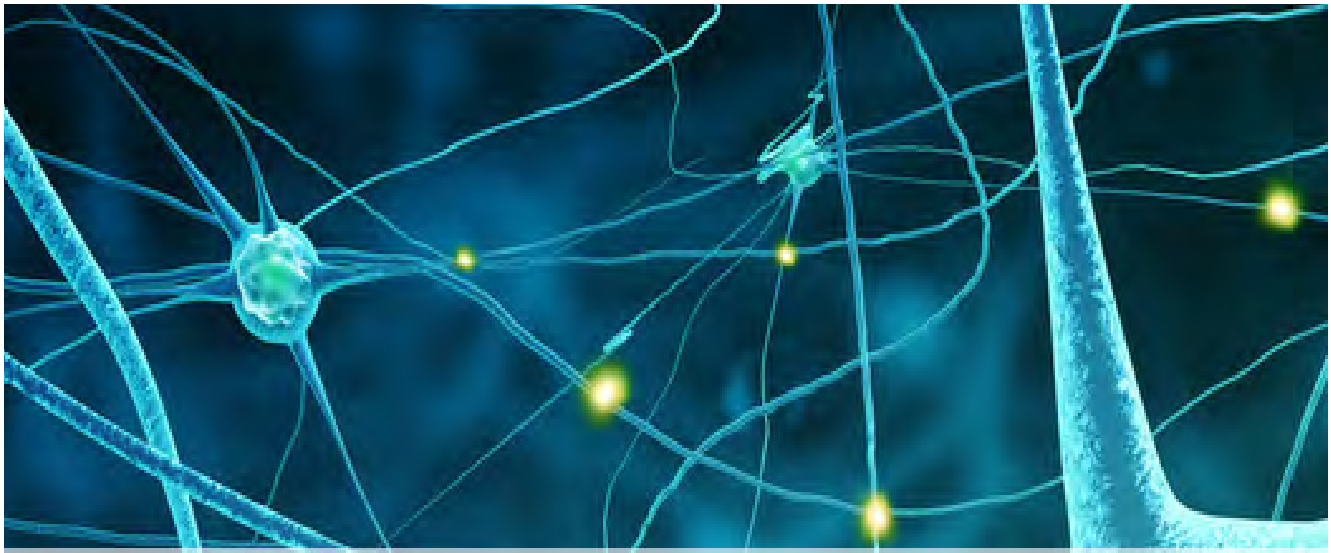
i. Work out from the diagram the water loss in urine and from skin and lungs. Copy and write the correct figures.

Urine.....cm³

Skin.....cm³

Lungs.....cm³

ii. When it is hot, much more water is lost from the skin. Which other method of water loss would also change significantly? Explain your answer.



4 RESPONSE AND COORDINATION IN HUMAN

All living things respond to stimuli of one kind or other. Some stimuli arise externally to an organism, while others arise from internal environment. One of the essential survival features of all living things is their ability to coordinate internal activities. The processes by which the internal systems of an organism are made to function as an integrated system are referred to as coordination. The processes of coordination and responses to stimuli of plants and animals are quite different. Animal responses are quick and often respond to change by adjusting their behaviours. In contrast, responses in plants are normally slow growth movements.

In humans, detection and response to external environmental changes and the regulation of internal environment of the body are brought about by two systems: The Nervous System and the Endocrine System.

4.1 Nervous System

Learning Objectives

On completion of this topic, you will be able to:

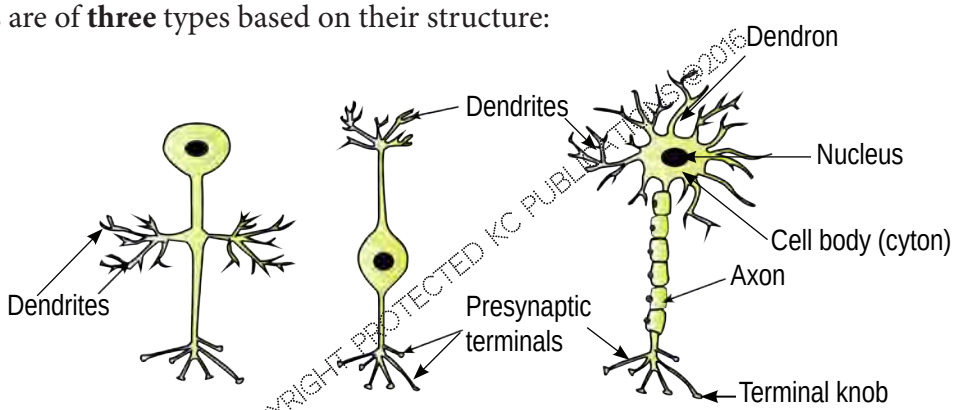
- state the roles of receptors, sensory neurons and motor neurons.
- describe the pathway taken by nervous impulses in response to a variety of stimuli.
- explain the rapid responses to dangerous stimuli by the reflex arc and the relay neuron.

The **nervous system** allows the body to respond to changes in the environment. In humans it consists of the **brain**, the **spinal cord** and all of the **nerves** that branch off from the spinal cord. The Central Nervous System (**CNS**) refers to the brain and spinal cord. There are two ways in which the nervous system responses to these changes, depending on how urgently an action is needed. A response coordinated by the brain is the usual and slower way of responding. **Reflex actions**, on the other hand, are rapid responses to stimuli that by-pass the brain. **Stimuli** are things that set off a reaction in the nervous system - for example, *light*, *heat*, *sound*, *gravity*, *smell*, *taste*, or *temperature*.

a. Types of neurons

The nervous system consists of nerve cells called neurons. Neurons are of different types based on their **structures** and **functions**.

Neurons are of **three** types based on their structure:



1. ***Unipolar neuron*** has **only one process** emerging from the cell body that branch into axon and dendrites.

2. ***Bipolar neuron*** has **two processes** emerging from the cell body. One of them emerges to form dendrite, while other emerged as an axon.

3. ***Multipolar neuron*** has **many processes** emerging from the cell body in the form of dendrites and an axon.

Figure 4.1: Types of nerve cells based on their structures

There are *three* different types of neurons, each with a slightly different function: sensory neurons, relay neurons and motor neurons.

1. ***Sensory neurons*** carry sensory signals from the receptors to nerve centres in the central nervous system (CNS). They are also called afferent neurons.
2. ***Relay neurons*** are entirely found in the central nervous system. They carry messages from one part of the CNS to another part. They are also called interneurons or association neurons.
3. ***Motor neurons*** carry impulses outward from the CNS to effector organs such as muscles, glands and tissues. These neurons are also called efferent neurons.

Where two neurons meet, there is a tiny gap called a synaptic cleft. Signals cross this gap using chemicals called neurotransmitters. One neuron releases the chemical into the gap. The chemical diffuses across the gap and makes the next neuron transmit an **electrical signal**.

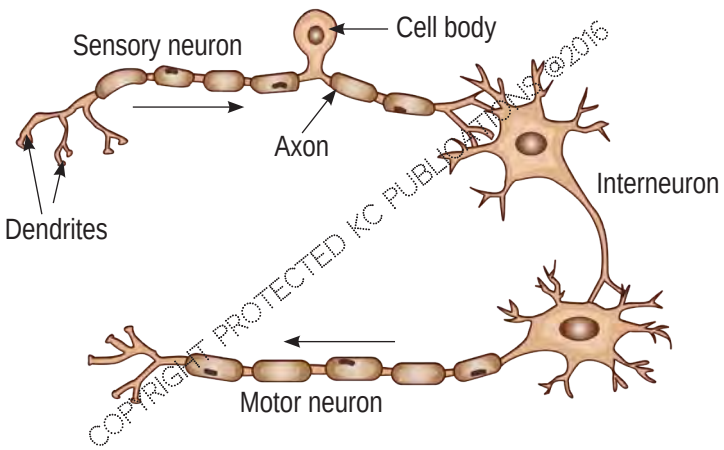


Figure 4.2: Types of nerves based on their functions

b. Receptors and effectors

i. Receptors are groups of specialized cells **sensitive to a specific stimulus**. They can detect changes in environment, which are called stimuli. Receptors are often *located in the sense organs*, such as eyes, ears, nose, tongue and skin. When a receptor is stimulated, it sends a signal along the nerve cells to the **central nervous system**. The nervous system allows the body to respond to changes in the environment.

The **role of receptor** is to detect the stimulus by changing its energy into the electrical impulses. For example, the eye converts light energy into nerve impulses, and the ear converts sound energy into nerve impulses. This **conversion of a sensory impulse from one form to another** is called transduction. All receptors are transducers of energy (Table 4.1).

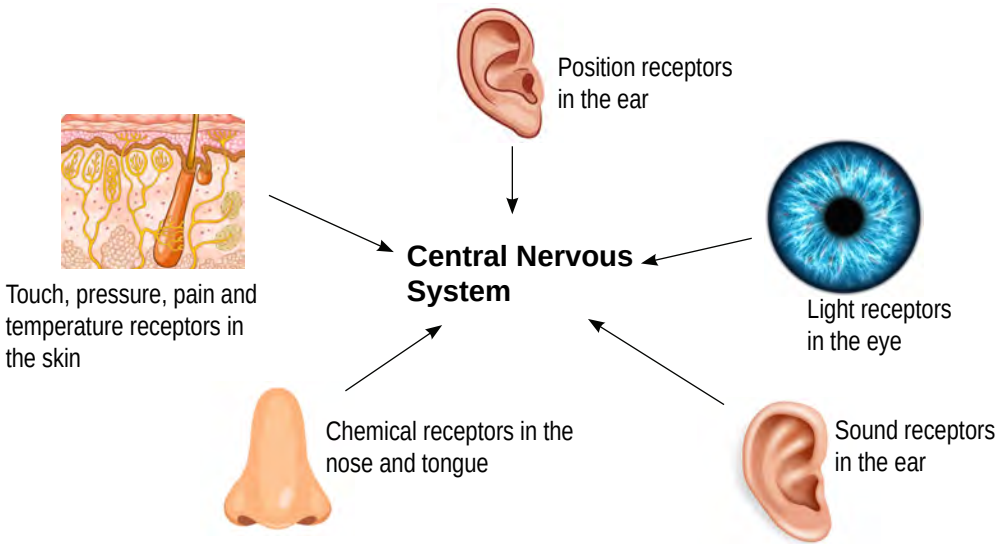


Figure 4.3: Receptors in sense organs

Table 4.1 Human receptors that transduce the energy into electrical impulses

Sense organs	Receptors sensitive to	Transforms energy to
Eye (retina)	Light	Light
Ear (organ of balance & hearing)	Sound, position of head	Sound or mechanical (kinetic)
Tongue (taste buds)	Chemicals in food	Chemical
Nose (organ of smell)	Chemicals in the air	Chemical
Skin (touch/pressure/pain/ temperature receptors)	Pressure, pain, temperature, heat	Mechanical (kinetic)

All sensory receptors can be classified by their **structure and type of stimulus that they detect**. Some of the major classes of receptors are:

1. ***Mechanoreceptors*** those are sensitive to mechanical stimuli like *touch*, *pressure*, *vibration*, and *blood pressure*. They are mostly located in the **dermis of the skin**.
2. ***Photoreceptors*** in the **retina** of the eye detect light to provide the *sense of vision*.
3. ***Chemoreceptors*** those detect chemicals in the bloodstream and provide the *senses of taste and smell*. They are located in the **nose**, **tongue**, **carotid artery** and the **brain**.
4. ***Thermoreceptors*** detect temperatures inside the body and in its surroundings. They are located in the dermis of the **skin** and the *hypothalamus* of the brain.

ii. An effector is any part of the body that

Brain snack:

Touch receptors are not distributed evenly over the body. The fingertips and tongue may have as many as 100 per cm^2; the back of the hand has fewer than 10 per cm^2.

responds to nerve impulse. Some **examples of effectors** are: a muscle contracting to move arm, a gland releasing a hormone into the blood, a muscle capable of squeezing saliva from the salivary gland, etc.

c. Organization of the nervous system

The **nervous system** is the major controlling system in the human body. It is structurally subdivided into: ***central nervous system*** and ***peripheral nervous system***.

i. Central nervous system (CNS) consists of organs that are located in the bony structure of the skull and the vertebral column: brain and spinal cord respectively. It forms the largest part of the nervous system as a whole and is covered and protected by **meninges**. **Retina** is the only part of the central nervous system that is found outside bony structures.

ii. Peripheral nervous system (PNS) consists of the nerves that are distributed outside the skull and the spinal cord: **cranial nerves** and **spinal nerves**. These peripheral nerves allow the central nerves system to communicate with the body`s tissues and organs through receiving sensory information and sending *motor commands*. It is functionally subdivided into **somatic nervous system** and **autonomic nervous system**.

The somatic system consists of sensory receptors in the head and extremities. It contains two sets of nerves known as cranial nerves and the spinal nerves respectively. Cranial nerves emerge from the **brain**. There are **twelve** pairs of cranial nerves. Some of the examples include **olfactory nerve** for nose, the **optic nerve** for eyes, **auditory nerves** for ears, etc. Spinal nerves emerge from the **spinal cord**. There are **31** pairs of spinal nerves: **8 pairs** in the neck, **12 pairs** in the thorax, **5 pairs** in lumbar region, **5 pairs** in the sacral, and **1 pair** in the coccygeal region. Every spinal nerve is a mixed nerve having both sensory and motor fibres. They are the nerves that carry sensory information to the CNS and also carry instructions back from the CNS to the skeletal muscles.

The autonomic system controls glandular secretions and the functioning of the **smooth** and **cardiac muscles**. This system is further divided into ***sympathetic*** and ***parasympathetic***. Nerves of sympathetic system arise from the spinal cord between the neck and the waist region. The sympathetic nervous system is stimulated by the hormone adrenaline secreted by the adrenal gland, located on the kidneys. The parasympathetic system is located at two places, *one anteriorly* in the head and neck and the *other posteriorly* in the sacral region.

Sympathetic and **parasympathetic** nervous systems often **work in opposition** to each other in regulating the involuntary processes of the body (Figure 4.4). **Involuntary processes**, such as heartbeat and peristalsis are those that do not require, or involve **conscious control**.

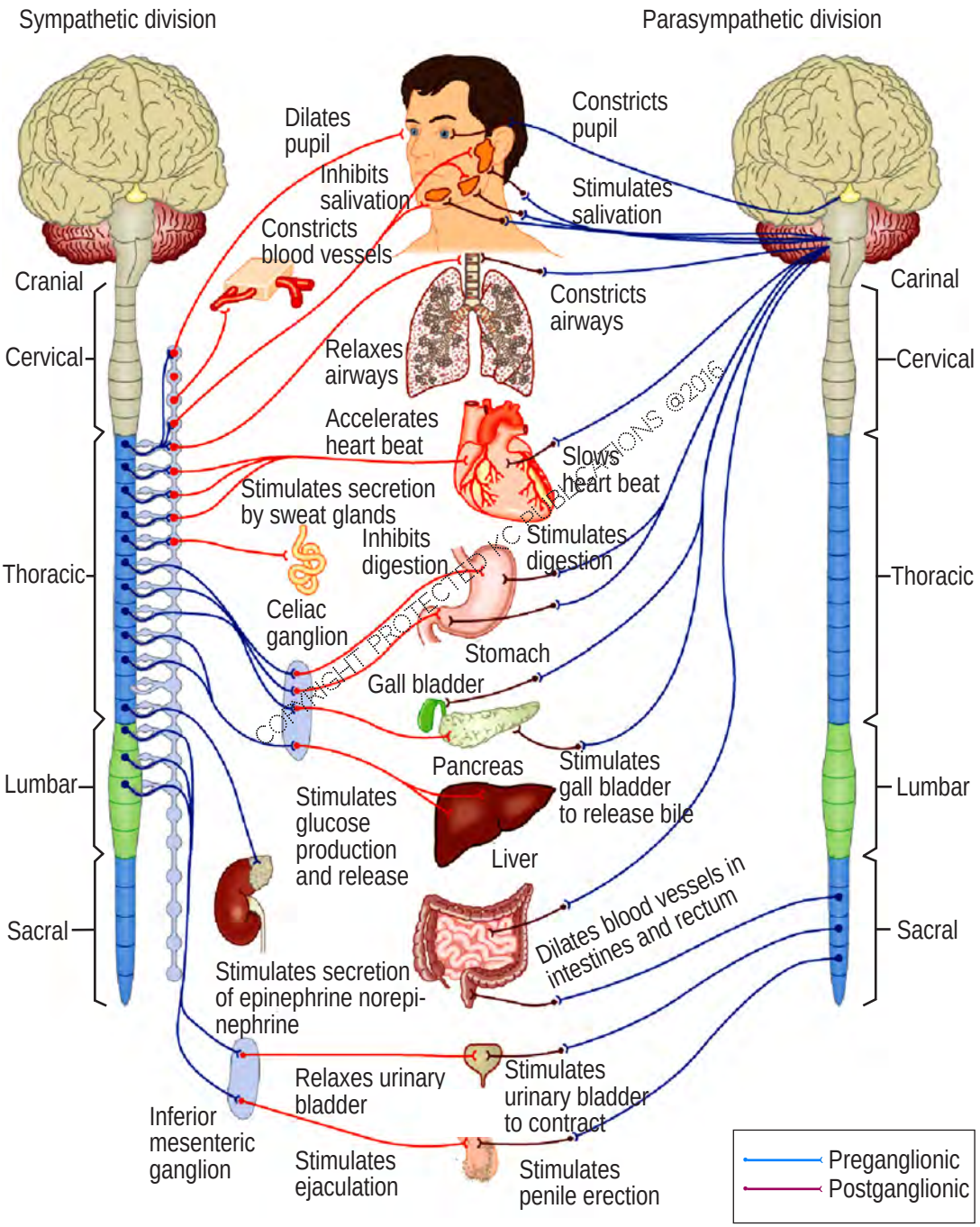


Figure 4.4: Autonomic nervous system: showing the opposing effects of sympathetic and parasympathetic nervous system

d. Reflexes

Our body actions are of *two* types: voluntary and involuntary. For example, you greet your teacher to show respect, dial a particular phone number to call someone, drink water to quench your thirst, etc. are **voluntary actions**. A few **examples of involuntary actions** are shivering when too cold or sweating while too hot, immediate withdrawal of hand when touching a hot object, etc. These involuntary actions are also called reflexes.

Reflex action is defined as the **quick**, **automatic** and **involuntary action** in the body brought about by a stimulus.These actions are *innate* or *inbuilt* and *do not require any thinking* by the brain. They are controlled by the **spinal cord**. They allow the body to respond to stimuli very quickly by sending responses to effectors before the nerve signals reach the brain. Reflexes play an important part in humans to respond to the world around them.

A stimulus is any agent or environmental change which initiates a response in the body. The **stimuli** can be of several types: physical or mechanical such as touch, prick, pressure, etc.; chemical; thermal such as heat, cold, etc.; electrical.

i. Types of reflexes

Reflexes are o*f two* types: **natural** *(inborn)* **reflexes** and **conditioned** *(acquired)* **reflexes**.

1. Natural (inborn) reflex is one in which **no previous experience** or **learning** is required. It is **inborn** and **inherited** from the parents. These reflexes produce rapid involuntary responses to a stimulus. This, in turn ensures that an animal responds in the way most likely to result in its survival. Examples include the *grasping reflex* in babies, *coughing*, *salivation*, *sneezing*, *blinking eyes*, etc.
2. Conditioned (or acquired) reflex is one that **develops during one's lifetime due to experience** or **learning**. This type of reflex is **acquired** and **not inherited** from the parents. Examples include *salivating* at the sight or smell of food, *tying shoe-laces* while talking, *unlocking a lock* using key in the dark, *playing musical instruments* without looking, *typing words* without looking at keyboard on the computer, etc.

   Conditioned reflexes are useful because they increase an **animal's chances of survival**. For example, birds will not eat caterpillars with bright colouring because they are conditioned to think of bright colours as poisonous.

Use of reflexes in hospital

Reflexes are so important that doctors use them to **test** if our bodies are working and responding as they should. New born babies have more reflexes than that of older

children. For example, a child has better gripping reflex than an adult. A doctor will check the pupil reflexes to see if a patient is responding normally to light after a head injury.

Pavlov's experiment on a dog

A reflex response to a new stimulus can be learned. A Russian scientist called Ivan Pavlov noted that under normal conditions, no animal would secrete saliva in response to the blowing of whistle or any other sound. But after repeated blowing of whistle simultaneously in the presence of food, after an adequate length of time, the dog eventually produced saliva at the sound of whistle even when there was no food at that time. This is an example of a *conditioned reflex*.

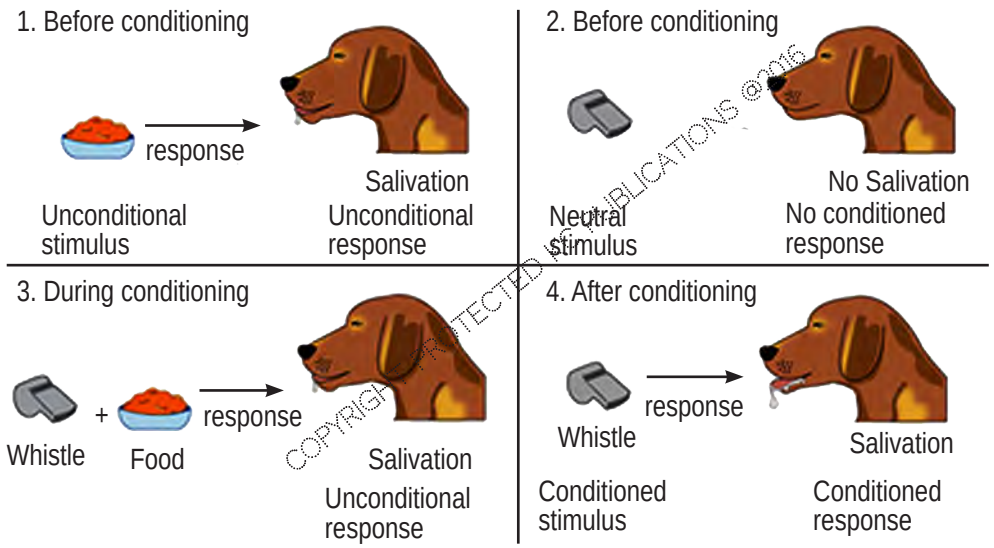


Figure 4.5: Palvo's experiment on a dog

Important terms

Response: A change in an organism (an action) resulting from a stimulus.

Receptors: They transform stimuli into electrical nerve impulses.

Sensory neurons: They relay the nerve impulse to the central nervous system through the dorsal root of the spinal cord.

Relay neurons: They transmit nerve impulses within the CNS.

Motor neurons: They receive nerve impulses from the CNS via the ventral root and relay the signal to an effector.

Effectors (muscles or glands): They produce a response to the stimulus.

Synapses: They are the junctions between two nerve cells where transmission of a signal with the help of chemical neurotransmitters occur.

Reflex arc: It is the pathway of an electrical impulse in response to a stimulus.

e. Nervous pathways in reflexes

A **reflex action** must be quick to have immediate effect. Therefore, pathway for receiving and sending information must be short. A reflex arc is the **shortest route** that can be taken by an impulse from a receptor to an effector. A **reflex arc** is the nerve pathway of a reflex action. The pathway starts from the **stimulus** followed by the **transmission of sensory impulses from receptors in the sense organs to sensory nerve and then to the central nervous system** (CNS). In **CNS**, the **sensory information** would be **interpreted** and **processed** and **conducted back out** to **efferent nerve and then finally to the muscle or glands to cause effect** (contract or secrete). In some circumstances, the **brain can modify a reflex response**. It does this by sending an impulse along a motor neuron of the reflex arc. This enables us, for example, to hold onto a hot tea cup when normally one would drop it. The pathway of nerve impulse in a reflex arc consists of the parts in Figure 4.6.

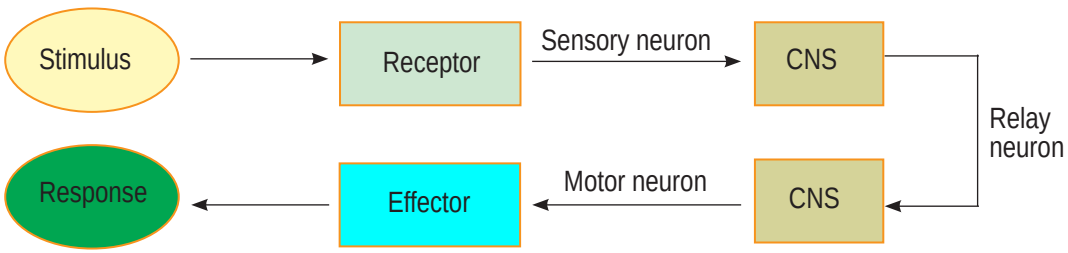


Figure 4.6: Simplified diagram of a reflex arc

The '***arc***' means the pathway that goes into the central nervous system (**CNS**) and then straight back out again in curve or arc. Nerve impulses travel through the reflex arc in a **fraction of a second**, so that the reflex action is very fast. However, this does not mean that the brain is unaware of what is going on. The brain receives information about the stimulus through synapses connected to reflex arc neurons. This is how we feel the pain.

Some of the common examples of reflex nervous pathway in humans are discussed below:

i. ***The pathway taken by nerve impulses in response to a pain***. The reflex response to a painful stimulus happens when part of your body, such as your hand, touches a sharp or hot object. *For example*, you would pull your hand away from a hot flame without thinking about it. The diagrams below show each stage of the reflex arc (Figure 4.7). The light brown and purple shape top right of each diagram is a cross-section through the spine, as it would appear if you looked down through the head of the man.

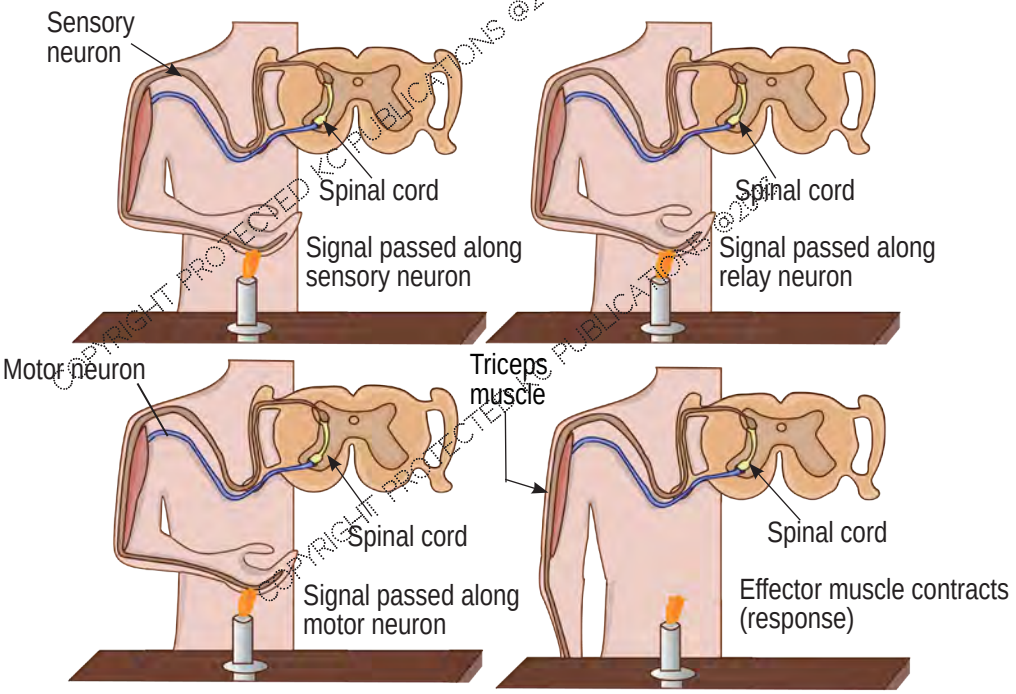


Figure 4.7: Different stages of a reflex arc for a pain withdrawal reflex

In Figure 4.7, the stimulus is the **touching of a hot flame** by a hand. This is what happens:

i. a **receptor** detects a **stimulus** (change in the environment). This is indicated by the red on the hand.

ii. a **sensory neuron** sends a signal to the **relay neuron**.

iii. the **relay neuron** sends the signal to the **motor neuron**.

iv. the **motor neuron** sends a signal to the **effector**.

v. the **effector** produces a **response**. The response is the **withdrawal of the arm** due to the contraction of the biceps muscle.

The sequence of events is

Stimulus (touching hot flame) ⟶ *receptor (pain receptors in skin)* ⟶ *coordinator (spinal cord)* ⟶ *effector (biceps muscle)* ⟶ *response (biceps muscle contracts, hand is withdrawn from hot flame).*

ii. ***Iris-pupil reflex*** found in humans protects the eye against damage by bright light. The eye needs to control the amount of light entering it in different light conditions. *In dim conditions*, more light is allowed to enter so that a clear image can be formed on the retina. *In bright conditions*, less light is allowed to enter so

that the retina is not damaged. This way the iris in our eye adjusts the size of the pupil in **response to bright or dim light** is also a reflex action. The path taken by nerve impulse in response to the stimulus of dim light and bright light is shown in Figure 4.8.

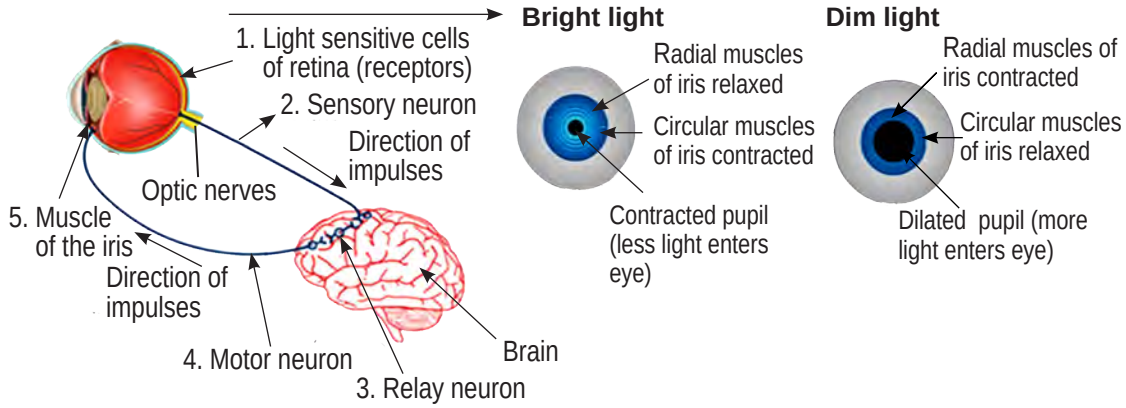


Figure 4.8: The pathway of impulses during pupil eye reflex

Activity 4.1

Knee-jerk reflex

Procedure

Sit on the chair and cross your legs so that the upper leg hangs freely over the lower one. Grip the muscles at the top of the upper thigh with one hand, and tap the area below the kneecap with the edge of the other hand. This may need a little practice, but you should eventually observe the lower leg jerk forward as the muscles at the front of the thigh contract.

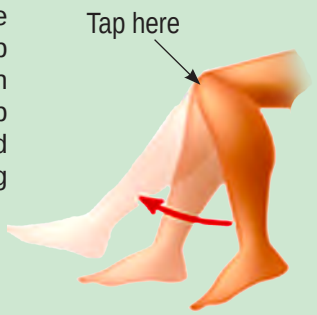


Figure 4.9: The knee-jerk reflex

Questions

i. Draw the reflex arc for the knee-jerk.
ii. How is it different from voluntary movement?
iii. What application does it have in our daily life?
iv. A physician taps on a patient's knee during a physical examination. Give reason.

4.2 Hormones

Learning Objectives

On completion of this topic, you will be able to:

- explain the way in which hormonal control occurs.
- explain the effects of insulin, adrenalin and sex hormones.
- •describe some medical uses of hormones, including the treatment of diabetes and thyroid- dysfunction.

Hormones are specific chemical substances which regulate normal **growth**, **development** and **functioning** of the body. They also maintain the internal environment of the body by their actions. The time and the amount of secretion of these hormones in our body are regulated by **feedback mechanism**. The main body systems involved in hormone regulation by feedback mechanisms are the nervous system and the endocrine system. Regulation of the concentrations of hormones in the blood and fluids within the tissues of the body is an important part of **homeostasis**.

Sex hormones play an important role in reproductive health as it has been widely used for controlling the child birth.

a. Hormone regulation feedback mechanism

Feedback mechanism is a method of controlling hormone production. In some cases the production of hormones is controlled by the nervous system. In other cases, the hormone itself acts as a control. The correct concentration of hormones must be maintained because **hormones have powerful effects** on the body. That is particularly important in the case of hormone levels because

i. ***hormones can affect target organs even at low concentrations***. Sometimes even at low concentration it can be too much for the target organs.

ii. ***hormones remain active in our body for a short duration of time***. So more hormones are required to replace those that are non-functional and inactive over time.

There are *two* types of feedback mechanisms, namely positive and negative feedback mechanisms. Our nervous and endocrine system is regulated by these two feedback mechanisms. The positive feedback mechanism **enhances the original stimulus** and the negative feedback mechanism **inhibits** them.

i. Regulating glucose in the blood

After eating carbohydrate foods like rice, bread, potato and sugary foods, the level of glucose in the blood rises. **Glucose** is important to the cells of the body as an energy source. However, the level of glucose in the blood must be regulated so that it does

not rise too high. When the bloodstream contains glucose, pancreas is stimulated to produce the hormone insulin. Insulin is a hormone produced by the **pancreas** that **regulates glucose level in the blood**. It makes glucose available to the body cells and the excess of it is stored in the liver and muscles as **glycogen**. If the body later needs glucose, **liver** converts glycogen back into glucose.

