BIOLOGY

CLASS

NINE

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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 scientific ideas are always in flux changing as our understanding of the world changes.

This book contains many experiments to test hypotheses and to form accurate conclusion based on the real world results, BCSE prescribed syllabus concepts to explain the living world in terms of scientific principles and relevant hands-on activities for complete understanding of the scientific concepts and fulfilling the vision of Gross National Happiness.

The assessments at the end of every activity, sub-topics, topics and chapter include many competency based questions (CBQ) for developing better scientific ways of thinking for informed decision making. Other important features of this book includes a summary, weblinks and review questions at the end of every chapter, glossary and a model test paper at the end of the book.

The acknowledgement extends to ALL the people, who one way or another, contributed in enriching this book.

Author

Syllabus

1. Cells

- *Describe the basic structure of an animal cell and plant cell as seen under light microscope and relate this to their structures as seen under a compound microscope.*
- *Explain the need for staining.*
- *Explain how different cells (e.g. root hair cells, sperm cells) are adapted to their functions. Relate cells and cell function to life processes in a variety of organisms.*
- *Explain that the nucleus contains chromosomes that carry the genes.*

2. Humans as organisms

A. Nutrition

- *Explain the processes of digestion, including the adaptations of digestive organs to their functions.*

B. Circulation

- *Describe and label the basic structure of the heart, veins, arteries and capillaries.*

C. Respiration

- *Explain that respiration is a chemical reaction that releases energy from glucose and oxygen.*
- *Describe the basic structure of the breathing system (lungs, diaphragm, bronchi and alveoli) and its role in providing cells with oxygen for respiration.*

D. Nervous system

- *State the structure and function of the nervous system and explain the role of neurons in transmitting electrochemical impulses*
- *Explain why some neurons have a myelin sheath.*

E. Hormones

- *Name glands and the hormones they secrete.*

F. Homeostasis

- *Explain that it is important for human body to maintain a constant internal environment.*

- *Describe how humans maintain a constant body temperature.*

G. Health, disease and drugs

- *Describe the defence mechanisms of our body, including the role of the skin, blood and mucous membranes of the respiratory tract.*
- *Explain the effect of solvents, alcohol, tobacco and other drugs on our body functions.*

3. Green plants

A. Nutrition

- *Write the balanced chemical equation for photosynthesis.*
- *Explain the importance to healthy plant growth by the uptake and utilisation of mineral salts.*

B. Hormones

- *Name the basic plant hormones and describe their roles in the growth and development of plants.*

C. Transport

- *Explain transpiration in plants.*
- *Explain the transportation of substances within plants that are required for growth and reproduction.*

4. Variation, inheritance and evolution

A. Variation

- *Describe that variation arises from genetic causes, environmental causes, and a combination of both.*
- *Explain the basic principles of cloning, selective breeding and genetic engineering and consider the moral and ethical implications of these procedures.*
- *Explain that selective breeding and cloning can reduce variation within a population and evaluate their implications.*

B. Inheritance

- *Define a gene as a section of DNA.*
- *Describe the relationship between chromosomes and genes.*

C. Evolution

- *State the theory of evolution.*
- *Explain why the fossil record is an evidence for evolution.*

5. Living things in their environment

A. Adaptation and competition

- *Explain, using ideas of interdependence, adaptation, competition and predation, about the distribution and relative abundance of organisms in a habitat.*
- *Explain how the impact of humans on the environment depends on social and economic factors, including population size, industrial processes and levels of consumption and waste.*

B. Energy transfer in an ecosystem

- *Describe energy flow in food chains quantitatively using pyramids of biomass and numbers.*
- *Explain how microbes and other organisms are involved in the decomposition of organic materials.*

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 .

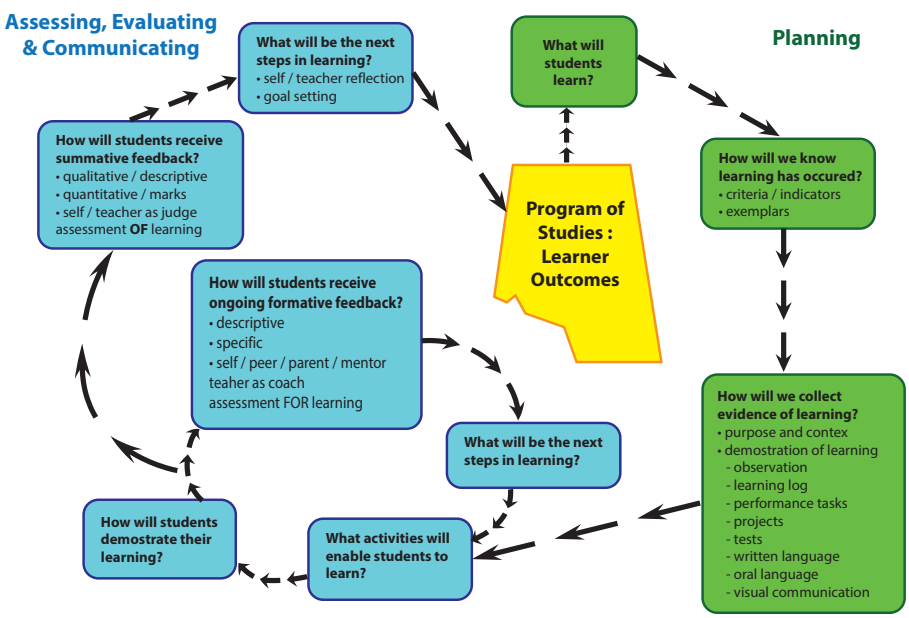
- **Working scientifically:** *Basic understanding of the nature of science, and how science works. Demonstration of logical and abstract thinking and comprehension of complex situations. Explore how technological advances are related to the scientific ideas underpinning them. Compare, contrast, synthesize, 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 Student Learning in 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.

3. 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										

2. 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.*

3. 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	

4. 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 0	Introduction	70	0%
Chapter 1	The Cell	390	11%
Chapter 2	Green Plants	740	23%
Chapter 3	The Digestive System	160	7%
Chapter 4	The Circulatory System	265	7%
Chapter 5	The Respiratory System	255	6%
Chapter 6	The Nervous System	390	8%
Chapter 7	The Endocrine System	200	6%
Chapter 8	Variation, Genetics and Evolution	730	16%
Chapter 9	Health and Harmful Substances	200	6%
Chapter 10	The Organisms in its Environment	200	10%
	Total	3600	100.00%

The total time required to complete the topics is 3600 minutes or 90 periods of 40 minutes in a period.

Table of Content

Chapter 7 Endocrine System

Chapter 8 Variation, Genetics and Evolution

Chapter 9 Health and Harmful Substances

Introduction

Biology is a branch of science, which deals with the study of life. It is concerned with the study of all living things, from simple to most complex forms of life on the Earth. The study of biology includes everything from the basic building blocks of life to the interactions between communities and populations. Hence, biology is also described as life science or natural science. The scope of biology is enormous that aims to provide the understanding of the structures and functions of organisms and their roles on the Earth. There are many branches of biology, each focused on different aspects of study.

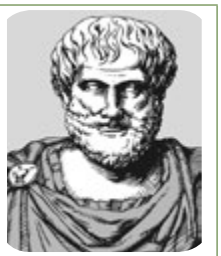
a. Biology as a life science

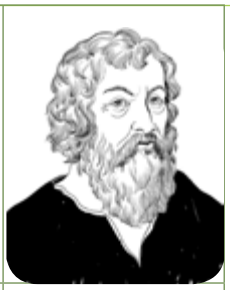
Life and science is defined in many ways as per individual context. However, biologists understand the word, **biology** as, '*bio*' for life that can carry out all the processes like respiration, nutrition, excretion, responsiveness and sensitivity, movement and locomotion, reproduction, growth and development of living things; '**logy**' as *logus* for '**study**'. Therefore, biology is the **study of life**.

Science begins with **curiosity** about the world and the desire to understand it. It involves testing ideas about how things work and how they are made; thereby, modifying ideas and developing knowledge. As a branch of science, biology encompasses the scientific methods. It starts with the processes of **questioning** and **observing** ourselves and things around us. The **similarities**, **differences** and **patterns** are perceived, through the steps of **investigation**, **measurement** and **classification**. The origin of biology can be traced back to human inquisitiveness about the things happening in nature. Today, biology is one of the fastest growing branches of science.

b. Pioneers of biology

In the **history of biology**, many important discoveries have taken place throughout the centuries. From the **discovery of vaccines** to theories of the beginning and progression of **life on earth**, that has improved not only our understanding of history but also our quality of living. A few individuals have started the revolution of ideas in the field of biology. Some of the **biologists** who have greatly impacted the way we think about the world and our surroundings are mentioned below.

Aristotle (384-322 B.C.), Greek philosopher and scientist studied a lot about animals and plants. His knowledge about study of biology served as the foundation for much of the science and philosophy of ancient and medieval times and for science of the present day. He was the tutor of **Alexander the Great**. He is sometimes referred as the **Father of Biology.**	
Theophrastus (372 - 287 B.C.), ancient Greek philosopher, successor of Aristotle as head of the Lyceum. His *Enquiry into Plants and Origins of Plants* are the beginning of all subsequent botanical thoughts. Remarkably, Theophrastus knew that plants engaged in sexual reproduction, a fact thereafter forgotten and not rediscovered until the eighteenth century. He is referred as the **Father of Botany.**	

Hippocrates (460 – 370 B.C.), ancient Greek physician who lived during Greece's classical period and is traditionally regarded as the **Father of Medicine**. It is difficult to isolate the facts of Hippocrates' life from the later tales told about him in the face of centuries of reverence for him as the ideal physician. About 60 medical writings have survived that bear his name, most of which were not written by him.	
Charles Darwin (1809-1882), English naturalist and geologist, best known for his contributions to evolutionary theory. Darwin published his theory of evolution with compelling evidence in his 1859 book *"On the Origin of Species"*, overcoming scientific rejection of earlier concepts of transmutation of species. He is known as the **Father of Evolutionary Science**.	
Gregor Mendel (1822-1884), an Austrian scientist and a monk had a deep interest in botany which led him to conduct experiments on pea plants. For eight years, he carefully crossbred and grew thousands of pea plants, and patiently analyzed and compared the plants and seeds for difference in colour and size of the seeds, and variations in length of the plants. His meticulous study and the resultant observations led to what is today known as Mendel's Laws of Inheritance. He is known as the **Father of Modern Genetics**.	

c. The scope of modern biology

Modern biology is a broad subject, consisting several important disciplines or branches of study. The two broad branches of biology are **botany**, the study of plants; and **zoology**, the study of animals. Some disciplines of biology are called pure science, because they are concerned with principles rather than with applications. Examples include study of cells and body structure, known as **cytology** and **anatomy** respectively. Other disciplines include applied science like pathology, immunology, biotechnology, etc. This branch of science is applied for the welfare of human and the animals and plants that are useful.

Interdisciplinary science includes **biochemistry**, **biogeography**, **bioinformatics** and others. This branch is interrelated to one another, which involves the use of knowledge from other branch or branches. These several branches assist the study of living organisms and their relationship with other living and non-living entities for the scientific investigation. The figure below describes the scope of branches of biology.

Biological Sciences

Interdisciplinary Science

- **Biochemistry** –study of chemicals and reactions that take place inside the living things.
- **Biophysics** - study of physical laws and principles in plants and animals
- **Biometry** - mathematical and statistical studies in correlating the various life processes
- **Bioinformatics** - applications of information technology in analysing biological data
- **Psychology** - study of human mind and how it influences behaviour

Pure Biology

- **Botany** - study of plants
- **Zoology** - study of animals
- **Anatomy** - study of internal structure of living organisms
- **Cytology** - study of structure and functions of cells
- **Embryology** - study of the formation and development of embryo of plants and animals
- **Ecology** - study of the relationship of an organism to both its living and non-living environment
- **Genetics** - study of heredity and variations in the organisms
- **Histology** - study of tissue in plants and animals
- **Palaentology** - the study of prehistoric forms of life through fossils of plants and animals

Applied Biology

- **Agriculture** - farming of crops and livestock for food.
- **Animal husbandry** - farming of domestic animals
- **Apiculture** - rearing of honeybees
- **Pisciculture** - farming commercial species of fishes
- **Conservation biology** - preservation of natural resources
- **Horticulture** - cultivating useful varieties of plants
- **Molecular biology** - molecular organisation
- **Pharmacy** - science of preparing and dispensing drugs
- **Sericulture** - rearing of silkworms for obtaining commercial silk
- **Veterinary science** - animal health, welfare and improved animal yield

d. Why study biology?

The study of biology becomes important for the following reasons:

i. Understanding your body

Through the study of different branches of biology such as **genetics**, **anatomy**, **physiology**, **cytology**, **immunology**, **pharmacology**, etc. we will understand about what the human body is made up of, how it works, and how it is affected by what we eat, the air we breathe, and every other aspect of the world around us. It can help us prevent, cure, and even eliminate disease. For example, pharmacology deals with medicine and **immunology** deals with our immune system and how it reacts to all sorts of harmful microorganism. Biology also deals with why our body need proper nutrition and exercise and how it affects. As we understand more about our nutritional needs, we also are discovering new ways to meet them-to grow, prepare, and preserve foods.

ii. Understanding your environment

Study of biology helps us understand not only that humans are living things, but also tells us all about **plants** and **animals** – how they live, what they are made up of, and how they interact with mankind and each other. Biology also connects us to the world we are living in, and reminds us of our interconnectedness with all other life forms. This enables us to make the best use of our planet's **natural resources**, while trying to minimize the impact we have on the environment.

iii. Career opportunities

Biology may be directly useful in finding employment, but all these opportunities arise through some form of advanced study in biology. Study of **biological science** becomes important for many careers like **agronomist**, **animal behaviour scientist**, **doctor**, **nurse**, **laboratory technician**, **biochemist**, **biotechnologist**, **conservation biologist**, **environmental analyst**, **environmental ecologist**, **fishery scientist**, **food** and **drink technologist**, **forestry technician**, **genetics technician**, **marine biologist**, **meat biochemist**, medical sciences technician, **nursery grower**, **horticulturist**, plant **pathologist**, plant **physiologist**, **teacher** and others.

In Bhutan, generally those students who pursue biological sciences find employment in medicine and health, environment, fishery, forestry, agriculture, veterinary, horticulture, animal husbandry, teaching and lecturing and few others.

The figure in the following page shows biology courses and their related career fields.

Career guidance: Biology

Major disciplines	Examples of courses	Career fields	Examples of industries or activities
Applied physical sciences	• meteorology • forensic science	• laboratory works	• scientific and industrial research into pharmaceuticals and health care, process such as gene action, cell growth, selective breeding, hybridisation, etc
Pure sciences	• physics • chemistry • geology • biology • biochemistry • microbiology • genetics	• biology in industry • ecology/fieldwork • agriculture, horticulture, forestry	• testing products, quality control, inspecting and advising, selling and marketing, management • environmental conservation, natural resource management, agriculture and horticultural field trails, ecological research on habitats, organisms and human influences
Applied biological science	• environmental science • environmental health • medicine • dentistry • pharmacy • agriculture • veterinary science • horticulture • forestry	• work with animals • health care • marine and freshwater biology • information science • teaching and lecturing	• agricultural and horticultural advisory works in livestock husbandry, soil science, plant pathology • work of veterinary scientists, animal nurses/ technicians/keepers • work of doctors, nurses, dentists, opticians, dieticians, radiographers, occupational therapists, pharmacists, physiotherapists • ecological and environmental research for water industry, fish farming • information technology, librarian, museum curator, publishing, journalism, broadcasting, statistical and data processing • primary education, secondary education, colleges and universities.

iv. Improve social and economic issues

An understanding of the **principles of biology** can make more **informed decisions** about our own **health**, and about significant **biological issues**, such as **genetically modified** crops and animals, the use of **antibiotics** and **vaccines** and the eradication of **invasive species**. The knowledge of **agriculture** and **horticulture** will contribute to improvement of plants and animals yields. Biologists contribute to medical and biotechnological advances. For example, food **microbiology** has helped people to preserve foods in the form of frozen food, canned and bottled foods, freeze-dried foods. Unlocking the **DNA codes** have helped develop genetically modified crops, carry out **livestock cloning**, human **invitro fertilization**, human **tissue cultivation**, **stem cell therapy** and **gene therapy**. The products of **bioengineering** such as kidney dialysis machine, pacemaker, prosthetic limb, prosthetic disc, coclear implant, endoscopy, laser surgery and radial keratotomy have improve people's health and lives.

v. Become aware of ecological issues

By studying biology, one become much more aware of **ecological issues**, and better able to debate on situations, where **exploitation of the environment** (for example, for farming, mining or hydropower purposes) clashes with **conservation** objectives, or where we need to develop more **sustainable ways** of using our natural resources like soil, land and water.

e. Biology - A science of exceptions

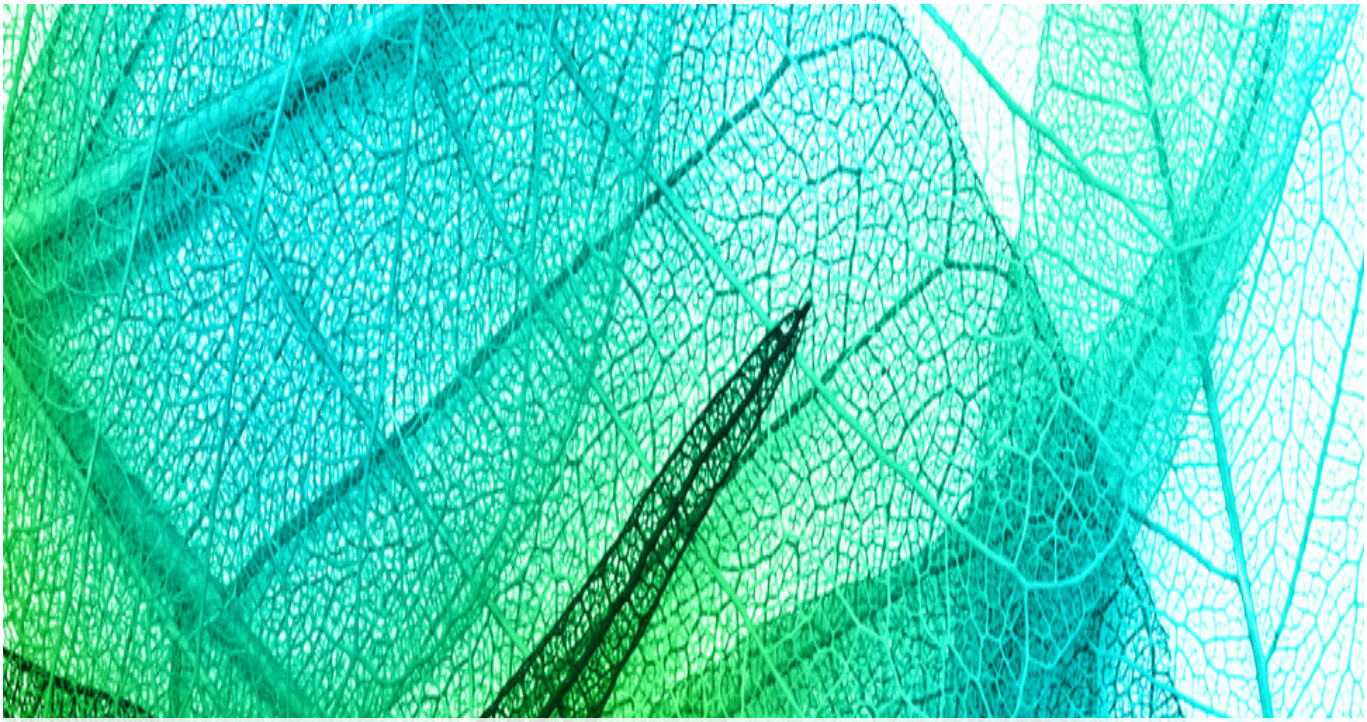
Physics, **chemistry** and **mathematics** and other sciences *follow a specific set of rules and regulations*. These fields of studies are governed by a set of laws such as the law of gravity, the laws of thermodynamics, the law of conservation of mass and so on. However, biological sciences, in the strict sense, do not follow any rules or regulations. The reason for this is that living organisms show a rich diversity that has resulted from **mutations**, **genetic re-combinations** and **evolution**. Biology is thus, regarded as '**a science of exceptions**'. Following are some of the interesting exceptions in biology.

1. **Parallel venation** is a characteristic feature of **monocot leaves** and **reticulate venation** is a characteristic feature of **dicot leaves**. However, the leaves of some monocots like *Smilax* and *Colocasia* show reticulate venation and the leaves of some dicot like *Calophyllum* and *Corymbium* show parallel venation.
2. The **embryo** of dicot seed shows the presence of **two cotyledons**. However, the embryo of a dicot plant *Cuscuta* totally lacks cotyledons.
3. **Roots** are **positively geotropic**, growing towards the soil. However, the roots of some mangrove plants like *Rhizophora* and *Sonneratia* grow away from gravity, which is **negatively geotropic**.
4. **Blood** of all vertebrates is red in colour due to the presence of **haemoglobin** in the RBC, but the blood of a shark, *Carcharhinus* is colourless.
5. Fishes do not have lungs and respire through **gills**, but some fishes like *Protopterus* possess both gills and lungs.
6. The heart of all reptiles is **three chambered**, but in crocodiles, it is **four chambered**.
7. Usually the embryo develops from a **fertilized egg**. However, in the bee colony, male bees, called drones develop from **unfertilized eggs**.

These are only a few examples of the innumerable exceptions that we come across in the living organisms. Such examples have made ***biology a science of exceptions***.