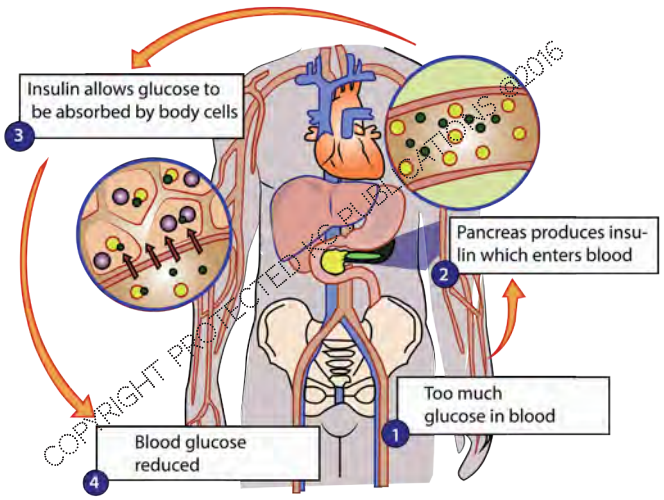


Figure 4.10 (a): Effects of high glucose in blood

When the **blood glucose level is too high** in the body, **insulin is secreted** into the blood by the **β-cells** of the pancreas. The presence of insulin in blood stimulates the liver to convert glucose into insoluble glycogen and store in it. This happens because insulin increases the rate of cellular respiration; so more blood glucose is absorbed by the cells. Hence, the **glucose level goes down** in blood as in Figure 4.10 (a).

On the other hand, when the **glucose level is too low in the body**, insulin is not secreted into the blood. As a result, liver does not convert glucose into glycogen. This leads to **increase in glucose level** in blood as in Figure 4.10 (b).

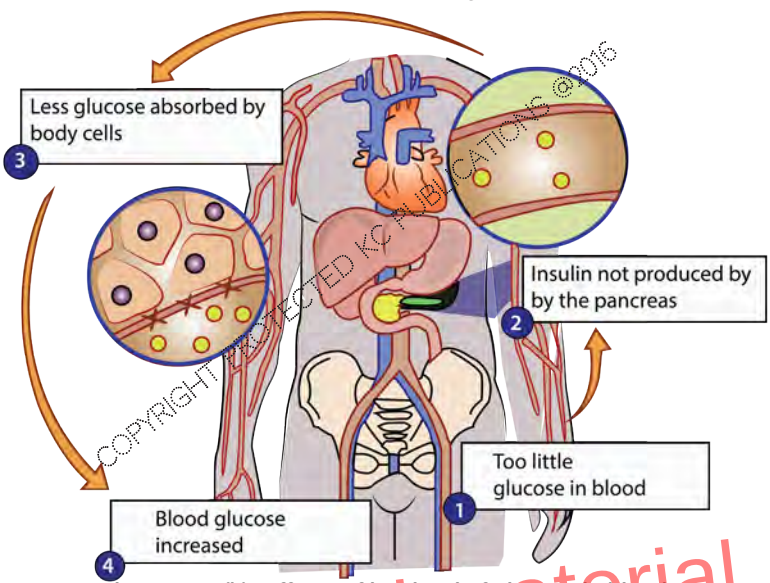


Figure 4.10 (b): Effects of low level of glucose in blood

Diabetes

Diabetes is a condition, in which the level of glucose in the blood cannot be regulated. The **normal level of glucose** in the blood is 0.1gm per 100 cm^3 of blood. The diabetes mellitus is a metabolic disease in which there are high blood sugar levels over a prolonged period. A diabetic patient cannot store glucose and the level in the blood can rise to a level that is very dangerous. It is **not a curable disease but can be controlled**, so that most diabetic patients can lead a full and normal life. However, if blood sugar levels are not controlled the diabetic could suffer from **high blood pressure**, **kidneys** and **nerves failure**, **retina** and **blood vessels** may become damaged. Glucose is excreted in the urine by the kidneys when the glucose level is above the normal range.

There are **two** types of diabetes. Type 1 Diabetes is a condition in which a person's blood glucose may rise to a **fatally high level** because the **body does not produce insulin**. A good diet is important but this type of diabetes must be treated with **daily injections of insulin**. Type 2 Diabetes develops, when the body can still make some insulin, but **not enough**, or when the insulin that is produced does not work properly. This kind of diabetes usually appears in older people, typically over the age of 40, and overweight. Losing weight and eating a controlled diet can sometimes control type 2 diabetes, but in some cases, **oral drugs** and **injections** may be needed.

c. Anabolic steriods

Anabolic steroids are the synthetic versions of the male hormone **testosterone**. These steroids have *two* main effects on the human body; **i)** an **anabolic** or **muscle building effect ii)** an **androgenic** or **masculinising effect**. The use of these steroids result in increasing **body weight** and **strength**. Therefore, many atheletes nowadays take these drugs to increase their body strength and size. Anabolic steroids are considered illegal drugs in many countries. However, their availability from illicit sources made them readily available and now they are widely used in the field of sports. *The side effects of anabolic steriod use are shown in Figure 4.12.*

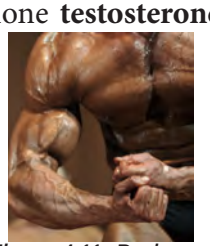


Figure 4.11: Body muscle

Figure 4.12: Effects of anabolic steroids

C. Medical uses of hormones

Hormones are widely used for **medical purposes**. Some of the uses of hormones in the field of medicine are discussed below.

1. Hormone therapy (HT)

Hormone therapy (HT) refers to either **estrogen** or a combination of **estrogen** and **progesterone** treatment. **HT** is the most highly effective medication for treating **menopause symptoms**. It reduces or eliminates several symptoms of menopause such as *hot flashes*, *disturbed sleep* resulting from hot flashes, and *vaginal dryness*. Treatment with progesterone along with estrogen substantially reduces the risk of **uterine cancer**.

Estrogens are occasionally used in hormone replacement therapy to treat more severe symptoms of menopause in women whose bodies are no longer able to produce estrogen in sufficient quantities. However, they are no longer recommended for long-term treatment or replacement therapy in most patients. Users of oral hormone therapy for more than five years are slightly at an **increased risk of breast cancer**.

2. Antidiabetic drugs

Insulin regulates the level of glucose in the blood, as well as the metabolism of carbohydrates and fats. Another hormone called glucagon stimulates the liver to release stored glucose. Both insulin and glucagon must be present in the right amounts to maintain the blood sugar level in the body at normal levels. When the body is not able to produce and utilize insulin due to diabetes mellitus, the treatment involves an **adjustment of diet** or the **administration of insulin or oral antidiabetic drugs**. Glucagon is given only in emergencies, such as insulin shock, when blood sugar levels must be raised quickly. People with type 1 or insulin dependent diabetes must use insulin to control their blood sugar levels. People who have type 2 or non-insulin dependent diabetes may be able to regulate their blood sugar levels through diet modification alone. If not, they may be prescribed oral antidiabetic medications, such as **glimepiride**, **metformin**, **acarbose**, etc. Some people with type 2 diabetes may need both insulin and oral antidiabetic drugs.

3. Thyroid drugs

Human Growth Hormone (**HGH**) is formed in the **pituitary gland** as a result of the stimulus of a hormone released from the **hypothalamus**, ***growth hormone releasing hormone***. This is transported to the pituitary gland which then releases **GHG** into the circulation. There is another hormone, somatostatin, released by the hypothalamus, which reduces the amount of **GHG** formed and these two hormones control the level of **GHG** in the circulation.

In the past, **thyroid drug preparations** were made by drying and pulverizing the thyroid glands of animals into tablets. This medication, however, is in minimal use

today because people who are **unable to produce a sufficient amount of thyroid hormones** are usually prescribed a synthetic form, such as levothyroxine. Human growth hormone (**HGH**) stimulates growth in children and adolescents. It helps to regulate *body composition*, *body fluids*, *muscle* and *bone growth*, *sugar* and *fat metabolism*. The synthetically produced **HGH** is the active ingredient in a number of prescription drugs and in other products available in medical stores. HGH is now made commercially and produced by **genetic engineering** and has specific medical uses

4. Steroids hormones

The **pituitary gland** secretes **adrenocorticotropic hormone (ACTH)**, which directs the **adrenal glands** to produce adrenocorticosteroids, such as **cortisone** and **prednisone**. These corticosteriods are medically prescribed to treat **asthma** and **skin disorders** or as **anti-inflammatories**. Oral steroid preparations like prednisone are used to treat *poison ivy*, *hay fever*, or *insect bites* as well as inflammatory diseases such as **arthritis**, **allergies**, and **asthma**. These corticosteroid hormones do not have **muscle building** or **masculinising effects** (compare *anabolic steroids*).

5. Other uses of sex hormones

Though the main components in the hormonal therapy are the **sex hormones**, there are several other uses of sex hormones. Two examples are discussed below.

i. ***Most oral contraceptives or birth control pills*** are the combination of estrogen and progestine but some contain only progestine. Examples of contraceptives that contain only progestine include the **Norplant implant** and the **Depo-Provera contraceptive device**. Progestine aids in **preventing ovulation**, alters the lining of the uterus, and thickens the cervical mucus. These processes help to **prevent conception** and **implantation**. The estrogen in **birth control pills** prevents egg production. Oral contraceptives have many side effects, so their use should be discussed with a physician.

ii. ***Medroxyprogesterone*** is used to treat **uterine bleeding** because of its ability to induce and maintain a lining in the uterus that resembles the lining produced during pregnancy. It also suppresses the release of the pituitary hormone that initiates ovulation, and it is used for **menstrual problems**.

6. Diuretics

Diuretics are used by athletes to lose weight and, at times, the bloated look of water retention due to **anabolic steroid** use. They all cause the body to lose water.

4.3 Reproductive Health

Learning Objectives

On completion of this topic, you will be able to:

- discuss hormonal contraceptive methods of birth control.
- explain the uses of hormones in controlling fertility.

Reproductive health implies that people are able to have a responsible, satisfying and safe sex life and that they are capable to reproduce. **Reproductive health** includes *family planning, human sexuality and sexual health, fertility control and treatment of fertility, prevention and treatment of infertility, safe motherhood, child survival, and free from STIs including HIV*. Some of the important components of reproductive health are discussed in this topic.

a. Birth control

The population of the world is growing at an alarming rate due to which it severely **imbalances the carrying capacity** of the earth. One of the means to control population growth is through '*birth control*'. The term '***birth control***' includes **fertility control** and **family planning**, and **contraception** and **pregnancy prevention**. If a woman does not want to become pregnant, she can choose a variety of **contraceptive methods** to reduce the possibility of becoming pregnant. *In birth control methods*, a man's sperm is not allowed to fertilize with a woman's egg or prevent fertilized egg from implanting in the woman's uterus.

i. Fertility control and family planning

The term '***fertility***' means the ability to bear children or young ones. It is also referred to as natality. Fertility can be controlled by using a variety of scientific methods. The control of fertility depends on many factors such as the **level of literacy, time of marriage, living standard, use of contraceptives**, etc. New methods of contraceptives are being developed and tested to control fertility and birth.

A couple controls the size of their family and spacing between pregnancies through a practice known as family planning. It refers to practices that help an individual to:

i. space pregnancies for better growth and health of the child.
ii. regulate the number of children in the family.
iii. avoid unwanted births, and conceive only when desired.

The modern concept of family planning, according to the **World Health Organization** (**WHO**), includes, among others, the following.

i. ***Pregnancy test.***
ii. ***Advice on sterility.***
iii. ***Genetic counselling***.

iv. ***Sex education in schools.***
v. ***Provision of adopted services.***
vi. ***Premarital consultation and examination.***
vii. ***Screening for pathological conditions as cervical and breast cancer.***

Family planning is globally recognised as one of the basic **human rights**.

ii. Contraception and pregnancy prevention

Contraceptive methods are preventive methods to help women avoid unwanted pregnancies. It includes both temporary and permanent measures to prevent pregnancy. These methods of contraception by men and women help families to **space births, prevent unwanted pregnancies** and, even in some cases, from infection of STIs, including HIV.

The methods of contraception can be categorized into **hormonal, barrier, preventing implantation, sterilization or surgical and natural**. The hormonal methods of contraception are discussed below.

1. Hormonal methods

Human fertility is controlled by hormones. The knowledge of hormones has been used to increase or reduce the chances of fertilisation and pregnancy in woman. There are several different hormonal methods of birth control by using hormones such as *estrogen* and *progesterone*. Some examples of hormonal contraceptive methods are:

i. ***Contraceptive pill***: Pill contains female sex hormones, often a combination of oestrogen and progesterone, which **prevent ovulation**. It prevents the release of egg from the ovary by inhibiting the secretion of **follicle stimulating hormone** (**FSH**). Progestine thickens the cervical mucus, making it more difficult for sperm to enter through the cervix. It also makes the lining of the uterus less receptive to the implantation of a fertilized egg. The pills are in the form of tablets in *21-day packs* or *28-day packs* depending on the manufacturer. The 28-pill pack has active pills for the first 21 'on' days and seven inactive or reminder pills for the following seven 'off' days. A prescription by doctor is required and the pills should be taken daily for 3 weeks of the cycle. It is very reliable but side effects may occur. Some of the common side effects include *light spotting between periods and breast tenderness*. More serious side effects can include raised blood pressure and blood clots.


Figure 4.13: Contraceptive pills

ii. ***Birth control patch***: This is another type of hormonal contraceptive. The patch is applied to the skin and left in place for a week. It is changed weekly for 3 weeks, and for the fourth week, no patch is worn. This patch is called ortho-evra and contains the same types of hormones as


Figure 4.14: Birth control patch

the pill. The woman using this control patch experiences lighter periods with less cramping. Its side effects may cause skin irritation.

iii. ***Vaginal ring***: It is a ring-shaped device that contains the hormone **oestrogen** and **progestine** like the pill and patch. It is worn inside the vagina and is replaced once a month. It may cause irritation of the vaginal wall along with the same side effects as the pill or patch. Woman will experience lighter and regular periods. It is about 99% effective in preventing pregnancy.

Figure 4.15: Vaginal ring

iv. ***Birth control shot***: A hormonal injection called depo medroxy progesterone acetate (DMPA) can protect against pregnancy for three months. **DMPA** does not contain estrogen. Like other progesterone-based contraceptives, DMPA prevents the release of the egg from the ovary and thickens the cervical mucus which slows down the sperm's progress. It is more effective than the birth control pill. However, it may cause spotting or other side effects.

Figure 4.16: DMPA shot

v. ***Birth control implant***: A contraceptive implant known as implanon contains same hormone in the birth control shot. The implant is a **small, matchstick-sized device implanted beneath the skin of the upper arm**. It provides contraception by the slow release of the progestine over a period of three years. Its effect lasts about 3 years. Like other hormonal methods, it can cause side effects including spotting or irregular bleeding.

Figure 4.17: Implant

vi. ***Emergency contraception:*** It is hormonal contraception used after sexual activity to prevent unwanted pregnancy if no birth control was used. It contains a high dose of hormones used in the birth control pills. However, this must be taken within 72 hours of the sexual activity. Examples of emergency hormonal contraceptive are i-pill and ella.

Figure 4.18: i-pills

2. Implications of hormonal birth control methods

The **hormonal birth control methods** have both advantages and disadvantages. These methods of birth control are highly effective and their effects are reversible. They do not rely on spontaneity and can be used before any sexual activity. Some of the disadvantages include:

i. *the medication is required to be taken continuously.*
ii. *one has to bear the cost of the medications.*
iii. *women must remember to take them regularly as prescribed by the Doctor.*
iv. *hormonal birth control methods do not protect a woman against sexually transmitted infections (STIs).*
v. *women must begin using hormonal contraceptives in advance before the ovulation.*
vi. *for some women, hormonal preparations are associated with unpleasant side effects or increased health risks.*

b. Sexually transmitted infections (STIs)

A sexually transmitted infection (STI) is an infection that anyone can get from having sex with someone who has the infection. The causes of STIs are bacteria, parasites and viruses. Most STIs affect both men and women, but in many cases, health problems caused can be more severe in women. If a pregnant woman has STI, it can cause serious health problems for the baby. If the STI is caused by bacteria or parasites, health care provider can treat it with antibiotics or other medicines. If the STI is caused by a virus, there is no cure. Sometimes medicines can keep the disease under control. Correct usage of condoms greatly reduces the risk of contacting STIs, but does not completely eliminate the risk.

Some of the common signs and symptoms of STIs include:

i. *Pain during sexual intercourse or when urinating.*
ii. *Vaginal and penis itching or irritation.*
iii. *Thick, cloudy or bloody discharge from the penis or vagina.*
iv. *Abdominal pain or discomfort, especially in the area of the liver on right side beneath the lower ribs.*
v. *Dark urine, swollen glands, loss of appetite, persistent night sweats, weight loss, unexplained fatigue, muscle or joint pain, fever and body aches, etc.*
vi. *Several warts close together that takes on a cauliflower shape.*
vii. *Small red bumps, blisters (vesicles) or open sores (ulcers) in the genital, or small, flesh-coloured or gray swellings nearby the genital area.*
viii. *Heavy menstrual bleeding or bleeding between periods in female.*

i. Prevention of STIs

Some of the ways to prevent from being infected with STIs are:

i. ***Health education***: education and counselling are the main strategies in the prevention and control of STIs. This aims to help individual change their behaviour in effort to avoid STIs while taking into account each patient's individual risk factors and goals.

ii. ***Use of contraceptives***: using condoms and other barrier methods for safer sex can minimize the risk of being infected with STI.
iii. ***Abstinence***: the most effective way to avoid STIs is to abstain from sex.
iv. ***Vaccination***: getting vaccinated early, before sexual exposure, is also effective in preventing certain types of STIs. Vaccines are available to prevent human papilloma virus (HPV), hepatitis A and hepatitis B.
v. ***Personal hygiene***: the exposed parts of the body should be washed properly with soap and water.
vi. ***Social welfare measures***: STIs are a social problem with medical aspects. Therefore, do get tested for STIs before sexual intercourse with new partners. This service can be availed from any public or private hospital in Bhutan.

4.3 Activity

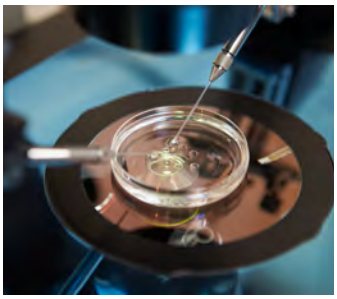
Poster competition

You are asked to organize an International AIDS Conference (IAC) in Bhutan by the UNESCO section on HIV and AIDS. Therefore, design a poster on the theme, 'Empowering Young People against HIV and AIDS', which can be used for the Conference. The poster should be related to the Conference theme 'Right Here, Right Now'. Your poster should include a slogan of not more than 10 words and a visual design.

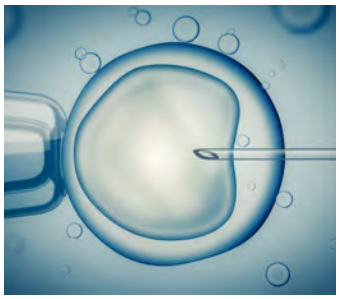
c. Infertility treatment

Some women have difficulty in becoming pregnant because they do not produce enough **follicle stimulating hormone** (**FSH**) which stimulates their eggs to mature. Similarly, some males produce low sperm count that makes fertilisation difficult. The term infertility is the inability to conceive. The common treatments for infertility are the use of *f***ertility drugs** and **in-vitro fertilisation** (**IVF**).

1. Fertility drugs contain **follicle stimulating hormone** (**FSH**), which stimulates eggs to mature in the ovary. Fertility treatments increase a woman's chance of becoming pregnant, although the treatment may not always work. It improves the production of mature eggs due to which multiple conceptions occur in some cases. This increases the risk of complications in pregnancy and childbirth, and may lead to premature or underweight babies.
2. In In-vitro fertilisation (**IVF**) treatment, the egg is fertilised outside the woman's body and then implanted back into her uterus. It might be necessary to remove the mature eggs from the woman´s body and mix them with sperm in a laboratory. Some of the fertilised eggs that resulted from IVF are placed in the woman's uterus where they can develop as normal foetus. The IVF procedure in brief is as shown in Figure 4.19.



Several thousand sperm are added to each egg



An egg which has just fertilized, (in vitro fertilization or insemination of egg with microscope)

An ultrasound image of developing baby

Figure 4.19: IVF procedures

Activity 5.2

Debate on the statement 'STIs is a social defamation'

Instructions: Divide the class into three groups. One group defends the statement, while the second group is against the statement. Identify 4-5 criteria for evaluation.

The third group as the audience gives points for each speaker in the score sheet provided.

Sl No	Name	Motion	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Total
1.		F					
2.		A					
3.		F					
4.		A					
5.							
6.							
	Total score	For the motion (F+F+..)			Against the motion (A+A+...)		

Questions

i. Why do you think STI is a social stigma?
ii. What makes you think STI is not a social defamation?
iii. How should you treat people with STI?
iv. What are the sources of STI?
v. What are the health hazards of STI?
vi. What are the methods of STI prevention?
vii. How does STI impact the society?

Lesson Summary

- Sensory neuron, relay neuron and motor neuron are three types of neurons based on their functions.
- The human nervous system is made of two parts-central nervous system (CNS) and peripheral nervous system (PNS).
- The CNS includes the brain and spinal cord, which have the role of coordination.
- PNS includes nerves, which connect all parts of the body to the CNS.
- Sense organs are linked to the PNS, and contain groups of receptor cells.
- When exposed to a stimulus receptor cells generate an electrical impulse, which passes along the peripheral nerves to the CNS, triggering a response.
- Reflexes are of two types: natural reflex and conditioned reflex.
- The nervous system and the endocrine system are the two body systems involved in hormone regulation by feedback mechanisms.
- Insulin regulates glucose in the blood.
- Diabetes is of two types: type 1 diabetes and type 2 diabetes.
- Estrogen and progesterone are female sex hormones, and the testosterone is the male sex hormone.
- Reproductive health implies that people are able to have a responsible, satisfying and a safe sex life and that they are capable to reproduce.
- The knowledge of hormones has been used to increase or reduce the chances of fertilisation and pregnancy in women.
- There are different types of hormonal contraceptive methods of birth control.
- Contraceptives are devices used for family planning through birth control.
- The two common methods of infertility treatments are the use of fertility drugs and in-vitro fertilization (IVF).

Weblink

- http://www.innerbody.com/image/nervov.html
- http://www.sumanasinc.com/webcontent/animations/content/reflexarcs.html
- http://www.biotopics.co.uk/humans/recodr.html
- https://www.plannedparenthood.org/learn/birth-control/birth-control-implant-implanon

Review Questions

A. Each question in this part is followed by four possible choices of answer. Choose the correct or the most suitable response.

1. Suppose you are walking along, you see a football coming at high speed towards your head. You would probably move or duck quickly to avoid the contact. A summary of the sequence of events is

   A. stimulus ⟶ receptor ⟶ coordination ⟶ effector ⟶ response.

   B. stimulus ⟶ effector ⟶ coordination ⟶ receptor ⟶ response.

   C. response ⟶ receptor ⟶ coordination ⟶ effector ⟶ stimulus.

   D. response ⟶ effector ⟶ coordination ⟶ receptor ⟶ stimulus.

2. A person accidentally touches a hot pan. Her hand automatically moves away from the pan. The diagram shows the structures involved in this action.

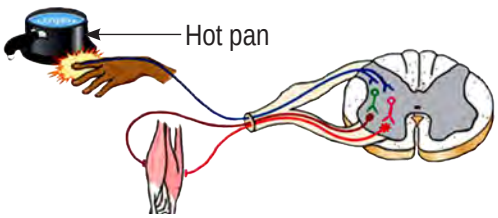
   The structure that detects the stimulus is

   A. an affector.

   B. an effector.

   C. a receptor.

   D. a response.



3. Doctors check the knee jerk reflex to diagnose disease in the cerebellum. This is an example of

   A. natural reflex.
   C. reflex.
   B. conditioned reflex.
   D. reflex arc.

4. An individual requires family planning to attain certain objectives. Which one of the following is not the objective?

   A. For proper spacing between the pregnancies

   B. To properly regulate the number of children in the family

   C. To avoid unwanted births and conceive only when desired

   D. To prevent from STIs

5. A 45 year old woman has several symptoms of menopause such as, hot flashes, disturbed sleep resulting from hot flashes and vaginal dryness. As a gynaecologist, you would prescribe her

   A. thyroid drugs.
   C. steroids hormones.
   B. hormone therapy.
   D. insulin shock.

6. The picture on the right shows one of the birth control (contraceptive) pills for women. Some of the facts about using the birth control pills are

- *birth control pills are 99 per cent effective in preventing pregnancy.*
- *the hormones in the pills have some rare but serious side effects.*
- *this method of birth control gives no protection against sexually transmitted diseases.*
- *the hormones in the pills give protection against some women's diseases.*
- *the woman has to remember to take the pill every day.*

One advantage of using birth control pills is that they

A. are very effective in preventing pregnancy.
C. need to take periodically.
B. have rare but serious side effects.
D. do not protect against STIs.

7. If a dog at a distance sees you simply bending down, the dog runs away. This is an example of

A. natural reflex.
C. reflex.
B. conditioned reflex.
D. all of the above.

8. Which is the odd one among the following?

A. Vaginal ring
C. Contraceptive pill
B. Birth control patch
D. Cervical cap

9. Every reflex action in human is under the control of

A. brain.
C. autonomic nervous system.
B. spinal cord.
D. peripheral nervous system.

10. When you are unhappy, your body would have high amount of which of the following substance?

A. Insulin
C. Thyroxine
B. Serotonin
D. Adrenaline

B. Differentiate between the following pairs of words based on what is given in brackets.

1. Natural and conditioned reflex *(nature of reflex).*
2. Type 1 diabetes and type 2 diabetes *(body's ability to produce insulin).*
3. Receptors and effectors *(direction of impulse carried).*

4. Central nervous system and peripheral nervous system *(parts consist of)*.
5. Sympathetic and parasympathetic nervous system *(overall effect on body)*.

C. Name the following.

1. The only part of the central nervous system that is found outside bony structures.
2. Substance that carries nerve impulse from one end point of neuron to another.
3. The nerve cell that carries sensory information from receptors in the sense organs to the brain and spinal cord.
4. The hormone responsible for regulating of glucose concentration in blood.
5. The system that prepares the body for emergency such as danger, cold or heat.

D. Copy and complete the table below.

Refer Figure 4.4 and complete the table below.

Sl No.	Organs	Sympathetic system	Parasympathetic system
E.g.	Heart	Accelerate heart beat	Slows heart beat
1	Pupil of an eye	.....	.....
2	Lungs	.....	.....
3	Blood vessels	.....	.....
4	Salivary glands	.....	.....
5	Urinary bladder	.....	.....
6	Intestine	.....	.....
7	Stomach	.....	.....

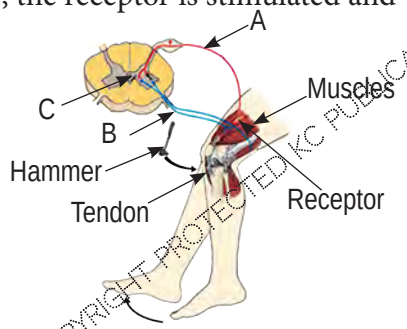
E. Give reasons.

1. When you are angry, adrenaline secretion increases.
2. Playing a guitar is a conditioned reflex.
3. Two friends entered a restaurant and saw dishes lying on the table. One salivates at the sight of it and another did not.
4. Spinal cord and brain are referred to central nervous system.
5. Anabolic steriods are widely used by atheletes.

F. Answer the following questions.

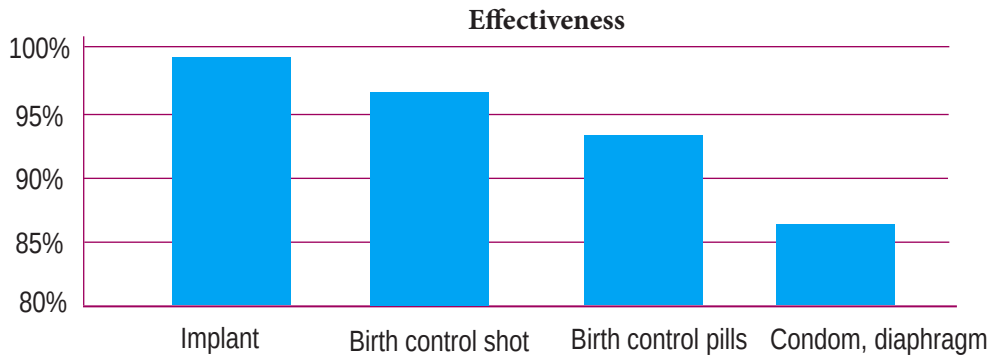
1. Explain the role of insulin in maintaining blood sugar level.
2. Mention three side effects of anabolic steriod use.
3. Differentiate between anabolic steriods and corticosteriods,

4. The diagram on the right shows the structures involved in the knee-jerk reflex. When the knee is gently tapped with the hammer, the receptor is stimulated and the lower leg moves forward.



   i. Name the structures labelled A, B and C.
   ii. How is the information passed from structure A to structure B?
   iii. What is the effector in this response?

5. Hormonal methods of birth control are some of the most effective forms of birth control available. When used properly, their effectiveness in preventing pregnancy can approach 99%-100%. With any form of hormonal contraception, precisely following instructions for proper use will increase its effectiveness. Study the graph on the right plotted based on the research findings and answer the questions that follow.



   i. Which method of birth control is the most effective? Support with reason.
   ii. Which method is mostly likely to cause pregnancy? Why?
   iii. If you are a gynaecologist, which method would you recommend for your client and why?
   iv. In brief, write your perspectives about the use of contraceptive methods in Bhutan.

6. While observing mouse behaviour, a student drops a pen near the mouse's cage. The mouse jumps at the noise. Describe, as fully as you can, the processes by which the mouse responds to the stimulus of the dropped pen.

7. Read the information about the trialling of the first contraceptive pill.

   Hormones are used in contraceptive pills. The pill was developed by a team of scientists led by Gregory Pincus. The team needed to carry out large-scale trials on humans. In the summer of 1955, Pincus visited the island of Puerto Rico. Puerto Rico is one of the most densely populated areas in the world. Officials supported birth control as a form of population control. Pincus knew that if he could demonstrate that the poor, uneducated women of

Pincus ignored these side effects. The women in the trial had been told only that they were taking a drug that prevented pregnancy. They had not been told that the pill was experimental, or that there was a chance of dangerous side effects.

i. Explain how a contraceptive pill works.

ii. Evaluate the methods used by Pincus in trialling the contraceptive pill.

iii. Identify any possible ethical issues that could have arisen due to the use of contraceptive pill in Puerto Rico.

iv. If you were the head of the Island of Puerto Rico, how you could have reacted to the proposal of trailing with your people.

v. Identify any ethical issues pertaining to the use of contraceptive pill in your community.

5 MICRO-ORGANISMS, DISEASES AND DRUGS

In everyday life, we hear about people suffering from different kinds of diseases. Similarly, animals and plants also suffer from diseases. Most of these diseases are caused by organisms such as viruses, bacteria and fungi. They are extremely diverse and found in almost all kinds of environment. In a handful of soil, there will be many micro-organisms which are not visible to our naked eyes. These organisms occur in variety of sizes and shapes. Some of them are harmless to man, animals and plants, while others are pathogenic and cause several diseases.

In human, many diseases are caused by micro-organisms such as bacteria, virus and fungi. Some diseases are easily curable with vaccination and immunization, while vaccines for a few others are yet to be discovered. Different types of drugs are used for medical purposes to cure diseases.

5.1 Micro-organisms

Learning Objectives

On completion of this topic, you will be able to:

- describe the basic structure of bacteria, viruses and fungi.
- relate their structures to their functions.

Micro-organisms are very tiny living organisms. They are so small that you need a **microscope** to see them. Micro-organisms such as **virus** do not have proper cellular structure while others such as **bacteria** and **fungi** have proper cell structures. Bacteria are usually **prokaryotes** while fungi can either be prokaryotes or eukaryotes. Some of them are **unicellular** and others live in colonies of similar cells. The construction of bacterial cells, virus and fungi are simple and made up of primitive cells.

a. Bacteria

Bacteria (*singular*: **bacterium**) are the earliest forms of life on the earth. They are the most abundant **unicellular micro-organisms**. Their cells are very small ranging from 0.15µm to about 15µm. They exist in many sizes and shapes and are found everywhere on the earth. For example, in a cup of pond water, hundreds of bacteria might be present. Bacteria also live in **extreme habitats** such as hot springs, deserts, snow and deep oceans, where very few other life forms can survive. Some of them live in or on other organisms as **parasites**. Bacteria are mostly **useful**, but few others cause **diseases**. The study of bacteria is known as bacteriology.

i. Sizes and shapes

Bacteria are made up of simple cells and **lack true nucleus**. Their cell shapes and sizes vary greatly depending on growth conditions. Bacteria are grouped under *four* categories based on their shapes. They are:

i. coccus (*pl*: **cocci**) which is *spherical* in shape.
ii. bacillus (*pl*: **bacilli**) which is *rod*-shaped.
iii. spirillum (*pl*: **spirilla**) which is *spiral* shaped.
iv. vibrium (*pl*: **vibrio**) which is *comma*-shaped.

Coccus bacterium occurs **singly** in chains (streptococcus) or in **clumps** (staphylococcus). They also occur in two called diplococcus. The average diameter of coccus bacteria is about 1µm or less. *Bacillus* and *spirillum* are about 2-5 µm long. Some rod-shaped bacteria are about 10 µm long and 0.5-1 µm in diameter.

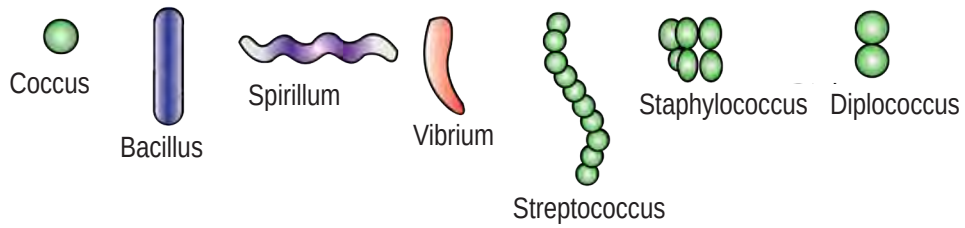


Figure 5.1: Different shapes of bacteria

ii. Structure of bacteria

Unlike the structure of a plant and an animal cell, the bacterial cell structure is very **simple** and contains numerous **unique cell structures**. The internal structure of a bacterium with its parts is shown in Figure 5. 2. Certain features shown are common to all bacteria, but other structures such as **capsule**, **flagella**, **pilla**, etc. are not common to all. The functions of each structure (see Table 1.2) are discussed.

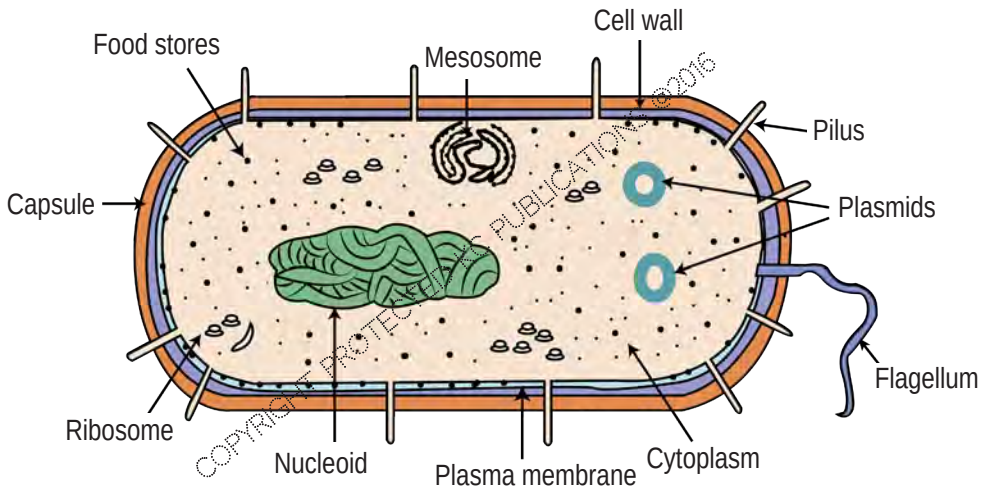


Figure 5.2: The structure of a bacterium cell (prokaryotic cell)

Bacteria are of *two* types: ***Gram-positive bacteria*** *(***Gram**$^{+}$*)* and *Gram-negative* ***bacteria*** *(***Gram**$^{-}$*)*.

Gram + bacteria have thick cell wall layer made of **peptidoglycan** complex and **lipids**. It stains **purple** with gram stain. E.g. *Actinomycetes, Clostrium, streptococcus, etc.*

Gram - bacteria have a thin cell wall layer made of **peptidoglycan** complex and a layer of **lipids** outside. It stains **pink** or **reddish** with gram stain. E.g. *Rhizobacteria, Rickettsiae, Rhizobium, etc.*

iii. Movement and nutrition

Most bacteria do not have **locomotive ability**; therefore, they are transported from one place to another by wind, water or other organisms. But most bacteria have flagellum that helps in its **locomotion** and **movement**. There are *four* methods of nutrition in bacteria.

i. Saprobes are those that feed on **dead organic matter** for food.

ii. Parasites are those that feed on a **host cell** or other living organisms.

iii. Photoautotrophs are those that **synthesis their own food** using sunlight for energy.

iv. Chemoautotrophs are those that obtain food by using **chemical substances** instead of using sunlight.

The followings are the types of bacteria based on their *methods of respiration*:

i. Obligate aerobic bacteria cannot live without oxygen. E.g. *tuberculosis bacteria*.

ii. Obligate anaerobes die in the presence of oxygen. E.g. *tetanus bacteria* that causes lockjaw.

iii. Facultative anaerobes do not need oxygen but do not die in the presence of oxygen. E.g. *E. coli*.

iv. Anaerobes carry on **fermentation**, while aerobes carry on cellular respiration.

iv. Reproduction in bacteria

How do bacteria grow and reproduce? Bacteria have the ability to reproduce both **sexually** and **asexually**. In favourable conditions, most bacteria reproduce asexually by binary fission. **Binary fission** is an asexual process whereby, one bacterium **splits** into two. Bacteria can multiply and reproduce every 20 minutes under ideal conditions. Bacteria grow best at the temperature of about **25-45^0 C** and at pH value of **6.5** to **7.4**.

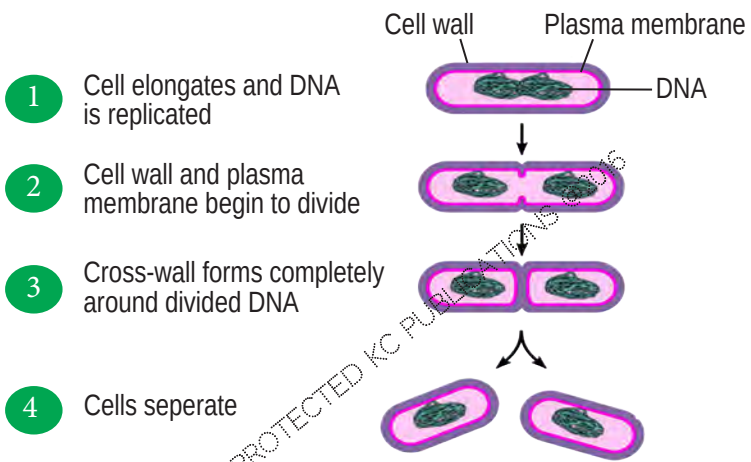


Figure 5.3: Process of asexual reproduction by binary fission

Sexual reproduction, in some bacteria occurs by means of conjugation. This involves exchange of genetic material between two bacteria cells through a **bridge-like projection** called conjugation tube. An elongated appendage called pili holds the bacteria together. The genetic material is transferred from one bacterium cell to the other.

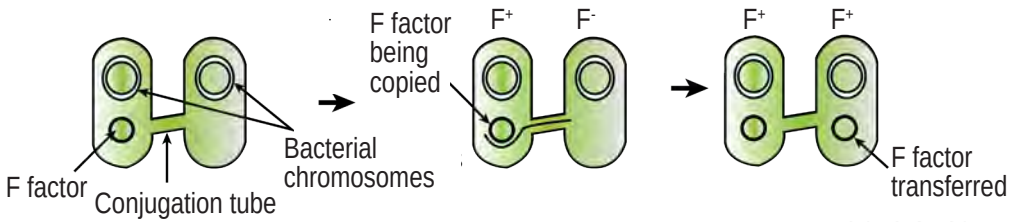


Figure 5.4: Process of asexual reproduction by conjugation

During *unfavourable* conditions, some bacteria form spores with thick, protective coats called endospore, which open only during favourable conditions. Endospore is **resistant to** low and high temperature, pH change, dryness and effects of chemicals. *Anthrax* has survived for millions of years in its endospore form.

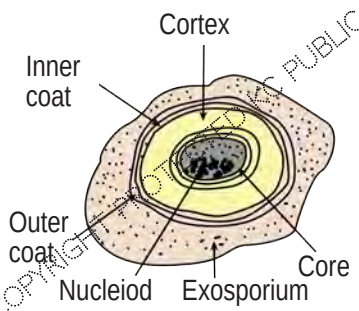


Figure 5.5: The structure of a bacterial endospore

v. Importance of bacteria

Most bacteria are helpful to nature, humans and the environment. They play important roles in *agriculture*, *industry*, *genetic engineering*, etc.

1. ***Agriculture***

Bacteria decompose organic substances such as excreta, leaves, faeces, etc. thereby helping to **increase the fertility** of the soil. *Rhizobium bacteria*, living in root nodules of **leguminous plant** helps in **fixing atmospheric nitrogen** into usable ammonia for plants. It is important part of the earth's **nitrogen cycle**. Bacteria are also used to produce **biogas** from animal dung.

2. ***Industry***

Some bacteria such as *Streptococcus lactis* are used in diary industries to **convert milk sugar lactose** into lactic acid. The byproducts of milk like curd, yoghurt, cheese are due to bacteria. **Fermentation** by bacteria helps to produce various organic compounds such as alcohol, lactic acid, acetone, etc. The leaves of tea and tobacco, beans of coffee and coca are cured off their bitterness with the help of the actions of certain bacteria such as *Bacillus megatherium*. Bacteria such as *Streptomyces erythreus*

are used to produce **antibiotics**. Different kinds of vitamins are also produced from bacteria like **riboflavin**, **vitamin B-complex**, etc.

3. ***Genetic engineering***

Bacteria are used for the **genetic engineering** purposes. They have small rings of DNA called plasmids. Bacterial plasmids are used in genetic engineering to carry new genes into other organisms.

Activity 5.1

Making a bacterium cell

Using the waste materials at your home or school, make a model of a bacterium cell. Display in your class.

Questions

i. Draw a labeled diagram of your model.
ii. Lists all the materials you used for the model design.
iii. Write two interesting points about your model.
iv. Write a short report about how you design your model.

b. Virus

Viruses (*singular*: **virus)** are extremely small compared to bacteria and visible only under electron microscopes. They were discovered after bacteria by the Russian biologist, Dmitri Iwanowski in tobacco plants suffering from '***mosaic disease***' in 1892. He identified the agent of disease in the plant as virus. The word *virus* means '*poison*' in Latin. The study of virus is called virology. Viruses cause certain diseases in human, animals and plants.

i. Characteristics of virus

Viruses have the following characteristics.

i. They are **extremely tiny** and their sizes range from 0.02-0.4μm.
ii. They **do not have** *membranes, cytoplasm*, *ribosomes* or other *cellular components.*
iii. They **reproduce only inside a living host cell** by using its raw materials and enzymes. Therefore, all viruses are endoparasites.
iv. Viruses **cannot** grow or move on their own.
v. Virus consists of two major parts- a **protein coat** and **hereditary material** (**DNA** or **RNA**).
vi. Viruses cause **diseases** like smallpox, measles, influenza, colds, AIDS, ebola, etc.

ii. Structure of a virus

Viruses occur in different shapes such as **polyhedral**, **helical**, **spiral** and **cylinder**. In the structure of a virus (Figure 5.6), the inner core contains DNA or RNA. It is surrounded by protein coat called capsid. Capsid is made of **protein subunits** called capsomeres. Some viruses also have outer lipid layer covering around the capsid called the envelope. Envelope is usually formed from the host cell membrane, it may

have spikes to help chemically recognize and attach itself to the host cell. Viruses are usually **very specific** to the host cells they infect.

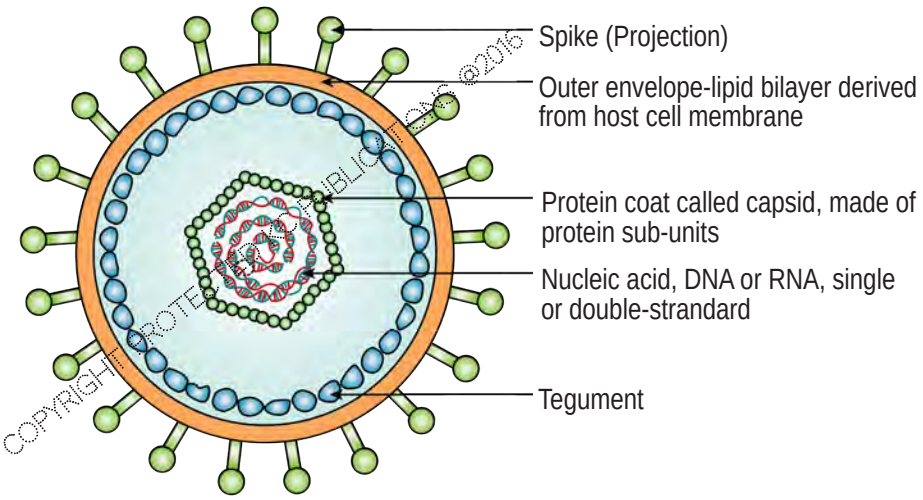


Figure 5.6: The model structure of a virus

Figure 5.7: The structure of some viruses

iii. Viral reproduction

Viruses **cannot reproduce** outside of the host cell. They multiply or replicate using their **own genetic material** and substances from the **host cell**. Once the virus is inside the host, host cells are affected in *three* ways:

i. the host cells may be **destroyed**.
ii. they may **swell** and **burst** and
iii. the virus can interact with the host cell's chromosomes causing a **mutation**, e.g. *warts* and *cancer* cells.

When an organism is affected by virus, the **immune system** of the organism becomes activated in order to fight the infection. This may lead to fever, tiredness or suffer from disease. After the viral infection host cells may not be able to function in normal conditions.

iv. Types of virus

Viruses are of the following types:

i) Bacteriophage

The virus that infects **bacterial cell** is known as bacteriophage. It has a more complex structure composed of **head**, **tail**, **baseplate** and **tail fibres**. The head contains a long **DNA molecule**. Tail helps inject the **viral DNA** into the host cell. Tail fibres are used to **attach** to the host.

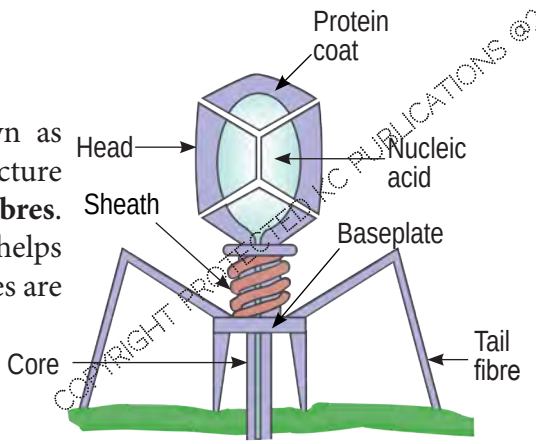


Figure 5.8: A model structure of bacteriophage

ii) Retroviruses

Retrovirus is a particular virus that contains RNA. When it infects a host cell, it carries protein, which is an enzyme called reverse transcriptase. This enzyme helps the virus to use the RNA to make DNA. It causes some **cancers** and **AIDS**.

iii) Other related virus

Viroids are the smallest form of viruses able to replicate. They are composed of a short, **single strand** of RNA with no capsid. They cause disease in plants. Prions are infectious protein particles similar to virus and have **no nucleic acid** or **capsid**. Prions attack the **central nervous system** and cause diseases in cows (*mad cow disease*), sheep, and humans.

c. Fungi

You might have seen that bread develops **mould** or an **orange rots**; this is because of fungi. The common mushroom that we eat is also fungi. Some examples of fungi

Figure 5.9: Examples of fungi

are moulds, mushrooms, yeasts, puffballs and rusts. They are mostly free-living, living in the soil, air and dead matter. Fungi grow best in warm, moist environments and under shades. Fungi are diverse and widespread. The study of fungi is called mycology.

i. Structure of fungi

The body of a fungus consists of **long, slender thread-like structures** called hyphae. A network of hyphae is known as mycelium. The **horizontal hypha** that connects groups of hyphae to each other is called stolon. The root like parts of hyphae that anchor the fungus is known as rhizoid. Hyphae contain **cytoplasm** and **nuclei** enclosed by a rigid cell wall. Cell walls are made of a **complex polysaccharide** called chitin. The hyphae are **multi-branched tubular cells** that are separated by cross walls called **septa** or **continuous**. Hyphae with septa or cross walls are called septate hyphae. Hyphae with continuous tubes filled with multinucleated cytoplasm are called coenocytic hyphae.

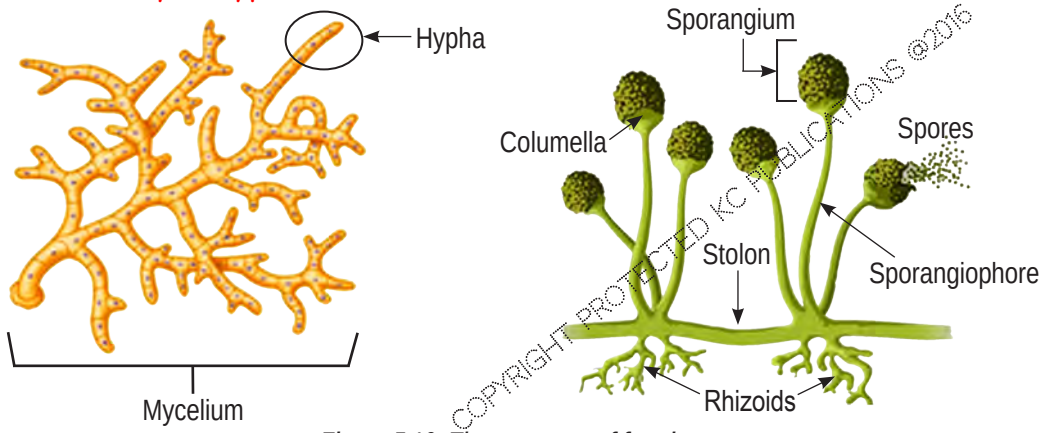


Figure 5.10: The structure of fungi

Activity 5.2

To observe the fungus mould in bread

Materials required: bread, petri dish, magnifying glass or microscope.

Procedure

1. Take a piece of bread in a petri dish and moisten it with water.
2. Leave it in a warm place for 2 to 3 days till fluffy patches appear on them.
3. Observe the patches under a magnifying glass or microscope.

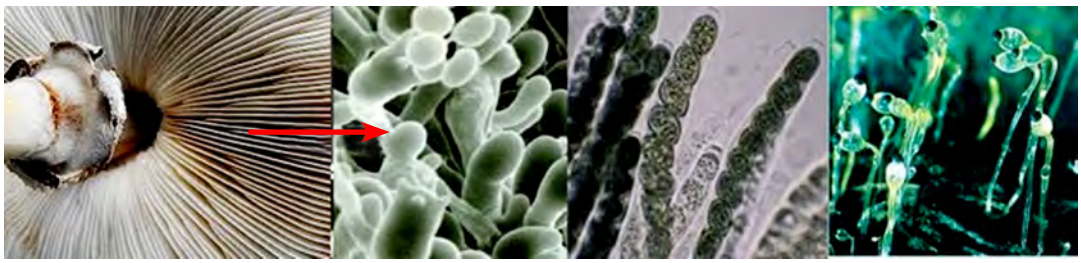
Questions

i. Describe in your own words what you observe under a magnifying glass.
ii. Draw the structure observed.
iii. Why do you need to moisten the bread?
iv. Why is it not advisable to keep cooked food for longer duration?

ii. Reproduction in fungi

Have you ever wondered how moulds grow and reproduce on bread? Fungi **reproduce asexually** when environmental conditions are favourable. **Asexual reproduction** produces **genetically identical organisms** and is the most common method of reproduction in fungi. **Sexual spores** are formed in the fruiting body. The modified hyphae with asexual spores are called **fruiting body**. Fruiting bodies consist of an upright stalk or sporangiophore with a sac containing spores called the sporangium. Spores are **haploid** (**n**) cells with dry cytoplasm and a protective coat capable of developing into new individuals. Wind, animals, water and insects spread spores. When spores land on moist surface, a new hyphae grows.

Types of fruiting bodies include **basidia**, **sporangia** and **ascus** (Figure 5.11). *Penicillium* mould produces spores called conidia on the top of a stalk called the conidiophores. Yeast cells reproduce by budding, where a part of the cell pinches off to produce more yeast cells.



a) Basidia b) Ascus c) Sporangia

Figure 5.11: Types of fruiting bodies

Sexual reproduction in fungi occurs when nutrients or water are scarce. There are *two* mating types of fungi as **plus** (+) and **minus** (-). Fertilization occurs when (+) hyphae fuse with (-) hyphae to form a 2n or diploid zygote (Figure 5.12).

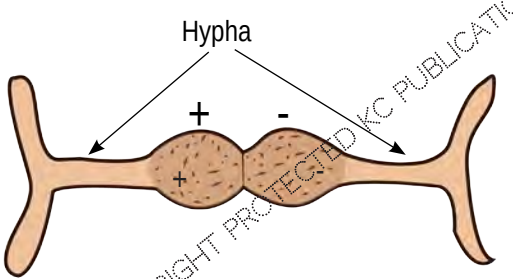


Figure 5.12: Sexual reproduction in fungi

iii. Nutrition

Like animals, most fungi are **heterotrophic**. Some fungi are parasitic and depend on living plants and animals. They also live as symbionts, in association with algae as in lichens, and with roots of higher plants. Fungi obtain food from their substrate by digesting food externally with the help of enzymes called exoenzymes. These enzymes are transported out of the hyphae where they break down nutrients in the

environment. The smaller molecules produced by **external digestion** are absorbed through the large surface areas of the mycelium. They absorb **soluble organic matter** from dead substrates, and hence are called saprophytes.

Lichen is the **symbiotic association** between a **fungus** and photosynthetic green **algae**. Algae make **food** and fungus supplies **moisture**, **shelter** and **anchorage**; therefore, both organisms are benefited. They grow on rocks, trees, buildings, etc.

Mycorrhiza is the **symbiotic association** of a fungus living in plant roots. Fungus absorbs sugars made by plant, and plants absorb more water and minerals with the aid of fungus.

iv. Importance of fungi

- They play an important role in the ecosystem by - **decomposing dead organisms**, **fallen leaves**, **faeces**, and other **organic materials**.
- Some **higher plants** such as pine depends on fungi to help their roots absorb minerals and water from the soil.
- Humans have **cultivated fungi** for centuries for **food**, to produce **antibiotics** and other **drugs**, to make **bread**, and to **ferment beer** and **wine**.
- ***Aspergillus*** is used to make soy sauce.
- Antibiotic ***penicillin*** comes from *Penicillium mould*.

Activity 5.3

Library research

Go to library or internet café and collect information on the following topics. You are required to share your work with other members in the class.

1. Discovery of antibiotics.
2. Outline the different types of antibiotics.
3. Uses of antibiotics.
4. The side-effects of antibiotics.
5. Antibiotics overuse - a worldwide concern.
6. Interesting facts about antibiotics.

Figure 5.13: Alexander Fleming discovered ***penicillin, the first natural antibiotic, in 1928***

5.2 Disease and Protection against Infection

Learning Objectives

On completion of this topic, you will be able to:

- name examples of pathogens from the three types of micro-organisms.
- evaluate the protection by vaccination from contracting infectious disease.

Every time, you a visit hospital, you come across people suffering from several diseases. You might have also seen a diseased tree. These diseases are due to certain disease causing **microorganisms**. All the main groups of microorganisms such as **viruses**, **bacteria**, **fungi**, **algae** and **protozoa** may cause disease in living organisms. Some of them are **harmless** to plants and animals. In this topic, you will study some of the **human diseases** caused by bacteria, virus and fungi and their prevention. All these diseases are grouped into communicable disease (**CD**) and non-communicable disease (**NCD**). Some of these diseases are curable while a few others are non-curable.

a. Disease causing micro-organisms

Microorganisms such as bacteria, virus and fungi can be grouped into: ***pathogenic*** and ***non-pathogenic***. The micro-organism that causes disease by infecting other organism (**host**) is called pathogenic. Most of the pathogenic diseases in animals are caused by viruses or bacteria, whereas fungi cause most of the diseases in plants. Some microorganisms are free living and harmless; therefore, they are called non-pathogenic.

All disease caused by microorganisms can be broadly classified into communicable disease (*infectious*) and non-communicable (*non-infectious*) disease. Communicable (infectious) disease is caused by agents called pathogens. Some examples of communicable disease in humans include **tuberculosis**, **whooping cough**, **measles**, **poliomyelitis**, etc. Non-communicable diseases are self-inflicted or created by environmental conditions. **Coronary heart disease** and **lung disease** due to smoking are some examples of self-inflicted non-communicable disease. Other groups of non-infectious diseases include those inherited from parents such as **haemophilia**, **albinism**, etc.

i. Bacterial diseases in human

Pathogenic bacteria infect our body as it draws nutrition. They release harmful substances, called toxins into the human body. These toxins may cause symptoms like a **rash** or a **high temperature**. Examples of bacterial disease in humans, its **causative organisms**, **mode of transmission**, **symptoms** and **prevention** are given in Table 5.1.

Table 5.1 Some bacterial diseases in human

Name of disease	Causative organism	Incubation period	Mode of transmission	Symptoms	Preventive, control and treatment
Tuberculosis	*Mycobacterium tuberculosis*	2-10 weeks	Contact with nasal discharge, and sputum of patient	Infection of lungs followed by cough, sputum containing blood, pain in chest, loss of body weight	• Isolation of patient, BCG Vaccination for children. • Multi-drug therapy (DOT (directly observed treatment)
Typhoid	*Salmonella typhi*	1-2 weeks	Close contact with infected person, by drinking or eating contaminated food or water	High fever, sweating, gastroenteritis, and diarrhoea.	• Antibiotics, drinking fluid to prevent dehydration and eating a healthy diet
Cholera	*Vibrio cholera*	6 hr-3 days	Contaminated food and water	Vomiting, acute diarrhoea	• Cleaning drinking water, proper sanitation, vaccination
Tetanus	*Clostrium tetani*	4-21 days	Direct entry of pathogens	Pain in neck and jaw muscles, paralysis of thoracic muscles	• Clean the wound DTP vaccine with an interval of 6 weeks
Syphilis	*Treponema pallidum*	3 weeks	Sexual contact with infected person	Painless lesion, fever, illness, skin rash, hair loss and swollen joints	• Avoid sexual contact with an infected person, antibiotics
Gonorrhoea	*Neisseria gonorrhoeae*	2-4 weeks	Sexual contact with infected person	Greenish yellow or whitish discharge from the vagina and penis, lower abdominal or pelvic pain, burning sensation when urinating	• Avoid sexual contact with an infected person, antibiotics • Use condom • Avoid polygamy

Name of disease	Causative organism	Incubation period	Mode of transmission	Symptoms	Preventive, control and treatment
Botulism	*Clostridium botulinum*		Consume infected, packaged, canned org smoked foods	Vomiting, constipation, thirst and paralysis of muscle	• Antitoxins to neutralise toxins
Whooping cough	*Bordetella pertussis*		Spread by droplet infection	Severe coughing which infects children, with 'whoop' sound.	• Vaccine of killed bacterium, DTP vaccine

ii. Viral diseases in human

Several human diseases caused by viruses include **measles**, **rubella**, **mumps**, **chicken pox**, the **common cold** and **poliomyelitis**. The deadly viral infection, **small pox** was eliminated from all the countries in 1977 by the International Medical Action.
AIDS in humans is caused by a virus. In plants, the symptoms can be **mosaic formation**, **leaf rolling and curling**, **yellowing and vein clearing**, **dwarfing and stunted growth**. Examples of plant viruses are Tobacco Mosaic Virus (**TMV**), Virus Barley Dwarf, bud blight, etc.

Activity 5.4

Evolving viruses

Go to the library or an internet café and then make a lists of evolving (new) viral diseases over the past ten years. Write their casuative agents, symptoms and preventive methods. You are required to display your work in the class.

iii. Fungal diseases in human

Most fungi do not cause disease. However, some of the **pathogenic fungi** cause serious diseases in man, animals and plants. Fungi attack animals directly by attacking and destroying tissues. Humans and other animals can be poisoned by **eating toxic mushrooms** or foods contaminated by fungi. In addition, individuals may develop strong and dangerous **allergic reactions** to moulds and spores. Infections caused by fungi are usually on the skin, lungs, mouth, vaginal tract, etc. Some of the diseases caused by fungi in humans are given in Table 5.2.

Table 5.2 Some fungal diseases in human

Diseases	Symptoms	Transmission	Treatment
Ringworm	Itchy patches, red scaly skin, usually ring-shaped on face, legs and back	Physical contact	Fungicide ointment, antibiotics if serious
Athlete's foot	Itchy red and scaly patches on feet	Physical contact	Fungicide ointment, antibiotics if serious
Scabies	Red itchy patches on the head, body and in between fingers and toes	Physical contact, through contact with clothing	Ointments, antiseptics and antibiotics
Tinea	White patches on skin, can spread to whole body, not itchy	Spores of fungi which fall on moist soil	Sulphur powder

b. Immunobiology

Our body is under constant attack by **bacteria**, **viruses**, **fungi** and **parasites**. The **immune system** governs these attacks by foreign bodies. Without it, no human being would be alive. Our body defence system is made up of an array of cells, all arising from **stem cells** in the bone marrow. Some immune cells release large proteins called antibodies into the bloodstream that rush to the enemies and attack with lethal chemicals. Some others envelop and consume the invaders. Immune cells multiply in response to a threat and signal other immune cells to join the fight.

i. How antibodies work

As you have studied in class IX biology, antibodies are chemicals that stick to specific kinds of germs flagging them for destruction. Once an antibody cell has been **activated by meeting a matching germ**, it makes copies of itself and makes the body immune. Antibodies work in following ways.

1. ***Infect***: A new germ invades the body and mutiplies.
2. ***Detect***: Antibody cells touch the germ to see if it matches molecules on their surface. Eventually, an antibody with matching molecules sticks to the germ.
3. ***Activate***: Matching cell makes many clones. It will also make **memory cells**, which will stay in the body for years in case germ returns.
4. ***Seek***: Clones make antibodies and release them into the blood. When they find germs, they stick to them.
5. ***Destroy***: Antibodies act as signposts to cells called macrophages, which swallow and destroy germs.

ii. Vaccines and vaccination

Vaccines offer a kind of advance warning, arousing the immune cells to prepare **defences against specific pathogens**. They do this by **mimicking a natural infection**- getting the threatening organism into the body, but in a form the immune system can easily fight off. A vaccine may be filled with bacteria or viruses that have been weakened in the laboratory or killed. It may also contain chemically weaken **tokins** released by the organism. Or it may contain just pieces of pathogen- the antigens that cover the surface of a microbe and mark it as foreign to the immune system.

Vaccination is the practice of **artificially introducing germ or germ substance** into the body for developing immunity against a particular disease. The **killed or weakened germ or germ substance** introduced into the body is called vaccine. Vaccine can be introduced into the body through injection or orally. Once introduced into the body, vaccine stimulates the WBCs to produce antibodies against the germs for particular diseases. It boosts our body's ability to fight against certain diseases.

Vaccines are of the following types based on their sources:

1. In ***live attenuated (weakened) vaccines***, the organism in the **vaccine is alive but weakened to infect a person** with a normal immune system. Patients with impaired immunity, such as those with i**mmune deficiencies suffering from cancer**, or **AIDS** and **pregnant women** must not be given live vaccines. Examples of live weakened vaccines are the vaccine for measles, **rubella** (MMR), **mumps**, **oral polio** (OPV) and the '**Bacillus of Calmette and Guerin**' (BCG) vaccines for tuberculosis.
2. ***Inactivated*** or ***killed vaccines*** contain **dead, but intact,** organisms so the immune system can still recognize them. Most vaccines are inactivated. These inactivated vaccines are produced by growing bacterium or virus in culture by heat or chemicals. These vaccines cannot cause disease, but **allow the body to develop immunity**. While these vaccines are safe, they do not produce protection as good as that from live vaccines. Examples of such vaccines are **typhoid** (TAB) vaccine for typhoid, ***Salk's vaccine*** for poliomyelitis, and vaccine for rabies, etc.
3. ***Vaccines produced by toxoids*** are the poisonous substances secreted by plants or animals or bacteria as toxins. In diseases like diphtheria and tetanus, bacteria produce toxins that are harmful to an organism. These toxins are made harmless by the addition of dilute formalin. Toxoid vaccine is made from a toxin that has been made harmless but that excites an immune response against the toxin. These vaccines are safe because they cannot cause diseases.

Immunization is the process, whereby a person is **made immune or resistant to an infectious disease**, typically by the administration of a vaccine. Vaccines stimulate the body's own immune system to protect the person against infection or disease. Passive immunization refers to the injection of **prepared antibodies** into a person who has either already been infected or is at risk of acquiring an infection. In this

case, the infected person's immune system is not actively protecting the body, hence he has to be given **prepared antibodies**. It is thus named passive immunization. Examples of passive immunization include rabies and hepatitis A.