Summary

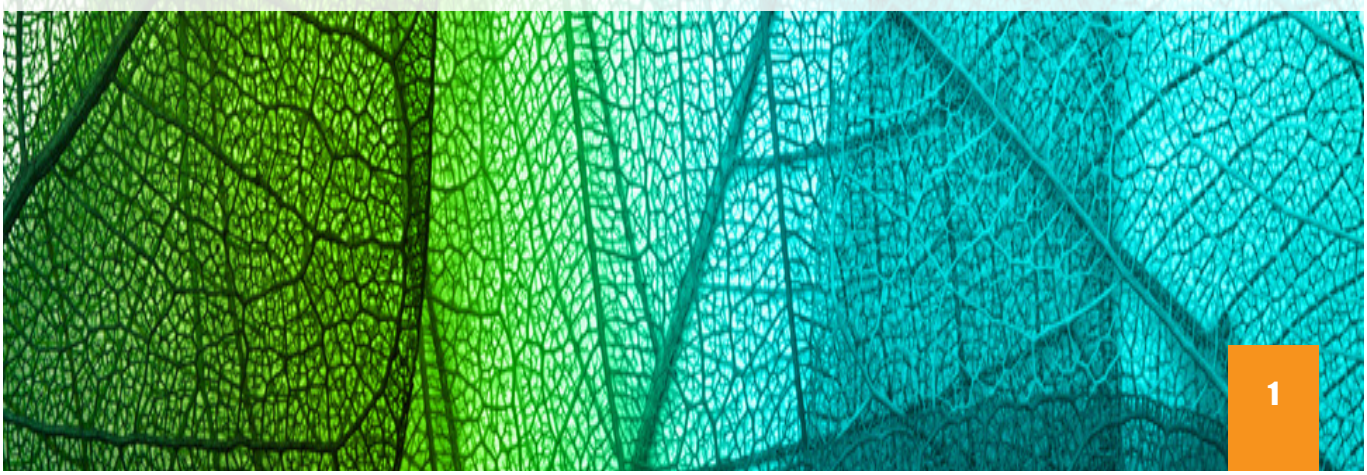
- Biology is a branch of science that deals with the study of life. Hence, it is also called life science.
- Biology is a vast field that it encompasses the study of various aspects of living organisms, as well as, their interactions with the non-living components.
- Biology has two primary branches - botany, the study of plants; and zoology, the study of animals.
- Interdisciplinary branches indicate the relationship of biology with other branches of science.
- Applied branches of biology enable us to apply the knowledge gained from different areas to be used for the welfare of humans, animals and plants.
- Biology helps us to know about the diversity in the living world and the ways by which it can be preserved.
- Applied branches of biology provide career opportunities for students pursuing Biology as a subject.



1 Cell

The Unit of Life

All living things, we see around us are complex structure made up of cells. The cell is the fundamental unit of all life on the planet. All the functions of an organism are the product of cell activities. Nearly every cell in the body contains the genetic material that tells the tissues and organs what to be and do. There are hundreds of cell types in the body, each with its special function.



A. The Cell

Learning Objectives

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

- describe the basic structure of an animal cell and a plant cell as seen under microscope.
- state how different cells are adapted to their functions.
- relate cells and cell function to life processes in a variety of organisms.
- explain the process and purpose of staining in the study of cells and tissues.

Individual cells are too small, and can be properly seen only when viewed through the **lenses of microscope**. The average cell is less than half as wide as a human hair, but some are so tiny that 30,000 could fit inside a full stop. A cell is the **basic unit** of all living organisms, performing the essential functions of life. Thus, the cell **is the structural and functional unit of living organism**. If we examine the cell of an apple plant or a frog under a microscope, it will show the cell structures. All the life functions of a young apple plant or a frog are the functions of a cell. All organisms start their life as a single cell. An apple tree and a frog started its life from a single cell of their parents.

a. Discovery of cell

In 1665, Robert Hooke, an English scientist while studying a **slice of cork** under his microscope, observed a large number of compartments joined together in a '*honey-comb*' like structure (Figure. 1.1). He called these compartments as *'cells'*. The cells which Hooke saw were all *dead cells* and they had only the empty '*compartments*' or the cell walls.

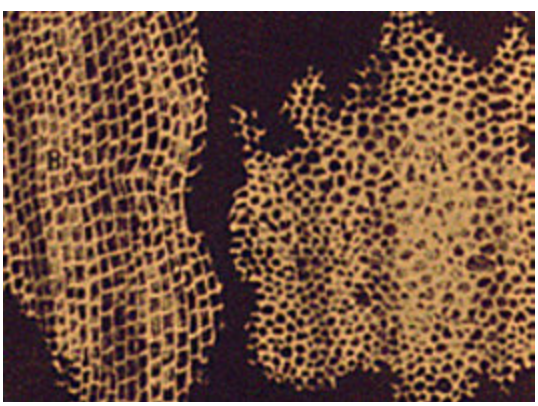


Figure 1.1 Cells as observed by Robert Hooke in a slice of cork

After Hooke, there were many scientists who contributed to the understanding of cell structure and its function.

In the 21st century, the cell is still a frontier, as scientists seek novel ways to improve and save lives- and even create new ones.

Table 1.1 shows the discovery of the cell and understanding of cell concepts.

Inventions of microscopes

***Magnification** = size of the image as seen through the microscope / actual size as seen by naked eye*

Figure 1.2 Leeuwenhoek's simple microscope

The first microscope was constructed by **Antony van Leeuwenhoek** (1632-1723). He used it to view blood cells and sperm. He is said to have constructed about 400 microscopes. All his microscopes consisted of a **single biconvex lens** and were called simple microscope. Some of his microscopes had a magnifying power up to 200 times compared to a naked eye. One of Leeuwenhoek's microscopes is shown in Figure 1.2. In this microscope, he clamped a very tiny biconvex lens between two brass plates and make microscopic observations.

Robert Hooke (1635-1703), an English scientist, developed compound microscope using **two lenses**. It uses the beam of light which is bent by glass lenses to magnify the object. Later on, improvements were made in Hooke's microscope (Figure 1.3). The compound microscopes which are used in science laboratories are the improved design of Hooke's microscope. Some compound microscopes have a magnification up to 2,000 times.

Figure 1.3 Compound microscope

Figure 1.4 Electron microscope

Ernst Ruska (1906-1988) and **Max Knoll** (1897-1969), German scientists, invented the electron microscope which could magnify an object up to 40,000 times. In this microscope, **a beam of electrons** are sent through a thin section of an object and projected on the **fluorescent screen** to produce a virtual image of the object. The beams of electrons are focussed by magnets. These days, improved electron microscopes (Figure 1.4) are available which could magnify up to 200,000 times and more and could produce a **three-dimensional image** of an object.

Activity 1.1

Information hunt

Find out about the compound microscope and the electron microscope from resources in the school library, or through the internet. Discuss about it with your teacher on the following areas:

Questions

i. When and who invented the compound microscope and the electron microscope?

ii. How did the discovery take place in each case?

iii. What are their characteristic features?

iv. How different is the electron microscope from the light microscope?

v. How have these two inventions contributed in the field of science?

Make a neat presentation of your group work. Answer questions of other group members.

b. Cell theory

The cell theory was jointly proposed by a German botanist, Matthias J. Schleiden and a German zoologist, Theodor Schwann. Schleiden, in 1838 concluded that cells are the basic units forming the plant tissues. In the following year, Schwann proposed that bodies of animals are made up of cells (Table 1.1). But their theory did not mention anything about how new cells are formed. It was only in 1858, Rudolf Virchow observed that **cells arise from pre-existing cells**. Therefore, these discoveries lead to the cell theory. The important features of cell theory are:

1. The cell is the basic unit of structure of all living things.
2. The cell is the basic unit of function of all living things.
3. All living cells arise from the pre-existing cells by cell division.
4. Cell contains a unit of hereditary material called genes.

Table 1.1 Key steps in cell theory

Robert Hooke 1665	Introduce the term "*cell*" in describing the structure of cork.
Matthias Schleiden 1838	Explained the occurrence of cells in plants.
Theodor Schwann 1839	Explained the occurrence of cells in animals.
Rudof Virchow 1858	Established the idea that cell arise from pre-existing cells.

Exception to cell theory

1. **Viruses** have characters of both living and non-living. They are made up of **protein** and **Deoxyribonucleic Acid** (**DNA**) or **Ribonucleic Acid** (**RNA**). They lack nucleus, cytoplasm or enzymes. They cannot multiply outside the living system and do not perform any life activities
2. **Bacteria** and **blue-green algae** lack well organized nucleus and are not true cells.
3. Some **mould fungi** are not cellular.

c. Cell structure

The cells within the body of a multi-cellular organism differ in shape, size and functions. In spite of these differences, every cell consists of **three essential parts**: Cell membrane (**plasma membrane**), cytoplasm and nucleus. Figure 1. 5 and Figure 1.6 shows the structure of a typical animal cell and a plant cell as seen under the microscope. Inside the cell, there are small structures which have definite shape, structure and function called cell organelles (the '*little organs*'). Cell organelles are living parts of the cell.

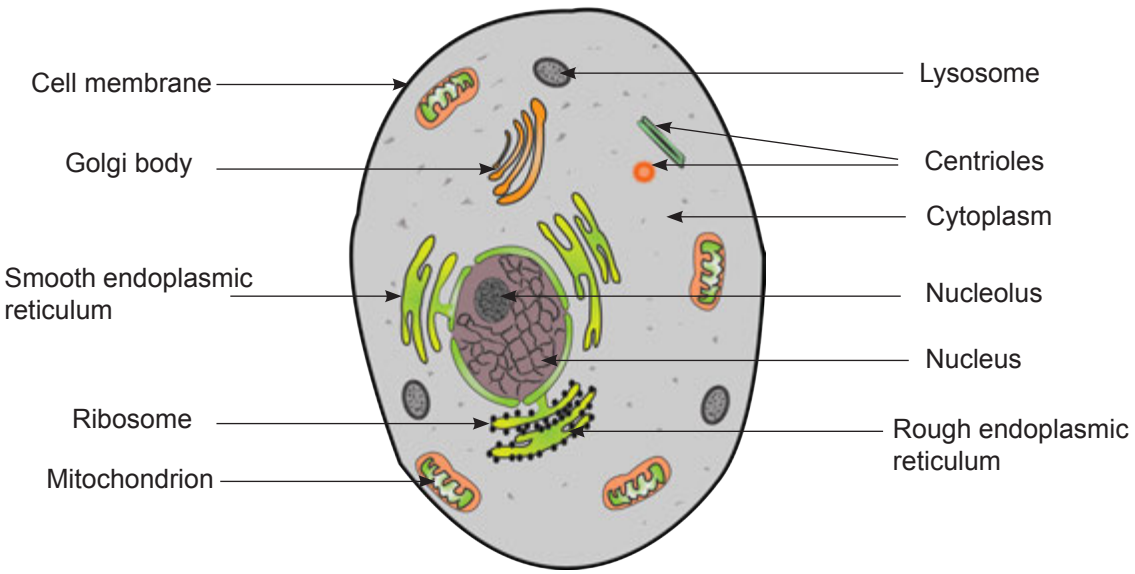


Figure 1.5 Structure of a typical animal cell

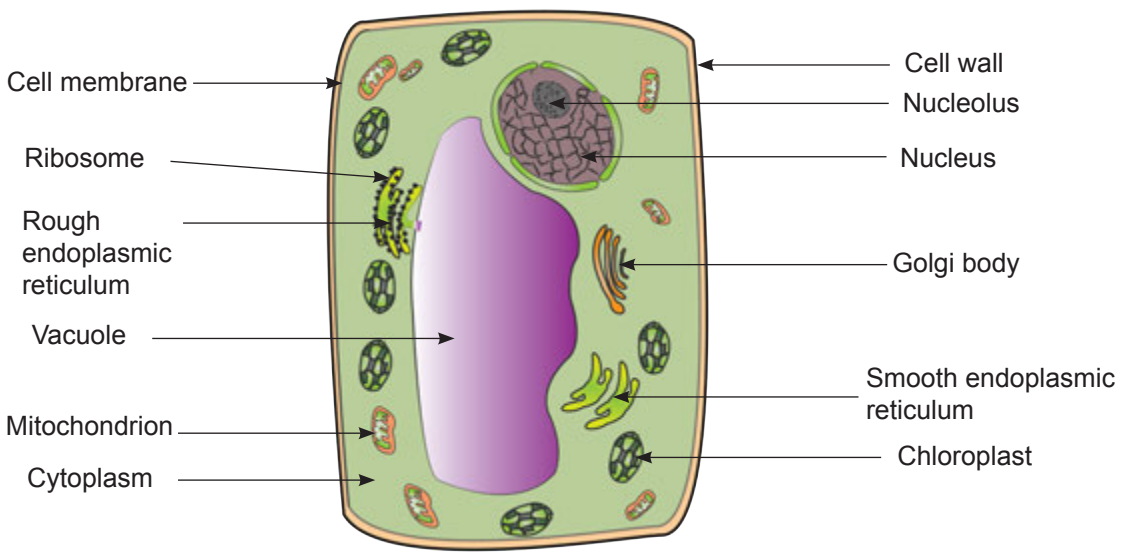


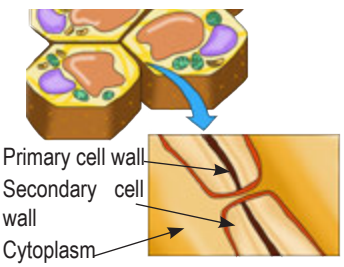
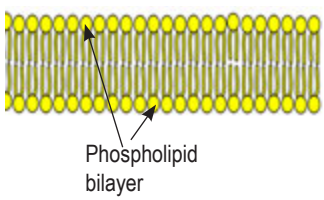
Figure 1.6 Structure of a typical plant cell

d. Components of cell

i. Cell membrane

Cell membrane is the outermost membrane in animal cells. It consists of two layers of special molecules (**phospholipids**) that together form an oily film around the cell's watery contents. Large protein molecules are embedded in the membrane. These act as gates, allowing only certain molecules to enter and leave the cell. In plant cell, the cell wall is the external structure.

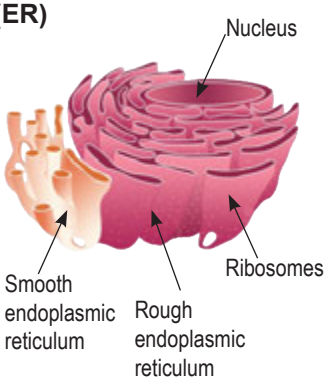
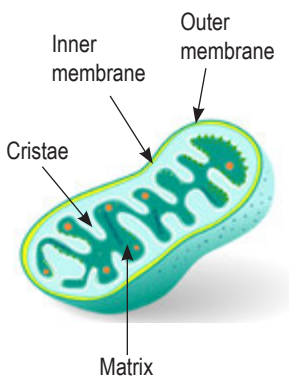
Table 1.2 Cell membrane and cell wall

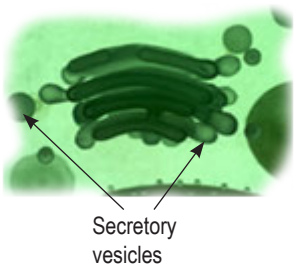
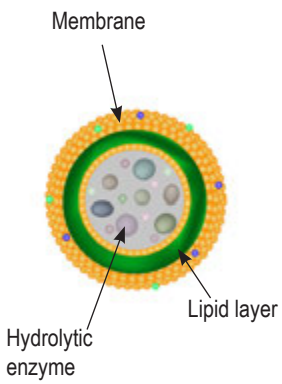
Cell parts	Characteristics	Functions
Cell wall  	Cell membrane is **selectively permeable** that allows only certain substance to pass through while it prevents other substances. It has **fine pores** through which substance leave and enter the cell. It is made up of **lipid** and **protein**. In plant cell, the cell membrane is covered with a cell wall.	• **Regulates the entry of certain substances**. • Maintains the shape of an animal cell.
Cell membrane or plasma membrane  	Cell wall is made up of mainly **cellulose**, a non-living substance, which is a product of various cell activities. It allows the free entry and exit of substances in solution, as cell wall is **freely permeable**.	• Provides **shape** and **rigidity** to the plant cell. • Protects cell membrane and internal structure of a cell.

ii. Cytoplasm

The space between the cell membrane and the nucleus is filled by **semi-liquid fluid** made mostly of water called the cytoplasm. It appears to be colourless, partly transparent and somewhat watery under a microscope. In the cytoplasm, many chemical reactions take place catalyzed by enzymes. Cytoplasm helps in **exchange of materials between different cell organelles**. Several cell organelles, each concerned with some specific function are found embedded in the cytoplasm (Table 1.3). The liquid part of the cell, other than cell organelle, is called cytosol.

Table 1.3 Cell structures

Picture	Characteristics	Function
Endoplasmic reticulum (ER) 	The endoplasmic reticulum is an **irregular network** that extends across the entire cytoplasm. It is **doubled membrane** cell organelle that connects cell membrane and nuclear membrane. Thus, provides a large surface area inside the cell for various cell activities. Endoplasmic reticulum can be observed only through the electron microscope. Based on the appearance, endoplasmic reticulum can be of two types: rough endoplasmic reticulum (**RER**), if ribosome is attached to it; and smooth endoplasmic reticulum (**SER**), if it does not bear ribosome.	Acts as the supporting framework of the cell. Serves as the pathway for the distribution of materials from one part of the cell to the other.
Ribosome 	Ribosome is a tiny structure, lying free in the cytoplasm, or seen attached to the membrane of endoplasmic reticulum. There are several thousand ribosomes per cell. They are made up of mainly Ribo Nucleic Acid (**RNA**) and **protein**.	Ribosomes are the sites of protein synthesis. Hence, they are called *'protein factories' of the cell*.
Mitochondrion 	Mitochondria (*singular*: **mitochondrion**) are mostly **rod-shaped** or **cylindrical** organelles. Each mitochondrion is bounded by a **double membrane**; outer layer is smooth but the inner membrane is folded to form finger-like processes called cristae. The mitochondria are the sites where cell respiration occurs wherby cells get their power, during the break down of sugar molecules to released stored chemical energy.	The digested food molecules of glucose are further broken down in the presence of oxygen to release energy. This energy is stored in the form of ATP (adenosine triphosphate) and is used in various metabolic functions of the cell. Thus, mitochondria are called '*power houses of the cell*'.

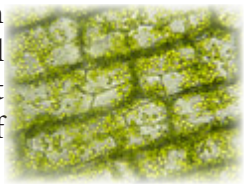
Picture	Characteristics	Function
Centrosomes 	Centrosome occurs in animal cells but not in plant cells. It consists of two **hollow cylindrical bodies** called centrioles which lie at right angles to each other. The centrioles separate and move to opposite ends of the nucleus before cell division.	**Initiates** and **regulates cell division** in an animal cell.
Golgi apparatus 	The Golgi apparatus is a very small vesicle of different shapes, generally found near the nucleus. It consists of a **stack of flattened membranous sacs**. In most plant cells and in the cells of invertebrates, several units of golgi apparatus are found diffused in the cytoplasm and are known as dictyosomes.	Helps in **secretion of mucus, enzymes and hormones**. Helps in storage of secretory products. Helps in development of acrosome of sperm.
Lysosomes 	Lysosome is small rounded or **spherical bodies** containing digestive enzymes. These **enzymes digest** and destroy the foreign substances around them. When the cell dies, its own lysosome releases the enzymes that digest the remains of the cell. Hence, lysosomes are known as the '*suicide bags*' of the cell. Lysosome originates either from Golgi apparatus, or directly from the endoplasmic reticulum. It is present in all the animal cells, except in red blood cells (**RBCs**). In plant cells, lysosomes are only a few in number.	Helps in **intra-cellular digestion**. Provides energy during starvation.

Plastids is the largest cytoplasmic organelle bounded by **double membranes**. It is found in plant cell and absent in an animal cell. It is of *three* types:

a) Chloroplast

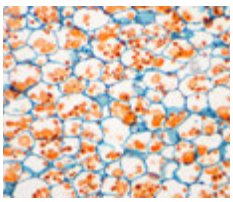
The chloroplast can be spherical, ovoid and discoid or lens shaped. It greatly varies

in shape and size. It has a green pigment called chlorophyll, which helps the plant to harness the solar energy for photosynthesis. All living organisms, directly or indirectly, depend on the chloroplast for obtaining food and energy. It helps to carry out the process of **photosynthesis**.



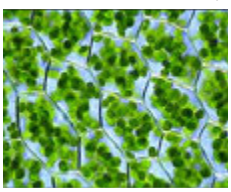
b) Leucoplast

Leucoplasts a (**Gk leucos** = *white*; **plastos** = *formed*) are the **colourless plastids**. These are found in the cells that are not exposed to sunlight such as seeds, tubers and rhizomes. These are found in rice grains, potato tubers, castor seeds, wheat grains, etc. They store food.



c) Chromoplasts

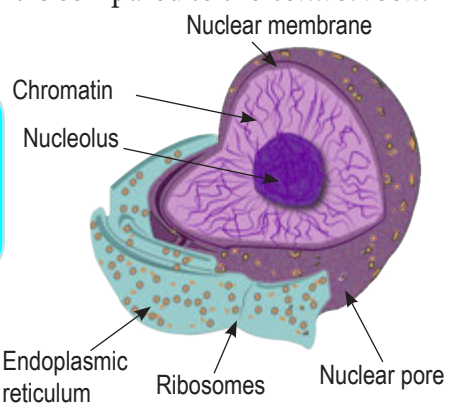
Chromoplasts (**Gk chroma** = *colour*; **plastos** = *formed)* are **coloured plastids**. They are mostly present in petals of flowers and in fruits and colouring substances (pigments) associated with them are xanthophyll (**yellow**) and carotene (**orange-red**). The change of colour of tomatoes and chillies at the time of ripening is due to the change of **chloroplasts** to **chromoplasts**. They impart colours to flowers, fruits and other plant parts.



iii. Nucleus

Nucleus is generally round, but may be cylindrical, elliptical or lobed. The size of the nucleus varies in different organism of different species. It is the most essential part of cell which directs and controls all the cell activities. It is compared to the *'control room of a factory'*. The main functions of the nucleus are:

1. *It regulates and coordinates various life processes of the cell.*
2. *It plays an important role in the cell division.*
3. *It carryies hereditary factors (genes).*



Structure of nucleus

A typical nucleus consists of **nuclear membrane**, **nucleoplasm**, **chromatin fibres** and **nucleolus**.

Nuclear membrane separates the nuclear material from the cytoplasm. It has numerous fine pores through which substances enter and exit the nucleus. It regulates the entry and exit of substances in the nucleus.

Nucleoplasm is the transparent, **semi-liquid ground substance** of the nucleus. It

supports the chromatin material, and **provides rigidity** to the nucleus.