Table 5.3 Immunization schedule for Bhutan

Antigen	Age of administration	Antigen	Age of administration
Bacillus of Calmette and Guerin (BCG)	*At birth*	*Measles and Rubella (MR)*	*9, 24 months*
Diphtheria and tetanus (DT)	*2 years*	*Oral Polio Vaccine (OPV)*	*At birth; 6,10,14 weeks*
Diphtheria Tetanus Pertussis Hepatitis B (DTwPHep)	*At birth*	*Tetanus Toxoid (TT)*	*1st contact pregnancy; + 1 month*
Human papilloma virus (HPV)	*12 years; +2, +6 months; 12-18 (females)*	*Vitamin A*	*6,12,18,24,30,36 months*

Source: UNICEF, WHO, 2013

c. Chemical substances used in medicines

Some of the chemical substances used in the field of medicine are discussed below:

1. Antiseptics are the chemical substances, which when applied to the body, kill **germs**. These substances are in **mild condition** that they cause no harm to the skin or the body. They are applied on *wounds, cuts, ulcer and infected skin surface*. Examples are **iodine**, **dettol**, **iodoform**, **boric acid**, **antiseptic ointments**, etc.
2. Disinfectants are **strong chemicals** that are applied on spots and places where germs thrive and multiply. These are applied in *toilet, floor, surgical instruments*, etc. Commonly, used disinfectants are **phenol**, **chlorine**, **sulphur dioxide**, **lysol**, **40% formalin**, **lime**, **Bordeaux mixture**, etc. All disinfectants are strong and **should not come in contact with the skin or the body**. Strong heating and boiling also destroy germs and may be called **physical disinfectants**. Many disinfectants are used alone or in combinations in the health-care. These include **alcohols**, **chlorine**, **formaldehyde**, **hydrogen peroxide**, etc.
3. Antibiotics are chemicals **produced by bacteria**, **fungi and molds** that inhibit or slow down the growth of other microorganisms. Examples include ***penicillin*** and ***chloramphenicol***.
4. Antacids are the substances wh ich neutralize excess acid and pH to the optimum level in stomach. Examples are **sodium bicarbonate**, **magnesium hydroxide**, **omeprazole**, etc.
5. Antipyretics are compounds, which are used for the purpose of **reducing fever** by lowering the body temperature to normal. The most common antipyretics are **aspirin**, **paracetamol**, **antipyrine**, etc.
6. Analgesics are the drugs used for **relieving pain** without the loss of consciousness. They are also called pain killers or pain relievers. Examples include **aspirin**, **novalgin**, **ibuprofen**, etc.

Lesson Summary

- Three majors groups of micro-organisms are bacteria, virus and fungi.
- Bacteria are prokaryotes and are made up of simple cells.
- The four types of bacteria based on their shapes are coccus, bacillus, spirillum and vibrium.
- Saprobes, parasites, photoautotrophs and chemoautotrophs are the four modes of nutrition in bacteria.
- Asexual reproduction in bacteria is through binary fission and sexual reproduction is through conjugation.
- Bacteria are important in agriculture, industry and genetic engineering.
- Viruses are acellular because they do not have cellular components.
- Virus reproduces only inside the host cell and cause several diseases in humans, animals and plants.
- Viruses' possess both the characteristics of living and non-living.
- Some fungi are used as food by animals.
- Fungi mostly reproduce asexually by spore formation.
- Most fungi are saprophytic as they draw nutrition from dead and decayed matter.
- Pathogenic fungi cause disease mostly in plants.
- Bacteria, virus and fungi all cause diseases in man, animals and plants.
- Immunity is of two types: active immunity and passive immunity.
- Based on the source, vaccines are classified as live attenuated vaccine, inactivated vaccine and toxoids.
- Chemical substances used in the field of medicine include antiseptics, disinfectants, antibiotics, analgesics, antipyretics and antacids.

Weblink

- http://www.mayoclinic.org/diseases-conditions
- http://www.johnkyrk.com/virus.html
- http://www.biology4kids.com/files/micro_main.html
- http://www.unfpa.org/sexual-reproductive-health

Review Questions

A. Each question in this part is followed by four possible choices. Choose the correct or the most suitable response.

1. The spherical structure in the figure on the right is

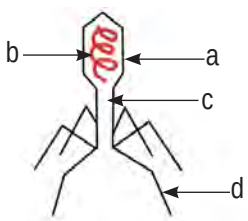
   A. a conidiophores.
   C. sporangium.
   B. basidium.
   D. ascus.

2. Over four thousand different antibiotics have been isolated, but only about 50 have achieved usefulness. The use of antibiotics, both in humans and in farm animals, has brought many bacterial diseases under control. The following are all uses of antibiotics except
   A. used in medicines to fight a wide range of infections. Some are used in controlling plant pathogens.
   B. certain antibiotics are used as food preservatives, especially in fish and meat products.
   C. some antibiotics are added in small quantities to feeds given to livestock and poultry to prevent internal infections.
   D. use in genetic engineering in the culture of plantlets.

3. Food is kept in the refrigerator to prevent food from
   A. viral infection.
   C. bacterial infection.
   B. fungal infection.
   D. both bacterial and fungal infections.

4. If a cell was the size of your classroom, then an average virus would be the size of a tennis ball.Viruses range in size from 20 nanometers (nm) – 400 nanometers (nm). Then the size of the smallest virus in inches can be about
   A. 20 nm.
   C. 40 nm.
   B. 400 nm.
   D. 210 nm.

5. The diagram below is the structure of a virus infected bacteria. The parts labelled a, b and c are



   A. a-head, b-DNA and c-core.
   B. a-head, b-RNA and c-core.
   C. a-DNA, b- head and c-sheath.
   D. a-DNA, b-head and c-core.

6. In an ideal condition, bacteria multiply every 20 minutes. In 1 hour, how many numbers of bacteria will be produced from a single bacterium cell?

A. 4
C. 10
B. 8
D. 12

7. A student has studied the basic structure of a fungus cell and an animal cell. Which of the following would be found in both of these cells?
   A. Cilia.
   C. Chloroplasts.
   B. Cell wall.
   D. Mitochondria.

8. Antiseptics and disinfectants both kill pathogens but only antiseptics are safe to use on the skin, if
   A. concentrated.
   C. diluted.
   B. mixed with disinfectants.
   D. mixed with antibiotics.

9. A contagious disease is one which is spread by
   A. eating contaminated food.
   C. touching an infected person.
   B. drinking contaminated water.
   D. droplets from an infected person.

10. The symptoms of food poisoning are nausea, vomiting, diarrhoea and abdominal pain. Which one of the following is least likely to cause food poisoning?
   A. Cooking pork and eating after 12 hours.
   B. Eating cooked pork straight from the refrigerator after several days.
   C. Preparing fresh pork and immediately eating.
   D. Using uncooked pork and immediately eating.

B. Copy and complete the table below.

Symptoms	Disease	Pathogens	Vaccine
Red itchy patches on the skin, usually ring-shaped on face, neck, legs and other body parts.	……	……	fungicide and antibiotics
A person sneezes and coughs because his upper respiratory tract is affected.	……	……	……
A person vomits, feels thirsty and starts to lose coordination of muscle after eating leftover food.	……	……	antitoxins
A patient has a lung infection that results in coughing out sputum with blood. A symptom of chest pain is experienced.	……	……	……
A child of five years has a swelling of the salivary gland due to a disease.	……	……	MMR vaccine

C. Name the following.

1. Through vaccination, a person is made resistant to an infectious disease by artificially introducing germ or germ substance into the body. The germ or germ substance administered into the body.
2. Part of virus that make it distinct from viroids.
3. Hypha of a fungus contains cytoplasm and nuclei enclosed by a rigid cell wall. The complex polysaccharide that makes up the cell wall.
4. The process by which, *Rhizopus sp.*, a fungus that grows on bread has the ability to chemically digests its food outside its body.
5. A researcher is studying a particular disease-causing agent. The agent has a protein coat and lacks a nucleus. It contains no other organelles, and can reproduce only when it is inside a living cell.

D. Write TRUE or FALSE against the following statements.

1. One student in a class becomes sick with fever and cough. Two days later, three other students in the same class become sick with the same symptoms. This illness in children is most likely caused by a pathogen.
2. Fungi, such as mushrooms and moulds, get their nutrition primarily by parasitic relationships with plants.
3. If a person has minor cut on the skin surface, tincture of iodine should be applied instead of bordeaux mixture.
4. Nurses rinsed their hands with sanitizer before they had contact with their patients, because bacterial substance in their hands may cause disease.
5. Vaccine is usually given at the time when disease-causing germs enter the body.

E. Fill in the blanks by selecting the appropriate word(s) from the list below.

In many cases, when you suffer from an infectious disease, your blood produces …….. against the infective organism. These …..…….. remain in the blood or can be rapidly made so that you are …….. to further attack of the disease. You can acquire ……..…..... by receiving injections of …..…….. form of the pathogen or its inactivated ……....….. The injected substance is called ……...…..

[immune, immunity, pathogens, disease, vaccine, antibodies, toxin, harmless, antigens]

F. Differentiate between the following pairs of words.

1. Infectious disease and non-infectious disease
2. Pathogenic and non-pathogenic
3. Attenuated vaccine and inactivated vaccine

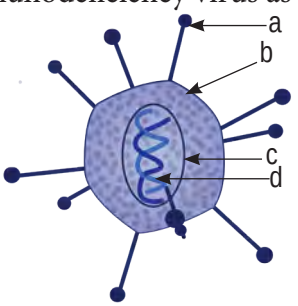
4. Antibody and antibiotics
5. Plasmid and capsid

G. Extend the following abbreviations.

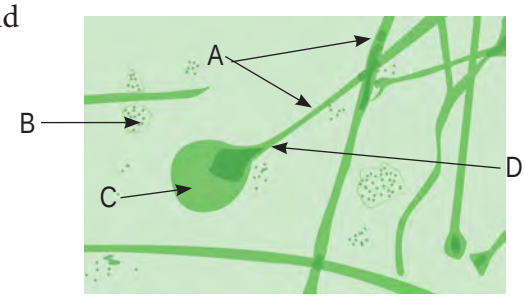
1. DPT
2. MMR
3. OPV
4. BCG
4. TAB

H. Answer the following questions.

1. Why are canned and smoked foods not always safe for consumption?
2. Classify the following diseases under the headings 'infectious' and 'non-infectious'.
   [anaemia, arthritis, appendicitis, AIDS, coronary heart disease, lung cancer, whooping cough, rickets, food poisoning, tuberculosis, measles, diabetes, syphilis, influenza, haemophilia]
3. A student made a structural model of a human immunodeficiency virus as part of her class project work as shown below. Observe and answer the questions that follow.

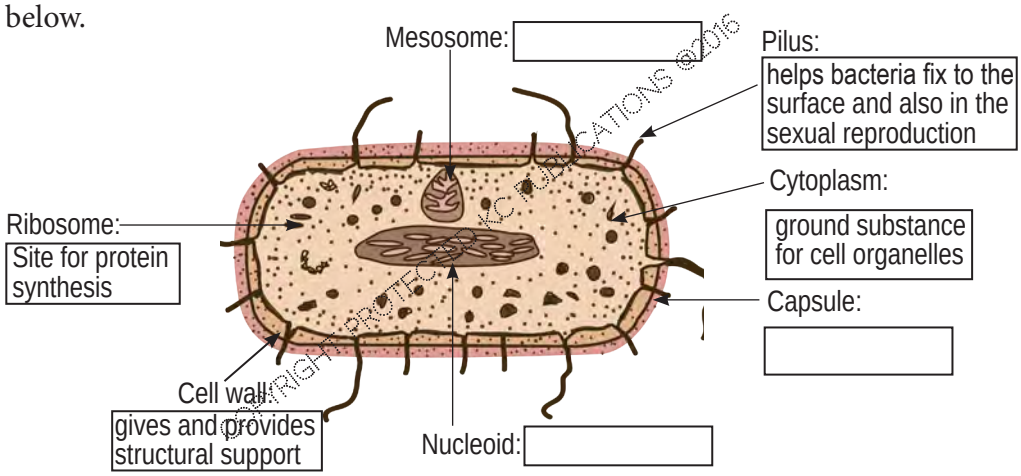


   i. Label the parts a, b, c and d.
   ii. Write one function of parts a and d.
   iii. Give a brief account of virus with respect to its nature of genetic materials.
4. Give two examples of diseases normally spread by droplets. How can it be prevented?
5. The figure below is the bright field light micrograph showing the release of spores from a sporangium at the end of a hypha called a sporangiophore. This organism is a *Mucor sp*. fungus, a mould often found indoors.



   i. Label the parts A, B, C and D.
   ii. What is the significance of B?
   iii. Network of A is called.....

6. Copy and complete the diagram with the missing word/s and function in the box below.



7. The following events explain an outbreak of food poisoning in your school canteen. Arrange the events in appropriate order.
   i. Unwashed hands prepare food.
   ii. Outbreak of food poisoning.
   iii. Pathogenic bacteria in faeces.
   iv. Food ingested by healthy people.

8. Read the information given below and with your knowledge of biology, answer the questions that follow.

   Immunization protects the human body from disease. The success of vaccinations can be seen in the fact that smallpox has been eliminated worldwide from the list of common infectious diseases. The only remaining smallpox viruses on earth are thought to be those kept in certain research laboratories. Many developed countries in the world are now committed to the goal of immunizing all children against common childhood diseases. However, a few parents are choosing not to immunize their children against childhood diseases such as diphtheria, whooping cough, and polio. For example, the mother of a newborn baby is concerned about having her child receive the DPT (diphtheria, whooping cough, and tetanus) vaccine. Since these diseases are caused by bacteria, she believes antibiotic therapy is a safe alternative to vaccination.

   i. What is in a vaccine?
   ii. How does a vaccine promote immunity?
   iii. Give one advantage of the use of vaccinations to fight bacterial diseases.
   iv. Give one disadvantage of the use of antibiotics to fight bacterial diseases.

v. Discuss the use of antibiotics and vaccines in the treatment and prevention of bacterial diseases.

9. Complete the table below from your knowledge and understanding about viral diseases in human.

Common viral diseases in human

Disease	Virus/Transmission	Cause	Type of vaccine
Common cold	Rhinovirus, spread by touch (e.g. Hand to mouth)	Attacks upper respiratory tract, causing sneezing and coughing	Inactivated virus vaccine-ineffective
Influenza	.....	.....	Flu shot
Mumps	.....	Swelling of salivary gland, occurs mainly in children	.....
Measles	A paramyxovirus, spread by droplet infection	.....	.....
Rubella	.....	.....	Attenuated virus, MMR vaccine
Poliomyelitis (polio)	Poliovirus, spread by droplet infection or human faeces	Attach muscle fibres, leading to paralysis and muscle wasting	.....
Hepatitis B	.....	.....	.....

6 VARIATION, INHERITANCE AND EVOLUTION

All individuals of same species differ from each other due to variations. For instance, we look different from each other due to variations. In the natural system, the organisms whose variations best fit them to the environment are the ones who are most likely to survive, reproduce, and pass those desirable variations on to the next generation. Thus, over many generations, organisms have evolved through variations that involve small changes, which are passed to the next generation. Organisms inherit variations from their parents. The mechanism of inheritance of variations in an organism is based on Mendel's principles of heredity.

All animals and plants have evolved slowly over time. Therefore, all species are in a continuous state of change. These processes of nature result in the formation of a new species.

6.1 Variation

Learning objectives

On completion of this topic, you will be able to:

- explain that mutation is a source of genetic variation.
- list down the causes of genetic variations.
- explain that sexual reproduction is a source of genetic variation, while asexual reproduction produces clones.

Every individual differs from each other in characteristics. Any difference between individual organisms or groups of organism of any species is called variation. Variation may be shown in **physical appearance**, **metabolism**, **mode of reproduction**, **behaviour** and other measurable characters. Some variations are the result of **genes** only, but most variations are caused by a **combination of genes and the environment**. Variations occur within the same species or between the species.

a. Types of genetic variation

There are of *two* types of genetic variation: **continuous variation** and **discontinuous variation**.

i. Continuous variation

Continuous variation refers to a variation in characteristics within a species that do not fall into particular categories. In such variation, **range of differences in characteristics can be observed** in a population. For example, human height ranges from that of the shortest person in the world to that of the tallest person. Any height is possible between the shortest and the tallest height range. Other examples of such characteristics are weight, hair colour, heart rate, rate of photosynthesis, width of a leaf, foot length, etc. This type of variation is **controlled by more than one set of genes**. It is the result of the combined effect of a number of genes, called polygenes.

Continuous variations in a large number of different individuals can be studied by plotting a **frequency histogram** (Figure 6.1). When described using a graph, it shows a **normal distribution**.

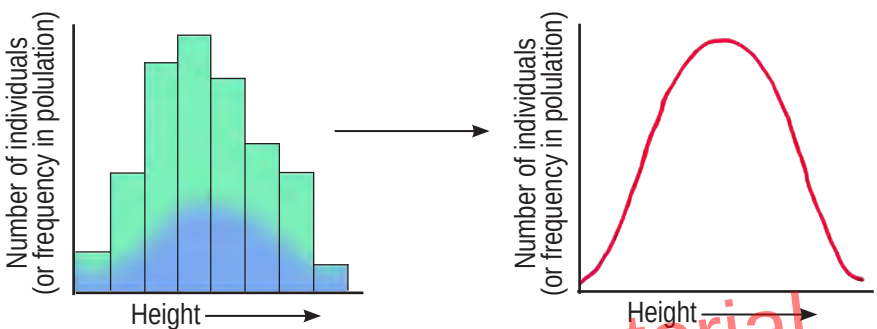


Figure 6.1: Height variation graph

The shapes of the above graphs have typical features of continuous variation. This type of variations is very common in humans and other animals.

ii. Discontinuous variation

Discontinuous variation refers to a variation in characteristics within a species that fall into particular categories. In such variation, clearly defined **differences in a characteristic can be observed in a population**. For example, there are only four types of **blood group** (**A**, **B**, **AB** or **O**) in humans and there are no other possibilities. Some other examples of discontinuous variation are gender (*male or female*), eye colour (*blue, brown, green*), ear lobes *(hanged, attached*), seed colour, colour of flowers, etc. This type of variation is usually controlled by **one set of genes**.

When graphed it shows distinct groups such as **A**, **B**, **AB** and **O**.

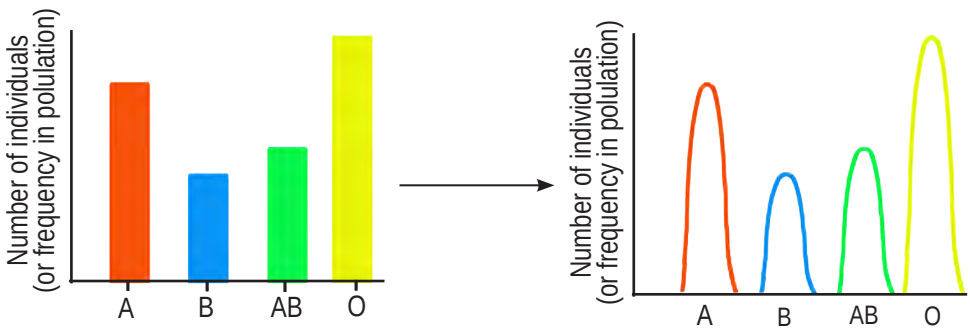


Figure 6.2: Blood groups variation graph

Discontinuous characteristics are **rare** in humans and other animals, but are more common in **plants**.

Sometimes, you can see the effect of both variations. For example, the histogram of height of humans can be bimodal (i.e. *it has two peaks*) as shown in the Figure 6.3. This is because the **two sexes** (*a discontinuous variation*) each have their own normal distribution of height (*a continuous variation*).

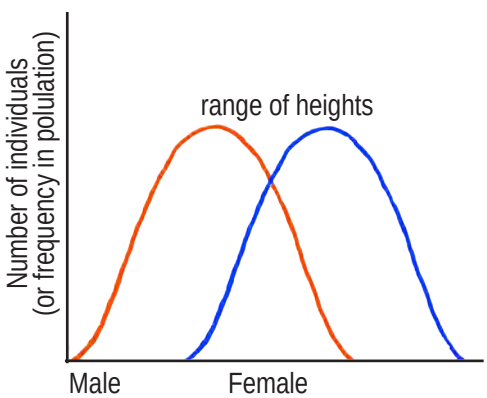


Figure 6.3: Bimodal graph

b. Causes of genetic variations

Some variations within a species are **inherited**, and some **variations are due to the environment**. Variation in a characteristic as a result of genetic inheritance from the parents is called genetic variation. Characteristics of animal and plant species can also be affected by factors such as climate, diet, culture, lifestyle, etc. Such variations caused by the surroundings are called environmental variation.

Genetic variation is caused by different factors. Some of the common causes of genetic variations include the following:

1. Mutation

A mutation is a **change in the amount, arrangement and structure** of the DNA of an organism resulting in a new gene. This can result in a new characteristic that may be passed onto the next generation. It is the ultimate source of genetic variation. Mutations happen naturally at **random**, or in **response** to natural background radiation. The probability of occurrence of mutation is increased if a person is exposed to: **radiations, X-rays**, **ultra violet radiation** from the sun, and and **toxic chemicals** (*mutagens*).

The substances that cause mutation are called mutagens. **The greater the amount of mutagens, the greater the chance of mutation in genes**. Most mutations are not noticed, either because the mutant cell is just one amongst millions of ordinary cells, or because it is destroyed by the white blood cells. Mutations are only passed on if they are in a **gamete** (*sex cell*). Some mutations may be beneficial, but many are harmful and increase the risk of diseases such as cancer.

i. Harmful mutations: In reproductive cells, mutations can cause **abnormalities** or death in young ones. Mutations in body cells can cause cells to divide uncontrollably and cause cancer.

ii. Neutral mutations: These do not affect the survival of an organism.

iii. Beneficial mutations: These mutations give an organism an advantage that allows it to survive and breed, e.g. *bacteria that are resistant to antibiotics are able to survive and create an antibiotic resistant strain of bacteria*. This is an example of **natural selection** and **evolution**.

Mutations can be classified into various types according to the nature, place of occurrence, source and cause. ***Some of the various types of mutations are***:

1. Somatic mutations occur in cells of the **body** (*soma*), other than the germ cells. Mutations of this kind are not **inherited** to the next generation, but may be significant in the life of an organism. It **disappears** with the death of the animal.

2. Germ cell mutations occur in the **reproductive**, **germinal tissue** such as *ovaries*, *testis*, *anthers* or *embryo sac*, and result in changes to the genome of the gamete. **Germ cell mutations** can be passed on to the offspring.

3. Gene mutation is caused by **change in the structure** of genes. It is also called point mutation or micromutation as it affects only particular **locus** in the chromosomes.

4. Chromosomal mutation is caused by change in **number and arrangement** of genes and in the number of chromosomes. This is also called macromutation.

2. Sexual reproduction

Sexual reproduction involves two parents both having different genetic compositions. It is the most important cause of genetic variation as it **mixes up the genetic material** of two parents. During fertilization, male gamete fuses with the female gamete. This leads to offspring with a combination of traits from both parents, resulting to variation between the parents and the offspring. There are *three* main causes of genetic variation in sexual reproduction.

i. Independent assortment in meiosis

Independent assortment is the **random assortment** of chromosomes during the production of gametes, which results in genetically unique individual gametes. Since chromosome can line up in any orientation on the equator, the maternal and paternal versions of the different chromosomes can be **mixed up** in the final gametes (Figure 6.4).

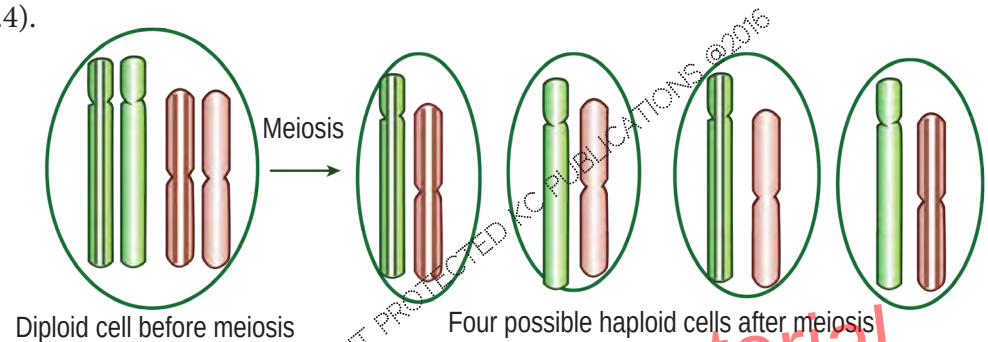


Figure 6.4: Independent assortments during meiosis

ii. Crossing over in meiosis

This happens in **meiosis**, when the **bivalents** are first formed. The homologous chromosomes line up and **parts of one chromosome are crossed over with the corresponding parts** of the other chromosome. This result in mixing of genetic material in the gametes produced (Figure 6.5).

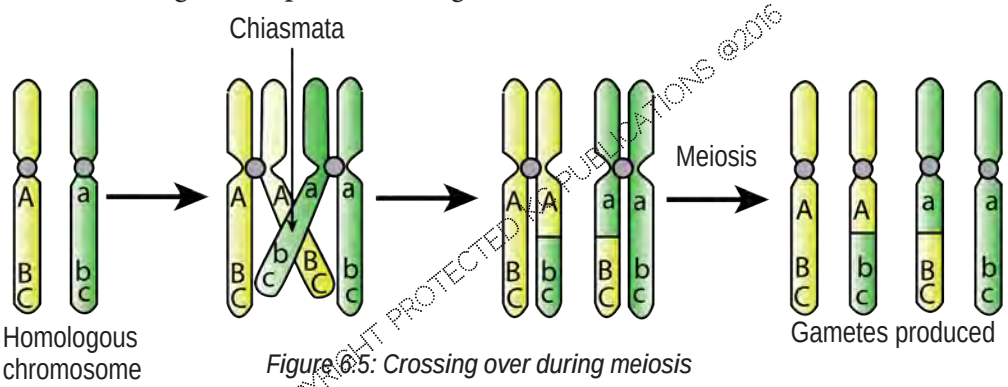


Figure 6.5: Crossing over during meiosis

The points at which the chromosomes actually cross over are called chiasmata (*singular*: **chiasma**).

iii. Random fertilisation

This takes place, when male and female gametes fuse to form a **zygote**. Each gamete has a unique combination of genes, and **any of the numerous male gametes can fertilise any of the female gametes**. So, every zygote is unique.

Asexual reproduction is a form of reproduction by which a single parent produces offspring and the genes inherited are from that parent only. All offspring produced are **genetically identical** to each other and to the parent. There is no variation between the offspring. Genetically, identical organisms are called clones.

The offspring are usually produced by mitosis. The common modes of asexual reproduction are **binary fission**, **budding**, **fragmentation** and **vegetative propagation**. This causes no or very little genetic variation within a population.

Table 6.1 Difference between asexual and sexual reproduction

Asexual reproduction	Sexual reproduction
No variation between offspring.	*Variation* between offspring.
Offspring *genetically identical* (clones).	Offspring *genetically different*.
Offspring develop from *one parent*.	Offspring develop from *two parents*.

3. Recombination

Recombination is a process by which pieces of DNA are broken and joined to produce **new combinations of genes**. The offspring with combinations of genes have traits that differ from those found in both the parents. It is done through **genetic engineering**. The outcome of this technique is that the resulting offspring will inherit genes from its donor, thereby acquiring a genetic diversity. It also occurs in **prokaryotic cells**, and it has been especially well characterized in *E.coli*. Bacteria cells engage in a type of sexual reproduction called **conjugation**, during which genetic material is transferred from one bacterium to another. As in **eukaryotes**, recombination also plays important roles in the DNA repair and replication in prokaryotic organisms.

4. Hybridization

Hybridization is the process of interbreeding between individuals of different species or same species. This technique mixes up genes of characters of two parents in the new offspring. Offspring produced by hybridization is called hybrid. Generally, a hybrid will have **superior vigour** than its parents. For example a mule, a hybrid of female horse and a male donkey is stronger than both the parents. Hybridization is frequently employed in **agriculture**, to make stronger, healthier plants with desirable characteristics. In plants, it is done by **artificial cross pollination** or **somatic cell hybridization**. Somatic hybridization is the production of hybrid plants through fusion of two different plant **protoplasts** (*cells without cell walls*). This type of technique is used in **plant tissue culture**.

Figure 6.6: An animal hybrid

Figure 6.7: A plant hybrid

6.2 Inheritance

Learning objectives

On completion of this topic, you will be able to:

- describe the mechanism of monohybrid inheritance where there are dominant and recessive alleles.
- explain the mechanisms by which some diseases are inherited.

For many years, humans have understood that characteristics such as eye colour or flower colour are passed from one generation to the next generation. The passing of characteristics from parent to offspring is called heredity. **Inheritance** in genetics means an offspring receiving certain traits or characteristics from ones' mother or father. Our parents' genes will determine how we look. In this topic, you will study about how we have inherited genes from our parents.

a. Chromosomes-the carriers of heredity

Chromosomes are only visible when a cell nucleus is about to divide. During this stage photographs of chromosome can be taken using a high powered light microscope. These photographs are used for **artificially arranging** the chromosome according to their size and shape on a chart called karyotype. One such human karyotype model is shown in Figure 6.8.

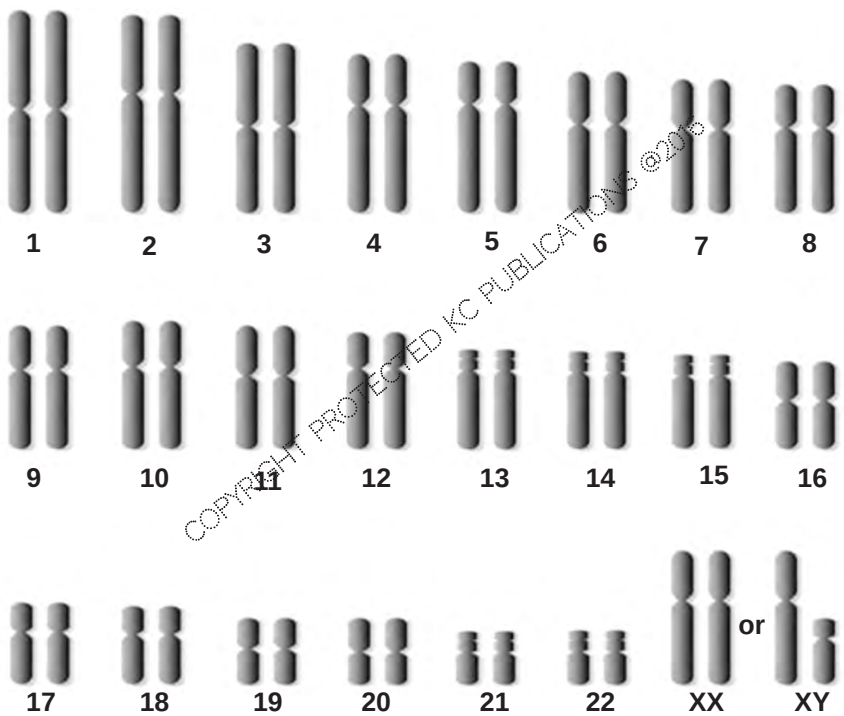


Figure 6.8: Human karyotype model

In Figure 6.8, you will notice that there are **23 pairs** of chromosomes in human. Numbered 1-22 chromosome pairs have **identical chromosomes** and are called as autosomes. But the **23rd pair** is different and it is called sex chromosomes which are represented as XX for female and XY for male. Y chromosome of male is much shorter and smaller than the X chromosome.

b. Genes and their alleles

There are **specific genes** for specific character in our body. Normally, every gene has **two alternative forms** of genes for a character, producing different effects. This **alternative gene** controlling a character is called allele. For example, *in the character of dimple*, there are two possibilities-**either dimple is present** or **absent** in a person. Thus there are two alleles; **one allele for the presence of dimple and another for absence of dimple**. Out of the two alleles, one allele expresses its character in the offspring. This allele is called the dominant allele and it is represented with capital letters. The character expressed is called dominant character. The dominant allele masks the expression of the other allele called the recessive allele. Recessive allele expresses only in the absence of dominant allele. It is represented with **lowercase letters**.

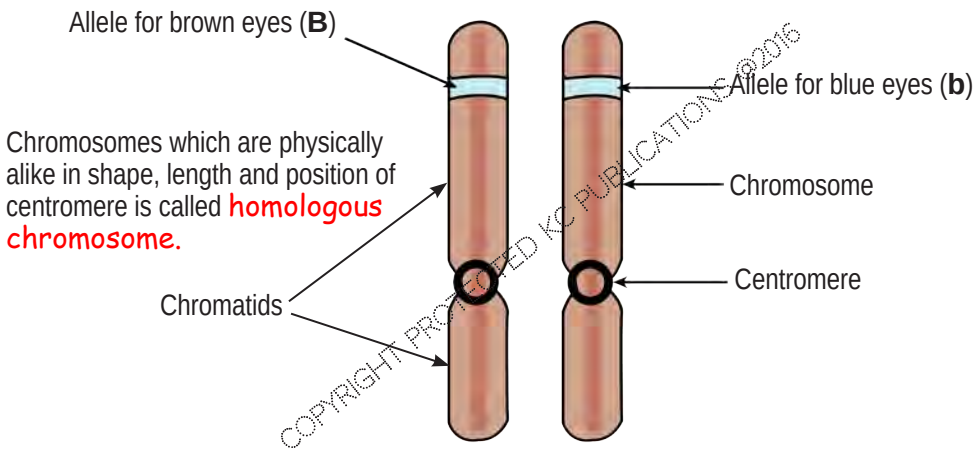


Figure 6.9: Homologous chromosome showing alleles

For example, the **dominant allele** for the trait of brown eye colour in human is represented by **'B'**. The recessive trait of blue eye colour is represented by **'b'**. A **true breeding**, brown eye colour would have **identical alleles 'BB'** in all its somatic cells. Likewise, true breeding plants for blue colour would have **identical alleles 'bb'** in all of its somatic cells. During gamete formation, each *gamete receives one copy of an allele*.

Activity 6.1

Knowing inheritance of common traits

Procedure

1. Work in groups.
2. Copy and tabulate the results in Table 6.1. Use the data to answer the questions that follow.

Table 6.1

Traits	Dominant	No. of students	Recessive	No. of students	Total no. of students
Ear lobe	Hang freely		Attached		
Tongue	Ability to roll		Inability to roll		
Dimple	Presence		Absence		
Thumb	Curved		Straight		
Eye colour	Brown		Blue		
Hand	Right-handedness		Left-handedness		

Questions

i. Workout the percentage occurrence of each character within the class.
ii. Discuss the concept of dominance and recessive of the above characters.
iii. Derive conclusions based on your observations.
iv. Relate your findings to parents' genotype and characteristics.

Activity 6.2

The fundamentals of genetic cross

Study the genetic cross in the Figure 6.10 and answer the right extended box.

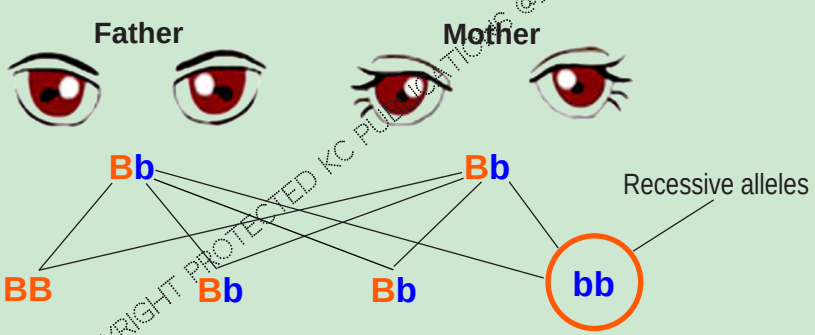


Figure 6.10: Genetic cross

From Figure 6.10, some possibilities of eye colour in human.

A person with *two brown alleles* (BB) will have *brown eyes*.

A person with *two blue alleles* (**bb**) will have *blue eyes*.

A person with one brown allele (B) for brown eyes and one blue allele (**b**) for blue eyes will have alleles B**b**. Alleles can be dominant or recessive. Sometimes, a child can have blue eyes even though their parents have brown eyes.

- What will be the colour of eyes in the offspring having alleles B**b**. Why?

When fertilization occurs between gametes of these parents (B**b**), the offspring receives pairs of one allele from each parent.

The three conditions can be deduced from the pair of genes in the Figure 6.10.

BB (both dominant)

Bb (B-dominant, **b**-recessive)

bb (both recessive)

One can see two types of genetic combinations for the brown eyes as (BB) and (B**b**). For blue eyes, there is only one type of genetic combinations as (**bb**). The type of genes present is called **genotype** and the expressed character is called **phenotype**. Therefore, in the above example, there are three types of genotype as 'BB', 'B**b**' and '**bb**' and two shown characters (*phenotype*) as brown eyes (BB, B**b**) and blue eyes (**bb**).

- Derive the genotypic ratio.
- Derive the phenotypic ratio.

An individual who carries two copies of the same allele is homozygous (*homo:* **similar**; *zygos:* **pair**). For example, a blue eye (**bb**) is homozygous recessive. An individual, who carries two different alleles for a certain gene is heterozygous (*hetero:* **different**; *zygos:* **pair**). A brown eye (B**b**) has two different alleles.

- Write an alleles for homozygous dominant.
- Write an alleles for heterozygous dominant.

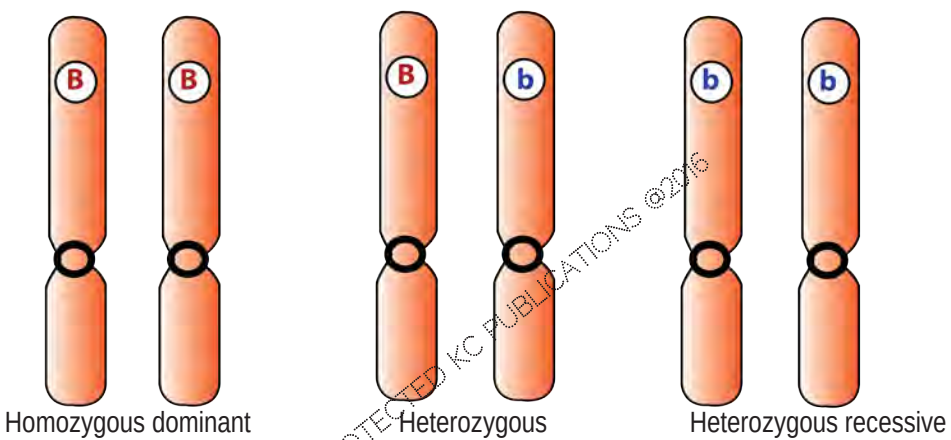


Figure 6.11 Homozygous and heterozygous conditions

Sometimes the two alleles of a character may be **equally expressed**. This is called codominance. For example, blood type **AB** in human is inherited in a codominant pattern. In some cases, none of the two alleles may fully express. These alleles produce an **intermediate phenotype** in the hybrids. This phenomenon is called incomplete dominance. Incomplete dominance is seen in cross-pollination experiments between red and white *snapdragon* plants. The allele that produces the red colour (**R**) is not completely expressed over the recessive allele that produces the white colour (**r**). The resulting offspring are pink. The genotypes are: (**RR**) Red, (**rr**) White, and (**Rr**) Pink.

Important terms in genetics

1. **Alleles**: The two alternative forms of the same gene. E.g. Bb
2. F_1 is the irst ilial generation.
3. F_2 is the second ilial generation.
4. **Genotype**: It is the set of genes present in cells of an organism, i.e. alleles.
5. **Phenotype**: The observable characteristic which is genetically controlled.
6. A **dominant allele** will always show in the phenotype when present. This is represented with a capital letter.
7. A **recessive allele** will be hidden when a dominant allele is present. This is represented with a lower case letter.
8. **Homozygous**: If the two alleles for a gene are identical. E.g. BB or bb
9. **Heterozygous**: If the two alleles for a gene are different. E.g. Bb

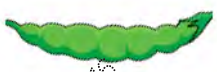
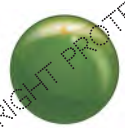
c. Mendelism

Gregor Johann Mendel was born in a peasant family in 1822 in Austria. He studied at Brunn monastery as a monk and later studied science at the University of Vienna. Then he returned back to the monastery and worked as a teacher of physics and natural science. Mendel was fond of gardening from his childhood. When he was working as a teacher, he performed a number of experiments with **pea plants** in the garden of the monastery. His works contain **inheritance of characters in 22 varieties of pea plants** and published his results in 1866. Mendel passed the rest of his life as the Abbot. He died in 1884. However, the works of Mendel remained unnoticed to the world for 33 years. In 1900, the **principles of genetics** worked by Mendel were rediscovered by three scientists and made known to the scientific world. When Mendel's work was recognised and appreciated, he was no more. The contribution of Mendel to the genetics is called Mendelism. Now, Mendel is recognised as the '***Father of Genetics***'.

Figure 6.12: Gregor Mendel

d. Mendel's experiments

Mendel performed a series of experiment by collecting several types of pea plants from a salesman and studied the differences among them. The pea plants contained a number of contrasting characters. Out of these contrasting characters, Mendel selected only *seven characters*. Each of these seven characters had two *varieties* or *alternatives*. The seven characters and their seven contrasting alternatives are given in Figure 6.13.

No.	Characters	Alternatives	
		Dominant	Recessive
1.	**Height**	 Tall (6-7 ft)	 Dwarf (1/2ft)
2.	**Flower position**	 Axial	 Terminal
3.	**Pod shape**	 Inflated	 Constricted
4.	**Pod colour**	 Green	 Yellow
5.	**Seed shape**	 Round	 Wrinkled

No.	Characters	Alternatives	
		Dominant	Recessive
6.	**Seed colour**	 Yellow	 Green
7.	**Flower colour**	 White	 Purple

Figure 6.13: Characters selected by Mendel in pea plants

Mendel's experiments were successful because

i. The flowers of pea plant are *normally self-pollinated*, allowing self crosses to be performed.

ii. Pea plants *show clear cut contrasting characters*.

iii. Many *pure breeding varieties of pea plants were available*.

iv. Pea plant has *short growth period and life cycle*.

v. He *studied the inheritance of only one character* at a time such as flower colour or seed shape. This makes complex problem simple.

vi. He *maintained a proper statistical record of all the results*. It helped Mendel to derive numerical ratios of significance.

e. Genetic cross

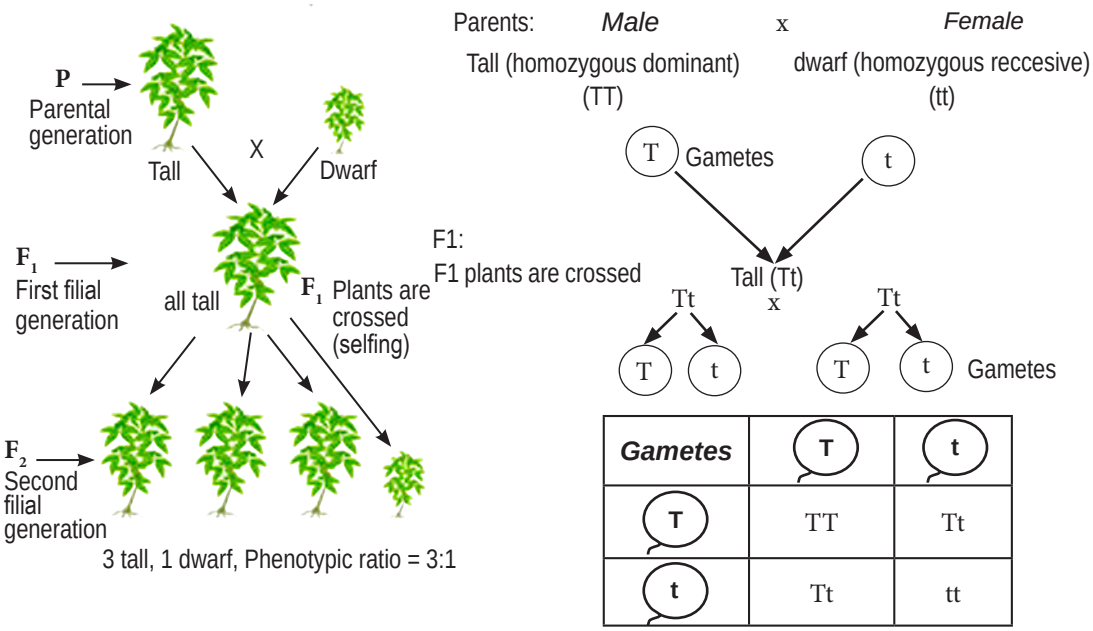
A genetic cross is defined as the **conscious breeding of two different individuals** resulting in offspring that carries a portion of the genetic material of both the parents. The individual parents involved in the cross may be from species that are closely related, or from different varieties. The different genetic crosses occurring between breeding individuals are **monohybrid cross** and **dihybrid cross**.

i. Monohybrid cross

The crossing of plants differing in **only one character** is called monohybrid cross. The resulting hybrids are known as monohybrids. Mendel in his first experiment crossed two parents different in one character only. A plant having a tall stem was crossed with another parent having a dwarf stem. **Tall** and **dwarf** are the two varieties of a single character, height.

He took pure breeding tall pea plants and crossed them with pure breeding dwarfs (tall (TT) x dwarf (tt). A pure plant is one that breeds a particular character for a

number of generations. All the plants in the **first filial,** the F_1 **generation** were tall. The selfing of these F_1 **generation** plants resulted in a F_2 **generation**, which were found to be of two types. They were tall and dwarf. **75%** of the plants were tall and **25%** were dwarf. Thus, the tall plants and the dwarf plants occurred in the ratio 3:1 (*phenotypic ratio)*. A details of the experiment looked like Figure 6.14.



Punnet square for monohybrid F_2
Phenotypic ratio: **3:1** *(three tall and one dwarf)*
Genotypic ratio: **1:2:1** *(one TT (homozygous dominant), two Tt (heterozygous), one tt (homozygous recessive)*

Figure 6.14: Mendel's monohybrid experiment

The above monohybrid experiment can be explained in the following cases.

Case I

When two parents with genotypes TT and tt are crossed. Parent TT produces only one type of gamete (T). Similarly, parent tt also produces one type of gamete (t). These two gametes from two different parents fuse to form F_1 generation with genotype Tt. F_1 offspring is tall because dominant gene T mask the expression of recessive gene t. Mendel's law of dominance states that when **two contrasting alleles are present together, only one is able to express itself, while the other remains suppressed**. Recessive allele will express only when in **homozygous condition**.

Case II

When F_1 with genotypes (Tt) is self crossed, each F_1 parent produces two types of gametes that are T and t. During the *gamete formation*, alleles Tt of each parent **segregate or separate** from each other as 'T' and 't'. F_1 gametes fuse at random, and there are four possible combinations. Mendel's law of segregation states that **during the gamete** (*egg or sperm*) **formation, the two alleles responsible for the trait separate or segregate from each other**. **Then, the alleles for a trait recombine at the time of fertilization to form the genotype for the traits of offspring**.

The possible combinations of gametes can be clearly represented by placing the gametes in a Checker board or Punnet square. The four possible combinations are TT, Tt, Tt and tt. First three combinations (TT, Tt, Tt) contain dominant genes and hence, they are tall plants. The fourth combination (tt) contains recessive genes and hence, the plant is dwarf.

Case III

In F_2 **generation**, three-fourth of the plants is tall and one-fourth of the plants are dwarf. The tall and dwarf plants occur in the ratio 3:1. Therefore, the phenotypic ratio is 3:1. But the genotypic ratio is 1:2:1, which means that there are three types of gene combination in their F_2 **generation** (TT, Tt, tt). Out of four offsprings, one is homozygous tall (TT), two are heterozygous tall (Tt) and one is homozygous recessive (tt).

Solved questions

Problem 1:

Gene W is dominant over gene w. What will be the phenotypic ratio in the offspring obtained from the following mating: Ww X ww?

Solution:

Parents: Ww X ww

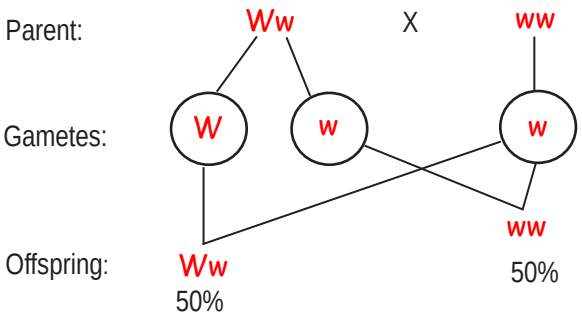
Step 1: **Determination of the type of inheritance**. This is a monohybrid cross and presents a simple case of complete dominance. Gene W is dominant over gene w.

Step 2: **Determination of genotype**. One parent has genotype Ww and the other has ww.

Step 3: **Types of gametes.**

Parent Ww produces two types of gametes (W, w).

Parent ww produces only one type of gamete (w).



Answer: Phenotypic ratio is 1:1.

Problem 2:

In the garden pea, red flower (R) is dominant to white (r). A pure red flower is crossed with white coloured plant. Give the genotypes of the parents and phenotypic ratio of F_2.

Solution:

Step 1: **Determination of the type of inheritance**. This is a monohybrid cross and presents a simple case of complete dominance. Gene R is dominant over gene r.

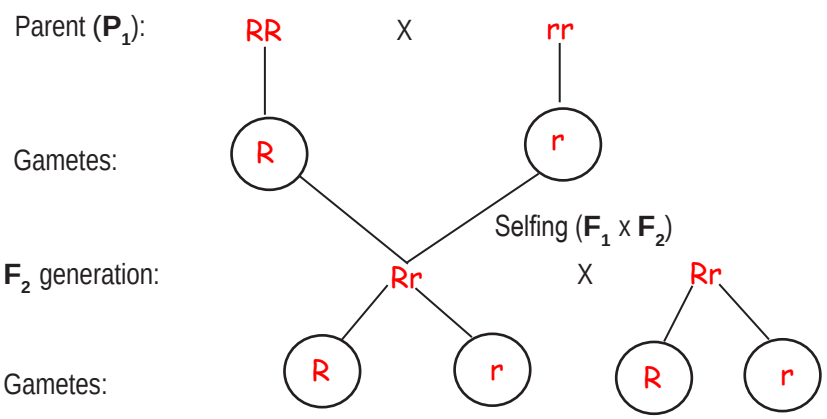
Step 2: **Determination of genotype**. One parent will have genotype RR as it is pure red and the other will have rr as it is homozygous recessive.

Step 3: **Types of gametes**.

Parent RR produces only one type of gamete (R) and similarly, parent rr produces only gamete (r). These two gametes fuse to formed offspring (F_1) with Rr.

Rr produces two types of gametes R and r.

By selfing F_1



Step 4: Draw a Punnet square and fill up the genotypes of all the possible offspring.

Gametes	R	r
R	RR	Rr
r	Rr	rr

Step 5: Determine the phenotypic and genotypic ratio of the offspring.

Answer: Phenotypic ratio of F_2 is 1:1 (Red = RR, Rr and White = rr).

Genotypes of parents are RR and rr.

Genotypic ratio is 1:2:1 (RR, Rr, Rr and rr).

ii. Dihybrid cross

Mendel also studied the inheritance of two different characteristics at a time in pea plants, such as **seed colour** and **shape**. Dihybrid cross is a genetic cross that deals with the cross between two individuals considering two different traits. The offspring of such a cross are called dihybrids. A dihybrid crosses result in a phenotypic ratio of 9:3:3:1 (Figure 6.15).

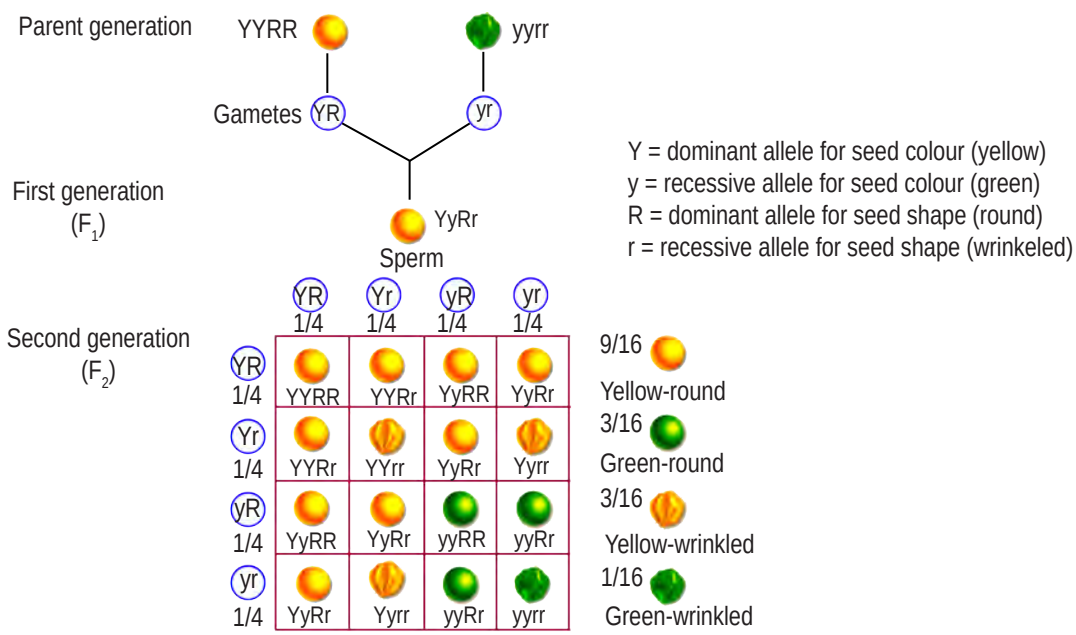


Figure 6.15: Dihybrid experiment

Mendel's law of independent assortment is applicable to **dihybrid cross**. It states that **the inheritance of one trait will not affect the inheritance of another. That is, genes are inherited independently of each other in the offspring**.

f. Sex linked inheritance

Genes are present both on autosomes and sex chromosomes. The genes present on the autosomes control the **somatic characters** of an organism. But the genes present in the sex chromosomes control the **sex characters**. However, certain genes present in sex chromosomes control the somatic characters. Such genes are called sex linked genes. The body characters controlled by sex linked genes are called sex linked characters.

The sex chromosome, Y is **very small** and contains very **few genes**, but the X chromosome is **large** and contains **thousands of genes**. The transmission of sex linked characters from parents to young ones is called sex linked inheritance. Certain disorders due to the heredity such as *colour blindness* and *blood disease haemophilia* are sex linked inheritance.

i. Colour blindness is a hereditary disease and the affected person cannot distinguish red colour and green colour. In colour blindness, the gene for colour blindness is found on the X chromosome. A woman is rarely colour blind because the dominant gene for normal vision is present on one of her X chromosomes. However, a male shows colour blindness because there is no gene to supplement a gene for colour blindness on the X chromosome. As a result, the gene for colour blindness expresses itself in the male.

The mechanism of inheritance of colour blindness is shown in Figure 6.16.

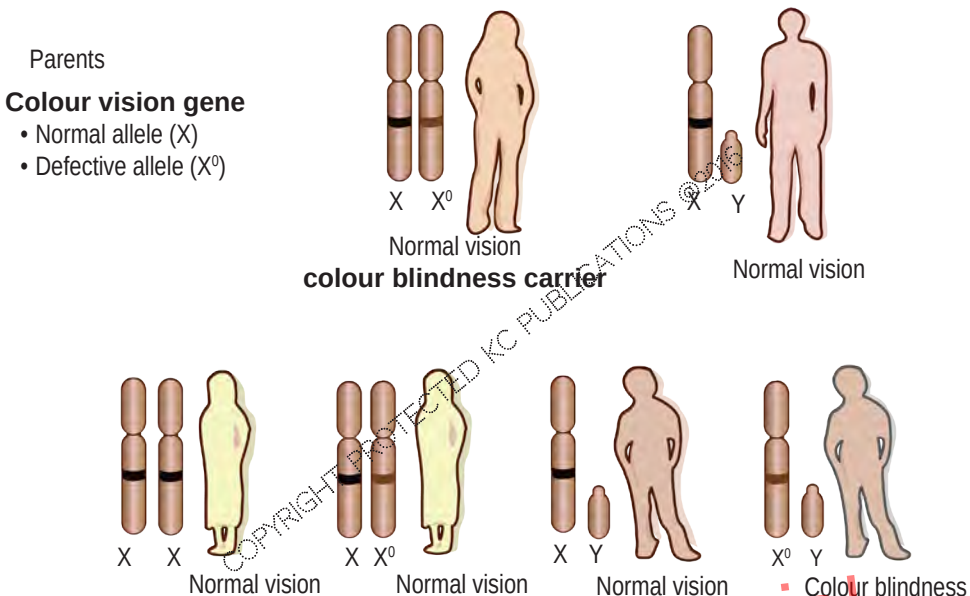


Figure 6.16: Mechanism of inheritance of colour blindness

Most colour blindness is inherited, and effects more men than women. Colour blindness usually involves confusion between red, green and yellow. If you cannot see the writing as indicated in the circle below, you may suffer from colour deficiency.

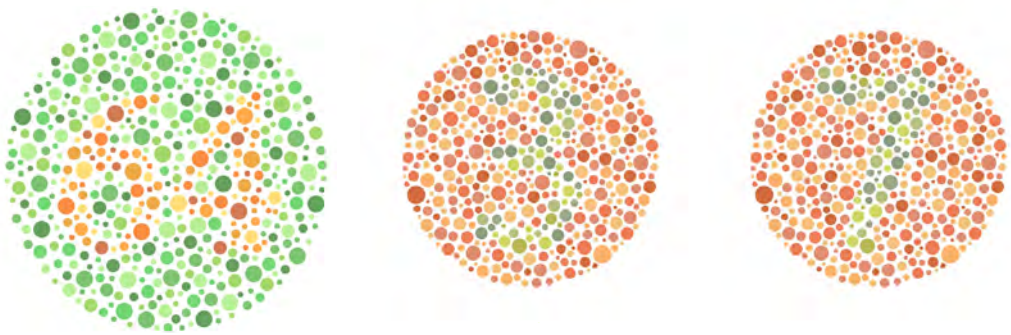


Figure 6.17: Test for colour blindness

ii. Haemophilia is also a **hereditary disease** characterised by delay in blood clotting. In a normal person, the blood clots after about 2 to 8 minutes. But in a haemophilic person, clotting is delayed for 20 minutes to 24 hours. Hence, a person suffering from the disease **bleeds continuously** from the wound. So, haemophilia is also called bleeders disease.

In haemophilia, the blood does not clot normally because an important blood-clotting protein is missing. The gene for haemophilia occurs on the X chromosome. As females have two X chromosomes, one X chromosome usually has the gene for normal blood clotting. Therefore, the female may be a **carrier of haemophilia**, but normally does not express haemophilia. Males have no genes to suppress the gene for haemophilia on X chromosome, so that it expresses in the male. This is why most cases of haemophilia occur in males.

Activity 6.3

'X'- linked inheritance

Procedure

Think of a possibility of a marriage between haemophilia carrier woman (XX^o) and a father without haemophilia (XY). Is there a possibility of the birth of a haemophilic son? What about the possibility of carrier daughter? Copy and work out the offspring in the Punnet square below.

Father without haemophilia (XY)
sperms (X and Y)

Carrier woman (XX^o) Eggs (two types)		

6.3 Deoxyribonucleic Acid (DNA)

Learning objectives

On completion of this topic, you will be able to:

- describe the structure of DNA and its functions.
- state the important characteristics of DNA.

A cell of most of the organisms carry a chemical substance called deoxyribonucleic acid (**DNA**). DNA is present in all cells except plant virus. The DNA of an organism is packed in the nucleus of the cell. **Packaging of DNA** helps conserve space in the cells. Approximately, two metres of the human DNA can fit into a cell that is only a few micrometres wide. Chromosomes contain DNA segments. A section of DNA is called genes. They carry all the information that help a cell grow, survive and reproduce.

a. Structure of DNA

The DNA molecule is a *twisted ladder like* with the **phosphate** and **sugar molecules** running in opposite orientation to one another (Figure 6.18). The structure of the DNA molecule is called a double helix and was proposed in 1953 by James Watson and Francis Crick. A DNA molecule is made up of thousands of building blocks called nucleotides. Each nucleotide is made up of *three* parts:

i. ***a phosphate group***
ii. ***a sugar group***
iii. ***one of four types of nitrogen bases***

The phosphate and sugar groups join together with the nitrogen base to form a nucleotide. Two nucleotides are attached together by hydrogen bonds to form **base pairs**. Thousands of nucleotides together form the *double helix* shaped DNA molecule. The phosphate and the sugar groups form the **backbone**. Thus, a DNA molecule is similar in structure to a ladder in which the sugar and phosphate groups make the '*railings*' and the nitrogen base groups the '*rungs*'.

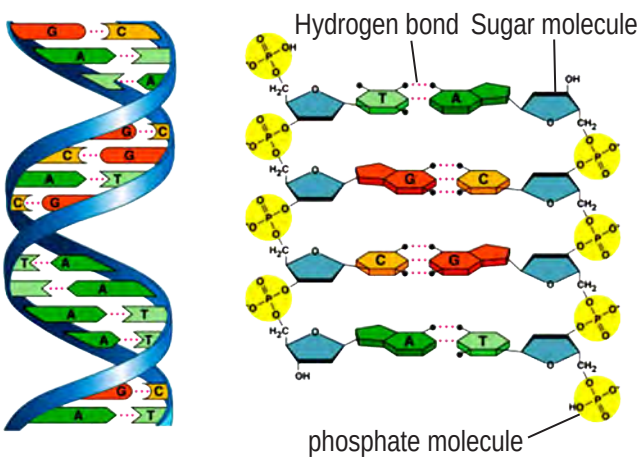


Figure 6.18: Double helix and nucleotides of DNA

There are four nitrogen bases: adenine (A), guanine (G), cytosine (C) and thymine (T). The nitrogen bases in the nucleotides always pair up in the same way as the complementary pair given below.

Adenine (A) ------ **Thymine (T)**

Guanine (G) ------ **Cytosine (C)**

Each pair is held together by **hydrogen bonds**. In humans, all bases are the same but the combination or sequence is unique to every individual.

b. Characteristics of DNA

1. DNA is a big single molecule and referred to as a **macromolecule**.
2. DNA segments contain genetic information called the **genes**.
3. The **backbones of DNA** are made of sugar and phosphate groups.
4. The two strands of DNA are **anti-parallel**, they run in opposite directions.
5. Each sugar molecule is attached to one of the **four nitrogen bases**.
6. Inside the cell, the DNA is arranged in long structures called **chromosomes**.
7. In **eukaryotic organisms**, most DNA is found in the nucleus of the cell and some in mitochondria or chloroplast.
8. In **prokaryotes**, DNA is found in the cytoplasm.

Activity 6.4

Extraction of DNA from onion cells

Work in groups.

Materials required: Onion, mortar and pestle, knife, hot water bath, beaker, filter paper, funnel, test tube, ice water, glass rod, laboratory thermometer, table spoon, salt, shampoo, 95% ethanol, distilled water

Procedure

1. Pour two tablespoons of shampoo into the beaker and put one table spoon of salt. Add some distilled water to make it 100mL.
2. Chop the onion into small pieces and add the solution prepared in step 1. Then grind it with mortar and pestle.
3. Transfer the ground mixture into a small beaker and keep it in water bath maintained at 60^0C for about 10 minutes. Remove the beaker from the water bath and cool in ice water for 5 minutes.
4. Filter the mixture into a test tube.

5. Pour 10 mL of ice-cold ethanol slowly down the wall of the test tube containing onion extract. Leave the test tube for 2 to 3 minutes without disturbing.
6. Observe what rise into the alcohol layer.
7. Gently twirl the glass rod to pick up substance in the solution.

Questions

i. Describe what you observed?
ii. Name the substance that rises in the alcohol layer.
iii. Why is ethanol used for the extraction of DNA?
iv. Instead of onion, what other specimens can you use for the extraction of DNA?

Not for examination purposes: **Additional information on DNA extraction**

Q. *If you do not see DNA clearly, what should you be looking for?*
Ans: Look closely because your DNA may be lingering between the two layers of alcohol and onion paste. Try to rise to the top, alcohol layer using wooden stick.

Q. *What can you do to increase your DNA yield?*
Ans: Allow more time for each step to complete.You will see more DNA precipitate into the alcohol layer over time.

Q. *Why salt is added?*
Ans: Salt helps the DNA to solidify and appear when alcohol is added.

Q. *Why cold water is better than warm water for extracting DNA?*
Ans: Cold water helps keep the DNA intact during the extraction process.

Q. *What is the purpose of using physical force of mortar and pestle?*
Ans: It is to break down the onion cell walls.

Q. *Why does DNA clump together?*
Ans: DNA does not dissolve in alcohol.

Q. *Is RNA also present in your DNA extract?*
Ans: Yes, it is a mix of DNA and RNA.

Q. *What can be done with my DNA extraction?*
Ans: Your DNA extract can be used for gel electrophoresis. A scientist can further purify your sample for experiments.

Q. *Can I use a microscope to see my DNA extract?*
Ans: Unfortunately, a microscope will not allow you to see the double helix structure of DNA molecule. You will only see clump of many DNA molecules.

6.4 Evolution

Learning objectives

- explain the two types of species.
- discuss the mechanisms of speciation.
- name the factors responsible for speciation.

You have already studied the four theories of evolution. The theory of natural selection by **Darwin** supports that evolution takes place slowly. The fossil records also show that a species changed gradually over time. The theory that explains evolution as a gradual process is known as gradualism. Most scientists agree that natural selection is one of the most important factors in **evolutionary changes** in an organism. Evolution resulted in the **formation of new species** and extinction of others as well.

a. Types of species

Humans are one of the species on the earth. A species comprises of several populations. A species is a group of individuals that are **similar in structure and behaviour and are able to interbreed** with one another and produce fertile offspring. Based on the geographical and ecological conditions, species are of two.

i. Allopatric species: When an individual of same species are geographically separated from one another, they are called **allopatric species**. This can happen due to land formation, mountain formation, migration and human activities. For example, many years ago, the Death Valley region of the western United States had a rainy climate which produced an interconnecting system of freshwater, rivers and lakes. Later on due to dry climatic conditions, lakes and rivers connecting system dried up and many fish populations became **geographically isolated**. The new species formed are the result of geographic isolation and therefore it is known as geographic speciation.

ii. Sympatric species: When an individual of related species live in different **ecological conditions**, but in the same region, such species are called *sympatric species*. This type of species arises due to some **biological barrier** for interbreeding. It is very common in plants than in animals. For example, modern bread wheat is the result of wild grasses grown near agricultural fields.