Chromatin fibres is thread-like network of fibres in nucleoplasm. During cell division, it becomes thick and ribbon-like. These fibres are then called chromosomes. **Chromosomes** are made of chromatin, which contains a hereditary unit called genes. Genes are made up of a complex chemical substance DNA (**deoxyribonucleic acid**). Chromosome number in each cell of all the members of a species is the same and is fixed for the a species. For example, each cell of onion has 8 pairs, frog has 13 pairs and human being has 23 pairs. It carries hereditary information or the genes.

Nucleolus is the dense, spherical body in the nucleoplasm. It plays an important role in cell division. It produces ribosomes and participates in protein synthesis.

Chromosome numbers of some common animals and plants including human are as follows:

Round worm (Ascaris)	2	Human	46 (23 pairs)
Onion	16	Chimpanzee	48
Rice	24	Potato	48
Frog	26	Horse	64
Lion	38	Sugar cane	80
Wheat	42	Crayfish	200

iv. Non-living substances or cell inclusions

Cell inclusions are the **non-living part** of the cell that are usually the result of metabolic activity of the cells in which they are found. In most cases, they require special stains to be seen clearly. They may be pigments produced in the cell, or they may be accumulations of nutritive materials such as fats or carbohydrates.

1. Vacuoles

Vacuoles are fluid-filled cavities bounded by a **single membrane**. This membrane is called tonoplast (Figure 1.7). The vacuole contains fluid called cell sap, which contains dissolved food materials, ions, waste products and pigments. In animal cells, vacuoles are usually very small and less permanent than plant cells.

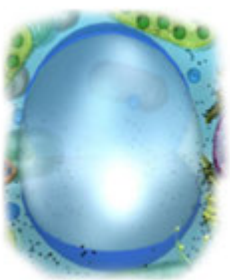


Figure 1.7 A plant cell vacuole

2. Granules

Granules are **minute particles**, **droplets** or **crystals**. There are numerous granules in the cytoplasm, which carries food materials such as **starch**, **fats** and **glycogen**.

e. The plant cell and animal cell

The basic structure of all plant cells and animal cells are same. However, there are a few structural differences between an animal cell and a plant cell.

1.2 Activity

What are the differences?

Copy and complete Table 1.4. Use library books or browse internet.

Table 1.4 The difference between a plant and an animal cell

A Plant Cell	An Animal Cell
1. A definite cell wall made of cellulose.	1. _____
2. _____	2. Cytoplasm denser and _____granular.
3. _____	3. Cytoplasm almost fills the _____cell.
4. Vacuoles very prominent, one or more.	4. _____
5. Usually contains _____.	5. Do not contain plastids.
6. _____	6. Centrosome present.
7. _____	7. _____

f. Cell size and shapes

Cells are extremely small in size because:

1. different regions of cell can communicate with each other rapidly for the cell to function effectively.
2. to increase surface area for greater diffusion of substances in and out of the cell. Cell sizes are measured in micrometre (μm) or microns (μ). A **micron** is one-thousandth part of a millimetre. Most cells are in size range of 10-150 μm. The basic unit used to describe the length scale of molecules is nanometre (nm). A nanometre is one-thousandth of a micrometre. It is represented as **nm**.

$$1 \text{ micron } (\mu) = \frac{1}{1000} mm = 10^{-3} mm$$

$$1 \text{ nanometre} = \frac{1}{1000} \mu m = 10^{-6} mm$$

The shapes of the cells vary widely, though most are **globular**. The other shapes are **oval**, **discoid**, **thread-like**, **cubical**, **cylindrical**, **branched** or **irregular**. This variety is because of the many functions for which cells are adapted. For example, our nerve cells are long to conduct nerve impulse to distant parts of our body to the brain. Similarly, xylem vessels are elongated and tubular for the conduction of water and minerals from the soil to aerial parts of the plants.

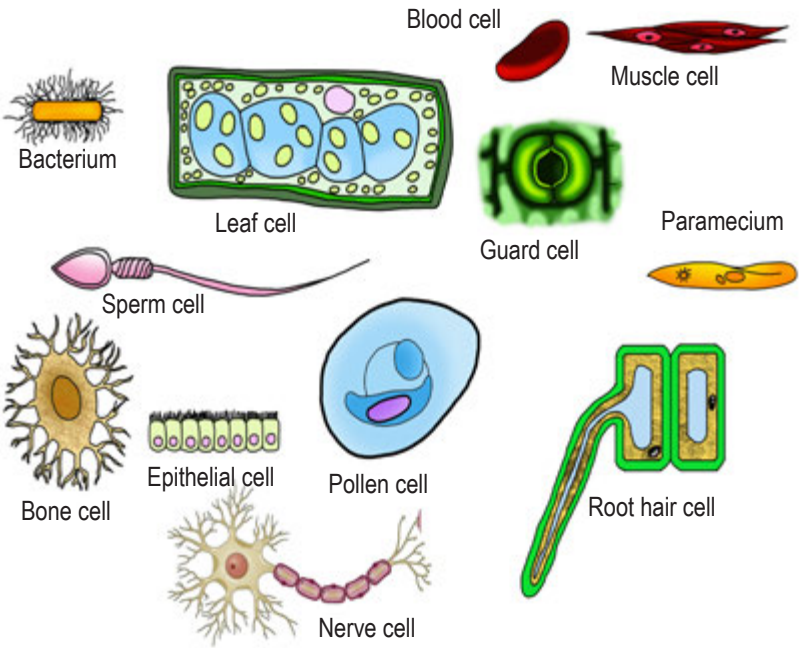


Figure 1.8 Different shapes and sizes of cells

g. Cell structures and their adaptation to functions

In **multicellular organism**, the cells are usually specialized to carry out the particular functions. This **specialization of cell** is due to differences in **cell structures** within the same organism, and the **different functions** the cells provide within the organism. For example, the human body consists of trillions of cells that vary greatly in shape, size and function. Some of the examples of how cell structures are adapted to their functions in animals and plants are discussed below.

1. The **sperm cells** in human body are a few micrometres wide. The enzymes present in the sperm acrosome help dissolve the egg membrane and allows the sperm nucleus to **enter and fuse with egg nucleus**. Its tail or flagellum helps to swim inside the uterus and in the cytoplasm of the egg. The mitochondria in the middle piece provide energy for its mobility.
2. **Root hair cell** is delicate tubular projection, which is numerous to **increase the surface area** for water absorption. It has thin cell wall that helps to imbibe water freely. The large vacuole in the centre contains a more

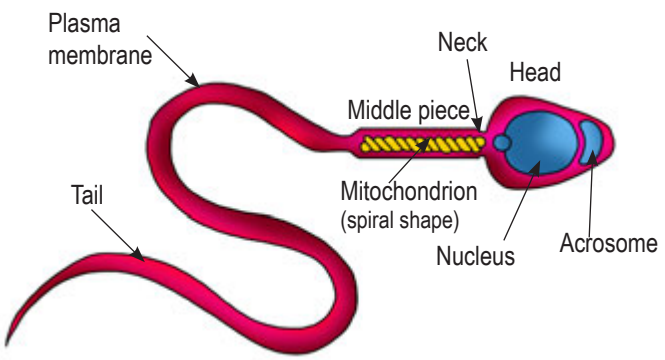


Figure 1.9 Sperm cell

concentrated solute than the aqueous solution present in the soil, which helps water to enter the cell sap. Thus, the structure of root hair cell helps in **absorption of water** from the soil.

3. Specialized cells called photoreceptors within the eye have the **ability to detect light**. These cells contain special pigments that absorb light, and also has special organelles that can turn the absorbed light into electrical impulse that is transmitted to the brain and is perceived as vision.
4. Stoma is an **elliptical pore** found in the **epidermis** of leaves and green stems. The pore is bounded by **two kidney-shaped guard cells**. The wall of guard cells is **thick towards the stoma**, while the **outer wall is thin**. These thick walls of guard cell help during the inflow of water that cause the bulging of outer wall, drawing the inner wall apart and **opening the pore**. Decrease in water content of the guard cells causes the inner walls return to their original positions resulting in the **closure of pore**.

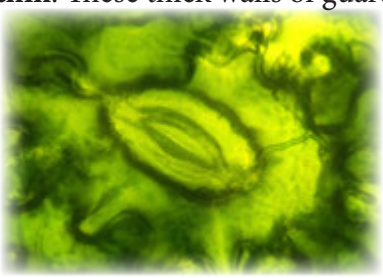


Figure 1.10 Guard cells

h. Cell functions related to life processes

Every activity in a living organism such as **movement**, **reproduction**, **nutrition**, **growth**, **respiration**, **excretion**, **response** and **metabolism** is due to the activities of the cells inside its body. A few examples of cellular activities resulting to the functions of an organism are mentioned below.

1. **Body movements in plants** like drooping of leaves are due to cell activity at the base of the leaves. Similarly, closing and opening of stomata is affected by water content of the cells. Animals walk, jump, swim because of the activity of **contractile cells** such as muscle cells.
2. **Reproductions** in organisms or producing young ones occur through the activity of germ cells (sperms and eggs).
3. **Nutrition** in animals is through the activity of cells such as cells of inner lining of small intestine, cells of digestive glands, sensory cells, etc. In plants, nutrition is through the activity of root hair cells, phloem cells, xylem cell, chloroplast, guard cells, etc.
4. **Growth** in plants and animals is due to the growth in size and number of cells.
5. **Repair** of damaged and diseased cells in plants and animals is due to cell division.
6. **Respiratory gases are transported by** blood cells from one part of the body to another part of the body in animals.
7. **Light** is trapped by leaf cells for photosynthesis.
8. **Response by animals** to outside stimuli is through sensory cells.

i. Techniques for the preparation of temporary slides

i. Staining

Cell contains many microscopic structures that need a microscope for observation. These structures cannot be seen clearly, and often cell staining is necessary as structures are difficult to distinguish due to **insufficient contrast**. Cell staining **is a technique used for increasing contrast by changing the colour of some of the parts of the structures to be observed. Thus the cell organelles are distinguishable to the observer**. There are a variety of microscopic stains that can be used for different cell organelles (Table 1.5).

Table 1.5 Types of stains and their effects

Stain	Effects
Iodine stain	Use for staining nuclei of cells, cell walls, flagella and cilia.
Methylene Blue	For plant and animal temporary preparations; cytoplasm stains blue and nucleus dark blue.
Eosin	Animal tissue stain red.
Safranin	Lignified, cutinised tissues and nucleus satin dark red, cytoplasm stains light red.

Staining is one of the essential steps in biological studies. The cells, tissues, organs or small organisms are stained with specific dye (stain), so as to differentiate their various parts under the microscope. *Steps to remember while staining*:

1. Take a clean slide and put a part of section or drop of material to be studied.
2. Put a few drops of suitable stain on the material. Cover it with the stain properly.
3. Leave the slide for 2-3 minutes.
4. Drain off the excess stain and wash with water if necessary.

Activity 1.3

Preparation of iodine stain

Materials required: potassium iodide, iodine crystals, measuring cylinder, burner, beaker, spatula, watch glass, glass rod and water.

Procedure

1. Boil 100 mL of water in a beaker.
2. Dissolve 10 grams of potassium iodide in it.
3. Add 5 gram of iodine crystals into the solution and stir it with glass rod until the crystals disappear.
4. Pour the solution into a beaker and store it at room temperature until ready for use.

ii. Mounting

Mounting is done to avoid drying of material while studying. The material is mounted in glycerine and covered with a coverslip. The material is also mounted using water instead of glycerine. This is called wet mounting.

Steps to remember while mounting:

1. Place the study material at the centre of the slide.
2. Put a drop of glycerine over the material.
3. Cover it with a coverslip with the help of needle.

Precautions

- Use very clean and properly dried glassware for stain preparation.
- Always use correct solvent and use distilled water for aqueous solution preparation.
- Alcoholic stains should be stored in glass bottles with stoppers.
- Stains should be kept in a cool and dark place.

Activity 1.4

Onion cells observation

Materials required: onion bulb, small knife, razor, mounting needle, forceps, microscope, microscope slide, coverslip, watch glass, water, iodine solution, blotting paper and dropper.

Procedure

1. Take a layer of onion leaf. Peel off the skin (epidermis) from the inner concave layer with the help of forceps.
2. Mount a small piece of the peel on the centre of a clean microscope slide in a drop of water. Take care to avoid curling of the peel.
3. Stain the peel with iodine solution using a dropper, and put cover slip on the specimen.
4. Observe under the low and high power of microscope.

Precautions

- Be careful while using razor and knife.
- Make sure that the stain is not too dark.

Questions

i. Draw a labelled diagram of what you observe under the microscope.
ii. What will you do, if the section is over-stained?
iii. What is the main purpose of mounting?
iv. What difference do you observe under low and high power of microscope?

Brain Snacks

- **100** is the number of times your body's cells would wrap around Earth if laid out in a line.

1.5 Activity

Human cheek cell observation

Materials required: scalpel, a mounting needle, forceps, microscope, microscope slide, cover slip, methylene blue, water, filter paper and dropper.

Procedure

1. Gently scrape the inner lining of your cheek, using a scalpel.
2. Stain the scrape with methylene blue solution, using a dropper and place a cover slip on to it.
3. Mount a small piece of the scrape on the centre of a clean microscope slide in a drop of water. Avoid entry of any air bubbles.
4. Observe under the low and high powers of the microscope.

Precautions

- Do not use sharp object to scrape your cheek.
- Be careful! Methylene blue will stain your clothes and skin.

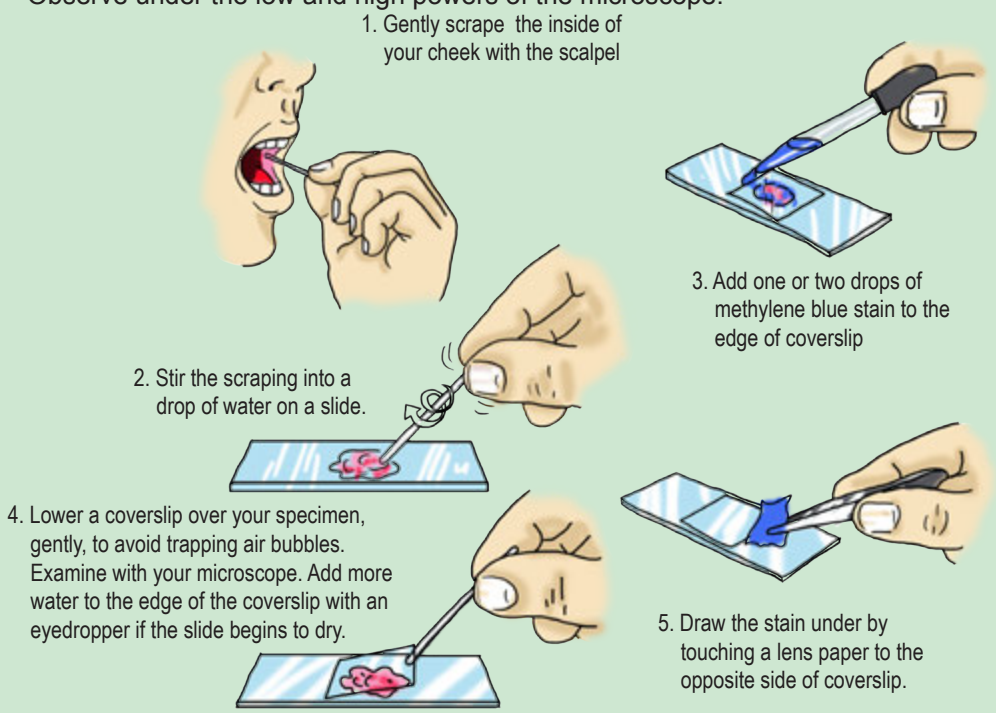


Figure 1.11 Procedure for temporary mount of human cheek cells.

Questions

i. Draw what you observe under the microscope.

ii. Why are sections stained before observing under the microscope?

iii. What difference do you observe under low and high power of microscope?

iv. Why methylene is used for staining human cheek cells?

Summary

- A cell is the structural and functional unit of an organism.
- The four major points of the cell theory are: the cell is the structural unit of all living things; the cell is the functional unit of all living things; cell contains a unit of hereditary material called genes; and all cells arise from the pre-existing cells.
- A cell consists of three essential parts: cell membrane, cytoplasm and nucleus.
- A cell has living parts called cell organelles, and non-living component called cell inclusions.
- The vacuole of a plant cell contains cell sap, which is a solution of sugars and other substances in water.
- A nucleus consists of nuclear membrane, nucleoplasm, chromatin fibre, and nucleolus.
- Cells are of different shapes and sizes to do specific functions in the body of an organism.
- Plants have variety of plastids. Chloroplasts is green plastids that helps plants in photosynthesis.
- Chromoplasts is coloured plastids for pigment synthesis and storage.
- Leucoplasts is colourless plastids present in potatoes.
- Staining and mounting are essential steps in the observation of an animal and a plant cell under microscope.

http://www.cellsalive.com/
https://www.wisc-online.com/learn/natural-science/life-science/ap11403/a-typical-animal-cell
http://ww2.valdosta.edu/~tjyoung/topic.html

Review Questions

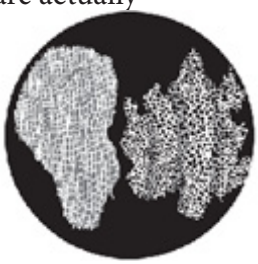
A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. Using the equipment tool shown on the right, Antony Van Leeuwenhoek was the first scientist to

   A. discover the vacuole.
   C. see cell organelles.
   B. magnify plant cells.
   D. study electrons.

2. A cell is considered to be the basic unit of life because
   A. it has various cell organelles.
   B. an organism is made up of cells.
   C. no smaller unit has yet been discovered.
   D. it is a smallest structure that has ability to grow, reproduce and metabolise.

3. In 1665, Hooke observed a thin slice of cork under a microscope and drawn similar picture as shown on the right. What he had observed are actually



   A. cellulose.
   C. protoplasm.
   B. nuclei.
   D. cell walls.

4. A cell organelle called plastids is absent in
   A. animal cells.
   C. yeast cell.
   B. fungi.
   D. an apple cell.

5. Which one of this statement supports cell theory as stated today?
   A. Not all cells are alive
   B. All organisms are composed of more than one cell
   C. All cell must contain nucleus
   D. All cells exist from pre-existing cells

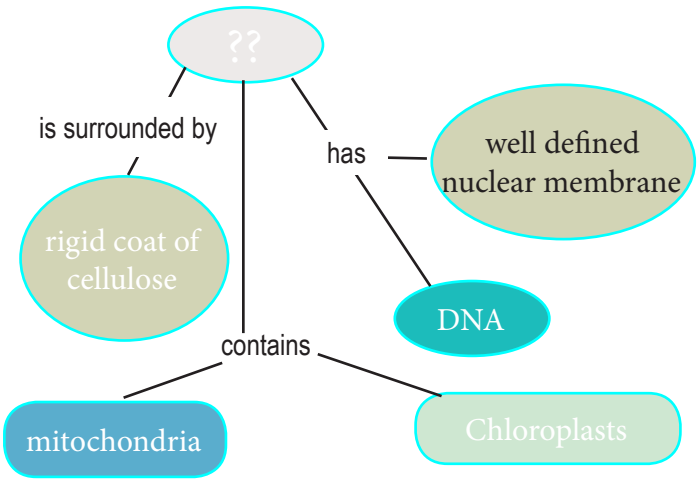
6. Cell structure and function

Cell structure	Function
1	Protein synthesis
2	Storage of water, fat droplets and food
3	Control of cell functions
4	Support

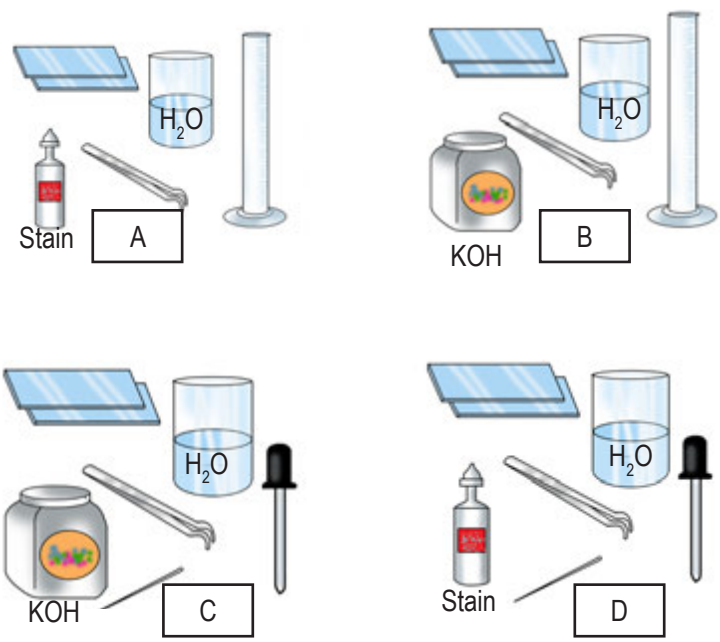
The name of structure 3 is
   A. cell wall.
   C. nucleus
   B. ribosome.
   D. vacuole

7. Animal cells differ from plant cells in having
   A. plastids.
   B. dictyosome.
   C. centrosome.
   D. cell wall.

8. Which of these best completes this concept map?
   A. An animal cell
   B. A bacterial cell
   C. A virus
   D. A plant cell



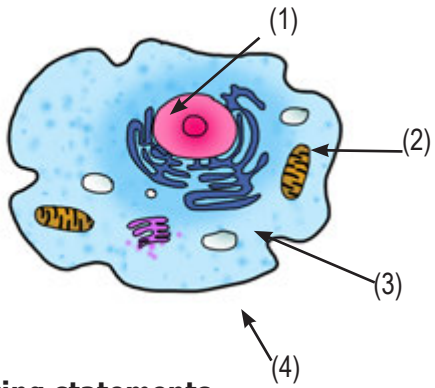
9. Which sets of materials would be best to use to prepare a wet mount of an onion cell?
   A. A
   B. B
   C. C
   D. D



10. In the diagram of a cell, which structure performs a function similar to a function of the human brain?

A. (1) C. (3)

B. (2) D. (4)



B. Write TRUE or FALSE against the following statements.

1. Mounting is a technique used for increasing contrast by changing the colour of some of the parts of the structures to be observed.
2. Plasma membrane is selectively permeable.
3. Centrosomes are kitchen rooms of the cell.
4. Smooth endoplasmic reticulum bears ribosomes.
5. Genes are located in chromosome.