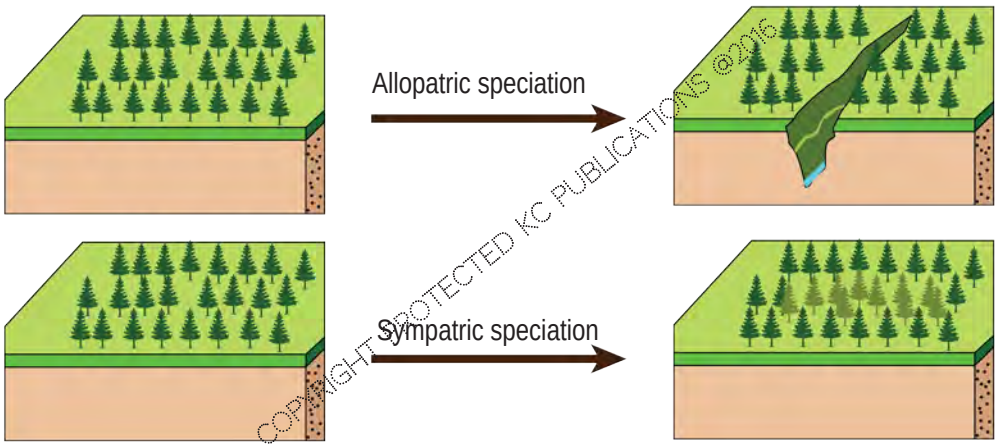


Figure 6.19: Types of species

A group made up of members from the same species in a given geographic area at the same time is called population. The total number of genes present in the population is called the gene pool. Members of species in a population share the common gene pool. The composition of genes making up the gene pool changes in accordance with adaption with environment over time. As a result, new species are evolved. The **formation of a new** species is called speciation.

b. Hardy-Weinberg Law

This law is proposed by G.H. Hardy and W. Weinberg in 1908. It states that '**the frequency of all the alleles of a particular gene in an ideal population remains constant from generation to generation in the absence of mutation, selection and gene flow'**. This law provides a situation, where the genes in the population have reached the equilibrium and the gene pool is constant. In such case, a population is not undergoing any evolutionary change.

In nature, **mutations**, **natural selection**, **random mating**, **genetic drifts** and **differential migration** operate to change the genetic equilibrium. If the evolutionary forces are **absent** and the **population is large**, then individuals will have **random mating** and have equal opportunities of producing offspring. Thus each parent produces equal number of gametes. Such gametes combine at random and the **gene frequency remains constant**. In other words, each allele has a constant frequency or proportion and the sum total of all the allelic frequencies of a particular gene makes 1 or 100 percent.

Mathematically it is written as

$$p + q = 1$$

Where, **p** and **q** are the frequencies of a *dominant allele* and a *recessive allele* respectively,

in a population. If the organisms constituting the population are diploid, then the allelic frequencies will be

$$(p+q)^2 = p^2 + q^2 + 2pq = 1$$

The Hardy- Weinberg law is based on an entirely theoretical population because the set of assumptions under which this law holds true can scarcely be fulfilled in any natural population. However, an understanding of *Hardy-Weinberg law* is helpful in recognizing the forces responsible for bringing *evolutionary changes* in a population.

The principle of **Hardy-Weinberg law** states that the original proportion of genotypes in a population remains constant if

- ***population size*** is large.
- ***random mating*** occurs between the individuals of population.
- ***no mutations*** in the individuals of population.
- ***no genes*** are introduced or lost in the population.
- ***no selection*** occurs in the population.

c. Factors responsible for speciation

Some of the factors responsible for speciation are **mutation**, **natural selection**, **genetic drift**, **isolation of species** and **migration**.

i. Mutation

A **sudden**, **large** and **heritable variation** is called mutation. Many mutations result in a change in an organism's genetic makeup; therefore, they are a cause of genetic variation in a population. Organisms having mutations are called mutants. Mutation is a driving force of evolution, which influences the population's gene pool. Some **beneficial mutations** have positive effects on the organisms in which they occur. This leads to new versions of genes that help organisms adapt to changes in their environment. Over time, these types of individuals survive and reproduce, so that they are likely to become more common. On the other hand, organisms **without mutations** are more likely to perish. Therefore, beneficial mutations are essential for evolution and speciation to occur. *For example*, mutations in many bacteria allow them to survive in the presence of antibiotic drugs by developing antibiotic-resistant strains of bacteria.

The causes of genetic variation such as **mutation**, **sexual reproduction**, **recombination**, and **hybridization** are responsible in speciation and the emergence of new species. Therefore, existence of numerous species of flora and fauna on the earth is accounted to it.

ii. Natural selection

Natural selection includes both physical forces and biotic factors and determine how and in what direction an organism is to change. Natural selection has **no favouritism**. But the organisms, which are **better suited** to specific environmental conditions will survive in the force of competition. The better survivors are retained in the nature. Natural selection occurs when populations of organisms are subjected to environmental changes. In nature, **Darwin** has *observed following operations*:

1. Tendency of overproduction: All living organisms have **high rate of reproduction**. Darwin thought that if all the newborns of one particular species happen to survive and reproduce there would hardly be any space left for others to live. For example, a **female Salmon fish** produces around 28 million eggs at one spawning; a tropical orchid plant may form over 1 million seeds in a year. Though the reproduction rate of a species remains high, the actual size of population of that species remains relatively constant over long periods under a fairly stable environment.

2. Stability of population size: There are competitions for survival among the species in the population. Some individuals have characteristics or features that give an advantage for them. For example, it may involve an **individual's ability** to **avoid predators**, **a greater resistance to disease**, **better ability to obtain food or resistance to drought**. Over long periods, the advantageous gene becomes more common among the population. Competitions lead to a **struggle for survival** or **existence** and keep the number of individuals of a population in a particular range that can be sustained by the available resources.

3. The fittest individuals are more likely to reproduce and pass their genes to their offspring, producing a population that is better adapted to the environment. The **genes of less-fit individuals** are less likely to be passed on to the next generation.

4. There are variations in a population and new variations appear in the population because of **mutation** that are inherited. Species that have a lot of variation carry **many versions** of the same genes. These species are more likely to be able to survive if the environment changes suddenly. Species that do not have much variations are less likely to adapt quickly when the environment changes and will become **extinct**. These variations could be both **heritable** and **non-heritable**. Because of variations, the different individuals in a population exhibit different performances with respect to various traits in a prevailing environment. For example, if different individuals in a plant species posses different heights, the taller plants will be at an advantage in getting more sunlight and pollinators due to extra exposure to these factors.

An example of natural selection

During the mid 20th century, many scientists observed the predominance of **dark coloured moths** in the **industrial areas** of England and Germany. Before industrialization, in early 1800s, the **light-coloured** variety of peppered moth (*Biston betularia*) was dominant in Manchester in England as it could escape from being eaten by birds. They could easily **camouflage** on **bright-coloured-lichen** covered trunks of oak trees. On the other hand, **dark-coloured** peppered moth was at a disadvantage as they were spotted easily by birds. Therefore, they comprised less than 1 percent of population in 1848. However, after the industrialization of Manchester area, in 1898, **dark-coloured moth** became dominant and comprised 95 percent of population because sooty-black oak trunk helped protect them from birds. This significant change in the colouration of moths has been termed as industrial melanism.

iii. Genetic drift

Genetic drift is a change in the **gene pool** of a population due to chance. **Gene frequencies randomly change** over generations brought about by chance. It occurs when a small group of individuals leaves a population and establishes a new one in a **geographically isolated** region. For example, when a small population of fish is placed in a lake, the fish population will evolve into one that is different from the parents or ancestors. The occurrence of genetic drift can be explained with two mechanisms, namely, bottleneck effect and founder effect.

1. Bottleneck effect

Natural disasters may have a significant effect on the population size thereby reducing the gene pool size. Survivors may represent certain alleles more than others by chance. **Genetic variation** of the population is decreased; this may in turn have an impact on the survival of the population (Figure 6.20).

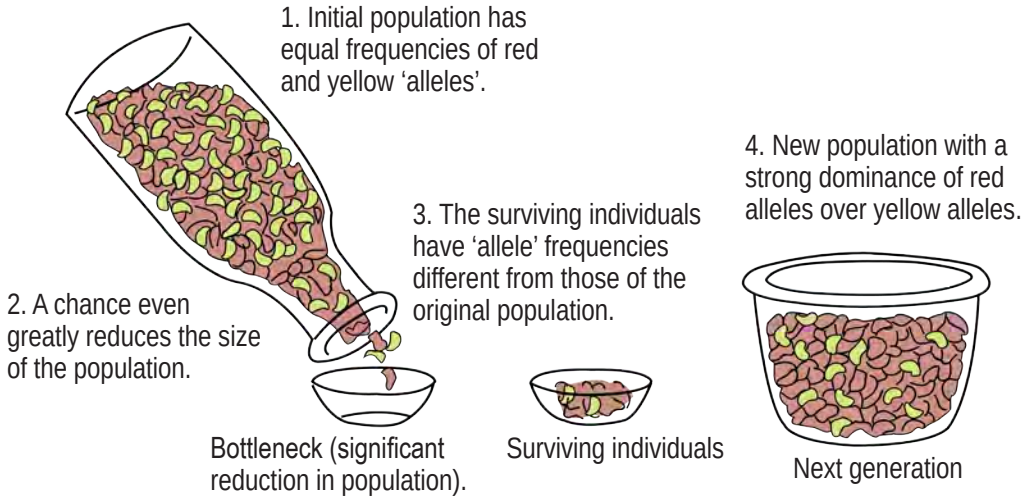


Figure 6.20: Bottle neck effect

2. Founder effect

Allele frequencies change as a result of the migration of a small subgroup of a population. A few individuals colonize a new habitat. **Founding individuals** may carry alleles that differ in frequency to their main population, just by chance (Figure 6.21).

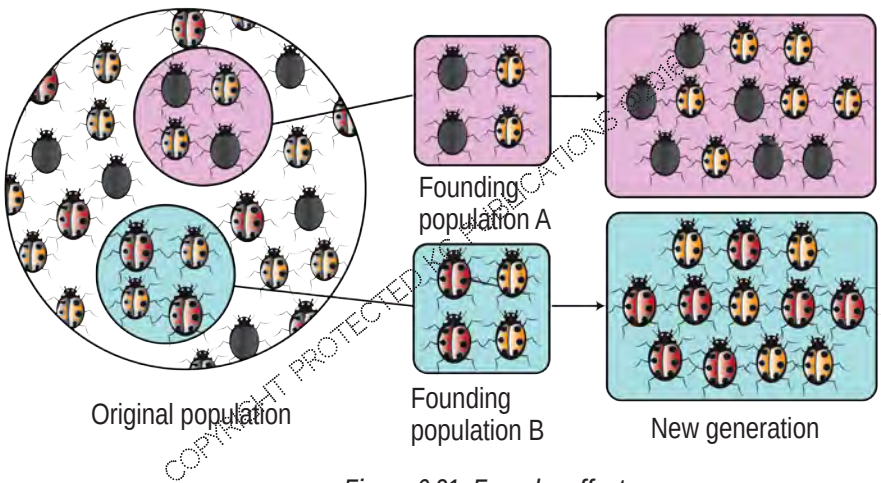


Figure 6.21: Founder effect

iv. Isolation of species

The separation of a single population into two or more groups because of some **barrier for interbreeding** is called isolation. There are a number of processes by which two related populations living in the same area can remain distinct. Speciation can occur when a population is isolated by geographic barriers, such as water bodies,

mountains, desert, etc. Such type of isolation is known as geographic isolation. When the species are isolated from breeding due to different timing of sexual activity is called temporal isolation. **Mating** with other members of the population may result in the formation of a new species. Sometimes, **species occur in the same area**, but they **occupy different habitats** such as treetops while another species lives at ground level. This type of isolation is called ecological isolation (Figure 6.22).

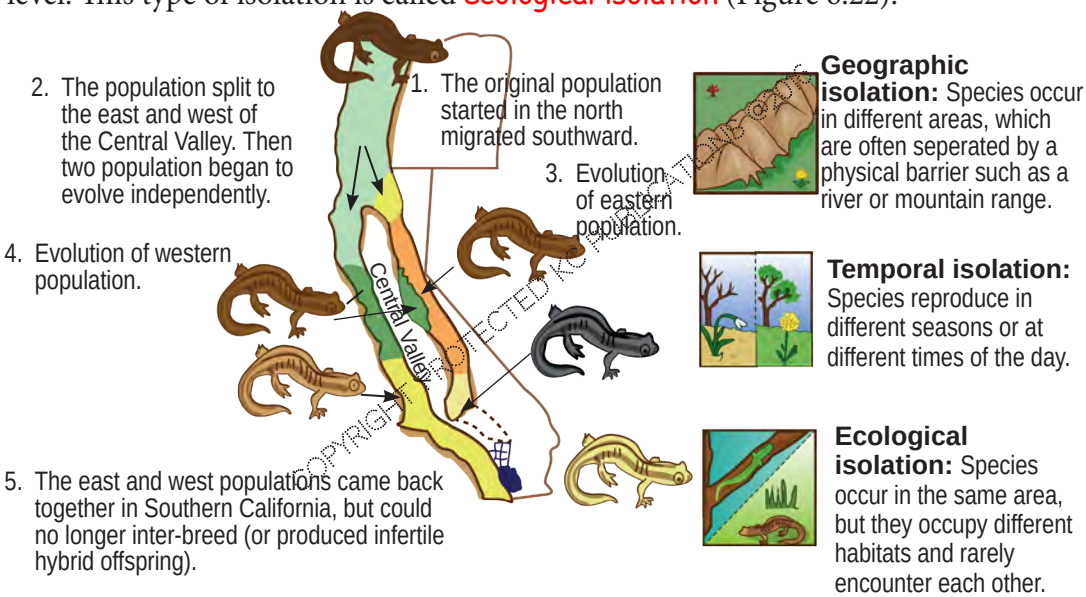


Figure 6.22: Ecological isolation

v. Migration

Gene flow is an **exchange of genes** between populations. It can be one way or two ways. It occurs during the migration of individuals from one group to another, or location. When the migrating individuals interbreed with the new population, they contribute their genes to the gene pool of the local population. This establishes gene flow in the population.

Gene flow occurs, for example, when wind carries seeds far beyond the bounds of the parent plant population. Animals may be driven off from the herd. This forces them to migrate to a new population, thereby **bringing new genes** to a **gene pool**. The **change in gene pools** gradually leads to the formation of new species.

Lesson Summary

- Variation is of two types; continuous variation and discontinuous variation.
- Some variations are caused due to the environment, and some are due to genetic or both.
- Causes of genetic variation are mutation, sexual reproduction, recombination, and hybridization.
- The various types of mutations are somatic mutation, germ cell mutation, gene mutation and chromosomal mutation.
- Mutations may be due to environmental factors (mutagens) or may occur spontaneously.
- Beneficial mutations may accumulate in a population resulting in evolution.
- The causes of genetic variation in sexual reproduction are due to independent assortment in meiosis, crossing over and random fertilization.
- Genetic cross is defined as the conscious breeding of two different individuals resulting in offspring that carries a portion of the genetic material of both the parents.
- Alleles can be dominant allele and recessive allele.
- The ideas and conclusions drawn from Mendel's experiments are called Mendelism.
- The three laws of inheritance are law of dominance, law of segregation and law of independent assortment.
- A DNA molecule is made up of phosphate, sugar and nitrogenous bases.
- Adenine always pairs with thymine and guanine in pairs with cytosine.
- Two types of species are allopatric species and sympatric species.
- Hardy-Weinberg Law states that 'the frequency of all the alleles of a particular gene in an ideal population remains constant from generation to generation in the absence of mutation, natural selection and gene flow.'
- Mutation, variation, natural selection, genetic drift, isolation of species and migration are the important factors responsible in the formation of new species.

Weblink

- http://www.johnkyrk.com/
- http://www.brightstorm.com/science/biology
- http://evolution.berkeley.edu/evolibrary/article/evo_01
- https://www.dnalc.org/resources/animations/

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct or the most suitable response.

1. A farmer observed different lengths of chilli in the same plant in her garden under the controlled conditions. This type of variation is an example of

   A. discontinuous variation.
   B. continuous variation
   C. genetic variation.
   D. environmental variation

2. Which cross would best illustrate Mendel's Law of Segregation?

   A. TT x tt
   B. rr x rr
   C. Bb x Bb
   D. Hh x hh

3. Which among the following is not a condition of Hardy-Weinberg Law?

   A. No gene flow
   B. Natural selection
   C. Random mating
   D. Small population

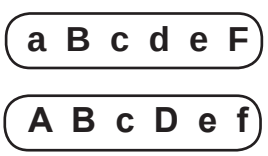
4. What would be the most probable effect of geographic isolation in a population?

   A. It allows the mixing of gene pools.
   B. It prevents the occurrence of mutations.
   C. It has no effect on variations in the species.
   D. It favours the production of new species.

5. In the cross Rr x Rr, what percent of offspring would have the same phenotype as the parents?

   A. 25%
   B. 50%
   C. 75%
   D. 100%

6. In the homologous chromosomes shown in the diagram on the right, which is a possible allelic pair?



   A. aB
   B. cD
   C. ef
   D. Ff

7. If individuals of tiger species are not able to interbreed because of different breeding season, it is due to

   A. geographical isolation.
   B. ecological isolation
   C. temporal isolation.
   D. reproduction isolation.

8. What is the best way to determine the phenotype of the feathers on a bird?

   A. Analyze the bird's DNA (genes).
   B. Observe the bird's feathers.
   C. Observe the bird's beak.
   D. Examine the bird's droppings.

9. A segment of DNA has one strand with the following sequence of bases:

   AGCGCATAGCAA

   The complimentary strand of DNA would be

   A. UCGCGUAUCGUU
   B. TCGCGTATCGTT
   C. GAUAUGCGAUGG
   D. AGCGCATAGCAA

10. A man was involved in a legal battle over the paternity of a child born to a woman. The baby has hemophilia, mother is normal and the man is also normal. At the time of the trial, the man was declared as the father of the child.

    A. Yes, he could have fathered the child.
    B. No, he could not possibly have fathered the child.
    C. Theory of sex-linked inheritance is inconclusive.
    D. In this case, more evidence must be given.

B. Fill in the blanks with the correct form of word(s).

1. There are no ribose groups in a……..molecule.
2. The total of all heritable genes for all the traits of a population constitutes the.....
3. In the genotype of an organism, number of alleles found is.....
4. The separation of alleles from each other during the formation of gametes is called .....
5. Animal breeders often cross members of organisms with different traits in order to obtain desirable traits by a procedure called.....

C. Name the following.

1. During meiosis, portions of one chromosome may be exchanged for corresponding portion of its homologous chromosome.
2. The primary evolution unit.
3. The nitrogenous base which is not found in RNA.
4. A process by which populations of one species diverge genetically and produce one or more new species.
5. The physical appearance due to gene expression of a trait in an organism.

D. Define the following terms.

1. Mutation
2. Evolution
3. Natural selection
4. Pure breeding
5. Alleles

E. Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.

Column A	Column B
1. Random changes in allele frequencies that occur by chance.	Dominant gene
2. No-random changes in allele frequencies that occur due to differing reproductive success.	Recessive gene
3. A type of inheritance in which neither allele in a hybrid is dominant.	Selection
4. Genes which exert no effect over an organism unless their alleles occur in a homozygous conditions.	Incomplete dominance
5. Genes whose presence controls the traits of an organism, regardless of which other alleles for genes are present.	Genetic drift

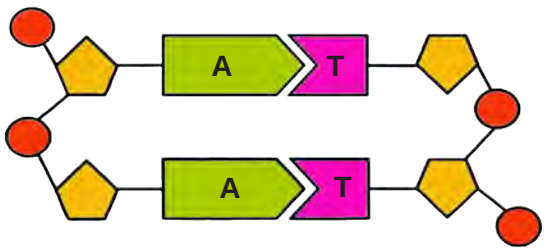
F. Write TRUE or FALSE against the following statements.

1. Maize plants grown in the dark will be white. The most probable explanation is that the expression of the gene for colour may be due to the environment.
2. Usually, two different species cannot mate. If mating happens to be successful, their offspring will not be fertile.
3. Mendel was the first to present a clear explanation of how hereditary traits are passed from one generation to next.
4. Mutagen agents are substances that decrease the rate of gene mutations.
5. In a plant that has red flowers, red flower colour, R, is completely dominant to white flower colour, r. If the plant is heterozygous for flower colour, gametes produced will have R and r alleles.

G. Answer the following questions.

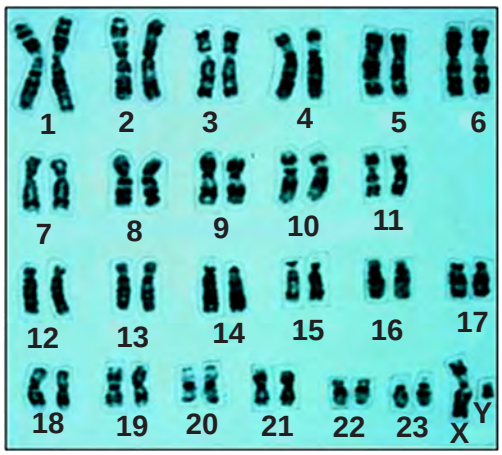
1. Describe the causes of genetic variations.

2. Being able to curl up your tongue into a U-shape is under the control of a dominant allele at one gene locus. Suppose a woman who can roll her tongue marries a man who can also roll his tongue. Their first child cannot roll her tongue. What are the genotypes of the parents?
3. A portion of a molecule is shown in the diagram below. Study and answer the questions that follow.



   i. Write the number of nucleotides present in the diagram.
   ii. What do the circles in the diagram indicate?
   iii. Name the molecule represented by the pentagonal structure.
   iv. How does this structure differ from RNA molecule?
4. Draw the Punnett square to show the inheritance for colour blindness if a carrier female is crossed with a normal male.
   i. Approximately, what percentage of their daughters will be colour blind?
   ii. What percentage of their daughters will be carriers?
   iii. What about their sons?
5. A white-flowered plant is crossed with a pink-flowered plant. All of the F1 offspring from the cross are white.
   i. Which phenotype is dominant?
   ii. What are the genotypes of the original parent plants?
   iii. What is the genotype of all the F_1 offspring?
   iv. What would be the percentages of genotypes and phenotypes if one of the white F1 plants is crossed with a pink-flowered plant?
   v. Which of the Mendel's Laws is/are illustrated in this question?
6. What is the relevancy of Mendel findings in your life?
7. Explain natural selection with the help of an example.

8. Study the karyotype of a chimpanzee and answer the questions i to iv.



i. Write the total number of autosomes.
ii. Determine the number of chromosome pairs.
iii. Identify the sex of a chimpanzee. Why?
iv. How is it different from human karyotype?

7 LIVING THINGS IN THEIR ENVIRONMENT

All life forms on earth and its environment makes the earth's rich biodiversity. The conservation and sustainability of rich flora and fauna, healthy ecosystems and natural landscape are essential for all life forms, including humans. Today, the world population continues to increase but our access to natural resources stays the same. This means that there are now more people using the same amount of natural resources than decades ago. The current rate at which humans consume resources and produce waste is unsustainable. The Earth will not be able to maintain this imbalance forever. Therefore, people's needs of today must be taken care of in such a way that it does not negatively impact the needs of the next generations.

7.1 Ecosystem

Learning Objectives

On completion of this topic, you will be able to:

- explain the components of ecosystem.
- differentiate the types of food chain.
- discuss the types of interactions.
- explain how a change in an ecosystem leads to competition.

Ecosystem includes both **living** and **non-living** factors. They interact with each other and keep the balance in the environment. In an ecosystem, living organisms interact with each other through food chains in which one organism consumes the other. **Green plants** prepare their own food and are called '**producers'**. Animals and other organisms are '**consumers**' as they depend on green plants directly or indirectly for food. There is a flow of energy from sunlight through the food chain. This energy is finally lost as heat in the ecosystem. **Resources** of every kind are in *limited supply*, and organism must **compete** in an ecosystem.

a. Components of Ecosystem

Ecosystem comprises of *two* main components: biotic (*living*) and abiotic (*non-living or physical*) components.

i. Biotic component

Biotic component includes living components of the ecosystem. Depending upon their **feeding relationships**, they are grouped as autotrophs, heterotrophs and decomposers.

1. Autotrophs (Greek *auto*: **self**, *trophos*: **feeders**) are those living organisms which are **self-dependent** and have the capacity to make their own food. With the help of sunlight and chlorophyll they prepare food by the process of **photosynthesis**. Autotrophs are also known as **producers**. They produce food for all other living organism of the ecosystem. Examples of producers are **green plants**, **blue green algae** (*cynobacteria*), some bacteria and free-floating phytoplanton.

Function of producers

i. Producers convert **inorganic substances** like sunlight, carbon dioxide and water into organic food.

ii. They are the **only source of atmospheric oxygen** to living organisms in an ecosystem.

2. Heterotrophs (Greek *hetero*: **other**, *trophos*: **feeders**) are those living organisms which consume food prepared by the producers. They are also known as consumers. All animals including human beings are consumers. They depend directly or indirectly on producers for food. Depending on their **feeding habits**, consumers are categorised as **herbivores**, **carnivores** and **omnivores**.
   i. Herbivores are those animals which directly feed on plants. They are known as primary consumers. Some of the examples are deer, horses, goats, sheep, rabbits, seed eating birds, small fish that feed on **aquatic plants**, etc.
   ii. Carnivores are those animals that feed on herbivores and **eat their flesh**. They are known as secondary consumers. Examples include *cats*, *foxes*, *sparrows*, *snakes*, *peacocks*, *frogs*, *small fish*, etc. These secondary consumers are further consumed by other animals which are known as tertiary consumers. Some of tertiary consumers include *lion, tiger, eagle, shark, crocodile*, etc.
   iii. Omnivores are those living organisms which feed both on plants as well as animals. Examples include *humans, bear, dog, cockroaches,* etc.

Some animals feed on the **flesh of dead organisms**. They are called scavengers. *Vultures, crows* and *hyenas* are scavengers.

Function of consumers

i. Consumers feed on the producers directly or indirectly and keep check on the population of producers.
ii. Scavengers eat dead bodies of animals and keep the environment clean.

3. Decomposers are organisms that break down the organic food matter in dead organisms into simpler substances. For example, an organism such as bacterium or fungus feed on dead animals and convert into simple nutrients. Decomposers release enzymes on the dead and decaying matter that help in **breaking down the nutrients**.

Function of decomposers

i. Decomposer **decomposes the bodies** of dead animals and plants.
ii. They help **recycle the material** and return it to the biosphere.
iii. Some decomposers help to **maintain the fertility of the soil**.

ii. Abiotic component

This component is comprised of nonliving things of the ecosystem. **Abiotic factors** are categorised as *organic substances, inorganic substances and climatic factors.* Organic substances include *carbohydrates, proteins, fats*, etc. Inorganic substances are *carbon, hydrogen, nitrogen, oxygen, sulphur, phosphorus, water*, etc. Climatic factors include *temperature, moisture, sunlight, soil texture*, etc.

b. Food chain

Food chain is the feeding relationship between organisms of different populations in an ecosystem. It describes the flow of energy from one population to the next. Generally, food chain comprises of more than 4 to 5 levels and starts with producers. **Producers** trap solar energy and make it available to the food chain through photosynthesis. Producers are eaten by herbivores, which are the primary consumers. These primary consumers are eaten by secondary and tertiary consumers. Therefore, in a food chain, different organisms of ecosystem are linked to each other by nutritional requirements.

There are *two* types of food chain found in a terrestrial ecosystem:

i. Grazing food chain

This is a simple food chain which starts from producers and ends at carnivores. It can be represented as:

producers → herbivores → small carnivores → large carnivores

Producers are the first level and are formed by **green plants** or **algae**. This is followed by grazing herbivores. Herbivores feed on green plants and convert the stored energy into other forms of energy. These are in turn eaten by small carnivores which are food for large carnivores. **Grazing food chain** is shown in Figure 7.1.

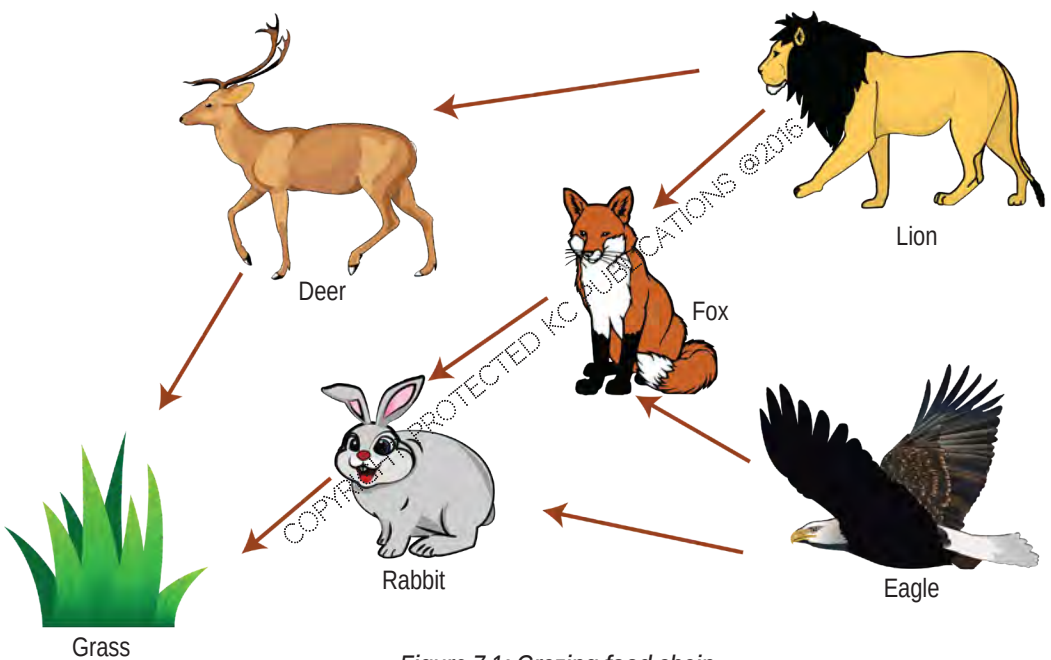


Figure 7.1: Grazing food chain

ii. Detritus food chain

Detritus food chain begins with dead organic matter and passes through detritivores feeders in the soil, to organisms feeding on detritus feeders. **Detritus feeders** include *earthworm, millipedes, mites, crabs, worms, bacteria and fungi*. Dead and fallen remains of plants and animals are decomposed and used by **microorganisms** like bacteria and fungi.

They are in turn eaten by carnivores. This can be represented as:

dead and decaying matter → detritus feeders → organisms feeding on detritus feeders

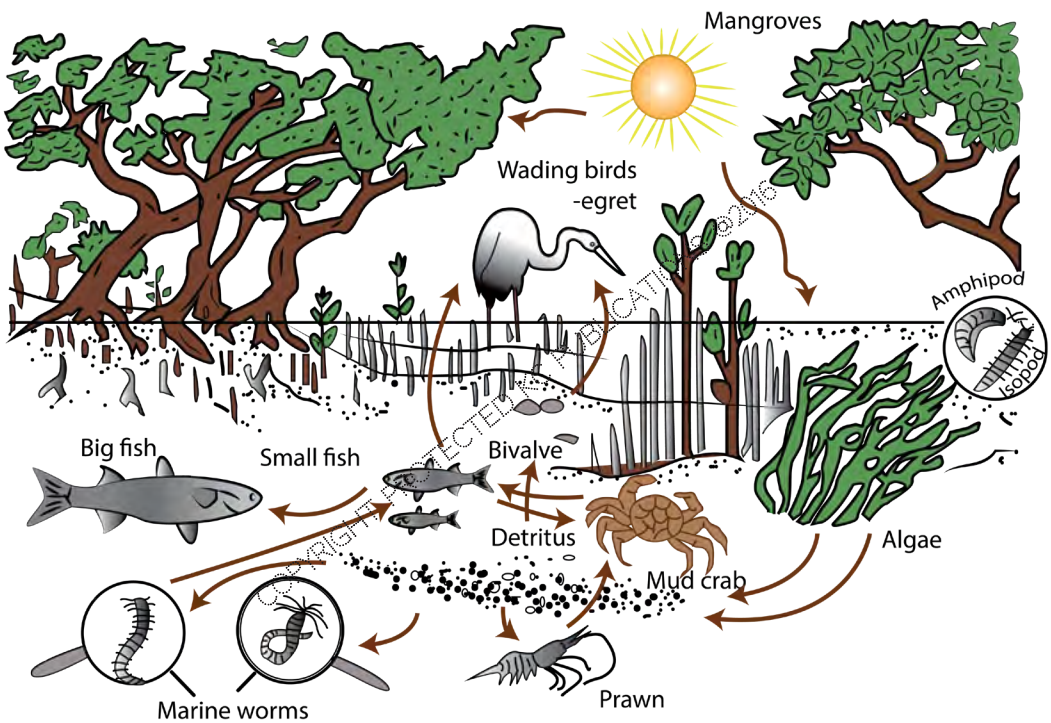


Figure 7.2: Detritus food chain

c. Food web

The **interconnection of a number of food chains** forms a food web. So a food web is defined as **a network of food chains**, which becomes interconnected at different trophic levels forming a number of **feeding relationships**. A food web gives alternative pathway for the availability of food. This helps organisms to survive even with the shortage of one or two organisms. The scarcity of food in the ecosystem is addressed thus because organisms can get energy from different sources. Food web also keeps **check on the population** of organisms.

d. Trophic level

Trophic level is the position of an organism in a food chain. They are made on the basis of steps found in the food chain. There are usually 4 to 5 trophic levels in the food chain. First trophic level is occupied by the **producers**, which are **autotrophs**. The second trophic level is occupied by the **primary consumers**, which are **hervivores**. The third trophic level is occupied by **carnivores** and **omnivores**, which are secondary consumers. The fourth trophic level is occupied by **tertiary consumers**, which are **large carnivores** (Figure 7.3)

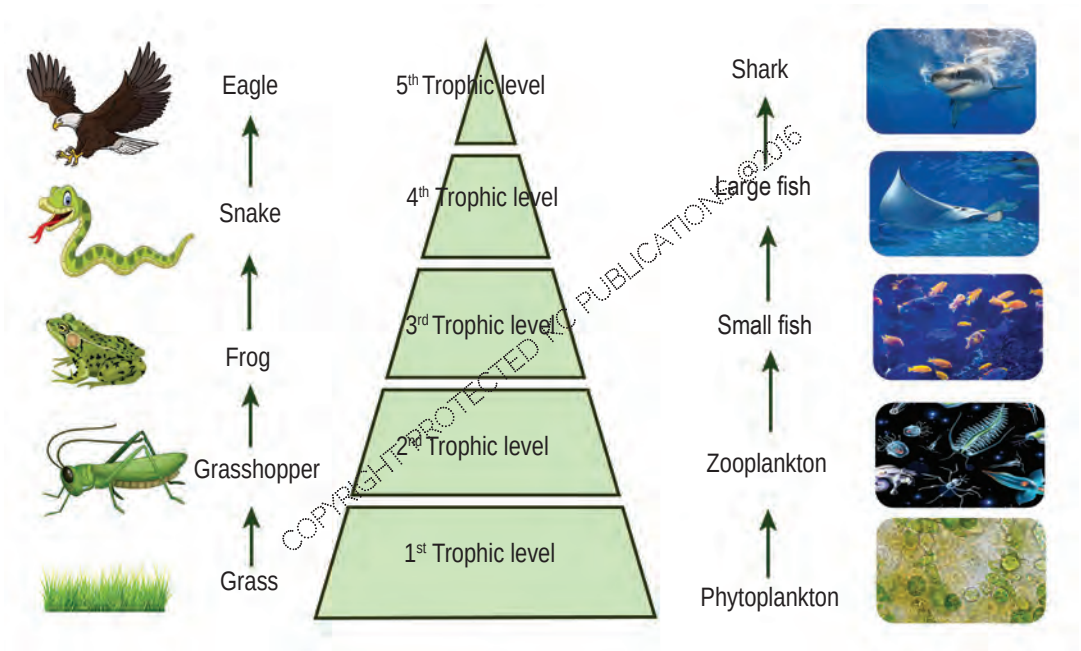


Figure 7.3: Trophic levels in food chain

e. Energy flow

Energy flows in an ecosystem from one trophic level to another trophic level. The flow of energy is based on two laws of thermodynamics. First law of thermodynamics states that **energy can neither be created nor destroyed**. However, i**t can transform from one form to other**. For example, solar energy from sun changes into **chemical energy** (food) and **heat energy**. Second law of thermodynamics states that **during transformation of energy some amount of energy is always lost in the form of heat**. Therefore, amount of energy decreases as it moves up trophic levels because some amount of energy is lost in each trophic level.

f. Ecological interdependence

In an environment or ecosystem, individual organisms cannot survive alone. They are dependent on each other. This dependence is called ecological interdependence. A **biotic community** is formed when there is a union of a number of different interrelated populations of different species. There are a number of different interactions existing in nature between organisms. *A few examples are*:

i. Plants depend on insects for **pollination** and insects in turn are dependent on plants for nectar.

ii. Plants depend on animals and birds for **dispersal of seeds** and in turn deliver food for their living.

iii. By **camouflaging**, animals blend with their surroundings to save themselves from predators. This is done by changing their colours or animals may have body shapes similar to their surrounding e.g. *stick insect* resembles a thin dry twig. *Praying mantis* resembles a green stem.

iv. **Mimicry** is a kind of protective measure by animals where they resemble other animals to avoid predation. Generally, weaker animals mimic a stronger animal e.g. *viceroy butterfly mimics monarch butterfly* which is avoided by birds because of its unpleasant taste.

g. Ecological services

Many ecological services are provided by an ecosystem. These services have greater influence on the health and wellbeing of an ecosystem. For example, the ecosystem helps to improve the quality of air and water.