C. Name the following.

1. An amorphous, translucent, homogeneous, colloidal liquid that fills the space between plasma membrane and nucleus in a cell.
2. Tangled fibrous mass inside the nucleus of an onion cell.
3. An interconnected system of membrane-lined channels that runs through the cytoplasm.
4. Miniature biochemical factories, where foodstuffs are oxidized and energy is released.
5. Cells of an organism during their life processes produce debris of dead cellular parts which are cleaned by a spherical vesicle with its digestive enzymes.

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

1. The membrane around the vacuoles is called……
2. In most algae, certain fungi and higher green plants, main component of cell wall is……
3. ……. are the infolding of the inner membranes of mitochondria.
4. In higher plants, the organelle responsible for photosynthesis is……...……..
5. Chemically, cell wall is made up of cellulose and the cell membrane is made up of…….

E. Match the items of Column I with the most appropriate items of Column II. Rewrite the correct matching pairs.

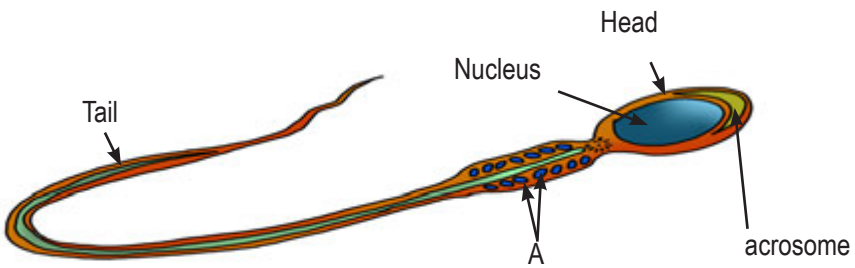
Column I	Column II
1. Lysosome	a. Gives shape to a plant cell
2. Genes	b. Separates the nucleus from the cytoplasm
3.. Nuclear membrane	c. Photosynthesis
4. Cell wall	d. Hereditary unit
5. Chloroplast	e. Intracellular digestion

F. Give reasons.

1. 'The function of an organism as a whole is the outcome of the combined activities and interaction of the constituents of the cells'.
2. The cell of an elephant will not be larger than that of an ant.
3. Is this statement true or false? Plant cells have chloroplast, but not mitochondria?
4. Robert Hooke discovered cell wall, but not cell organelles.
5. The colour of chillies at the time of ripening changes from green to red.

G. Answer the following questions.

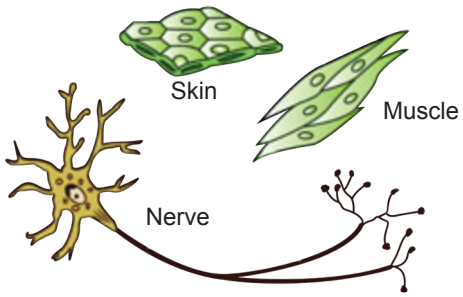
1. What are vacuoles? List one important function.
2. What is the most likely role of the pores in cell membrane?
3. State the main points of the cell theory. Name the scientists who put forth the cell theory.
4. The diagram below shows the structure of a human sperm. Study and answer questions a and b.



   a. Explain the part played by the organelles labelled A in the process leading to fertilization.

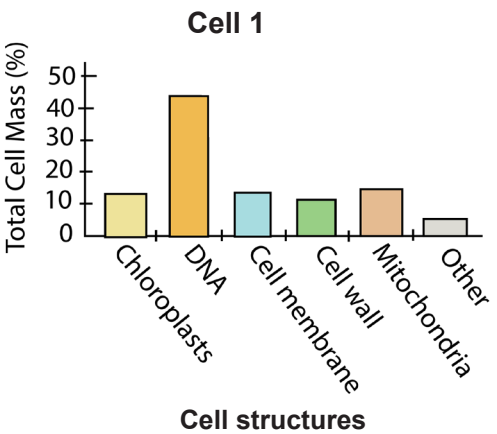
   b. Describe how this cell is adapted for fertilization with an ovum.

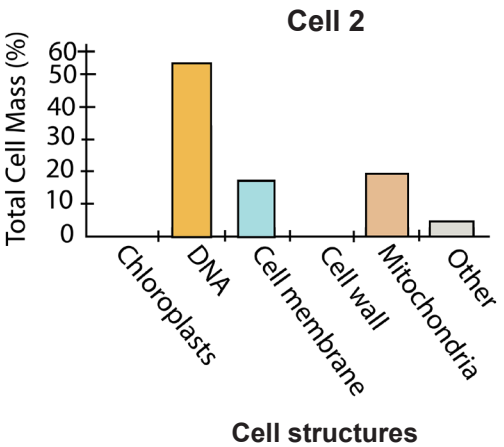
5. Classify plastids. Briefly describe the function of each type.
6. The types of human cells shown below are different from one another, though they all originated from the same fertilized egg and contain the same genetic information.



   a. Explain why these genetically identical cells can differ in structure and function.
   b. Cells are small in size. What might be the advantage of it?
   c. Name an instrument used to study cell.

7. Data from two different cells are shown in the graphs below. Study and answer the questions a through d.





   a. Which cell is most likely a plant cell? Support your answer.
   b. Identify two non-living substances represented as 'other' in the graph.
   c. From the graph, which cell structure is the heaviest?
   d. Why mass of cell membrane in Cell 1 and Cell 2 are equal?

2 Green Plants

All animals, including human beings, depend on plants for their food and shelter. Where does this food come from in plants? Green plants synthesise food that they need, and all other organisms derive food and shelter from them. Green plants make their own food using energy from sunlight to convert carbon dioxide and water into glucose. This process is called photosynthesis. This process is also responsible for the release of oxygen into the atmosphere by green plants.

This chapter focuses on the physiological processes of transpiration, photosynthesis, transport of substances in plants and plant hormones.

A. Transpiration

Learning Objectives

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

- explain transpiration in plants.
- examine the presence of stomata in a leaf.
- explain the mechanism of stomatal opening and closing.
- elaborate on the factors that affect the rate of transpiration.
- investigate the rate of transpiration using Ganong's potometer.

Activity 2.1

Do plants sweat?

Materials required: well watered potted plant, string, scissors, plastic bag.

Procedure

1. Take a small potted plant, two hours before your biology class.
2. Cover the plant with a transparent polythene bag, and tie its mouth around the base of the stem as in Figure 2.1.
3. Leave the plant in the sunlight.

Questions

i. Write your observations after two hours?

ii. Cobalt chloride paper turns pink when exposed to moisture. Put a dry cobalt chloride paper inside the plastic bag. What can you conclude from the test?

iii. How would your experiment change if your plants have more leaves?

iv. Design a control experiment for your experiment.

v. How would adding another plastic bag change your experiment?

Figure 2.1

a. What is transpiration?

In daylight, the stomata in the leaf of a plant open up and allow water vapour to escape. The water vapour is replaced by water drawn up through the **xylem vessels** from the plant stem and roots. This water is conducted upwards through the stem and is distributed to all the aerial parts of the plants. Only small quantity of this water (1-2%) is used by the plant in **photosynthesis** and other activities. The rest of the water is lost to the atmosphere in the form of water vapours from leaves and other aerial parts of the plants. **This loss of excess water from the aerial parts of the plant in the form of water vapour is called** transpiration.

Transpiration differs from evaporation

Transpiration	Evaporation
• Physiological process in plants	• Physical process
• Loss of water from living tissues	• Living tissues are not essential
• Loss of water vapours through pores	• Conversion of any liquid into vapours

b. Kinds of transpiration

Transpiration mainly occurs through **stomata**, **cuticle** and **lenticels**; and accordingly, there are **three** types.

1. **Stomatal transpiration**: Most of the transpiration takes place through stomata. It accounts for 80-90% of the water transpired from leaves. Stomata are usually found more in ventral sides of the leaves. In **monocots**, e.g. grasses stomata are equally distributed on all sides. While in **aquatic plants** with floating leaves, they are present on the dorsal surface of the leaf.
2. **Cuticular transpiration**: Water vapour directly diffuses through cuticle and escapes to the atmosphere. The cuticle is a **waxy covering on the epidermis** of leaves and green stems. **The greater the thickness of the cuticle, the lesser is the transpiration.** Desert plants tend to have thicker cuticle to reduce transpiration. This type of transpiration accounts for only about 5-10% of the total water loss from leaves.
3. **Lenticular transpiration**: Some woody stems lose water through lenticels. The lenticels are **special openings** found on the barks of woody stems and twigs. It never closes, and remains open all the time. Like cuticular transpiration, escape of water vapour through the lenticels is too low compared to stomatal transpiration.

c. Mechanism of stomatal transpiration

In stomatal transpiration, the water vapours escapes through stomata of the leaf. Water, after absorption by the roots from the soil, rise up through the stem and reaches the cells of leaves through veins. A large number of **spongy mesophyll cells** in the leaves have their surfaces exposed to the **intercellular spaces**. These surfaces of the cells give out some of the water as a thin film. The water from this film evaporates and the water vapour formed saturates the air in the intercellular spaces and finally reaches the **sub-stomatal cavity,** from where it escapes through stomata. The entire movement of water vapour from the surface of the cell into outside atmosphere is a result of diffusion. The molecules of water vapour, move from region of their higher concentration to the region of lower concentration.

Figure 2.2 shows a cross section through a leaf and movement of water through it. The cell sap in each cell exerts a **turgor pressure** outward on the cell wall. This pressure forces some water out of the cell wall into the air space between the cells. Here, the water evaporates and the water vapour diffuses through the air spaces between the mesophyll cells (both palisade and spongy) into the **sub-stomatal space** from where it finally goes out by diffusion through stomata. The cells that lose water in this way replace it by drawing water from the nearest vein.

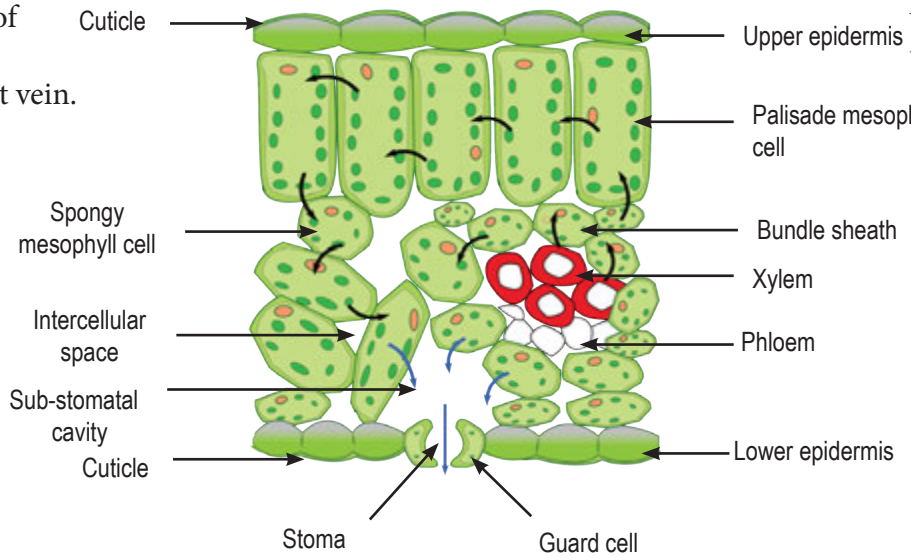


Figure 2.2 Cross section through a leaf showing movement of water

Inside a leaf (Figure 2.2) are thousands of microscopic cells that act as food factories. Each cell contains tiny structures called chloroplasts that are filled with green chlorophyll. The structure of a leaf consists of protective **cuticle**, upper and lower

Special structures in transpiration

Stomata (*singular*: **stoma**) are tiny apertures on plants found typically on the outer layer of leaf (**epidermis**). They consist of two specialized cells, called guard cells.

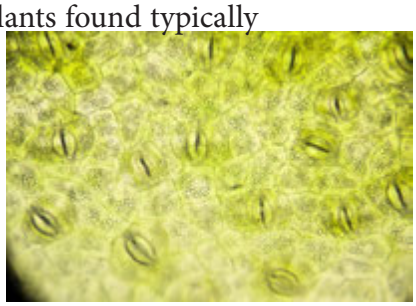


Figure 2.3 Stomata of plant leaf

Their main function is to draw in carbon dioxide water vapour and oxygen to move rapidly in and out of the leaf. Stomata are found on **aerial parts** of plants, including the petals of flowers, petioles, soft herbaceous stems and leaves.

Lower surface of the leaf has more number of stomata

compared to upper surface of the leaf. A stoma is a **physical gap between two special epidermal cells** called **guard cells**. When the pair of guard cells are turgid filled with water, they bulge outward and open. If a plant is deprived of water, it wilts. To compensate the water loss, guard cells become flaccid and the stoma is closed.

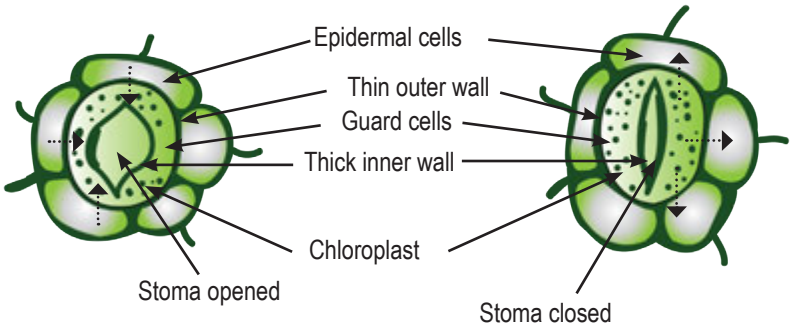


Figure 2.4 Opening and closing of stomata

The structure of guard cells explains, why they open when turgid.

1. The two guard cells are fused at their ends.
2. The inner cell walls, which form the stoma, are thicker than the outer walls.

Theory of stomatal opening and closing

There are different theories explaining the mechanism of stomatal opening and closing. One of the most recent theories is K^+ ion concentration. According to this theory, opening and closing of stomata depend on the generation of **potassium ion (K^+) gradient**. During daytime, the chloroplasts in the guard cells photosynthesise, which leads to the production of ATP (**Adenosine Triphosphate**). This ATP is used to actively pump the potassium ions of the adjacent cells into the guard cells. The guard cells become hypertonic to its adjacent cells, and so, more water is drawn in and it becomes turgid, leading to opening of the stomatal pore. Reverse happens during night, when the **K^+ ions leak out** of the guard cells; thus, reducing the turgor pressure and the stomata closes. Figure 2.5 illustrates this mechanism.

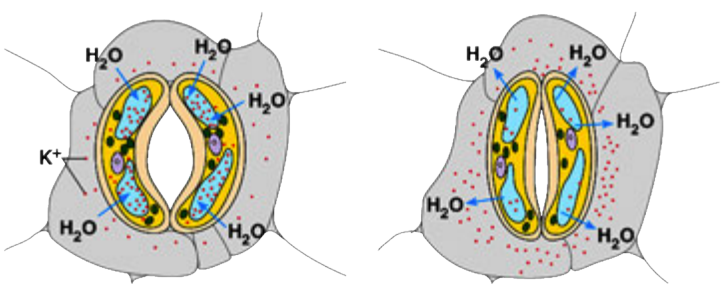


Figure 2.5 Mechanism of stomal opening and closing

Activity 2.2

Investigate stomata in leaf

Stomata are the microscopic pores in the epidermis of leaves. They are the passageways for gases and water vapours. A stoma is an opening through which leaves exchange gases and lose water (transpire). Each stoma is surrounded by two bean-shaped guard cells. The epidermis of leaves has stomata among its epidermal cells.

Materials required: Petri dish, healthy leaf, water, glass slides and cover slips, methylene blue, microscope

Procedure

1. Take a thick leaf and peel off a thin layer (epidermis) from its surface.
2. Place the thin layer in water in a Petri dish.
3. Cut a piece of the peeled off epidermis and place it in a drop of water on a glass slide.
4. Pour a drop of methylene blue and place a cover slip on the material.
5. Observe under the low and high power of the microscope.
6. Observe the epidermis and point out the stomata present in it. Count the total stomata; and count how many of these are open.

Questions

i. Draw your observations in notebook.
ii. How many stomata did you observe?
iii. Why did you add methylene blue?
iv. Why you need to place your specimen in water?
v. What is the structure of guard cells, and how do guard cells help in the opening and closing of stomata?

Activity 2.3

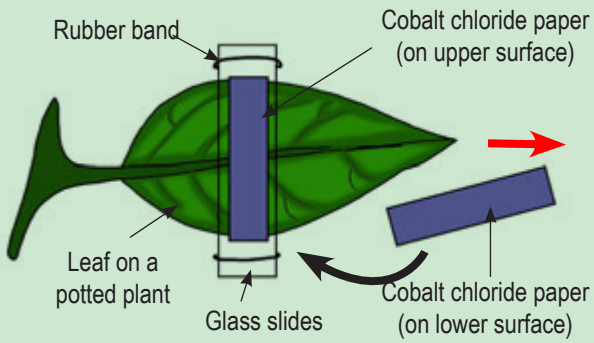
Investigating the rate of transpiration

Materials required: a potted plant, cobalt chloride filter papers, forceps, glass slides, rubber bands, filter paper discs, and stop clock.

Hypothesis: There is more transpiration from the ventral surface of leaf surface as compared to the dorsal surface.

Procedure

1. Take a potted plant. Water the plant and leave it for an hour.
2. Take two equal size cobalt chloride papers. With the help of forceps, place one piece of cobalt chloride paper on the dorsal surface and the other paper on the ventral surface of the leaf.
3. Place dry glass slides on the dorsal and the ventral cobalt chloride papers and fix them with a rubber band. The glass slides will prevent the cobalt chloride papers contacting the atmospheric humidity.
4. Note changes in colour of the two cobalt chloride papers write down in table given below.



Location	Time taken to change the colour	Inference	Conclusion
Cobalt chloride paper on the upper surface of the leaf			
Cobalt chloride paper on the lower surface of the leaf			

Questions

i. What does the colour change of blue cobalt chloride paper to pink show?
ii. What is the relationship between the rate of transpiration and the number of stomata?
iii. How would the rate of transpiration vary, if the setup is kept in the dark room?
iv. Relate this phenomenon to sweating.
v. What can you conclude from the experiment?

d. Factors affecting transpiration

Following environmental factors affect the rate of transpiration.

1. **Intensity of sunlight**: During the day, the stomata are open to allow the inward diffusion of carbon dioxide for photosynthesis. During night, stomata remain closed. Therefore, **more transpiration** occurs during the day. When it is cloudy during the day, stomata are partially closed and transpiration is reduced.
2. **Air temperature**: If the outside temperature is higher, there is more evaporation from the leaves; therefore, more transpiration. Increase in temperature allows more water to transpire and decreases the temperature, **reducing the transpiration**.
3. **Velocity of wind**: **Transpiration increases** with the velocity of the wind. If the wind blows faster, the water vapour released during transpiration is removed faster. The area outside the leaf is less saturated with water vapour. Hence, more transpiration takes place.
4. **Humidity**: Low and high humidity directly affect the transpiration. When the **humidity in air is high, transpiration is reduced**. High humidity in the air reduces the rate of outward diffusion of the internal water vapour across stomata. This reduces the rate of transpiration.

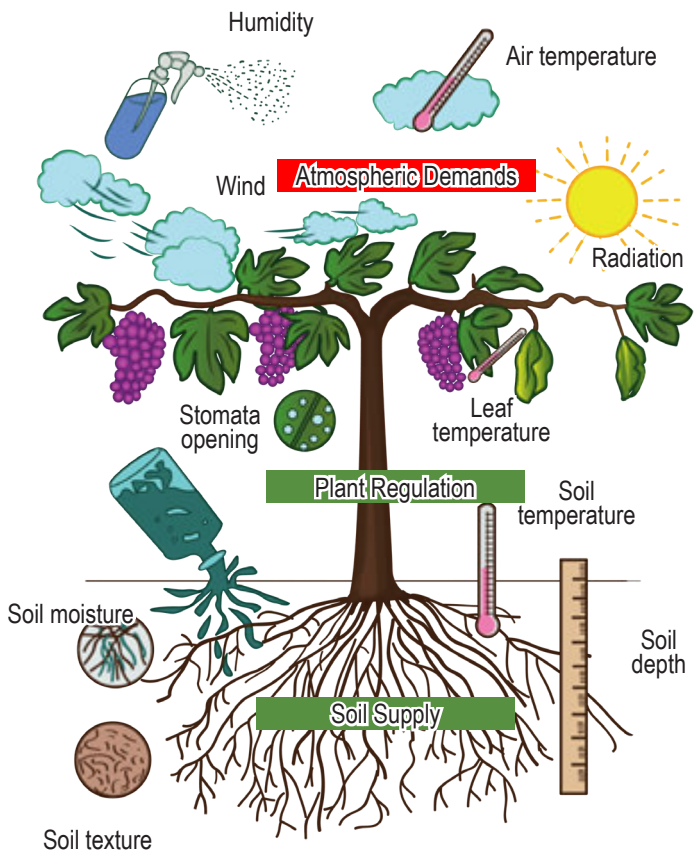


Figure 2.6 Factors affecting transpiration

5. **Carbon dioxide**: An increase in CO_2 concentration in the atmosphere leads towards **stomatal closure**; and hence, it reduces transpiration.
6. **Available soil water**: Rate of transpiration will decrease if there is less water in the soil. In such situation, stomata close to minimize transpiration. Such reduction in transpiration is a natural mechanism of conserving water within the plant.

e. Measurement of the rate of transpiration

The following methods are usually used for the measurement of transpiration in plants.

i. **Weighing method**: A small light weighted potted plant can be weighed before and after the certain period of time of transpiration. The soil surface and pot should be fully covered to prevent evaporation from the surfaces. The loss in weight by the plant during that time is due to the loss of water by transpiration. This method can be used in case of isolated parts of plants such as leaves, branches, etc. However, this method cannot be applied in case of large and tall plants.

ii. **Collecting and weighing transpired water**: This method consists of passing the air of known moisture content over a potted plant kept under a closed glass chamber through an opening. The air after being mixed with transpired water is passed out over anhydrous calcium chloride, whose weight is already known (Figure 2.7). The increase in the weight of the anhydrous calcium chloride will be equal to the weight of transpired water and the original moisture content of the air. The weight of the original moisture content of the air being known, the weight of the transpired water is easily calculated.

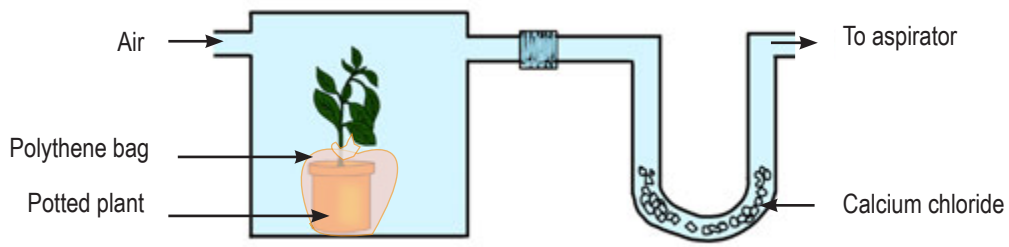


Figure 2.7 An apparatus for measuring transpiration

iii. **Potometer method**: Potometer is a device that works based on the assumption that the rate of water intake by a plant is equal to the rate of transpiration.

The rate of transpiration can be measured in laboratory using Ganong's potometer ('**drinking meter**'). During the day, plants often transpire more water than they take up, and during the night, plants may take up more water than they transpire.

2.4 Activity

Working of Ganong's potometer

Materials required: fresh leafy twig, cork, Ganong's potometer, water and petroleum jelly.

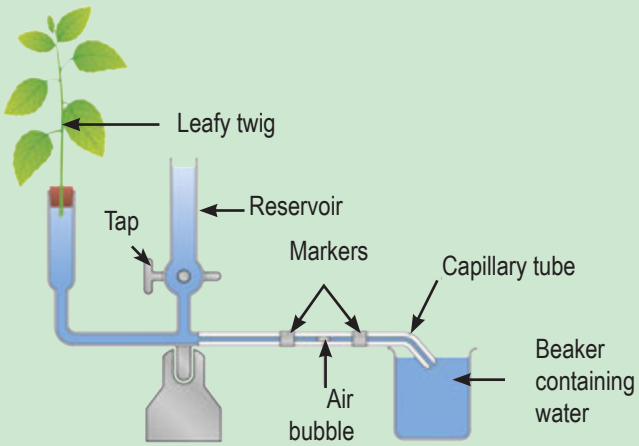


Figure 2.8 Ganong's potometer

Procedure

1. Fix a fresh leafy twig of a plant, which is cut underwater to the Ganong's potometer as shown in Figure 2.8.
2. Apply petroleum jelly to all joints to make it air tight.
3. Introduce an air bubble into capillary tube of potometer under the water. As soon as the air bubble enters into the capillary tube, its free end is dipped in water contained in a beaker. The movement of the air bubble in the capillary tube is noted on the scale, which measures the rate of transpiration.
4. Record the time taken for air bubble to travel a particular distance in the capillary tube. The air bubble can be pushed back by opening the water reservoir and many readings can be taken without disturbing the apparatus.

Questions

i What is the aim of the experiment?
ii. Why is it necessary to apply petroleum jelly at the joints of the apparatus?
iii. Why the twig has to be cut under water?
iv. Name any three factors that might affect your experiment?
v. How will you relate the rate of transpiration with the change in temperature?
vi. Relate the high humidity in the green house to transpiration.

Limitations in the use of Ganong's potometer

1. *Introducing the air bubble is not very easy.*
2. *The twig may not remain fully alive for longer time.*
3. *Any changes in the outside temperature may affect the position of air bubble in the capillary tube.*

f. Significance of transpiration

Transpiration is considered as a **necessary evil**, because it often produces water deficit in plants by which photosynthesis, plant growth are reduced and may cause death, if severe. Plants waste much of their energy in absorbing large quantities of water, most of which is ultimately to be lost through transpiration. However, transpiration has great significance to plants in the following ways:

1. **Movement of water**: Since leaves are present at the tips of all branches and twigs, transpiration from the surfaces tends to draw water towards them, and thus helps in the distribution of water throughout the plant body. **Higher is the rate of transpiration**, **greater the rate of absorption** of water and solutes from the soil.
2. **Absorption and translocation of mineral salts**: Transpiration helps in the ascent of sap by producing suction force acting from the top of a plant. Loss of water from the leaves makes the cell sap more concentrated resulting in increase of osmotic pressure. This draws water from the adjacent cells that are at the higher level of water concentration in and finally favours absorption of water from the soil by the roots.
3. **Regulation of temperature**: When the water evaporates from the leaf surface, temperature of leaves reduces. Therefore, this process helps the plant to reduce temperature during the intense heat.

g. Anti-transpirants

A number of substances are known, which when applied to the plants retards transpiration. These substances are called anti-transpirants. These substances are sprayed on crops during dry season to avoid water loss from plants, when the rate of transpiration is high. **Silicon oil** and **phenyl mercuric acetate** are examples of anti-transpirants. Abscisic acid (**ABA**), a plant hormone also induces closure of stomata reducing the rate of transpiration. An increase in **CO_2 concentration** in atmosphere from usual 0.03% to about 0.05%, causes partial closure of stomata. In very high concentration, it causes complete stomatal closure.

Adaptation of plants to reduce excessive transpiration

Environmental factors can play a important role in the rate of transpiration. Plants in hot arid environments have found ways of limiting their water loss to avoid dehydration. Some of the adaptations that the desert plants use are: **absence of leaves**, **stomata** that can open and close, or that opens only at night, special **water storage** capabilities, and **alternative root** structures.

Xerophytes are plants that have adapted by changing their physical structure. These plants exhibit several adaptations, which allow them to survive in harsh climates.

Xerophytic plants, such as cacti, do not have leaves, but instead depend on chlorophyll in the outer tissue of their skin to conduct photosynthesis. By **eliminating leaves** or greatly **reducing leaf size**, transpiration is reduced. The waxy surface of their skin seals in moisture and produces food for the plant.

Figure 2.12 Xerophytes

Phreatophytes have adapted to arid environments by **growing long roots**. These roots allow them to access water deep below the surface of the soil. The roots of mesquite trees are about 80 ft long and are considered as tap roots. Other plants have **radial root systems**, which spread out quickly during rainfall to absorb water.

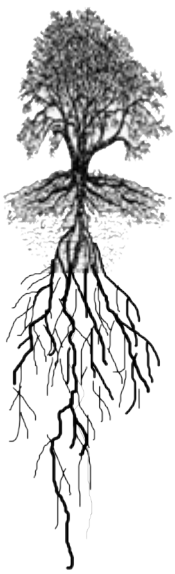
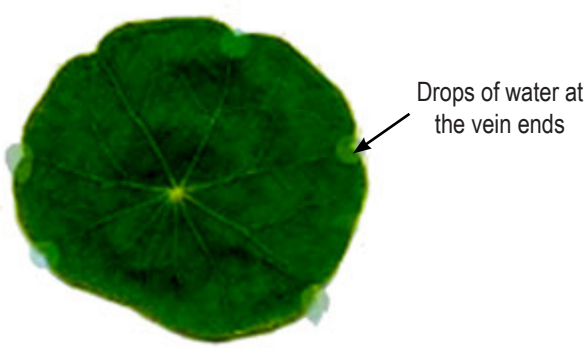


Figure 2.10 Phreatophytes

Loss of water by plants

Some plants lose water directly, i.e. in liquid form and not as water vapour. It occurs in two ways- **guttation** and **bleeding**.

In some plants such as garden *Nasturtium*, tomato, colocasia, etc., watery drops ooze out from the **uninjured margins of the leaves**. This is called guttation. The leaves of certain plants exhibit droplets of water along their margins in the morning (Fig. 2.11). This process is very common during warm humid nights. This process occurs in plants growing in high soil moisture. It occurs through specialised pores called hydathodes, present near the vein endings to allow **exudation**.



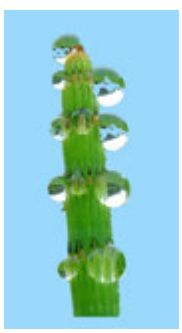


Figure 2.11 Nasturtium leaf showing guttation at the margin of leaf

The oozing of plant sap ('*bleeds*') from the ruptured or cut surfaces of a plant due to injury is called bleeding. The root pressure generated by a plant assists in bleeding. Root pressure in the pressure developed in the xylem of the roots due to inflow of water.

B. Photosynthesis

Learning Objectives

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

- write the balanced chemical equation for photosynthesis.
- name the factors affecting photosynthesis.
- compare and contrast light dependent and independent phase.
- articulate the importance of photosynthesis.

Activity 2.5

Priestley's experiments

Joseph Priestley, in 1770, performed a series of experiments that revealed the essential role of air in the growth of green plants. Figure 2.12 shows one of Priestley's experiments. Study and answer the questions that follow.

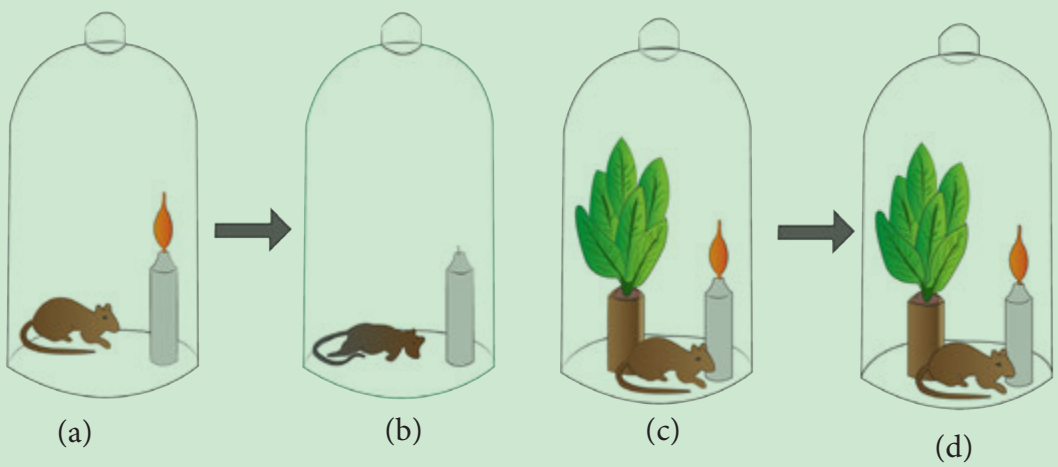


Figure 2.12 Priestley's Experiments

Questions

i. Why did the mouse in bell jar (b) die?

ii. Priestley hypothesised that plants restore air that are used by breathing animals and burning candles. What is your possible hypothesis for continuously burning of candle in the bell jar (d)?

iii. A control is an experiment meant for comparison. Identify the control experiment for Priestley's experiment.

iv. What can you conclude from this experiment?

a. What is photosynthesis?

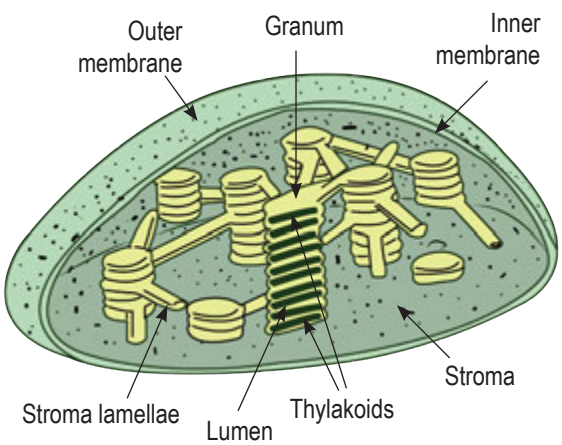
Photosynthesis literary means *'synthesis with the help of light'*, but this term is usually applied to an important process in green plants. The chemical process through which green plants produce glucose and oxygen from carbon dioxide and water by using light energy is called photosynthesis. This process by plants creates most of the food on earth and nearly all the oxygen that we breathe. During the process, reaction also releases oxygen into the air. The plant uses the glucose to make cellulose (plant fibre), and combines it with nutrients from the soil to **make proteins** that are used for growth.

In a single year, one mature tree releases enough oxygen to support ten people.

b. Chloroplast- food producer of the cell

Chloroplasts are small green structures present in plant cells and some **eukaryotic organisms**. They convert sunlight into chemical energy and use to split water into hydrogen and oxygen. Then they combine the hydrogen with carbon dioxide to form glucose. They are the most important plastids found in plant cells. The distribution of chloroplasts is homogeneous in the cytoplasm of the cells and in certain cells, chloroplasts become concentrated around the nucleus or just beneath the cell membrane. A typical plant cell might contain about 50 chloroplasts per cell.

A chloroplast is a **tiny oval body bounded by double membranes** that protect the inner parts. It has a system of three membranes: the outer membrane, the inner membrane and the thylakoid system. The outer and the inner membrane of the chloroplast enclose a **semi-gel-like fluid** known as stroma. This stroma makes up much of the volume of the chloroplast. The thylakoid system floats in the stroma. The thylakoid system is a collection of membranous sacs called thylakoids. The chlorophyll is found in the thylakoids and **is the site for** the process of light reactions of photosynthesis. The thylakoids are arranged in sacs known as grana (*singular*: **granum**). Each granum contains around 10-20 thylakoids. The walls of thylakoids contain chlorophyll molecules, which are very complex substance, composed of carbon, hydrogen, oxygen, nitrogen and magnesium. The stacks of sacs are connected by stroma lamellae. The lamellae act like the skeleton of the chloroplast, keeping all the sacs at a safe distance from each other.



C. Process of photosynthesis

Mesophyll cells (palisade cell and spongy cell) in a leaf (Figure 2.2) are the **principal centres of photosynthesis**. Palisade cells are tall, cylindrical cells packed with chloroplasts. During day time, when sunlight falls on the leaf, the light energy is trapped by the chlorophyll of the upper layers of mesophyll, especially the palisade cells. This light energy is utilized in chemical process involved in the preparation of food by the plants. **Carbon dioxide** from the atmosphere enters the leaf by **diffusion through the stomata** due to higher concentration of CO_2 outside than inside of the leaf. Water from the soil is absorbed by roots, and transported through the stem and finally reaches the leaves where it is distributed in the **mesophyll tissue**.

i. The photosynthesis reaction

Photosynthesis is a chemical process that takes place in the chloroplasts of the green plants. In this process, carbon dioxide and water are converted into **glucose** and **oxygen**. The process of photosynthesis is summed up in the word and chemical equation below:

$$\text{Carbon dioxide + Water} \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \text{Glucose + Oxygen}\uparrow\text{ + Water}$$

(*Raw materials*) (*Products*)

$$6CO_2\,(g) + 12H_2O\,(l) \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2\uparrow + 6H_2O$$

In the above chemical equation, **six molecules** of carbon dioxide and **twelve molecules** of water react to produce **one molecule** of glucose (sugar), **six molecules** of oxygen and **six molecules** of water.

Photosynthesis occurs in two stages. In the **first stage**, which is also known as light-dependent reaction, light energy is captured and used to make the energy storage molecules called ATP (**Adenosine Triphosphate**). The other reaction is the dark reaction.

1) Light reaction

Light reaction is faster than the dark reaction and occurs in the grana of chloroplast. The light energy is absorbed by chlorophyll. The chlorophyll is activated and it converts light energy into chemical energy in the form of ATP. This energy is used to **split water molecules** into **hydrogen** (H^+) and **oxygen** (O^{2-}) ions by the process known as photolysis.

$$H_2O \xrightarrow{\text{photolysis}} 2H^+ + 2e^- + \tfrac{1}{2}O_2$$

During this process oxygen is released. The products of the light dependent stage are ATP, NADPH (**Nicotinamide Adenine Dinucleotide Phosphate**) and oxygen.

2) Dark reaction

During the second stage (the dark reaction), the hydrogen ions and chemical energy that were produced during the light dependent phase are used to reduce carbon dioxide to form glucose. This reaction is **purely enzymatic and is independent of light**. It occurs in the stroma of the chloroplast.

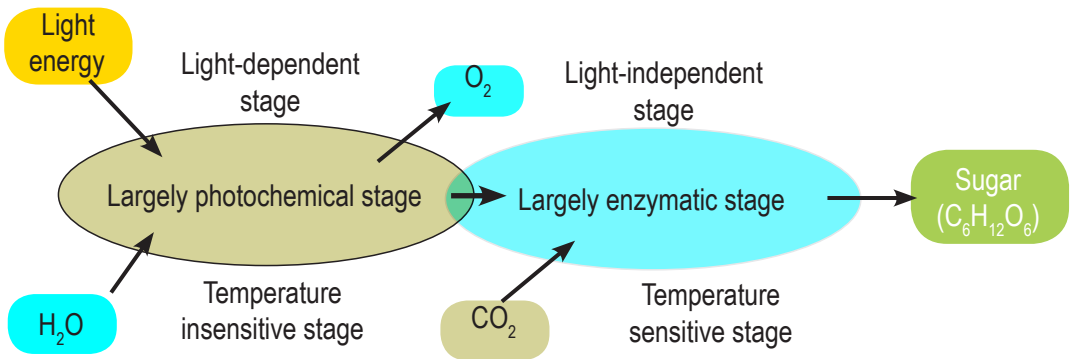


Figure 2.14 The two stages of photosynthesis

The **end products of photosynthesis** are glucose, water and oxygen. Glucose, 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 reutilized 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.

d. Factors affecting the photosynthesis

The rate of photosynthesis is affected by number of **external** and **internal** factors.

External factors

1. **Light intensity**: The rate of photosynthesis increases with increase in the light intensity. However, very high intensity slows down the rate of photosynthesis as it **bleaches** the chlorophyll.
2. **Carbon dioxide concentration**: An increase in the concentration of carbon dioxide results an increase in the rate of photosynthesis.
3. **Temperature**: The rate of photosynthesis increases with the increase in temperature.

The rate of photosynthesis increases till the temperature reaches to **optimum temperature of 35 ^{0}C**, which is the maximum suitable temperature.

4. **Water content**: The rate of photosynthesis increases with high water content because stomata remains open when the cells are turgid.
5. **Oxygen:** Photosynthesis does not take place in cells which lack oxygen. High concentrations of oxygen inhibit the rate of photosynthesis.

Internal factors

1. **Structure of the leaf**: The structure such as thickness and size of a leaf can affect the rate of photosynthesis.
2. **Chlorophyll content**: The rate of photosynthesis increases with the amount of chlorophyll content in a leaf because more chlorophyll can absorb more light energy.
3. **Protoplasm contents**: Less amount of water reduces the rate of photosynthesis and similarly, accumulation of carbohydrates reduces the rate of photosynthesis.
4. **Accumulation of the end products of photosynthesis**: The accumulation of end products of photosynthesis due to slow translocation reduces the rate of photosynthesis.

e. Importance of photosynthesis

All living organisms need food. Animals, including humans, obtain food from plants since plants are autotrophs. The process of photosynthesis benefits us in the following ways:

1. Photosynthesis converts inorganic raw materials into food that provides our ecosystem with energy.
2. Green plants provide organic food for all the animals and humans.
3. Photosynthesis helps in providing oxygen in the atmosphere, required by all living organisms.
4. Fossil fuels like coal, petroleum and natural gas are formed through the degradation of the plant and animal parts, which were originally formed by photosynthesis.
5. Plant products like timber, rubber, herbs, medicines, resin, oils, etc., are due to photosynthesis.
6. Photosynthesis decreases the concentration of carbon dioxide and other harmful industrial wastes that lead to respiratory problems in living beings.

Photosynthesis, therefore, can be considered as the **ultimate source of life** for nearly all plants and animals by providing the energy that drives all their metabolic processes.

2.6 Activity

Investigating if light is necessary for photosynthesis

Materials required: well watered de-starched potted plant, black paper, scissors, paper clips.

Procedure

1. Fix the black paper on one of the leaves as shown in Figure 2.15.
2. Make a sketch of the experimental leaf.
3. Keep the experimental set up in the sunlight for 4-6 hours.
4. Then remove the paper and test the leaf for starch.
5. Draw the leaf after starch test.

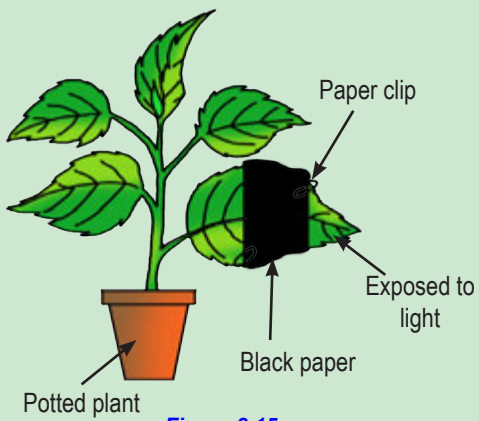


Figure 2.15

Questions

i. What is the importance of procedure number 3?
ii. Why is the plant de-starched before the experiment?
iii. Identify two precautions while setting up this experiment.
iv. Which leaf of the plant acts as control for the experiment?
v. What can you conclude from the experiment?

C. Transportation system in plants

Learning Objectives

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

- explain the transportation of substances in plants.
- explain the mechanism of ascent of sap.
- investigate the path of ascent of sap.
- explain the importance to uptake and utilisation of mineral salts.

Have you ever wondered how water reaches the top of a tall tree? All plants and animals need materials from environment and also need to dispose some materials into the environment. Over the small distances, substances move by **diffusion** and **cytoplasmic streaming** supplemented by active transport. In complex **multicellular bodies**, cells are far apart from environment, and such bodies need a comprehensive system for the transport of materials. In plants, the substances that are transported are **water**, **mineral nutrients**, **organic nutrients** and **plant growth hormones**.

a. Transportation in plants

The movement of glucose, water, oxygen, mineral nutrients, hormones and other organic and inorganic substances from one part of the body to other which is required for growth and development of plants is called internal transport of materials or transportation. The plant parts or organs associated with the transport of these substances constitute the transport system in plants.

Transportation system in plants is simple and slow compared to animals. Plants do not move and therefore, they require much less energy than in animals.