Activity 7.1

Identifying ecological services

Instruction:

1. Work in small groups. Use the school library or Internet resources for the information.
2. Identify different forms of ecological services provided by an ecosystem with special reference to ecosystems in your locality.
3. Make a flow chart of causes and effects relationships amongst the ecological services in the ecosystem.
4. Share your views to the class in any form of presentation.

Questions

i. What service(s) are critical for the good health of an ecosystem?

ii. Give reasons for the importance of ecological services for the survival of animals.

iii. From the ecological perspectives, explain the importance of wildlife sanctuaries in Bhutan.

h. Interactions between organisms

Different populations **interact** with each other for **food**, **shelter** and **defence** purposes. Interactions arise between populations of different species. The interactions of the organisms of the ecosystem can be **positive** or **negative** in nature. When two separate interacting organisms help one another, either benefiting one of the species or both, it is said to be a positive interaction. On the other hand, when organisms compete and interfere with one another, it is referred to as negative interaction.

i. Positive interaction

This type of interaction is of mutualism (symbiosis) and commensalism.

1. ***Mutualism*** is an interaction between two individuals or species where both the individuals benefit. In ***symbiotic interaction***, the organisms live together in a close physical association. If both the species are completely dependent on each other and one cannot survive without the other, it is called obligate mutualism. A few examples of obligate mutualism are as follows:
   i. Association between *Rhizobium* and leguminous plant. In this, *Rhizobium* fixes nitrogen for plant and in turn plant provides water and nutrients to the bacteria.
   ii. **Lichen** consists of two organisms, algae and fungi. The algae synthesise food and fungi provide minerals, moisture and support.

Figure 7.4: Examples of mutualism

When both the species can survive without each other, it is called facultative mutualism. The best example is the *association of hermit crab* and the *sea anemone*. Sea anemone provides protection to the hermit crab from predators and in turn is transported to new feeding places by the crab.

2. ***Commensalism*** is an association between two different organisms in which one individual or species benefits, whereas the other is **neither benefited** or **nor harmed**. This association may be permanent or temporary. For example, *cattle egrets* live near cattle because disturbances of grass by the cattle help them get more insects for food.

Figure 7.5: Examples of commensalism

This type of interaction occurs when there is limited supply of, at least one, resource such as *food, water* and *space*. It also occurs due to other factors such as reproduction; male organisms of the same species compete for females.

ii. Negative interaction

Interaction is **negative** when one or both the species are harmed. It is also negative interaction when species may benefit at the cost of the other. Negative interaction can be of the following types:

1. Predation

Predation is a type of direct food relationship between two species of animals in which **stronger animals prey on a weaker one**. A predator is an organism that feeds on a prey. If there is a **decline in the predator population**, t**he population of prey increases**. For example, tiger feeds on deer; the decline in tiger population would lead to an increase in deer population and vice versa. The eating of plants by herbivores is also an example of **predation**, although most commonly referred to as grazing or browsing. Plants have evolved various defence mechanisms to avoid predation.

i. Thorns in *Acacia* and *Cactus*.

ii. Toxic chemicals such as *nicotine, caffeine, opium, quinine*, etc. are released by certain plants (e.g. *Calotropis*) to keep away predators.

2. Parasitism

Parasitism is an interaction between **two species** in which one organism derives nutrition from another living organism (**host**). In this association, **parasites** may live in (endoparasites), or on the body (ectoparasites) of the host. As parasite derives nutrition from the host, it weakens and damages the host. *Examples of* **endoparasites** are tapeworm, roundworm, *plasmodium*, etc. and **ectoparasites** are *ticks, mites, leech, lice*, etc. *Cuscuta* is a plant parasite that has lost its ability to photosynthesise since it derives nourishment from the host plant.

(a)

(b)

(c)

Figure 7.6: Parasites: (a) dodder (b) rafflesia (c) mite

Parasites are host-specific and have special adaptations to live successfully in or on the host. Some of the adaptive features are:

i. Loss of sense organs.

ii. Presence of adhesive organs or suckers.

iii. High rate of reproduction.

3. Competition

Competition is the negative interaction between **two species** belonging either to the same species, or different species with the same needs. The use of resource by one individual reduces the availability of resources to the other individual. Competition may be for *food, water, space, sunlight, nutrients, mate*, etc. Competition is most intense between species occupying an identical or similar niche in the same ecosystem. In this type of interaction, both species are affected.

Some of the effects of competition include:

i. Sometimes, even when resource is plenty, the presence of 'competitor species' will **eliminate another species or force one species to migrate** to a different area. This is referred to as competitive exclusion.

ii. Competitions cause **species to evolve differences in traits,** sometimes resulting in speciation. Speciation is the formation of new species. These individuals develop reproduction and survival traits different from their competitors.

iii. Competition may also lead to **greater specialization**. For example, the long neck of a giraffe is specialisation as a result of scarcity of undergrowth grasses due to numerous herbivores living on them.

Activity 7.2

Investigating competition

Instruction: Students set this experiment prior to teaching of the topic.

Material required: a container, soil, water, bean seeds

Procedure

1. Take a small container filled with soil.
2. Sow about 20 bean seeds and spray some water into the container.
3. Observe after one week, two weeks and three weeks.

Questions

i. Propose a possible hypothesis for the experiment.
ii. Make a table and write all your observation after one week, two weeks, and three weeks.
iii. Identify and describe the competition in the experiment.
iv. Identify the resources that the bean seeds compete for in the experiment.
v. Describe the suitable control for the experiment.
vi. What is the most accurate conclusion for the experiment?
vii. Describe the application of your conclusion.

7.2 Biodiversity and Sustainability

Learning Objectives

On completion of this topic, you will be able to:

- appreciate Bhutan's biodiversity.
- explain the biodiversity support services.
- list the sustainability efforts in preserving biodiversity.

Biodiversity includes all forms of life and the ecosystems of which these life forms are a part. Biodiversity is the **variety within the living world**. The well being and survival of human beings depend on millions of plants, animals and microorganisms. It is the **source of economic** and **ecological security** for future generations. The **sustainable use** of these natural resources and ecosystems on which our future generations depend is crucial for improving lifestyles and well-being. *Clean air, drinkable water, food, clean environment, and shelter* are fundamental to human survival. All these resources come from the **natural systems**.

a. Types of biodiversity

Biodiversity can be broadly divided into *three* types: **genetic diversity, species diversity** and **ecosystem diversity**.

i. Genetic diversity refers to the **variation of genes within species**. Each individual species possesses genes, which are the source of its own unique features. In human beings, for example, there is a variation of people's faces due to different genes present within them. It gives genetic variation within a population or varieties within one species.

ii. Species diversity refers to the **variety of species within a region**. It refers to the abundance of different animals, plants and microbial species.

iii. Ecosystem diversity refers to **different kinds of ecosystems** such as deserts, forest, marine, aquatic, mountain, etc. Each ecosystem provides many different kinds of habitats or living places.

b. Bhutan's biodiversity

Biological diversity means the **variability among living organisms**. It includes diversity within species, between species and of ecosystems. Bhutan has one of the most remarkable biological diversities in the world. It is home to many exceptional species of plants and animals which are rare and **endangered** elsewhere in the Himalayas. Bhutan falls under one of the ten global biodiversity '***hotspots***' with many endangered animal and plant species. It has the highest fraction of land in protected areas as well as the highest proportion of forest cover in Asia. Its biodiversity includes about 5,500 species of plants including 46 species of *Rhododendrons*, 400 lichen species, some

430 orchid species, over 200 species of wild mushrooms and over 200 mammals, 770 bird species, 800 to 900 butterfly species, 55 species of snakes, 19 species of lizards and many are yet be discovered. Species which are globally threatened such as *Bengal tiger, red panda, takin, golden langur, black-necked crane and white-bellied heron* are found in good numbers in Bhutan.

Biodiversity of Bhutan includes **terrestrial** and **aquatic biodiversity**. Terrestrial biodiversity includes the forests, birds and land animals. Aquatic biodiversity includes a large number of high altitude lakes, marshes, hot springs, river systems, etc. Bhutan's **aquatic habitats** are found throughout the ecological zones.

c. Significance of biodiversity

The **sustainability** of biological diversity, ecosystems, and natural habitat is critically important to the survival of humans, plants, and animals. In addition to the fundamental value of nature and wildlife, biological diversity and healthy ecosystems provide humankind with many of the things that sustain our lives.

i. It provides *clean air, fresh water, diverse food products, timber, fuel, fertiliser, medicines* and *raw materials* for clothing.

ii. It helps to maintain the *ecological balance* necessary for all life forms.

iii. It also provides *raw materials* for plant and animal breeding.

iv. It provides social benefits like *recreation, tourism, cultural values, educational values*, etc.

Activity 7.3

Biodiversity services

Everything that lives in an ecosystem is part of the web of life, including humans. Each species, by virtue of its existence has a vital role to play in the circle of life. Maintaining a wide diversity of species in each ecosystem is necessary to preserve the web of life that sustains all living things.

Carry out a library research. Copy and complete Table 7.1.

Table 7.1

Sl No.	Biodiversity support services	Notes	Examples
1	***Source of food***	Biological resources have a crucial role as provider with 80 per cent of the needs of the poor derived from it. Many plants and animals are eaten as food. World's food demand is met by cultivating crops in agricultural fields. New breeding techniques are being used in developing disease resistant and high yielding varieties of crops and high yield varieties of animal. Thus, biodiversity serves as a source for raw materials for breeding programmes in agriculture, animal husbandry, sericulture, apiculture, fishery, etc.	1.....

Sl No.	Biodiversity support services	Notes	Examples
2	***Other useful products***	2	Resins, tannins, paper, tea, dry fruits, coffee, gums, fur, honey, leather, fur, pearls, hemp, cotton, jute, etc.
3	***Medicinal value***	Many medicines and important drugs are obtained from a variety of plants. Many animals are used in the production of hormones and enzymes. Bhutan has several plant species that can be used to obtain alkaloids and medicine.	Fungi and microbes are used to obtain antibiotics
4	***Sports and recreation***	3	Fishing, hunting, botanical park at Lamperi (1st recreational park in Bhutan), zoos, etc.
5	***Research and educational value***	4	Guinea pig, rat, monkey, chimpanzee, etc.
6.	***Aesthetic value***	5	6 .....
7.	***Cultural value***	7	Blue poppy (*Tsherngoen*), Bhutan Takin (*Drongemtse*), Weeping cypress (*Tsenden*), Raven (*Oro*), Swallowtail (*Ludlow*), etc.
8.	***Ethical value and right to live***	Every living organism has the right to live on the Earth. It is unethical to let any species disappear from earth because of human activities. Human is only a part of nature and has no right to exploit nature beyond its capacity. Nature is central to Buddhism, which respects all forms of life.	Mountains, rivers, trees, rocks and soils

d. Loss of Biodiversity

Human activities are placing a great deal of pressure on the **earth's resources**. As the demands of humans increase and the rate at which these demands for resources also increase, the earth is not able to replenish its resources. The present levels of human consumption are **unsustainable** due to which species of plants and animals are disappearing from the earth at an alarming rate. The **disappearance of species** from the earth is called extinction. More than 15, 500 species worldwide are facing the threat of extinction. A few examples of **extinct species** are dinosaurs and mammoths.

Though extinction is a natural phenomenon, man's interference hastens the rate of extinction. Figure 7.7 shows the causes of **biodiversity losses**.

Habitat destruction	The **natural habitat** of many resident species is being destroyed by humans for various purposes. The **developmental activities** like construction of factories, dams, roads, industries, factories, etc. threaten resident species and ecosystems. They have scared wild animals and limited their movements. The examples of habitat destruction are **deforestation** and **desertification**. Deforestation occurs as a result of human settlement, agriculture practices, fuel wood demand and demand of wood for industries and other commercial purposes. This changes the ecosystem significantly and results in a significant loss of biodiversity. The loss of biodiversity and trees alters the ecosystem and can result in **aridity and erosion**. It also results in climate change and extinction, and it can lead to desertification if on a significant enough scale. The social impacts can include **displacement of indigenous people**.
Pollution	**Pollution** is the **contamination or disruption** of the natural environment through the emissions of harmful substances. It is mostly associated with **anthropogenic sources** but can also occur from natural activity, such as volcanic eruptions. Pollution affects and alters the habitat. For example, presence of pesticides can upset the food chain. Pollution impacts **air, water, and land**. Pollutants include domestic, industrial, and agricultural waste. It comes in many different forms and can be chemical substances or noise, heat, or light.
Climate change	**Climate change** is one of the greatest threats to **sustainability** of biodiversity. The earth's climate fluctuates over time due to a variety of factors. There is a significant body of **scientific research** that indicates that global temperatures are rising. The rising global temperatures are directly linked to human activities which involve **greenhouse gases** (**GHG**) **emission**. **GHG** traps heat in the atmosphere and make the place warmer and habitable. One of the main **GHG** is **carbon dioxide** (**CO_2**), which is a vital gas in our earth system and is released from various sources, including the combustion of fossil fuels. Due to rapid industrialization, burning of fossil fuels and deforestation has resulted in significant increase of greenhouse gas concentrations in our atmosphere.
Habitat fragmentation	It is the **fragmentation** of a large habitat into smaller habitats. Many species of mammals such as bears, elephants and species of birds are unable to adapt to the change. Small population are more vulnerable to diseases and competitions.
Hunting	Wild animals are hunted for **products** such as hides, skin, tusk, fur, meat, medicines, etc. **Excessive hunting** leads to loss of biodiversity. For example, excessive poaching of large mammals such as chimpanzee, gorilla and orangutan in central Africa and East Asia has reduced the population in great numbers.

Overexploitation	**Overexploitation** is the consumption of a natural resource at a rate greater than that natural resource can maintain itself. It is the main cause of **loss of biodiversity**. Many economically important and biologically interesting species such as **insectivorous plants** are **overexploited**. Many plants of **medical value** were also over exploited. In our country, collection of *Yartsa goenbub* and *Thogsumpa* for medical value may in long run lead to significant decrease in numbers of these plants. **Land degradations** are human-induced changes that impair the capacity of the land to sustain life. **Deforestation** and **overgrazing exploit** the land and result in the exceeding of sustainable yield.
Introduction of exotic species	**Exotic species** are organisms introduced from another place to a local area. Exotic species compete for food and space with the native species and eliminate them. For example, about 200 native species of small fish were eliminated in Lake Victoria in East South Africa due to the introduction of exotic predatory fish, Nile perch. **Invasive species** are brought on by transporting species either intentionally or accidentally from other areas of the world. Introduction of exotic species may outcompete native species in the ecosystem, leading to the **decline or extinction of local species** and **overpopulation** as these invasive species may not have any predators in this new ecosystem. They also can be a major economic cost.
Control of pest and predators	The various pest and predator controls measures cause severe imbalance in the ecosystem.
Extinction of species	A species may become extinct naturally because of sudden environmental changes and population characteristics. Extinction is of following types: **natural extinction**, **mass extinction** and **anthropogenic extinction**. Natural extinction involves the slow process of disappearance of species due to change in environment. Mass extinction is the disappearance of a large number of species because of a catastrophe. For example, extinction of dinosaurs. Anthropogenic extinction is the extinction of species due to human activities. The extinction of Indian cheetah is an example of extinction due to hunting by man.

Figure 7.7: Causes of biodiversity loss

e. Sustainability of biodiversity

Biodiversity is the foundation on which the future well being of human society depends. Humans have the ability to **exhaust natural resources**, leaving nothing but polluted water and infertile soil for future generations. Therefore, all humans must use resources wisely and efficiently so that these resources never become **exhausted** or **over polluted**. This can only be achieved by the process of sustainable development.

Sustainable development is the **development that meets the needs of the present generation and conserves resources for the future generation**. Sustainable development should include – *reducing excessive use of resources* and *enhancing resource conservation*, *recycling and reuse of waste materials*, *scientific management of renewable resources*, especially bio-resources, *planting more trees*, green grassy patches to be interspersed between concrete buildings, using more **environment friendly material or biodegradable material** and u**se of technologies**, which are environmental friendly and based on efficient use of resources.

Some of the common strategies of conservation of the biodiversity include: **in-situ conservation and ex-situ conservation.**

i. In-situ conservation strategies

In-situ conservation is the conservation of wild animals and plants in their natural habitat. The **aim** of the *in-situ* conservation is to allow the population to continue itself within the community environment through adaptations. The *in-situ* conservation of plant genetic resources has a number of advantages as compared to ex-situ conservation. For example, *in-situ* conservation is suitable for species, which cannot be established or regenerated outside the natural habitats. *In-situ* conservation is done by providing protection to biodiversity rich areas through a network of protected areas. In Bhutan, the protected areas include:

1. ***Ramsar sites and world heritage sites***

Ramsar sites are the **wetlands of international importance** as per the Ramser Convention, which came into force for Bhutan on 7 September 2012. Bumdeling and Khotokha are two designated rasmar sites with a total surface area of 256 hectares.

A ***world heritage site*** is a place that has a special cultural or physical significance as per the **United Nations Educational, Scientific and Cultural Organization** (**UNESCO**).

2. ***National parks***

A national park is a **reserve of land, usually owned by a national government**. It is an area of land, which is declared public property to preserve and develop for

the purpose of **recreation** and **culture**. It is protected from human developmental activities and pollution. **Yellowstone National Park** in the USA was the world's first protected area. Bhutan has five national parks namely, **Jigme Dorji Wangchuck National Park, Jigme Singye Wangchuck National Park, Royal Manas National Park, Thrumshingla National Park and Wangchuck Centennial Park (WCP). The largest national park of Bhutan is Wangchuck Centennial Park (WCP)**.

3. ***Sanctuaries***

A sanctuary is a **reserved area for the protection of wildlife**. Collection of forest products and cutting tress for timber are allowed provided they do not affect animals. Bhutan has four wildlife sanctuaries namely, **Bumdeling Wildlife Sanctuary, Jomotsangkha** (earlier known as **Khaling) Wildlife Sanctuary (JWS), Phibsoo Wildlife Sanctuary,** and **Sakteng Wildlife Sanctuary**.

4. ***Nature reserve***

Jigme Khesar Strict Nature Reserve, covering 609.51 square kilometres, protects Bhutan's western temperate forests from broadleaf forests to alpine meadows. Its altitude ranges from 1,400 to 4,800 meters, and includes the small lakes of *Sinchulungpa*. Unlike Bhutan's other protected areas, *Torsa* has no resident human population.

5. ***Biological corridors***

Biological corridors mean **preserving connectivity between the protected areas with significant biodiversity to prevent the fragmentation of habitat**. Protected areas that are isolated from other protected areas may become ineffective for species conservation due to habitat fragmentation. Therefore, in order to avoid losing biodiversity, areas which are important to ensure the safe movement of wildlife between one protected area to one or more protected areas are referred to as biological corridors.

Currently, there are *nine* biological corridors in Bhutan that link all the protected areas. These corridors make up 8.6% of the country's total area. Human activities such as new settlements, quarrying, mining and leasing of land for grazing in the corridors are strictly prohibited.

6. ***Sacred Forests and Lakes***

Sacred forests or **lakes** are small patches of forest or area, which are conserved through man's spiritual belief and faith. Forests land cover 71 percent of Bhutan's total landmass. Our country has about 677 glaciers containing 2,674 glacial lakes which are also the sources to some of the largest river basins in the country. These forests and lakes are considered sacred and have **cultural** and **spiritual** significance since time immemorial.

ii. Ex-situ Conservation strategies

Ex-situ conservation is the conservation of plants and animals in locations **outside their natural habitats**. It includes the collection and conservation of species in specific locations such as *botanical gardens, zoos, safari parks, aquaria* and in institutes such as *gene banks*. Many species of plants and animals are conserved in **botanical gardens** and **arboreta**. Arboreta are gardens with trees and shrubs. Seed banks and tissue culture facilities have helped in conserving many specimens.

1. ***Gene bank conservation***

Bhutan National Gene bank was established in 2005. Gene bank is a p**lace where valuable plant material likely to be lost in the wild is preserved**. Gene banks conserve seeds, vegetative parts of plant, etc. It also includes *botanical gardens, zoological parks, orchards, aquariums, tissue culture centres*, etc. Cryopreservation is a technique useful for preserving vegetative propagated crops such as potato, seeds of plants, and for preserving sperms, eggs, embryonic tissues of animals. It involves the storage of specimen in liquid nitrogen at -196°C.

2. ***Restoration of species and populations***

Reintroduction of captive bred animal and plant species in zoos and parks have increased the number of endangered species and save them from extinction. For example, Bhutan has initiated **tiger species restoration**.

3. ***Ecosystem and landscape restoration***

Ecosystem restoration has mainly been practised on extremely degraded sites such as mine sites, spoil heaps and municipal dumps. Sometimes, restoration involves the replacement of the plant community, generally by plantings and taking care of perennial species in the hope that fauna will return. Increasing efforts are also being made to re-establish animal and soil communities as part of the reintroduction process.

Landscape restoration aims at **improving the design of the existing system by increasing the habitat area and connectivity and by providing buffer zones around the existing fragments to protect them from external influences**.

f. IUCN or International Union for the conservation of Nature and resources

The **International Union for the Conservation of Nature and resources** (**IUCN**), founded on October 5, 1948, is a leading international institution in the field of sustainable use and conservation of biodiversity. The headquarters is located at Morges, Switzerland, and has over 70 member organisations, both government and non-government agencies. The **IUCN** maintains a Red Data Book of animals and

plants that face the risk of extinction throughout the world. About 25 species of mammals and 14 species of birds found in Bhutan are in the **Red Data List**.

g. The Bhutan Trust Fund for Environment Conservation (BTFEC)

The **Bhutan Trust Fund for Environment Conservation** (**BTFEC**) is the world's first environmental trust fund in Bhutan, established in 1992 as a collaborative venture between the **Royal Government of Bhutan, United Nations Development Program,** and **World Wildlife Fund**. Today, it is a conservation grant making organisation autonomous of the government. The trust fund is governed by the **Royal Charter** of 1996 and a high-level management board. It provides grants to governmental and non-governmental organisations to support environmental initiatives. The Royal Society for Protection of Nature (RSPN) is a **non-government organisations** (NGOs) involved in the conservation of biodiversity in Bhutan. It works on environmental education and advocacy, conservation and sustainable livelihoods, research and addressing emerging issues like climate change, solid waste and water.

Biodiversity acts and policies for conservation in Bhutan

The Royal Government of Bhutan has enacted and has been revising acts and policies on biodiversity. *Some of the conservation acts and policies are mentioned below.*

1. Bhutan pledged to maintain at least **60 percent** of land as forests for all times to come.
2. Enacted the National Plant Quarantine Act, 1993, to control the movement of diseases, insects and other pests.
3. Included provisions for establishing **protected areas** and **conservation regulations** in the Forest and Nature Conservation Act, 1995.
4. Ratified in 1995, the international convention on **Biological Diversity and Climate Change**.
5. Adopted the **National Biodiversity Action Plan** in 1998.
6. Adopted the **Middle Path**, a National Environmental Strategy in 1998.
7. Initiated in 1998, a **National Biodiversity Program** to oversee ex-situ conservation and sustainable utilization of biodiversity.
8. Legislated in 2000, the **Environmental Assessments** for all development and industrial activities.
9. The establishment of **Nature Conservation Division** within the Department of Forestry Services, with a mandate to oversee and manage the protected areas system.

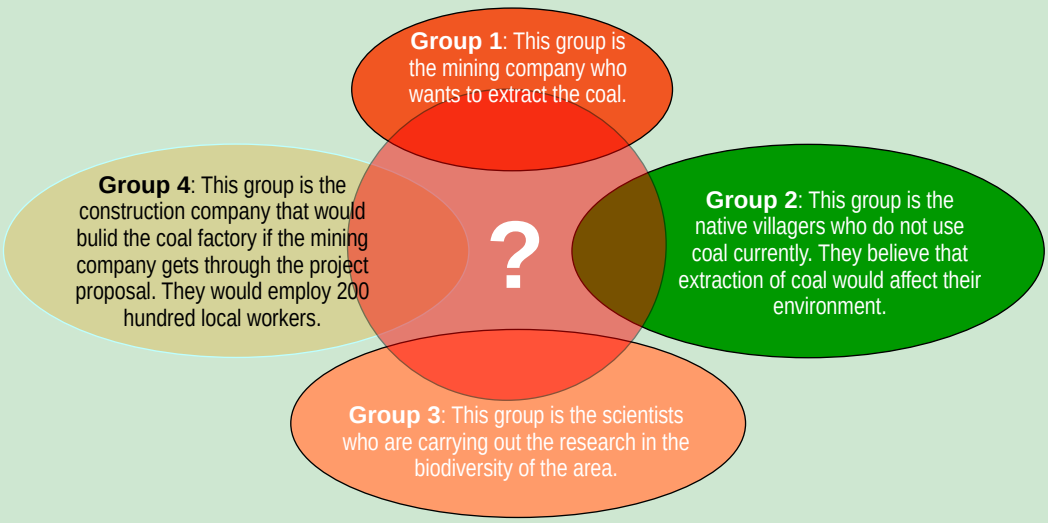
Activity 7.4

Panel discussion

1. Divide the class into four groups, conduct a panel discussion on the following scenario:

A mining company has discovered a large deposit of coal in a pristine area of Northern Bhutan that features high biodiversity. A native village currently lives on the site of the discovery. Try to reach consensus on what should be done.

2. Each group makes their views on the argument assigned as in the Figure below.



Questions

i. Why do groups have different views on the negative impacts of mining on biodiversity?

ii. How would decisions taken affect the biodiversity?

iii. If the decision is for the coal mining to go ahead, what compromises will you suggest to ensure that the impact on the biodiversity is minimum?

iv. How would the decision impact the local community?

Lesson Summary

- Ecosystem comprises of living and non-living components.
- The role of the autotrophs is to convert inorganic substances into organic substances.
- Heterotrophs depend on consumers directly or indirectly for food.
- Decomposers help to recycle nutrients on the Earth.
- Food web includes one or many food chains.
- Grazing food chain starts from producers and ends at carnivores.
- Detritus food chain starts with dead organic matters and passes through detritus feeders in the soil such as earthworms, bacteria and fungi.
- The energy flows from one trophic level to the next trophic level in an ecosystem.
- The dependence of one organism to another organism in an ecosystem is called ecological dependence.
- Mutualism and commensalism are examples of positive interaction.
- Negative interaction includes parasitism, predation and competition.
- Biodiversity includes a variety of life forms on the Earth.
- Biodiversity is the source of food for all living organisms.
- In-situ conservation involves the conservation of wild animals and plants in their natural habitat.
- Ex-situ conservation is the conservation of plants and animals outside their natural habitats, such as in labs, etc.
- Red Data Book has lists of animals and plants that are at the risk of extinction.

Weblink

- https://sustainabledevelopment.un.org/topics
- https://sustainabledevelopment.un.org/post2015/transformingourworld
- http://www.nature.com/scitable/knowledge/library/species-interactions-and-competition-102131429
- https://www.youtube.com/watch?v=6tUHNT6fvcE
- https://www.youtube.com/watch?v=SDlowkyqTqw

Review Questions

A. Each question in this part is followed by four possible choices of answer. Choose the correct or the most suitable response.

1. Researchers found that many plants prevent the growth of other plants in their habitat by releasing chemicals such as quinine, caffeine, etc. that kill other plants. This type of relationship is an example of

   A. mutualism.
   B. parasitism.
   C. interspecific competition.
   D. intraspecific competition.

2. The Bhutanese Government does not allow travelers from foreign countries to bring plants, fruits, vegetables, animals or other living organisms into the country. One of the main reasons for keeping exotic species out of the country is to

   A. increase native species population.
   B. prevent from pollution of ecosystem.
   C. conserve and protect native species from extinction.
   D. prevent form hybridization of native species with exotic species.

3. Which type of organism is not shown in the following representation of a food chain?

   grass → grasshopper → sparrow → hawk

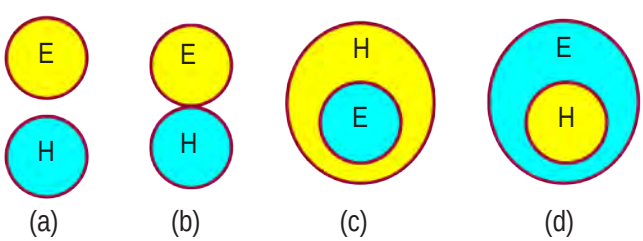
   A. Carnivore
   B. Producer
   C. Decomposer
   D. Herbivore

4. Most of the minerals within an ecosystem are recycled and returned to the environment by the direct activities of organisms known as

   A. producers.
   B. decomposers.
   C. primary consumers.
   D. secondary consumers.

5. Which diagram below represents the most appropriate relationship between humans (H) and ecosystems (E).

   A. (a)
   B. (b)
   C. (c)
   D. (d)



6. Aerobic organisms are dependent on autotrophs. One reason for this dependency is that most autotrophs provide the aerobic organisms with

   A. oxygen.
   C. nitrogen gas.
   B. hydrogen.
   D. carbondioxide.

7. A student while hiking took the photograph given below. This is an example of a type of relationship known as

   A. parasitism.
   B. mutualism.
   C. predator-prey.
   D. commensalism.

8. A pond ecosystem contains big fish, small fish, midges, caddis flies, stone flies and algae. If you remove big fish that eats other organisms in pond from the ecosystem, what will be the first probable observable results?

   A. Algae population will increase.
   B. Small fish population will increase.
   C. The number of midges, caddis flies and stone flies will increase.
   D. The number of midges, caddis flies and stone flies will decrease.

9. Humans have impacted ecosystems in many ways. The most positive impact on an ecosystem would result from

   A. planting only economically valuable trees and plants.
   B. planting trees and plants that are from another ecosystem.
   C. planting many different plants that are native to the area in a barren land.
   D. filling in a landfill and planting grass and trees.

10. A new stone quarry is opening near your village. It will have some negative environmental impacts. Villagers would most likely give their approval because the negative impacts would be compensated by

   A. increase of noise pollution.
   B. release of people's participation.
   C. creation of new employment opportunities.
   D. increase of communal harmony.