The main roles of transport system in plants are below.

1. It is essential for the movement of vital substances from source to storage organs.
2. It is required for the transport of mineral nutrients and water from the soil to leaves on tree tops.
3. Food synthesised in leaves needs to be distributed throughout the plant body.

There are two main transport systems in the plant: the xylem transport, transporting **water** and **minerals** and phloem transport, transporting **photosynthesised products** and other substances.

i. Transport of water and minerals (ascent of sap)

Roots absorb water and salts from soil. They also provide conducting tissues for distributing these substances to the tissues of stem. The water after being absorbed by roots is distributed to all parts of the plant. In order to reach the topmost parts of the plant, the water moves upward through the stem. This upward movement of water

and minerals is called ascent of sap. The ascent of sap takes place through xylem. Xylem tissue (Figure 2.16) forms water conducting system that helps in supporting the plant and in transportation of water and nutrients absorbed by the root hair from the soil to leaves at the top of the plant. The xylem tissue consists of vessel elements, conducting cells known as tracheids, supportive tissue, called parenchyma and fibres. These cells are joined end-to-end to form long tubes. **Vessels** and **tracheids** are dead at maturity. Tracheids have **thick secondary cell walls** and are **tapered at the ends**.

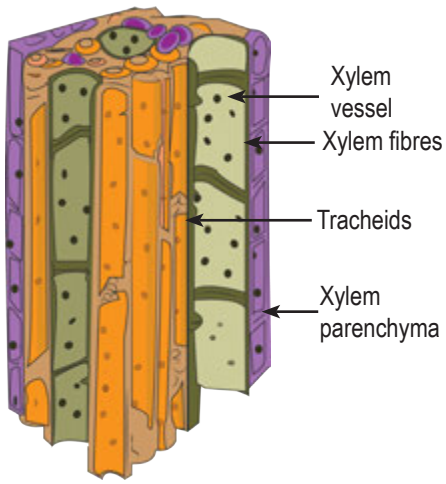


Figure 2.16 Xylem tissue

Mechanism of ascent of sap

Several theories have been put forward to explain the mechanism of ascent of sap in tall plants.

1. Root pressure theory: According to this theory, the root pressure, which is developed in the xylem of the root, causes the rise of water to certain height in a plant. But, now it is established that the magnitude of the root pressure is as low as 2 atmospheres, which is not an effective force for rise of water column in plant body. The study has found that even in the absence of root pressure, ascent of sap continues.

2. Physical force theory: This theory states that many physical forces like **atmospheric pressure**, **imbibitions** and **capillary forces** are responsible in the ascent of sap. However, many scientists reject the theory because of poor explanation.

3. Cohesion-tension theory: This theory was originally proposed by Dixon and Jolly in 1894. It is widely supported by many scientists. According to this theory, force which carries water with dissolved materials upward through the xylem is **transpiration pull**. Transpiration creates a **pressure difference** that pulls water and salts up from roots to considerable heights in plants.

When a **leaf transpires** (loses water), the water concentration of its mesophyll cells drops. This causes water to move by osmosis from the xylem of leaf into the mesophyll cells. When one water molecule moves up in the xylem of the leaf, it **creates a pulling force** that continues all the way to root. This pulling force created by the transpiration of water is called transpiration pull. It also causes water to move transversely from root epidermis to cortex and pericycle.

The reasons for the transpiration pull are (Figure 2.17).

1. Water is held in a tube (xylem) that has small diameter.
2. Water molecules adhere to the walls of xylem tube (adhesion).
3. Water molecules cohere to each other (cohesion).

These attractions make an overall **tension** among water molecules. This tension forms *'columns'* of water. As **columns of water** move from root to shoot, water content of the soil enters in these *'columns'* to fill the vacant space.

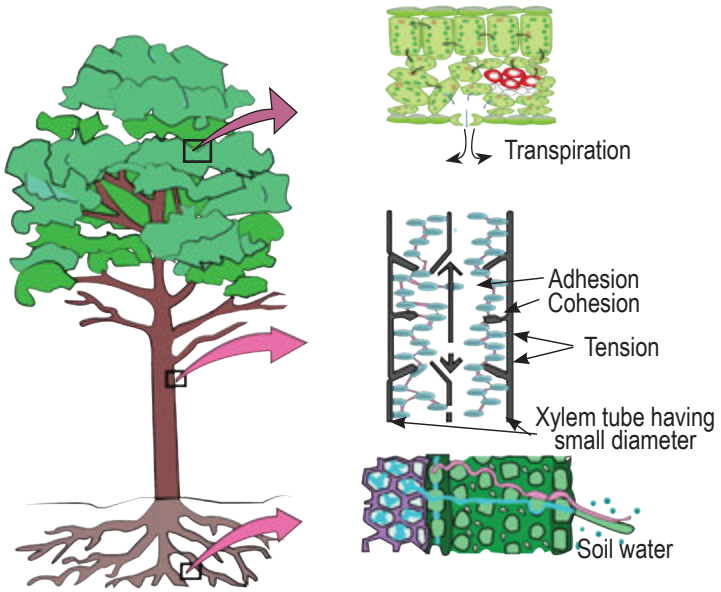


Figure 2.17 Transpiration pull

Activity 2.7

Investigating the pathway of water in a cut stem

Materials required: beaker, eosin, water, blade, herbaceous plant, and microscope.

Xylem tissue consists of vessel elements and tracheids. Vessel elements form long tubes, while tracheids are long cells with overlapping ends. Transpiration pull is the major force responsible for ascent of sap.

Procedure

1. Fill a beaker with dilute eosin solution.
2. Place the shoot of a herbaceous plant (e.g. white coloured Petunia) inside the beaker as shown in the Figure 2.18. The lower end of the shoot must be completely submerged in the solution.
3. Keep the apparatus for an overnight.
4. Cut the longitudinal sections of stem.
5. Examine and observe it under microscope.
6. Make a sketch of your observations.

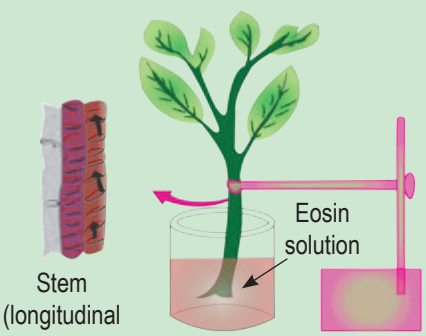


Figure 2.18

Questions

i. What is your observation on the longitudinal section of the stem?
ii. What is the reason for the change in the colour of the stem?
iii. Name any solution that we can use instead of eosin.
iv. How would your experiment vary if stem has no leaf?
v. Why is hard wood stem not suggested in this experiment?
vi. What can you conclude from this experiment?

ii. Transportation of food and other substances (translocation)

The food manufactured in leaves by the process of photosynthesis is transported to other parts of the plant body for utilization and storage. The transport of food from leaves to different parts of plants is called translocation. Phloem tissue (Figure 2.19) is responsible for translocation, which is the transport of soluble organic substances such as sugar. The phloem tissue consists of sieve elements, the companion cells, parenchyma cells, and fibres. The end walls, unlike vessel members in xylem, do not have large openings. The end walls, however, are full of small pores where cytoplasm extends from cell to cell.

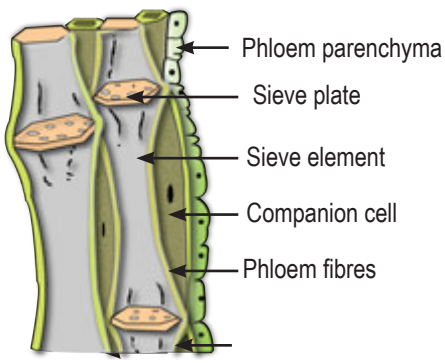


Figure 2.19 Phloem tissue

The glucose formed during photosynthesis in mesophyll cells is used in respiration and the excess of it is **converted into sucrose**. In most plants, food is transported in the form of sucrose**.** The currently accepted hypothesis states that transport of food is through pressure-flow mechanism. In pressure-flow mechanism, food is moved from **sources** to **sinks**. Sources include the exporting organs, typically a mature leaf or storage organ. Sinks are the areas of active metabolism or storage like roots, tubers, developing fruits and leaves, and growing regions.

At **source**, food (sugars) is moved by **active transport** into the **sieve tubes of phloem**. As the food moves through the sieve tubes, due to the presence of sugar in sieve tubes, the solute concentration increases, and hence **water enters** the sieve tubes from xylem by the process of **osmosis**. This results in higher pressure of water in these tubes, which drives the solution of food towards the sink.

At **sink**, food is **unloaded by active transport**. Water also exits from the sieve tubes. The exit of water **decreases pressure** in sieve tubes, which causes a mass flow of food from the higher pressure at the source to the now lowered pressure at the sink (Figure 2.20).

b. Adsorption of mineral salts

Before, it was thought that the adsorption of mineral salts from the soil took place along with the absorption of water, but it is now well established that the **mineral salt adsorption** and **water absorption** are two different processes.

Mineral salts are adsorbed from the soil solution in the form of ions. They are mainly adsorbed through the **meristematic regions** of the roots near tips. Plasma membrane of the root cells is not permeable to all ions. Not all ions of the same salt are adsorbed at equal rate rather, there is **differential adsorption of ions**. The adsorption of mineral salt is facilitated by following processes.

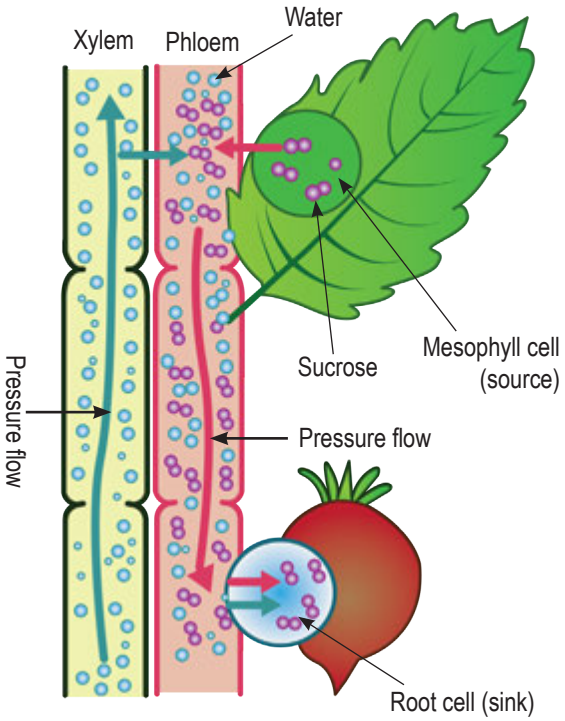


Figure 2.20 Transport of food

i. Passive absorption

When the concentration of mineral salts is higher in the outer solution than the cell sap of the root cells, the mineral salts are adsorbed according to the **concentration gradient** by simple process of **diffusion**. This is called passive absorption, because it does not require expenditure of energy.

Ion-exchange: This is the **first step in the adsorption** of mineral salts, which does not require energy that facilitates the mineral salt adsorption. The ions adsorbed on the surface of the walls, or membranes of the root cells, may be exchanged with ions of the same sign from external solution. For example, the cation K^+ of external soil solution may be exchanged with H^+ ion adsorbed on the surface of the root cells. Similarly, an anion may be exchanged with OH^- ion.

ii. Active absorption

It has been observed that the cell sap in plants **accumulates large quantities of mineral salts ion against the concentration gradient**. For example, in alga *Nitella*, the cell sap accumulated K^+ and phosphate ions to such an extent that their concentrations are thousand times greater than in the pond water where it was grows. This plant has adsorbed and accumulated mineral salts against the concentration gradient by **active process using its energy**.

D. Plant Hormones

Learning Objectives

- On completion of this topic, you will be able to:
- name the basic plant hormones.
- describe their roles in the growth and development of plants.

Why do you think plants have ability to recover repeatedly from grazing of their shoot tips? Most of the physiological activities and growth in plants are **regulated by the action and interaction of chemical substances** in them, called hormones. These hormones are called plant hormones or phytohormones. Plant hormones can have **positive effects** on the plant processes, or may have **negative effect** and inhibit the process. Therefore, plant growth hormones can be broadly divided into two groups, based on their functions in a living plant body. One group is called plant growth promoters, because these are involved in **growth promoting activities**, such as cell division, cell differentiation, tropic growth, flowering, and fruiting and seed formation. These are **auxins**, **gibberellins** and **cytokinins**.

The other group is called plant growth inhibitors, because these are involved in various **growth inhibiting activities** such as dormancy and abscission. These are **abscisic acid** and **ethylene**.

a. Auxins

Auxins (*Greek* word '*auxein*', to grow) are the first plant hormone to be isolated from human urine. It is found in the **active growing tissues**, especially shoot tips, young leaves, and developing fruits and seeds. Many synthetic auxins like indole acetic acid (**IAA**), indole butyric acid (**IBA**) and naphthalene acetic acid (**NAA**) are available for agricultural and horticultural practices.

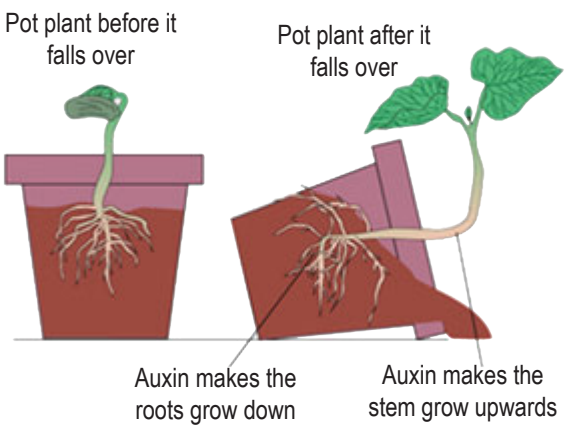


Figure 2.21 Geotropism - Under the influence of gravity, auxins accumulate in the lower side of a horizontal stem, causing cells to enlarge faster, turning the stem upright

Under the influence of gravity, auxins accumulate in the lower side of a horizontal stem, causing cells to enlarge faster, turning the stem upright. This is called geotropism.

Auxin produced in the dominant growing tip (usually

uppermost) inhibits growth in lateral branches. This results in the typical triangular shape of conifers. This phenomenon is called apical dominance.

Functions and uses

1. *They help to initiate rooting in stem cuttings, an application widely used for plant propagation.*
2. *Auxins promote flowering, for example, in pineapples.*
3. *They help to prevent fruit and leaf drop at early stages, but promote the abscission of older mature leaves and fruits.*
4. *In higher plants, the growing apical bud inhibits the growth of the lateral (axillary) buds, a phenomenon called apical dominance.*
5. *Removal of shoot tips (decapitation) usually results in the growth of lateral buds. It is widely applied in tea plantations, hedge-making, etc.*
6. *Auxins also induce parthenocarpy (seedless fruit produced without fertilization), for example, in tomatoes.*
7. *They are widely used as herbicides. It is used to prepare weed-free lawns by gardeners.*

b. Cytokinins

Plant hormones that cause **cell division** in plant cells together with auxins are called cytokinins. It is being **synthesised in roots**, but has most effects on shoot development. However, shoot tissues can also produce cytokinins, as in developing seeds. Some of the very commonly known naturally occurring cytokinins are **zeatin** and its derivatives contained in **coconut milk**.

Functions and uses

1. *Cytokinins in presence of auxin promotes cell division, and influences cell differentiation.*
2. *It helps in breaking the dormancy of seeds.*
3. *It promotes growth of lateral buds, when applied externally.*
4. *Application of cytokinins delays ageing of leaves by controlling protein synthesis.*

c. Gibberellins

Gibberellins were first isolated from the fungus *Gibberella fujikuroi*, the causative organism of '*foolish seedling*', which cause excessive stem and leaves elongation in rice. Plants possess many other unique gibberellins; and collectively, there are well over 100 identified compounds. Of these, gibberellins A3 or gibberellic acid is the most thoroughly studied. Its synthesis takes place mainly in developing leaves and stems, in developing seeds and during germination.

Functions and uses

1. *Gibberellins break dormancy of buds and tubers.*
2. *They promote seed germination in lettuce, cereals, etc.*
3. *They cause stem elongation and leaf expansion, but have no effects on roots.*
4. *They are used to increase the fruit size and bunch length of grapes.*
5. *They cause parthenocarpy (seedless fruit developed without fertilization) in apple and pear.*
6. *Promote flowering in some plants.*

d. Abscisic acid

Abscisic acid (**ABA**) is a **growth inhibitor**, which retards or suppresses growth. It is considered the **'*stress*' hormone** because it inhibits the effects of other hormones by reducing growth during times of plant stress. ABA has been isolated from several higher plants, including dormant buds and seeds. Many activities of ABA are **reverse** to gibberellic acid and cytokinins.

Functions and uses

1. *It prolongs dormancy in seeds.*
2. *It inhibits cell division in plants with approach of winter.*
3. *ABA helps the plant to cope with adverse environment conditions such as extreme cold, heat, etc.*
4. *It causes temporary closure of stomata due to which there is reduction in the rate of photosynthesis.*

e. Ethylene

Ethylene is a **unique gaseous hormone** that diffuses rapidly out of plant tissues. Ethylene is produced in response to cell damage and other stresses such as anoxia. It accumulates rapidly during fruit ripening and senescence. All living cells produce some ethylene. It is synthesised in large amounts by tissues undergoing **senescence** and **ripening fruits**. Influences of ethylene on plants include horizontal growth of seedlings, swelling of the axis and apical hook formation in dicot seedlings.

Functions and uses

1. *Ethylene modifies growth by inhibiting stem elongation and causes swelling of nodes.*
2. *It retards flowering in most plants.*
3. *Application of ethylene increases the number of female flowers and fruits.*
4. *It induces the ripening of fruits as in banana and citrus.*

Interactions among growth hormones

All developmental processes in plants are **controlled by growth hormones**. These hormones **do not act alone**, instead regulate the processes in plants by i**nteractions between different growth hormones**. For example, auxin produced in the terminal buds suppresses the growth of side buds and stimulates root growth (Figure 2.22) Gibberellins produced in the root growing tips stimulate the shoot growth.

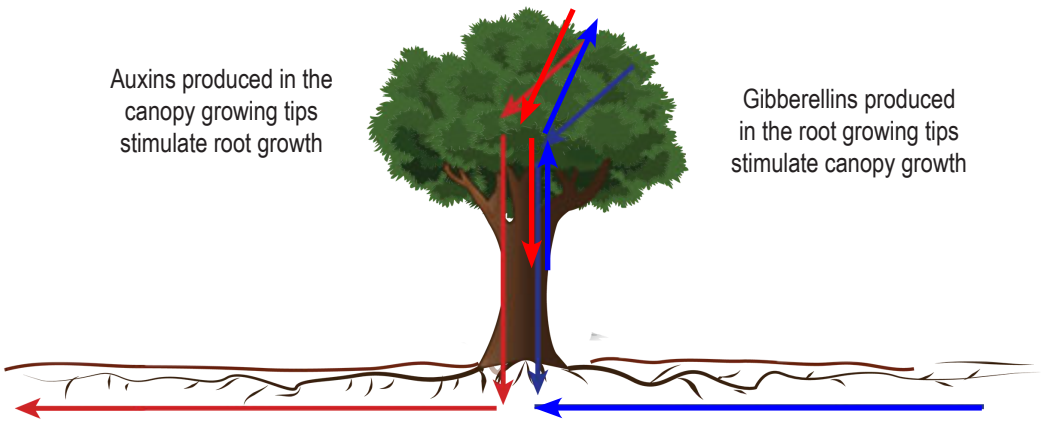


Figure 2.22 A tree balances canopy growth with root growth with the levels of auxins and gibberellins.

Brain Snacks

- Green plants have existed on Earth for about more than **400** million years.
- The green appearance of plant is only because of **green chlorophyll** in their cells.
- In every square millimetre of leaf, there are about **500,000** chloroplasts.
- **Tiny drifting algae** by the process of photosynthesis provides all the food that supports life in the ocean.

Summary

- Photosynthesis is the chemical process through which green plants prepare their own food with the help of carbon dioxide, sunlight and water in the presence of chlorophyll.
- Chloroplast is the structure in the leaf where photosynthesis takes place.
- Photosynthesis occurs in two stages; light-dependent stage and light independent stage.
- End products of photosynthesis are oxygen, glucose and water.
- Photosynthesis plays a vital role in the lives of animals including human.
- Transpiration is the loss of excess water in the form of water vapour from the aerial parts of the plants.
- Maximum transpiration occurs through the stomata.
- Transpiration has great significance to the plants as it helps in the movement of water, and absorption and translocation of minerals.
- The substances that retard transpiration is called anti-transpirants.
- Ganong's potometer is used to measure the rate of transpiration in plants.
- Plants have various adaptations to reduce the loss of water through transpiration.
- Adsorption of mineral salts is assisted by passive and active absorption.
- Plant hormones are chemical substances that regulated the physiological activities and growth of plants.
- Plant hormones can be plant growth promoters or plant growth inhibitors. The examples of plant growth promoters are auxin, gibberellins and cytokinins and plant growth inhibitors are abscisic acid and ethylene.
- Plant growth hormones interact to regulate the metabolic processes in plants.

http://education-portal.com/academy/lesson/plant-hormones-chemical-control-of-growth-and-reproduction.html#lesson

http://education-portal.com/academy/lesson/how-evaporation-transpiration-contribute-to-the-hydrologic-cycle.html#lesson

http://www.phschool.com/science/biology_place/labbench/

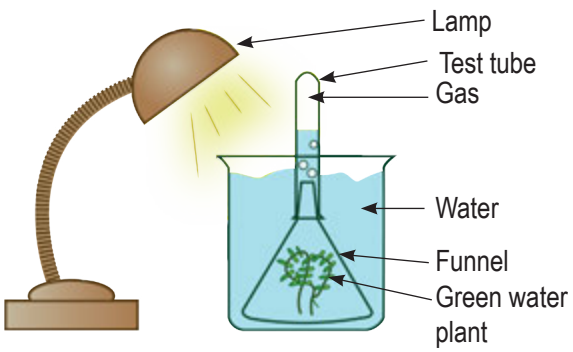
http://escambiaschools.org/L.14.7

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. Which molecule in plant cells first captures the radiant energy from the sunlight?
   A. Glucose
   B. Carbon dioxide
   C. Chlorophyll
   D. Adenosine triphosphate

2. What gas is formed in the test tube in the experiment below?
   A. Carbon dioxide
   B. Hydrogen
   C. Oxygen
   D. Nitrogen



3. Plant cells can synthesize energy-rich organic molecules, and later break them down to extract that energy for performing life processes. This break down of food occurs in the
   A. chloroplasts.
   B. ribosomes.
   C. mitochondria.
   D. cytoplasm.

4. The diagram below represents a change in guard cells that open and close pores in a plant. This change directly helps to
   A. regulate gaseous exchange.
   B. regulate water loss.
   C. absorb minerals.
   D. reduce glucose production.

5. During photosynthesis in plants, what is the source of the carbon in the sugar molecule $C_6H_{12}O_6$?
   A. Carbon dioxide in the air
   B. Carbon monoxide in the air
   C. Carbon particles in the soil
   D. Carbon particles in water

6. The potassium concentration in the root cells of certain plants is higher than in the surrounding soil. Potassium may continue to enter the root cells of the plant by the process of
   A. diffusion.
   C. respiration.

B. active transport. D. protein synthesis.

7. In what way, photosynthesis is similar to cellular respiration?
   A. Both require sunlight
   B. Both occur in chloroplasts
   C. Both involve organic and inorganic molecules
   D. Both require oxygen and produce carbon dioxide

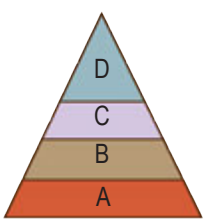
8. A student performed an experiment to demonstrate that a plant needs chlorophyll for photosynthesis. He used plants that had green leaves with white areas. After exposing the plants to sunlight, he removed a leaf from each plant and processed the leaves to remove the chlorophyll. He then tested each leaf for the presence of starch. Starch was found in the area of the leaf that was green, and no starch was found in the area of the leaf that was white. He concluded that chlorophyll is necessary for photosynthesis.

   Which statement represents an assumption the student had to make in order to draw this conclusion?

   A. The green areas of the leaf are heterotrophic
   B. The white areas of the leaf do not have cells
   C. Starch is converted to chlorophyll in the green areas of the leaf
   D. Starch is synthesized from the glucose produced in the green areas of the leaf

9. A student observes that an organism is green. A valid conclusion that can be drawn from this observation is that
   A. the organism must be a plant.
   B. the organism must be an animal.
   C. the organism cannot be single celled.
   D. not enough information is given to determine.

10. Which process provides the initial energy to support all the levels in the energy pyramid shown on the right?



   A. Circulation C. Photosynthesis
   B. Active transport D. Digestion

11. The equation below represents a summary of a biological process.

   carbon dioxide + water → glucose + water + oxygen

   This process is completed in
   A. mitochondria. C. ribosomes.

B. cell membranes. D. chloroplasts.

12. An experimental setup is shown on the right. Which hypothesis would most likely be tested using this setup?

A. Light is needed for the process of reproduction

B. Glucose is not synthesized by plants in the dark

C. Protein synthesis takes place in leaves

D. Sunlight is necessary for photosynthesis

B. Name the following.

1. The fine respiratory openings found on stems of woody plants.
2. The process by which plants lose water in the form of droplets early morning, due to certain process.
3. A special paper used to show the loss of water through stoma of a leaf during experiment on transpiration.
4. Dema observed two kidney-shaped cells under the light microscope enclosing a space through which most of the transpiration takes place.
5. The structure through which, guttation takes place.
6. A substance used by a farmer to prevent excessive transpiration in plants during the high light intensity.

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

1. During light phase of photosynthesis water is oxidised and ..... is reduced.
2. During photosynthesis, the oxygen in glucose comes from .....
3. A farmer, in order to let the leaves close their stomata, would prefer.....as the plant hormone.
4. Specific ions are acquired by root hairs by the process of .....
5. During daytime, more water is drawn into the guard cell and it becomes turgid. Where as during night time,.....ions leak out of the guard cell.

D. Write TRUE or FALSE against the following statements.

1. Transpiration takes place only in the green plants.
2. The wall of a guard cell that faces the stoma is thin.
3. Leaves are reduced to spines in xerophytic plants.
4. If the guard cells and surrounding epidermal cells of a leaf were deficient in potassium ions, the rate of photosynthesis would increase.

5. Water tension in a transpiring plant will exert a pull on water molecules in the lower plant's vascular system.

E. Give reasons.

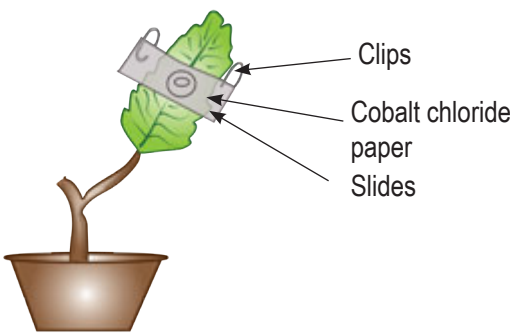
1. Xerophytes have their leaves modified to spines or reduced in size.
2. A higher rate of transpiration is recorded on a windy day, rather than on a calm day.
3. During the day, transpiration and photosynthesis are related.
4. Plants that live in deserts are adapted to constant water stress.
5. Food is transported in the form of sucrose in plants.

F. Differentiate the following pairs of words.

1. Light reaction and dark reaction.
2. Cuticular transpiration and lenticular transpiration.
3. Hydathodes and stomata.
4. Passive absorption and active absorption.
5. Growth inhibitors and growth promoters.

G. Answer the following questions.

1. List any three advantages of photosynthesis.
2. Diagram given on the right shows an experimental set up to study the process of transpiration in plants. Study the same and answer the questions that follow:
   a. What is the colour of dry cobalt chloride paper?
   b. Why is a glass slide placed over the dry cobalt chloride paper?
   c. After about half an hour, what change, if any, would you expect to find in the cobalt chloride paper placed on the dorsal and ventral surfaces of the leaf? Give a reason to support your answer.
   d. How would your experiment change if monocot leaf has been used instead of a dicot leaf?
   e. Why it is necessary to water the plant for the experiment?



3. A student performed an experiment to determine, if treating 200 tomato plants with an auxin (a plant growth hormone) will make them grow faster. The results are shown in the table below.

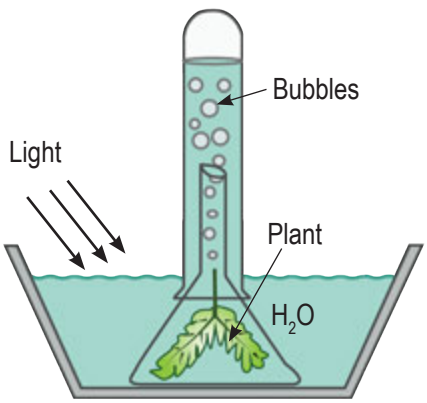
Days	Average Stem Height (cm)
1	10
5	13
10	19
15	26
20	32
25	40

a. Using the information in the data table, construct a line graph.

b. Explain why the student cannot draw a valid conclusion from these results.

c. If the above 200 tomatoes are treated with abscisic acid, what effects will you expect in an average stem heights.

4. The green aquatic plant represented in the diagram on the right was exposed to light for several hours.



a. Define the process?

b. Write chemical equation for the process.

c. The process illustrated occurs in.....

d. Write two importance of the above process.

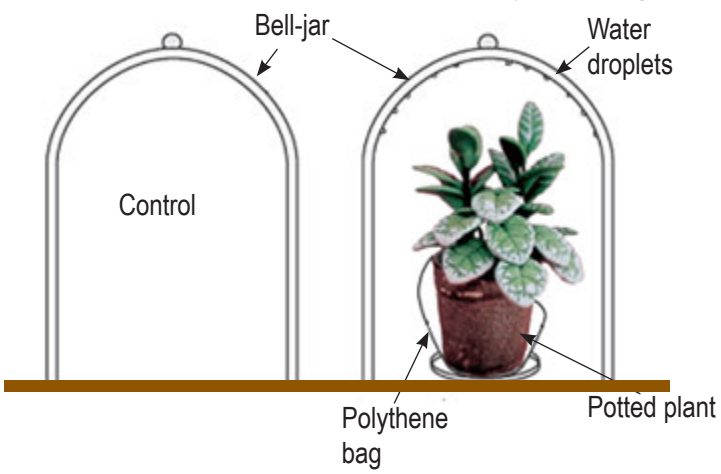
e. From where does air bubbles come from?

5. Briefly explain, how the rate of transpiration is affected by:

a. intensity of light.

b. humidity of the atmosphere

6. A class nine student sets up an experiment as shown below. Polythene bag stops the escape of water vapours.



After an hour, drops of colourless liquid are seen inside the bell-jar with the plant. To show that these drops are water, a student touched them with anhydrous copper sulphate (white) and its colour changes to blue. No

drops of water are found in the control experiment, where there was no plant as in the diagram.

a. Where do water droplets on the inside of the jar with the plant come from?

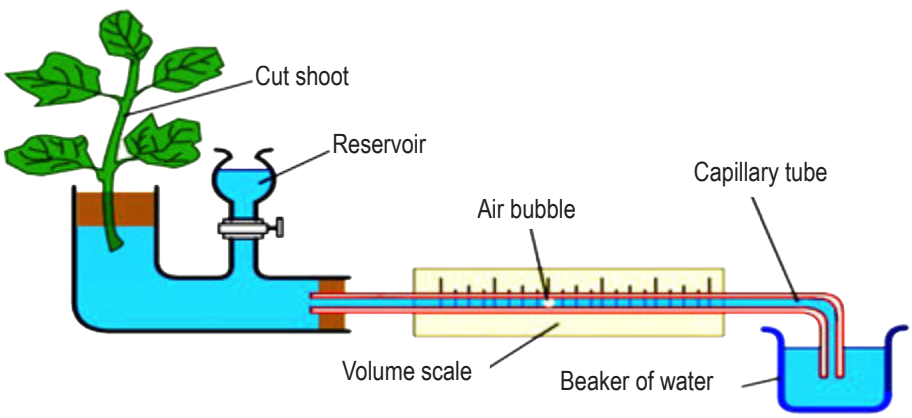
b. Identify the phenomenon.

c. How will this phenomenon get affected if

i. adequate water is supplied and

ii. plant is placed in light.

7. Draw a neat diagram of the stomata found in the epidermis of leaves, and label the stoma, guard cells, chloroplast, epidermal cells, cell wall and nucleus.
8. Explain the opening and closing of stomata with the help of K^+ ion concentration theory.
9. The diagram shown below is an apparatus used to study a particular phenomenon in plants.



a. Name the apparatus.

b. What is the role played by the air-bubble in this experiment?

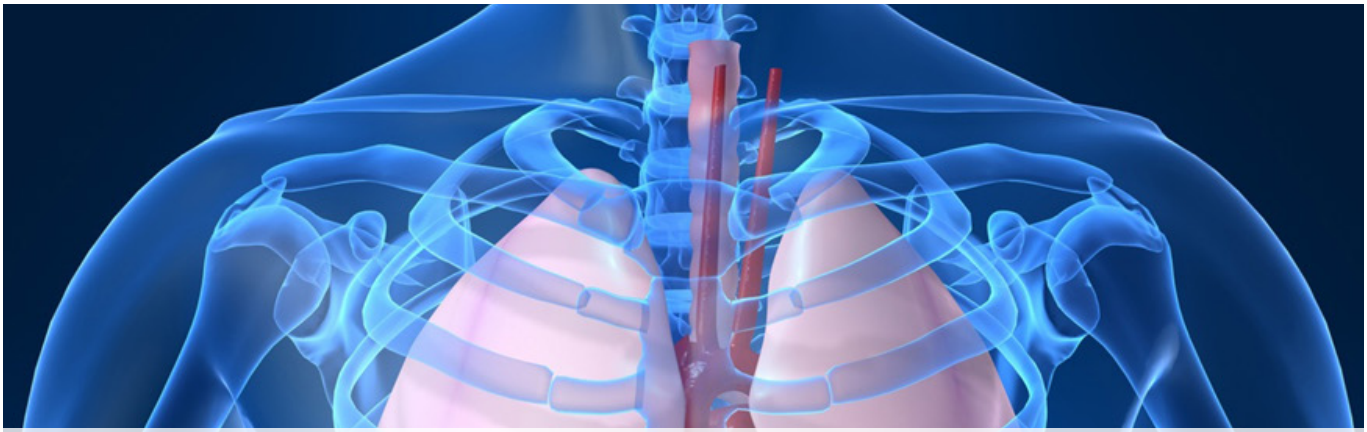
c. What is the use of reservoir?

d. Which phenomenon is studied with the help of this apparatus?

e. What happens to the movement of the air-bubble if the apparatus is kept :

i. In the dark. iii. In front of a fan. Give a reason for each case.

ii. In sunlight.



3 Human

Digestive System

Every cell in the human body needs continual supply of fuel and oxygen in order to stay alive. The fuel comes from food we eat, while oxygen comes from air. The food we eat cannot be utilized directly in the same form. Certain foods, like cane sugar are soluble in water, but they should be further broken down into smaller units so that they could pass through cell membranes for respiration. The parts of the body that break down food make up the digestive system. Food that we eat passes through a long tube inside the body, known as the alimentary canal. The alimentary canal is made up of the oral cavity, pharynx, oesophagus, stomach, small intestines, and large intestines.

Accessory organs of the digestive system include the teeth, tongue, salivary glands, liver, gall bladder, and pancreas that help your body to break down food.

Human Digestive System

Learning Objectives

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

- identify the human digestive organs.
- state the functions of each of the human digestive organ.
- explain the process of digestion.

The **digestive system** is a group of organs working together to convert food into energy, and provide nutrients for the growth of body. Food that we eat passes through a long tube inside the body known as the alimentary canal, or the gastrointestinal tract (**GI tract**). Digestion begins in the mouth, which breaks down food physically. Swallowed food then passes to the stomach and intestines, where it break down chemically.

a. Alimentary canal and accessory organs

The **alimentary canal** starts with a mouth and ends in anus. It consists of mouth, **oral cavity**, **pharynx**, **oesophagus**, **stomach**, **small intestines**, and **large intestines**. Besides, the alimentary canal, there are several important **accessory organs** that help your body to digest food.

i. Mouth

Food begins its passage into the digestive system through the mouth. Inside the mouth, food is mashed by teeth and mixed with a watery fluid called saliva. Saliva **moistens food to make it slippery and easier to swallow**. It also contains chemicals called digestive enzymes, which breaks large food molecules into fragments.

1. Teeth

The **teeth** (*singular*: **tooth**) are small, hard organs found along the anterior and lateral edges of the mouth. Our teeth are the first line of attack in the digestion process, **cutting**, **crushing** and **grinding** food into smaller pieces, so that enzymes will have greater surface area for chemical reaction. The teeth also help in speaking and give facial shape. Like most other mammals, humans have **two sets of teeth** during our lifetime. The first set of teeth is called temporary (deciduous teeth) and the second set is called permanent teeth. Humans have 20 primary and 32 permanent teeth.

According to the shape and size of the teeth; teeth are classified as **homodont** and **heterodont**. Homodont (*homo*: **similar**; *dont:* **teeth**) is a condition where the teeth

are all alike in their shape and size like those of the lizards and frogs. Heterodont (*hetero*: **different**) type has teeth of different shape, size and function. In such condition, the teeth can be distinguished into 4 types namely; **incisors**, **canines**, **premolars** and **molars**.

Incisors are the four front teeth in centre of each jaw. They are **conical**, **single-rooted** and **monocuspid**. They are used for biting and cutting.

Canines are the teeth found one on either side of the incisors in each jaw. They are **large-pointed**, **long-crowned** with a **single root**. It is used for gripping, piercing and tearing food.

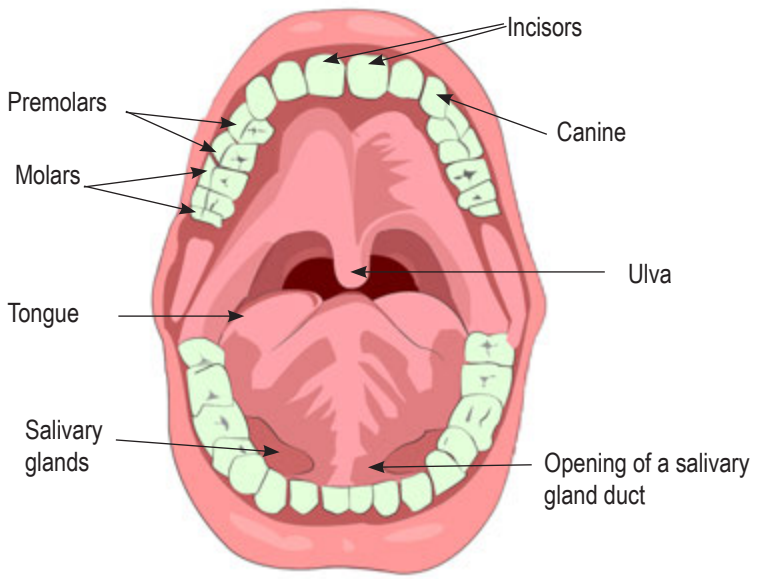


Figure 3.1 Different kinds of human teeth

Premolars are the two teeth on each side of the canines in each jaw. These have **two roots** and **two cusps**. Premolars help in grinding and crushing the food material.

Molars are the last three teeth on each side in each jaw. They have t**wo or more roots** and **several cusps**. They are used for crushing and grinding of food.

The number of teeth in any particular species remains constant but varies in different species. So the number of permanent teeth is usually indicated by a sort of equation called dental formula. The **dental formula is expressed by the number of each type of teeth in each half of the jaws**. The teeth of the upper jaw are placed as numerators and in the lower jaw as denominators. The numerators and denominators are separated by a horizontal line. The kind of teeth is indicated by initial letters i, c, Pm, m indicating incisor, canine, premolar and molar, respectively. When a certain type of tooth is absent, a zero is used to indicate the fact.

An adult human possesses 32 teeth and it is expressed.

i 2/2, c 1/1, Pm 2/2, m 3/3 = 16 x 2 = **32.**

In simpler forms, it can be expressed as

2.1.2.3/2.1.2.3 = 16 x 2 = 32.

The teeth of mammals are modified according to their food habit. For example, **carnivores** like cat, dog and lion have long and powerful canines to tear flesh. **Herbivores** like deer, cow and horses have large molars with broad flat grinding and chewing surface. Herbivores either have reduced canines or absent, as in sheep.

Structure of a tooth (Figure 3.2).

The general structure of all types of teeth is the same. Each tooth consists of a crown and one or more roots. The **crown** is the **functional part** that is visible above the gum. The root is the **unseen portion** that supports and fastens the tooth in the jawbone. All true teeth consist of three layers. In mammals, an **outer layer** is called enamel, calcium minerals make up 96 percent of tooth enamel, making it the **hardest tissue in the body**. The **middle layer** of the tooth is called dentine, which is less hard than enamel. This hard tissue is 70 percent mineral. Unlike enamel, **dentine can feel pain** as it is nourished by the pulp, which is the **innermost portion** of the tooth. The pulp cavity is the living heart of the tooth that consists of cells, tiny blood vessels, and a nerve and occupies a cavity located in the centre of the tooth.

Below the **gum** extends the root of the tooth, which is covered at least partially by **cementum** (**cement**). Cementum is bone-like structure covering and fixing the root in position. Gum is attached to the adjacent alveolar bone and to the cementum of each tooth by fibre bundles. The roots of teeth are cemented firmly into jawbones.

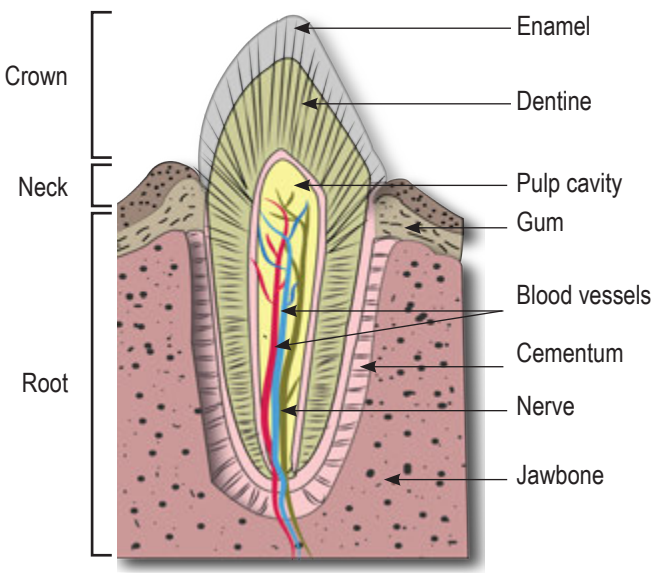


Figure 3.2 Internal structure of a tooth

2. Tongue

Tongue is an agile and powerful, **muscular organ** that helps to place food particles precisely between teeth to be crushed. It also mixes food with saliva, moulds it into lump, and pushes it into the throat. The tongue contains **taste buds** that detect taste of food molecules. Beside speech, tongue helps to push food during swallowing.

ii. Salivary glands

Surrounding the mouth, there are three sets of salivary glands: parotid, sub-mandibular and sublingual. The **salivary glands** are accessory organs that produce a watery secretion known as saliva. Saliva contains enzyme called ptyalin or salivary amylase. Saliva helps to moisten food and begins the **digestion of carbohydrates**. The body also uses saliva to **lubricate food** as it passes through the mouth, pharynx, and oesophagus.