B. Fill in the blanks with the correct form of word(s).

1. The attempt of two organisms to utilize the same resource is called ….....…..
2. In a particular area, living organisms and non-living environment function together as …….....
3. Human obtains food from plants and plants in turn use carbon dioxide released by humans. This dependence of individual organism to one another in an environment is known as ……
4. The protected areas of Bhutan are connected by strips of protected land, known as ……..
5. Lists of animals and plants in the Red Data Book are at the risk of …….

C. Write TRUE or FALSE against the following statements.

1. A community is made up of populations of different species which interact with each other.
2. All of the fish of same species living in the rivers of Bhutan is called population.
3. Crows in your locality help to keep the environment clean by feeding on the flesh of dead animals.
4. Decomposers are important in the environment because they convert large molecules into simpler molecules that can then be recycled.
5. The number of species in tertiary consumers is always more than the number of species in primary consumers.

C. Differentiate between the following pairs of words.

1. Ex-situ conservation and in-situ conservation.
2. National park and sanctuary.
3. Genetic diversity and species diversity.
4. Endo-parasites and ecto-parasites.
5. Grazing food chain and detritus food chain.

D. Answer the following questions.

1. If you create an artificial pond ecosystem near your house, what biotic factors and abiotic factors would you include in it.
2. Write two importance of biodiversity acts and policies of Bhutan.
3. Name two ex-situ conservation strategies of Bhutan.

4. Human activities continue to have impact on the environment. One of the negative impacts on the environment is the loss of biodiversity. Humans are involved in both the problem and the possible solutions.

   i. Define the term biodiversity.

   ii. Explain a few problems created by humans.

   iii. State one negative effect on humans if biodiversity continues to be lost.

   iv. Suggest one practice that could be used to preserve biodiversity in the cities of Bhutan.

5. Figure 6. 15 represents a partial food chain. The graph on the right shows the interaction of two populations A and B in the food chain. Study and answer the questions that follow.

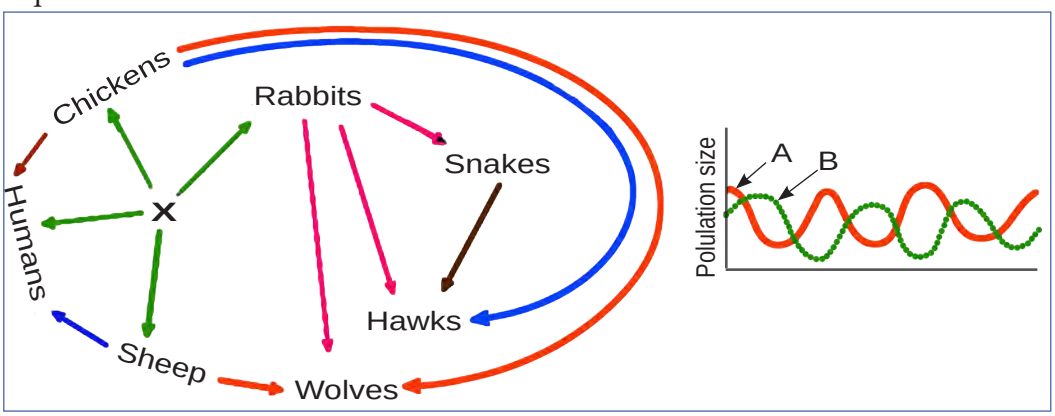


Figure 6.15 Food chain

   i. What does letter 'X' represent in Figure 6.15.

   ii. Why should humans be a part of the food chain?

   iii. Population A represents living animals. The members of population B feed on these living animals. Identify the members of population B?

   iv. Identify one heterotroph from the food web that could be a member of population A.

6. Explain how in-situ conservation and ex-situ conservation strategies will lead to sustainability of biodiversity.

7. Article 5:3 of the Constitution of the Kingdom of Bhutan states that

   "The Government shall ensure that, in order to conserve the country's natural resources and to prevent degradation of the ecosystem, a minimum of sixty percent of Bhutan's total land shall be maintained under forest cover for all time."

i. What could be the main objective of including Article 5:3, in the Constitution of the Kingdom of Bhutan?

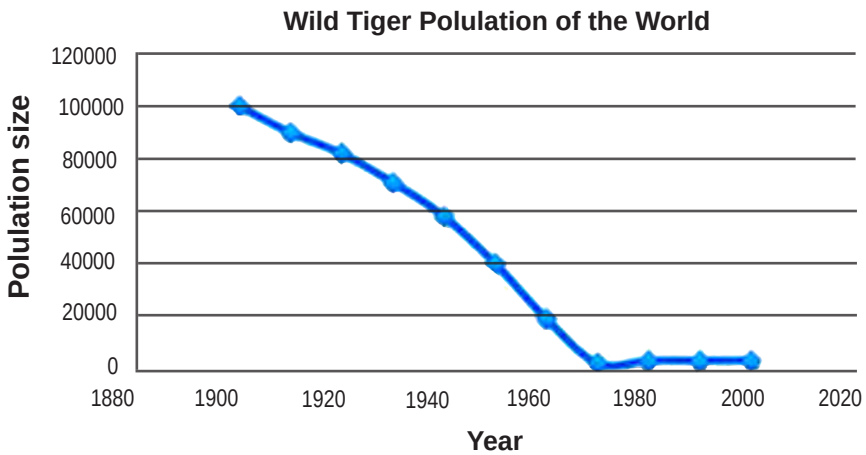
ii. What benefits are there for Bhutan by adopting Article 5:3?

iii. Explain briefly, how maintaining a minimum of 60% forest cover at all times would affect the economic development of the country?

iv. How would this article affect the lives of indigenous people?

v. Do you think this article needs to be changed after 100 years or so? Why?

8. The graph below shows changes in the tiger population of the world over 100 years. Study and answer the questions that follow.



i. How many wild tigers were there in the year 1920? What could be some of the reasons for the high number of tiger population?

ii. In which year there was more tiger death than they could reproduce?

iii. Mention three human activities that would have caused the decline of tiger population from the year 1900 to1970.

iv. Why is tiger conservation important for Bhutan?

9. Consider the following hypothetical situation and answer the questions that follow.

An area has a diverse ecosystem and is, therefore, home to a wide range of flora and fauna. The area contains over 80 kinds of trees and thousands of species of mammals, birds, reptiles and insects. A few species living there have not yet been classified and studied. The area could be a commercial source of food as well as a source of medicinal and household products. However, most of this forested area is not accessible because of a lack of roads and therefore, little commercial use has been made of this region. The building of paved highways into and through this area has been proposed.

i. State one possible impact on biodiversity.

ii. The animal mortality may increase due to road kills. State one action that can minimize road kills.

iii. Give one possible action that the road builders could take to minimize human impact on the ecology of this region.

iv. Roads can have a number of indirect impacts such as habitat fragmentation. For example, some snakes have been found to turn around and not cross the road when they encounter it. Some animals avoid the surface of the road even when there are no cars driving on it. Write short argumentative points against the road construction proposal.

10. Lekphel and Seldon are two friends. In their daily life both have different opinion on certain matters. Considering the necessity of sustainable development, answer the questions below.

Lekphel says - Polythene bags should be used to carry vegetables.

Seldon says – Jute bags should be used to carry vegetables.

i. Who do you think is right and why?

ii. Relate Bhutan's ban on use of polythene bags with Lekphel's opinion.

Sample Question Paper

Biology **Writing Time**: 2 Hours

Class X **Total Marks**: 100

READ THE FOLLOWING DIRECTIONS CAREFULLY:

1. Do not write during the first fifteen minutes. This time is to be spent on reading the questions. After having read the questions, you will be given two hours to answer all questions.
2. In this paper, there are two sections: A and B. Section A is compulsory. You are expected to attempt any five questions from Section B.
3. The intended marks for questions or parts of questions, are given in brackets [ ].
4. Read the directions to each question carefully and write all your answers in the answer sheet provided separately.

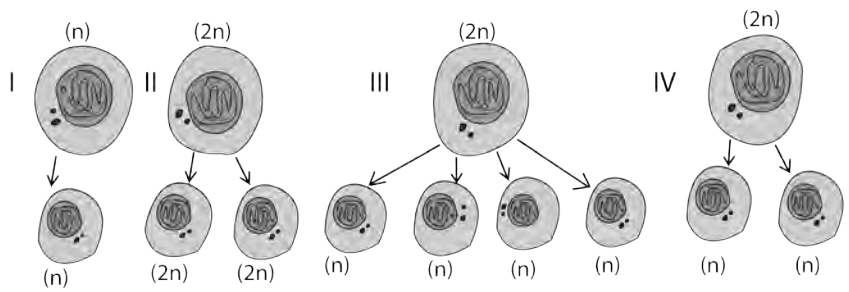
Section A (50 Marks)

Compulsory: Attempt **all** *questions.*

Question I

a. Each question in this section is provided with four possible options. Choose the most appropriate option.

1. Which of the following diagram best represents meiosis? **[1x25=25]**



A. I. C. III.

B. II. D. IV.

2. Which of the following organs is paired with its incorrect function?

A. Stomach-protein digestion. C. Large intestine-bile production.

B. Oral cavity-starch digestion. D. Small intestine-nutrient absorption.

3. Which one of the following is the least important in preventing the contamination of food?

A. Keeping food away from flies. C. Not coughing or sneezing over food.

B. Washing hands before preparing food. D. Not smoking while preparing food.

4. Speciation involves accumulation of variations in a population. Which one is not a factor responsible in the formation of new species?

   A. Mutation.
   C. Natural selection.
   B. Gene pool.
   D. Genetic drift.

5. A liquid extracted from the stomach was mixed with some finely ground meat and kept at body temperature. After 2 hours, the meat had disappeared. This is possible because of the presence of an enzyme called

   A. lipase.
   C. amalyse.
   B. protease.
   D. nuclease

6. The facts of commercial uses of plant hormones are

   [root initiation, parthenocarpic fruit development, delay of pre-harvest fruit drop,use as weedicides, flowering and ripeing of fruits, delay ripening, increase crop yield]

   Which of the following hormone would a farmer used to increase a yield in grapes and tomatoes?

   A. Ethylene gas.
   C. Gibberellin.
   B. Auxin.
   D. Abscisic acid.

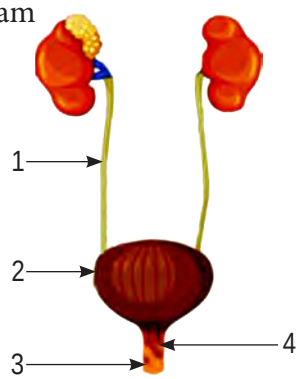
7. Antibiotics are helpful in treating an infection when the number of bacteria becomes too large for the body's immune system to fight on its own. What process enables the bacteria to multiply inside the body?

   A. Binary fission.
   C. Meiosis.
   B. Fertilization.
   D. Nitrogen fixation.

8. An ideal drug against an infectious disease would be one which destroys the pathogen but does not harm the

   A. host
   C. both host and pathogen.
   B. pathogen.
   D. None of the above.

9. Choose the correct combination of labelling in diagram below.



   A. 1-ureter, 2-urinary bladder, 3-urethral sphincter, 4-urethra.
   B. 1--urethra, 2-urinary bladder, 3-urethral sphincter, 4-ureter.
   C. 1-ureter, 2-urinary bladder, 3-urethra, 4- urethral sphincter.
   D. 1- urethra, 2-urinary bladder, 3-ureter, 4-urethral sphincter.

10. The following equation is a summary of an important biochemical process in plants.

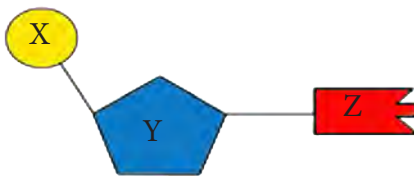
$$6H_2O + 6CO_2 \xrightarrow{\text{energy}} X + 6O_2$$

The product, X, in this biochemical process is

A. ATP.
B. a glucose.
C. an amino acid.
D. glycerol.

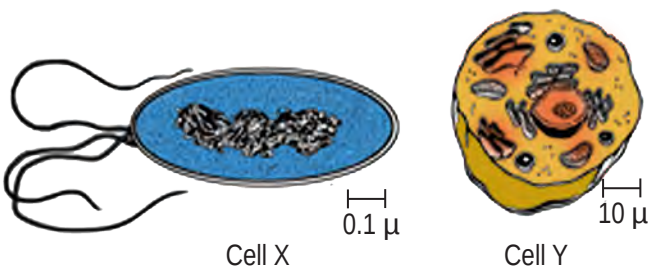
11. Figure below represents a nucleotide with subunits X, Y and Z.

This nucleotide could be identified as a DNA but not RNA if



A. Y is ribose.
B. Z is thymine.
C. X is phosphate.
D. Z is paired with cytosine.

12. Which of the following statements best identify these two cells?



A. Cell X is a prokaryote cell and Y is a eukaryote cell.
B. Cell Y is a prokaryote cell and X is a eukaryote cell.
C. Cell X is a plant cell and Y is an animal cell.
D. Cell X is a virus and Y is an animal cell.

13. A partial Punnet square is shown below.

AA	AA
Aa	Aa

Which of the following statements describe the parental genotypes that would result in this Punnett square?

A. Both parents are heterozygous.
B. Both parents are homozygous dominant.
C. One parent is homozygous dominant and the other parent is heterozygous.
D. One parent is homozygous recessive and the other parent is heterozygous.

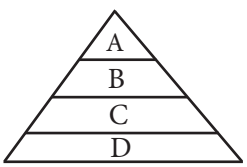
14. Which cross would produce phenotypic ratio of 3:1?

A. TT x tt
B. TT x Tt
C. Tt x Tt
D. tt x tt

15. Imported animal species often disrupt an ecosystem because in their new environment, they will most likely

A. have no natural enemies.
B. be unable to produce offspring.
C. eliminate the genetic variation of the autotrophs.
D. increase the number of mutations in the herbivores.

16. In an ecosystem, if birds eat insects that feed on corn, which level in the pyramid would birds occupy.



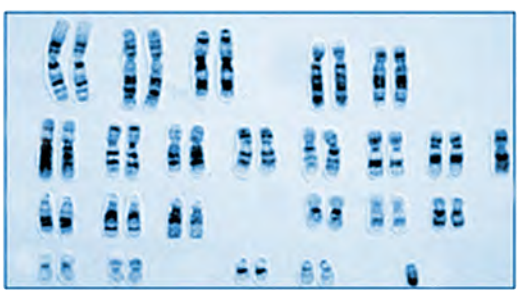
A. A
B. B
C. C
D. D

17. Trace out the non-related effects of adrenaline.

A. Increase heart rate.
B. Increase the blood sugar level.
C. Dilates the pupils.
D. Increase the mobility of sperm cell.

18. The following ultrasound image shows a fetus at the week 12th week stage of its development.

The area J surrounding the fetus contains amniotic fluid which includes skin cells from the fetus. A small sample of amniotic fluid can be extracted and the skin cells cultured. The following image is of a karyotype prepared from cultured skin cells of the fetus in the photograph. Study and answer the question.



Examination of the karyotype reveals that the fetus

A. is a male.
B. has a defective allele.
C. has an extra X chromosome.
D. has three number 13 chromosomes.

19. Which activity would reduce biodiversity in a forest ecosystem?

A. planting plants that are naturally resistant to insects.
B. protecting wildflowers from logging activities.

C. replacing harvested trees with young trees that are naturally found in the forest.

D. clearing a large area and planting one species of hardwood tree that can be used for timber.

20. The correct sequence of reflex arc during the pupil eye reflex is

A. light receptors → optic nerve → motor neuron → relay neuron → effector (iris muscle).

B. light receptors → sensory neuron → relay neuron → motor neuron → effector (iris muscle).

C. effector (iris muscle) → light receptors → sensory neuron → relay neuron → motor neuron → receptor

D. light receptors → motor neuron → relay neuron → sensory neuron → effector (iris muscle).

21. Growth of several trees and plants together in your backyard or garden is the best example of

A. parasitism.
B. commensalism.
C. interspecific competition.
D. intraspecific competition.

22. Which among the following does not describe how minerals occur in the soil?

A. Mineral ions in soil solution.
B. Mineral ions in humus.
C. Mineral ions on clay particles.
D. Mineral ions between the soil particles.

23. As a doctor, you would advise that STIs can be 100% prevented by

A. use of contraceptives.
B. abstinence.
C. vaccination.
D. immunisation.

24. Organic food materials are transported through plant stems in

A. vascular bundles.
B. the xylem.
C. phloem.
D. sieve cell.

25. Which population of organisms would be in the greatest danger of becoming extinct?

A. A population of organisms having few variations living in a stable environment.

B. A population of organisms having few variations living in an unstable environment.

C. A population of organisms having many variations living in a stable environment.

D. A population of organisms having many variations living in an unstable environment.

b. *Match each item under Column A with the most appropriate item in Column B. Rewrite the correct matching pairs in the answer sheet provided.* **[1x5=5]**

Column A	Column B
Allopatric species	fertility treatment
Sympatric species	speciation
Hormone therapy	ecologically isolated
Gene flow	geographically isolated
IVF	estrogen and progesterone

c. *Fill in the blanks.* **[1×5=5]**

i. A nutrient in the food which is too large to pass through the blood vessel but absorbed through the lacteals is.....

ii. The chemical substances produced in white blood cells that neutralise or destroy foreign substances in the blood such as bacteria or their product is.....

iii. Increase wild life management and habitat protection represents an attempt to prevent certain species from becoming.....

iv. The human body regularly sheds and replaces its skin cells. The process that is directly responsible for replacing these cells is.....

v. A farmer crossed a rose plant that bears red flowers with that of a rose plant that bears white flowers. All offspring obtained gave half white and half red flowers. This process of crossing two varieties with different characters to obtain a new variety is called..... cross.

d. *State whether the following statements are 'True' or 'False' and correct the false statements.* **[1x5=5]**

i. Geographic isolation can lead to physical separation of populations that prevents interbreeding and mixing of gene pools.

ii. Carbon dioxide is given off to the surrounding by organisms that perform aerobic cellular respiration.

iii. If you apply scent, your friends would be able to smell it because of diffusion.

iv. If the number of consumer decreases, the number of producer will also decrease.

v. In a molecule of double-strand DNA, the amount of adenine present is always equal to the amount of thymine.

e. *Answer the following questions.*

i. Copy and complete the table below. **[4×0.5=2]**

Components of Blood	Characteristics	Function
Plasma	.....	.....
.....	They are oval, larger and have clearly defined nuclei. They are not red in colour.	.....

ii. Define biodiversity? **[1]**

iii. Explain family planning in your own words. **[1]**

f. *Give reasons.* **[2×2=4]**

i. NPK are essential minerals.

ii. Competition within the member of same or different species is considered as negative interaction.

g. N*ame the following* **[4×0.5=2]**

i. The part of the human digestive system, where both physical breakdown and chemical breakdown of food first begin.

ii. An ecological unit in a given area where populations interact.

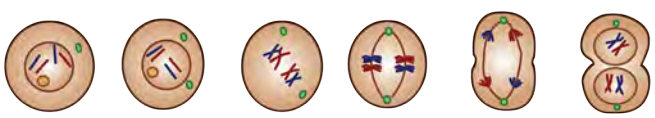
iii. The stage of the cell during which it gathers materials before cell division.

iv. A researcher is studying a particular disease-causing agent. The agent has a protein coat, but it lacks a nucleus, contains no other organelles, and can reproduce only when it is inside a living cell.

Section B (50 marks)
Attempt only FIVE Questions

Question 2

a. Study the diagrams below and answer the questions that follow:



i. Identify the type of cell division. Give one reason to support your answer. **[1]**

ii. Name the phases A, C, D and E. **[1]**

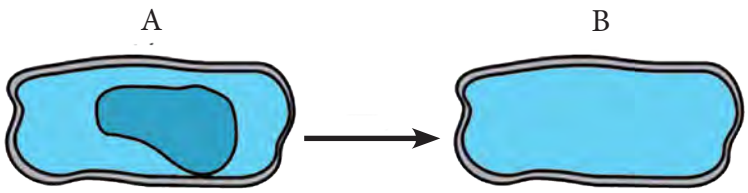
iii. Name the cell organelle that forms 'aster'. **[1/2]**

iv. What is the significance of phase A? **[1/2]**

v. What is the main feature in phase D? **[1/2]**

vi. Name one tissue in the human body, one in a flowering plant, where you would find this type of cell division. **[1/2]**

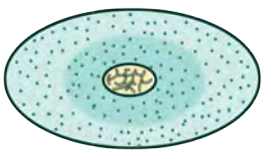
b. A student prepared a wet-mount slide of some red onion cells and then added some salt water to the slide. The student observed the slide using a compound microscope. Diagram A is typical of what the student observed after adding salt water.



An onion cell in salt water An onion cell after rinsing with distilled water

Copy and complete the diagram B to show how the contents of the red onion cells should appear if the cell were then rinsed with distilled water for several minutes. **[1]**

c. Figure below is an outline of a human cell. **[1]**



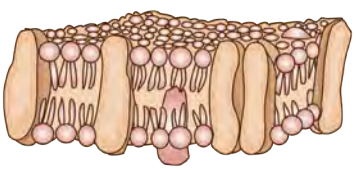
i. Copy the diagram and make one further drawing to show how the cell would appear if it were to be immersed for a few minutes in a solution with

(a) a higher osmotic potential (water potential) than its own cytoplasm.

d. Diagram below shows a cross section of part of a cell membrane. Study and answer the questions that follow. **[1x2=2]**

i. Describe the basic structure of the cell membrane.

ii. Describe the function of protein.



e. Define hydroponics? **[1]**

f. What is in-situ conservation? **[1]**

Question 3

a. In designing an experiment to find out whether light is needed for photosynthesis:

i. what is the principle of the design. **[1/2]**

ii. lists the steps of the procedure. **[1]**

iii. what control would you use? **[1]**

iv. write any one precaution. **[1/2]**

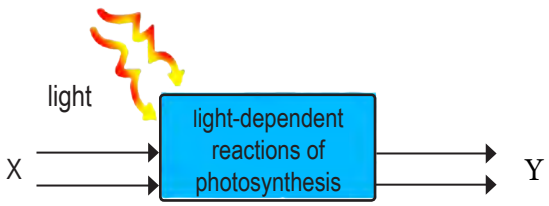
b. What are the important differences between the source and the sink region of the plant as regarded by the pressure flow hypothesis? **[2]**

c. Write one commercial application of each of the following. **[1x2=2]**

i. Auxin

ii. Ethylene

d. Figure below shows a simplified representation of the first stage of photosynthesis. **[1x3=3]**



i. Where in the plant cell would the first stage of photosynthesis occur?

ii. Name one input item that X could represent.

iii. Name one output item that Y could represent.

Question 4

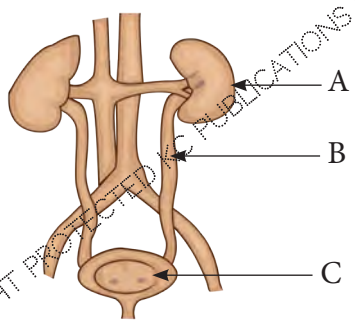
a. Study the human urinary system below and answer the questions that follow.

[1x3=3]

i. Name the fluid present in the part labelled B.

ii. Urea and carbon dioxide are excretory products of the human body. In the case of each product name a substance from which it is derived.

iii. Dawa was seriously injured in a vehicle accident. As a result, he had to remove part A from his urinary system. Does Dawa need haemodialysis? Why?



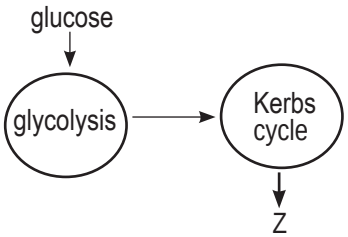
b. Name two enzymes present in the pancreatic juice. How does each help in protein digestion? **[2]**

c. The breakdown of glucose in aerobic respiration can be represented partially as shown below. Study and answer the questions that follow. **[1x3=3]**

i. Within a cell, where does the glycolysis stage of aerobic respiration occur?

ii. Describe what happens during the Krebs cycle.

iii. Identify the product Z.



d. Explain briefly about the exchange of substances between capillaries and tissue [2]

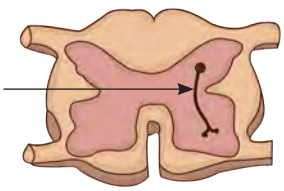
Question 5

a. Give one similarity between xylem parenchyma and phloem parenchyma. [1]

b. Explain why family planning is needed? [2]

c. Figure below shows a section through the spinal cord. Study and answer the question that follows.

Coordination of a reflex movement of the arm, in response to the hand touching a hot object, involves three neurons. One of these, the relay neuron, is shown in the Figure on the right.



i. Draw the diagram and complete the nerve pathway between the receptor and the muscle on the diagram by drawing and labeling: the sensory neuron and the motor neuron. [1]

ii. Draw and show the direction of nerve pathway. [1]

d. List down any four effects of adrenaline. [2]

e. Write two medical uses of sex hormones. [1]

f. State one biological benefit of preserving endangered species. [1]

g. State one way by which you would as an individual help Bhutan save endangered species from extinction. [1]

Question 6

a. AIDS is an infectious disease that has reached epidemic proportions. In your response include the following: [1x2=2]

i. the system of the body that is attacked by that pathogen.

ii. two ways to prevent or control the spread of AIDS.

b. Draw a structure of fungi and label the parts: hyphae, cell wall, stolon and rhizoids. [2]

c. Write the purpose of each of the following. **[1x2=2]**

i. TAB

ii. BCG

d. Bhutan's national parks are areas of spectacular beauty. Current laws usually prohibit activities such as hunting, fishing, logging and mining in these areas.

i. Choose one of the activities listed above and state one reason by which that activity could harm the ecosystem. **[1]**

ii. State one way by which allowing the activity you chose could benefit society. **[1]**

e. If you had to decide between allocating money to replant trees on a barren hillside above a village and to provide the village with petrol for its electric light generator, which would you choose? Why? In your answer, think about the relationship between environment and development. **[2]**

Question 7

a. Explain briefly the three main causes of genetic variation in sexual reproduction? **[3]**

b. The structure of DNA is directly linked to its function. Draw a diagram of DNA and label the parts: sugar, phosphate and two nitrogenous bases. **[2]**

c. Mendel carried out a monohybrid cross to examine the inheritance of the characteristic for seed colour. The dominant allele for yellow seed colour is Y, and the recessive allele for green colour is y. The two plants that were crossed were F_1 monohybrid Yy.

i. Draw a Punnett square to identify the ratios of traits that Mendel observed in the F_2 generation. **[1]**

ii. Write the phenotypic and genotypic ratio of F_2 generation. **[2]**

d. Speciation is the formation and origin of a new species. Explain any two mechanisms of speciation. **[2]**

Glossary

Abscission - the normal separation of a leaf, fruit, or flower from a plant.

Aldosterone - a hormone produced by the adrenal cortex; affects water balance by regulating sodium and potassium excretion.

Alimentary canal - the passage through which food passes, including the mouth, oesophagus, stomach, intestines, and anus.

Allopatric speciation - the formation of reproductively isolated species due to the divergence of populations that are geographically isolated from each other.

Asters - radial microtubule arrays found in animal cells that help to manipulate chromosomes during cell division.

Bile - a digestive chemical that is produced in the liver, stored in the gall bladder, and secreted into the small intestine.

Cellular respiration - a process by which cells obtain the energy stored in food.

Cellulose - a carbohydrate synthesized by plants.

Chitin - a polysaccharide that forms the exoskeleton of insects and other arthropods.

Chromatin - mass of genetic material composed of DNA and proteins that condense to form chromosomes during eukaryotic cell division.

Chyme - food in the stomach that is partly digested and mixed with stomach acids. Chyme goes on to the small intestine for further digestion.

Complete dominance - inheritance in which one allele for a trait is completely expressed over its paired allele.

Contraception - methods and devices used to prevent pregnancy.

Daughter cell - a cell resulting from the replication and division of a single parent cell.

Daughter chromosome - a chromosome that results from the separation of sister chromatids during cell division.

Diploid cell - a cell that contains two sets of chromosomes. One set of chromosomes is donated from each parent.

Donnan equilibrium (or **Gibbs-Donnan equilibrium**) - is a name given for the behaviour of charged particles near a semi-permeable membrane that sometimes fail to distribute evenly across the two sides of the membrane. The membrane is constructed such that it allows the passange of certain charged particles (ions) of the solution.

Electrical potential barrier - obstructive force for the flow of electrical charges or particles across the selectively permeable membrane. External energy must be applied to get the electrical charges to move across the membrane.

Fermentation - anaerobic oxidation of glucose.

F_1 generation - first filial generation resulting from the cross of first parental generation organisms.

F_2 generation - second filial generation resulting from the cross of F_1 generation individuals.

Foetus - a fertilized egg implanted in the womb that has grown beyond eight weeks.

Gene flow - the movement of genes from place to place. The term usually refers to movement in space but can also refer to movement between microhabitats or to introgression between the distinct populations or species.

Genetic code - code contained within segments of DNA that is transcribed and translated to produce proteins.

Genetic recombination - recombining of genes to produce organisms with new gene combinations.

Glycolysis - catabolism of glucose or other monosaccharides to pyruvate and 2 molecules of ATP in the absence of oxygen, or 34 molecules of ATP in the presence of oxygen.

Homologous chromosomes - chromosome pairs that are similar in length, gene position, and centromere location.

Hormonal contraceptives - prescription methods of contraception that use hormones to prevent pregnancy. These include the pill, implants, inter uterine devices, patch, vaginal ring and injectables.

Human papillomavirus (HPV) - a common, highly contagious virus spread by sexual activity and skin-to-skin contact in the genital area. Certain subtypes of HPV are responsible for most cases of cervical cancer; others cause genital warts.

Incomplete dominance - a form of intermediate inheritance in which one allele for a trait is not completely expressed over its paired allele.

Lacteal - is a lymphatic vessel in a villus of the small intestine which absorbs digested fats.

Light reaction - the phase of photosynthesis in which light energy is used to split water.

Light harvesting complexes (photosystems complexes) - multi-protein unit in the thylakoid membrane that absorbed light to serve as energy for chemical reactions.

Limiting factor - any environmental factor present in an environment that controls a process (growth, development, metabolic process, distribution)- by its decrease, increase, absence, or presence. For example, in a case of photosynthesis (metabolic process) in plants due to CO_2, temperature and sunlight.

Locus - a location on the genome. It may refer to a single nucleotide site or to a substantial stretch of DNA sequence.

Mendel's Law of Independent Assortment - allele pairs separate independently during the formation of gametes.

Mendel's Law of Segregation - allele pairs that separate during gamete formation randomly and fuse during fertilization.

Mesophyll cell - a type of plant cell located between the upper and lower epidermis of a leaf which is the site for photosynthesis.

Monosaccaride - a single sugar molecule.

Mutation - a heritable change in the genetic material of an organism that does not involve reciprocal recombination.

Nitrogenous waste -nitrogen containing waste.

Osmotic potential - in biology, the forces created by solutes in water to move in the direction of lower solvent activity. Water tends to move in the direction of a lower water potential across biological membranes.

Parthenogenesis – a type of asexual reproduction in which an unfertilized egg develops into an individual.

Phospholipid - a lipid containing a phosphate group in its molecule. Lipids are molecules that include fats, waxes, and some vitamins, among others. Each phospholipid is made up of fatty acids, a phosphate group, and a glycerol molecule.

Photons - in physics, photons are particles which transmit light. In other words, light is carried over space by photons.

Photolysis - (or **photodecomposition**) - is a chemical reaction in which a chemical compound is broken down by photons. For example, the photolysis of water molecule in photosynthesis occured under the influence of light.

Photosystem - a cluster of chlorophyll and other molecules in a thylakoid that harvest the energy of light for photosynthesis.

Plasmodesma (pl. plasmodesmata) - a connection between protoplasts of neighbouring cells through a canal in the cell walls.

Polysaccharide - a complex sugar molecule.

Purines - a class of nucleic acid bases including adenine (A) and guanine (G).

Pyrimidines - a class of nucleic acid bases including thymine (T), cytosine (C), and uracil (U).

Pyruvic acid – $C_3H_4O_3$, a three-carbon organic compound produced during the anaerobic phase of respiration.

Random segregation - during meiosis, the two chromosomes of a pair are distributed randomly to the gametes, each gamete having an equal chance of receiving either chromosome.

Reflex - is an involuntary or automatic action that an organism's body does in response to something (stimulus)-unconsciously.

Replication - exact duplication of DNA molecules.

Regeneration - in biology, it is the process by which an organisms replace or restore lost or amputated body parts.

Reproductive isolation - the separation of distinct gene pools, as a result of genetic differences that prevent successful interbreeding.

Sex chromosomes - chromosomes that determine the sex of an organism.

Sexually transmitted infections (STIs) - infections that are often or usually passed from one person to another during sexual or intimate contact.

Sister chromatids - two identical copies of a single chromosome that are connected by a centromere.

Speciation - the process by which new species are formed.

Spindle fibers - aggregates of microtubules that move chromosomes during cell division.

Sterilization - surgical methods of contraception that are intended to be permanent-blocking of the fallopian tubes for women or the vasa deferentia for men.

Substrate - the molecule upon which an enzyme acts.

Tonicty - is the concentration of a solution as compared to another solution. Concentration describes the amount of solutes dissolved by a solution.

True-breeding - an organism that only produces offspring with the same phenotypic traits.

Turgor pressure - the pressure that the water potential of an individual protoplast produces against the cell wall, which presses back with the same force.

Vascular bundle - a part of plant where water, nutrients, and organic molecules are transported. It consists of the phloem, xylem and cambium.

Villi - fingerlike projections that increase the surface area for absorption in the small intestine.