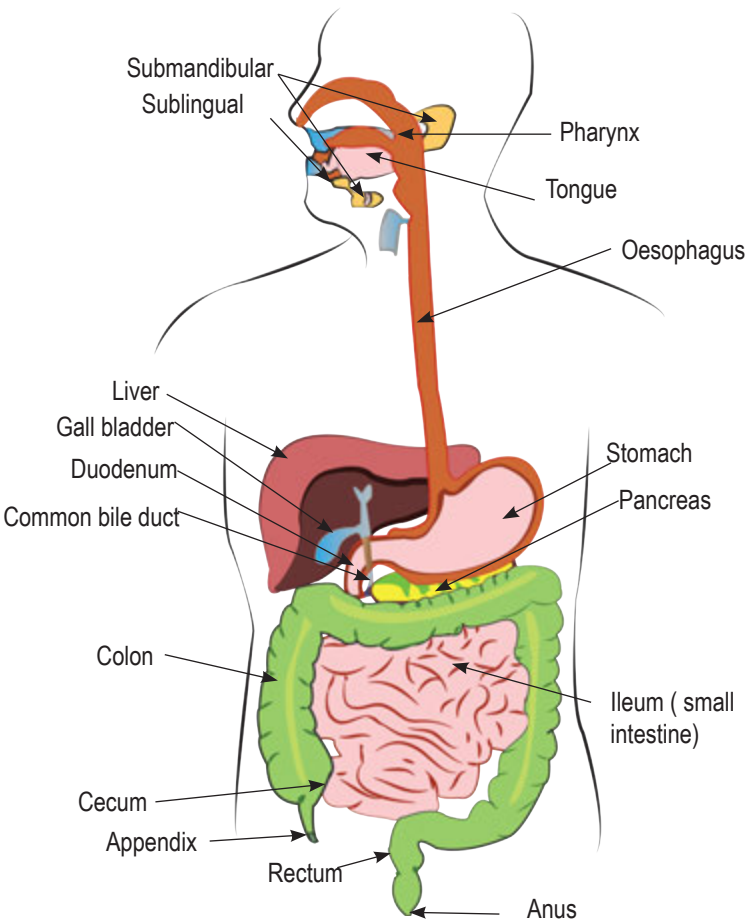


Figure 3.3 Human digestive system and its accessory glands

iii. Pharynx

The **pharynx**, or **throat**, is a **funnel-shaped tube** connected to the posterior end of the mouth. The pharynx is responsible for the passing of masses of chewed food from the mouth to the oesophagus.

iv. Oesophagus

The **oesophagus** is a **muscular tube**, connecting the pharynx to the stomach. It carries swallowed masses of chewed food from mouth to stomach. At the inferior end of the oesophagus is a muscular ring called the oesophageal sphincter. The function of this sphincter is to close the end of the oesophagus and trap food inside the stomach.

v. Stomach

The **stomach** is a **muscular sac** that is located on the left side of the abdominal cavity, just below to the diaphragm. Like a food processor, the stomach **churns and mixes food** until it turns into **thick liquid mass of partially digested food** called chyme. Glands in the stomach wall secrete acid and enzymes that work together to break down food molecules. Millions of **microscopic pits** in the stomach lining release a liquid called gastric juice, which is more acidic than lemon juice. The acid in gastric juice kills germs and activates enzyme called pepsin, which **breaks down proteins**. The stomach also secretes a layer of **protective mucus** to prevent the stomach from digesting itself.

vi. Small intestine

From the stomach, chyme is conveyed to the small intestine. The **small intestine** is a long and thin tube that occupies most of the space in the abdominal cavity. Small intestine has three sections: **duodenum**, **jejunum** and **ileum**. Duodenum is the **first portion** of small intestine. The proximal part of the duodenum is continous with the stomach. Jejunum is the next portion of small intestine from duodenum and ileum is the **last portion** of small intestine. Inside the small intestine, the food is mixed with powerful digestive chemicals from two nearby organs: gall baldder and the pancreas.

The entire small intestine is **coiled**, like a hose and its inner layer contains **numerous finger-like growths** called villi, each about 1 mm long. They absorb the small food molecules produced by digestion such as **glucose** and **amino acids**. Together, all the villi provide a huge surface area for digestion and absorption to take place. By the time food leaves the small intestine, almost all the nutrients have been absorbed from the food.

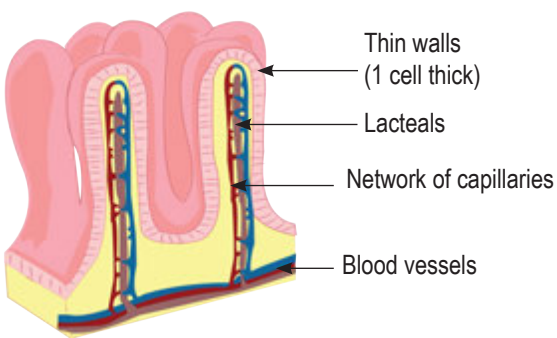


Figure 3.4 Villi

vii. Liver and gall bladder

The **liver** is an **accessory organ** of the digestive system, located to the right of the stomach, just inferior to the **diaphragm**. It is the **second largest organ** in the body. The nutrients absorbed from the intestines go to the liver to be processed and stored.

The gall bladder is a small pouch underneath the liver that **secretes a digestive fluid** called bile. It stores bile secreted from the liver and pour out the bile as and when required in the small intestine. Bile is used for the **digestion** (***emulsification***) **of fats**, which are absorbed by the lacteals.

viii. Pancreas

The **pancreas** is an organ located behind the stomach in the upper left abdomen. It is surrounded by other organs including the small intestine, liver, and spleen. It is spongy and about 6 inches long. The head of the pancreas is on the right side of the abdomen and is connected to the duodenum through a small tube called the pancreatic duct. The pancreas has two main functions: an exocrine function that **helps in digestion** and an endocrine function (*discussed later in chapter 7*) that **regulates blood sugar**.

The pancreas contains exocrine cells that produce enzymes important to digestion. These enzymes include trypsin and chymotrypsin to **digest proteins**; amylase for the **digestion of carbohydrates**; and lipase to **break down fats into smaller fat globules**. When food enters the stomach, **exocrine cells** of pancreas release the pancreatic enzymes into a system of small that lead to the main **pancreatic duct**. The pancreatic duct runs the length of the pancreas and carries pancreatic enzymes and other secretions, collectively called pancreatic juice. The main pancreatic duct connects with the common bile duct, which carries bile from the **gall bladder**, and together they connect with the duodenum at a point called the ampulla of Vater. The pancreatic juices and bile that are released into the duodenum, help the body to **digest fats**, **carbohydrates**, and **proteins**.

ix. Large intestine

The small intestine is connected to **large intestine**, which is a long, thick tube located just inferior to the stomach and wraps around the small intestine. The large intestine, is twice the width of the small intestine and a quarter of its length. It has three portions. Colon is the **middle portion** of large intestine. Caecum is the **pouch** at the junction of small intestine and large intestines. This pouch projects a narrow tube called vermiform appendix. Sometimes it gets inflamed which is called appendicitis. Rectum is the last portion of large intestine which opens to outside of human body as anus. The anus has **circular sphincter muscles** to keep it closed at normal.

The large intestine recieves watery leftovers from small intestine and turns them into **faeces**. It absorbs water, and contains many **symbiotic bacteria** that aid in the breakdown of the food wastes to extract the remaining nutrients from them.

Activity 3.1

Study the structures and functions of the alimentary canal of a human

Materials required: chart/model/computer illustration, showing gross external morphology and human alimentary canal.

Procedure

1. Observe the major parts of the alimentary canal in the charts/models/ computer illustrations provided by your teacher. Also observe the position of each part of the alimentary canal with respect to other organs.
2. Then examine the gross external morphology and internal structure of stomach, small intestine, large intestine and rectum.
3. Make appropriate notes and illustrative sketches of all your observations.

Questions

i. Why small intestine is coiled?

ii. Large intestine is shorter than small intestine. Comment

iii. Refer the chart and explain the process of ingestion of food, release of energy and removable of food wastes from the body.

iv. How do the unique characteristics of each organ contribute to the process of digestion?

v. Why digestion is important for healthy living?

vi. Explain a few of the disorders in digestion that affect the health of a person.

b. Physiology of human digestive system

Human digestive system has many **digestive organs**, which are responsible for converting **complex food particles** into **simpler soluble food nutrients**. There are several processes involved in the conversion of food in our digestive system, like **ingestion** of food, **secretion** of fluids and **digestive enzymes**, **mixing and movement** of food, **digestion** of food into smaller pieces, **absorption** of nutrients, and **excretion** of waste.

i. Ingestion

The process of taking food, drink, or other substances into the body by swallowing or absorbing by an organism is called *ingestion*. In humans, it is accomplished by taking in the substance through the mouth into the **gastrointestinal tract**, such as through eating or drinking. In **single-celled organisms**, ingestion can take place through taking the substance through the cell membrane.

The digestive system uses **two main processes** to move and mix food while in the alimentary canal.

1. Swallowing

Swallowing is the process of using smooth and skeletal muscles in the mouth, tongue, and pharynx to push food down the **alimentary canal**.

2. Peristalsis

Peristalsis is a **muscular wave** that travels the length of the alimentary canal. The waves of peristalsis travel from the oesophagus, through the stomach and intestines, and reach the end of the alimentary canal, which moves the partially digested food and waste down the tract.

ii. Secretion

In the course of a day, digestive system secretes about seven litres of fluids. These fluids include **saliva**, **mucus**, **hydrochloric acid**, **enzymes**, and **bile**, which are secreted by organs shown in Figure 3.5. Saliva moistens dry food and the salivary amylase, a digestive enzyme, contained in it begins the digestion of carbohydrates. Mucus serves as a protective barrier by **lubricating** the inner walls of the alimentary canals.

Hydrochloric acid helps to digest food chemically and protects the body by **destroying germs**, **worms** and **any harmful bacteria** present in our food. Enzymes help in breaking larger molecules like proteins, carbohydrates, and lipids into their smaller components. Finally, bile is used to **emulsify large masses of fats** into smaller globules for easy digestion.

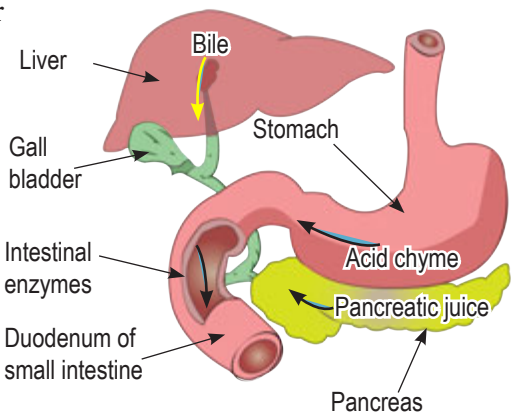


Figure 3.5 Secretion of digestive enzymes by gut

iii. Digestion

Mechanical digestion begins in mouth, which is the **physical breakdown** of large particles of food into smaller pieces. This mode of digestion begins with the chewing of food by the teeth and is continued 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. While food is being mechanically digested, it is also being **chemically digested** as larger and molecules that are more complex are being broken down into smaller molecules for easy absorption.

Chemical digestion begins in the mouth with **salivary amylase** present in the saliva, splitting the complex carbohydrates into simple carbohydrates. The enzymes and acid in the stomach continue the chemical digestion, but the bulk of chemical digestion

takes place in the **small intestine**. The **pancreas** secretes pancreatic juice, which is capable of digesting carbohydrates, proteins and nucleic acids. By the time food has left the duodenum, it has been reduced to its chemical building blocks—**fatty acids**, **amino acids**, **monosaccharide**, and **nucleotides**.

iv. Absorption

Once food has been reduced to its **simplest forms**, it is ready for the body to absorb. Absorption begins in the **stomach**, with simple molecules like water and alcohol

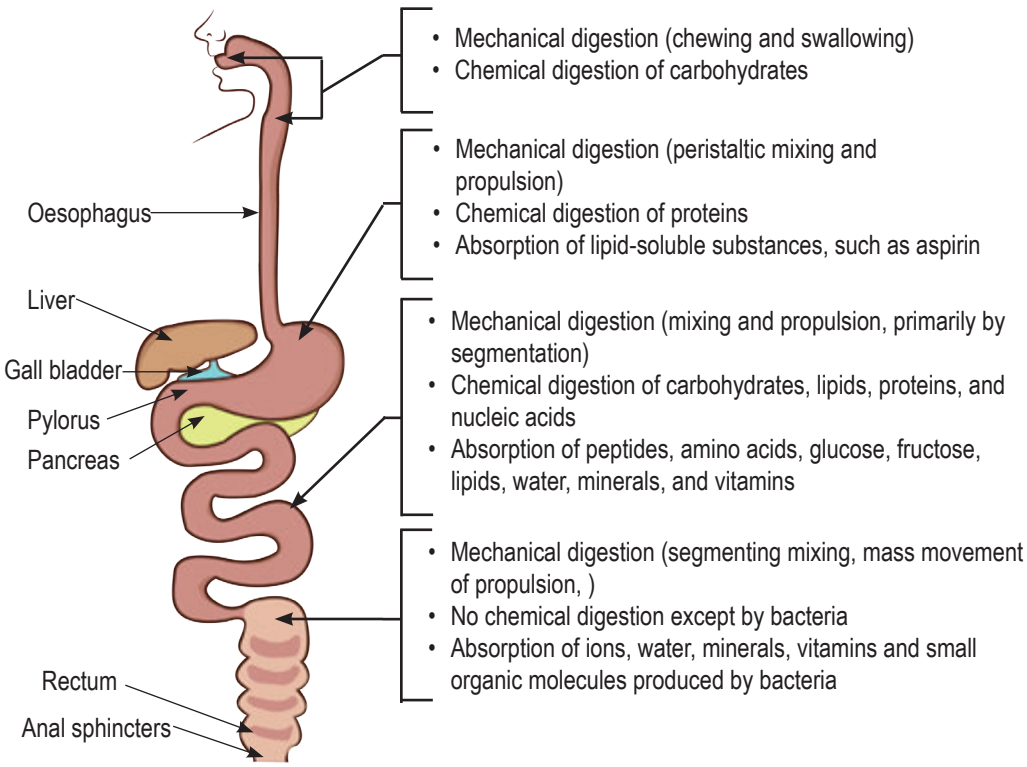


Figure 3.6 Digestion

being absorbed directly into the **bloodstream**. Most absorption takes place in the **walls of the small intestine**, which have **densely folded** villi to maximize the surface area for contact with the digested food. **Capillaries** and **lymphatic vessels** in the intestinal wall pick up the molecules and carry them to the rest of the body. The large intestine is also involved in the **absorption of water** and **vitamins** before foods leave the body as faeces.

Segmentation is **contraction of short segments of intestine**. It occurs only in the small intestine to increase the absorption of food and nutrients by mixing food, and increasing its contact with the walls of the intestine.

Egestion

Egestion is the removal of **unusable** or **undigested** food materials from a cell, in case of **unicellular organisms**, and from the digestive tract through the anus in case of **multicellular organisms**. In human digestive system, the **indigestible substances** such as **cellulose** are removed from the body, so that they do not accumulate inside the gut in a process called defecation. The timing of defecation is controlled voluntarily by the conscious part of the brain, but must be accomplished on a regular basis to prevent the accumulation of indigestible materials.

Table 3.1 Summary of digestion in various parts of human alimentary canal and associated organs

Region of alimentary canal	Secretion (Source gland)	Enzymes	Substrate	Product of digestion
Mouth	Saliva(Salivary glands)	Ptyalin/salivary amylase	Starch	Maltose
Oesophagus				
Stomach	Gastric juice and hydrochloric acid(Lining of stomach)	Pepsin	Proteins	Polypeptides and peptides
		Rennin(Not found in adult human)	Milk protein or caseinogen	Curdles milk casein
		Gastric lipase	Fats	Fatty acids & glycerol
Duodenum	Bile(Liver)		Fats	Emulsifies fats, food made alkaline
	Pancreatic juice (Pancreas)	Amylopsin(Pancreatic amylase	Starch	Maltose
		Trypsin	Proteins	Amino acids
		Pancreatic lipase	Fats	Fatty acids & glycerol
		Nucleases	Nucleic acid (DNA & RNA)	Nucleotides & nucleosides
Ileum	Intestinal juice (Intestinal glands)	Maltase	Maltose	Glucose
		Sucrase	Sucrose	Glucose and Fructose
		Lactase	Lactose	Galactose and glucose
		Erepsin	Proteins	Peptides, peptones & amino acids
		Lipase	Fats	Fats fatty acids & glycerol
Colon				Absorbs water
Rectum				Temporarily stores undigested food.

Activity 3.2

Action of saliva on starch

Materials required: starch solution, test tubes, iodine solution, motar and pestle, laboratory thermometer, Fehling's solution, saliva, water bath maintained at 38°C.

Procedure

1. Prepare a suspension of starch from fresh potato or cereal flour.
2. Iodine solution is prepared by dissolving 1 g iodine and 1 g potassium iodide in 100 mL of distilled water. The solution should be diluted.

Table 3.2 Procedure to carry out experiment on action of saliva

Sl. No.	Procedure	Observation	Inference
1	Take three test tubes and fill around 10 mL of starch suspension in each of the test tube. To the sample one, add a few drops of iodine solution.	What happens to the colour of the solution?	
2	To the second sample, add a few drops of Fehling's solution and warm the mixture.	What happens to the colour of the second sample?	
3	To the third sample, add around equal amount of saliva and keep it in water bath of 38°C for around 2 minutes.		
4	Divide the third sample into two test tubes. Perform sugar test on one sample, and starch test on other sample.		

Questions

i. What are your observations and inferences for starch and sugar samples?

ii. Why should you keep the third sample with saliva at 38°C?

iii. What can you conclude from your experiment?

Brain Snacks

- Saliva produced in a person's life is about **25,000** litres.
- The maximum internal volume of a full stomach is **3** litres.
- The average time a large meal spends in the stomach is **4** hours.
- The intestine is home for **100** trillion bacteria, more than human cells in the body. These bacteria release extra nutrients from food rich in fibre.

Summary

- Digestion is the breakdown of complex food molecules into simpler forms.
- The functions of the digestive system are to take in food, break down the food, absorb the digested molecules, and provide nutrients to the body.
- The digestive organ includes tongue, oesophagus, pancreas, liver, stomach, small intestine, large intestine and gall bladder.
- An alimentary canal consists of mouth, oesophagus, stomach, small intestine, large intestine, rectum and anus.
- There are 32 permanent teeth in humans, including incisors, canines, premolars, and molars.
- The dental formula for adult human is 2, 1, 2, 3/2, 1, 2, 3.
- Each tooth consists of a crown, neck, and root.
- The esophagus connects the pharynx to the stomach.
- The stomach has a cardiac opening from the esophagus and a pyloric opening into the duodenum.
- Small intestine is divided into three parts: duodenum, jejunum and ileum.
- The cecum forms a blind sac at the junction of the small and large intestines. The appendix is a blind sac off the cecum.
- The human digestion involves ingestion, secretion and absorption.
- The process such as swallowing, peristalsis and segmentation helps in mixing and moving food in alimentary canal.
- Segmental contractions occur over short distances and mix the intestinal contents.
- Peristaltic contractions occur the length of the intestine and push chyme through the intestine.
- Digested fats are absorbed through lacteals into the blood circulation.

http://www.biologycorner.com/anatomy/chap15.html

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. When we ingest food containing large molecules such as lipids, carbohydrates, and proteins, these molecules must undergo catabolic reactions whereby enzymes split these into smaller molecules. This series of reactions is
   A. absorption.
   B. secretion.
   C. chemical digestion.
   D. mechanical digestion.
2. What part of the tooth bears the force of chewing?
   A. Crown
   B. Enamel
   C. Pulp
   D. Dentine
3. The absorptive effectiveness of the small intestine is enhanced by increasing the surface area by
   A. villi.
   B. enzymes.
   C. digestive juices.
   D. elasticity of intestine.
4. Which of the following is not true of saliva?
   A. Cleanses the mouth
   B. Dissolves certain foods
   C. Moistens food and aids in swallowing
   D. Contains enzymes that begin the breakdown of proteins
5. If human dental formula is 2-1-2-3/2-1-2-3. What does the 1 stand for?
   A. Molar
   B. Canine
   C. Incisor
   D. Premolar
6. What happens when food reaches the stomach?
   A. No digestion occurs in the stomach
   B. The food moves quickly into the small intestine
   C. Juices mix with the food and stomach muscles squeeze it
   D. The food is completely digested and is absorbed by tiny blood vessels in the walls of the stomach
7. Which of the following does not produce digestive juices?
   A. Liver
   B. Kidneys
   C. Stomach
   D. Pancreas

8. The process that occurs only in the small intestine to increase the absorption of food and nutrients by mixing food.

   A. Digestion C. Absorption

   B. Peristalsis D. Segmentation

9. If the dental formula of adult human is 2,1,2,3/2,1,2,3, then the dental formula for Figure on the right is

   A. 2,0,2,3/2,0,2,3 C. 3,0,3,3/3,0,3,3

   B. 3,1,2,3/3,1,2,3 D. 3,1,4,3/3,1,4,3

10. The organ that stores swallowed food and liquid, mixes up digestive juices with the food and liquid, and sends it to the small intestine.

   A. Mouth C. Stomach

   B. Rectum D. Intestines

B. Write TRUE or FALSE against the following statements.

1. No enzymes are secreted in large intestine.
2. Absorption of food begins in mouth and ends in small intestine.
3. Peristalsis is the only process that mixes food with enzymes and digestive juices in human digestive system.
4. A patient in hospital thinks that digestion of carbohydrates will not be a problem even if liver is damaged.
5. The function of tongue is to sense the taste only.

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

1. The grinding and crushing of food in mouth is helped by .....
2. The acid that protects the body by destroying germs, worms and any harmful bacteria present in our food is .....
3. The process of removing indigestible substances from the body is .....
4. An enzyme that aids in breaking down of complex sugar into simple digestible sugars is .....
5. The part of intestinal wall that pick up the digested food molecules is .....

D. Differentiate between the following pairs of words.

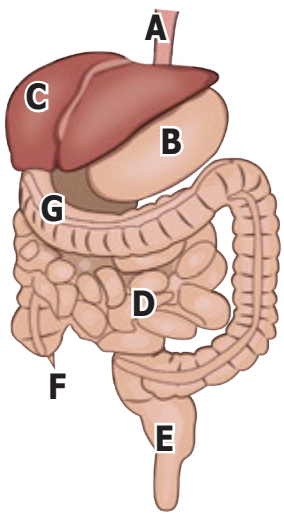
1. Segmentation and peristalsis
2. Ingestion and digestion
3. Gastric juice and intestinal juice
4. Absorption and excretion
5. Pancreas and gall bladder

E. Match the items of Column I with the most appropriate items of Column II. Rewrite the correct matching pairs.

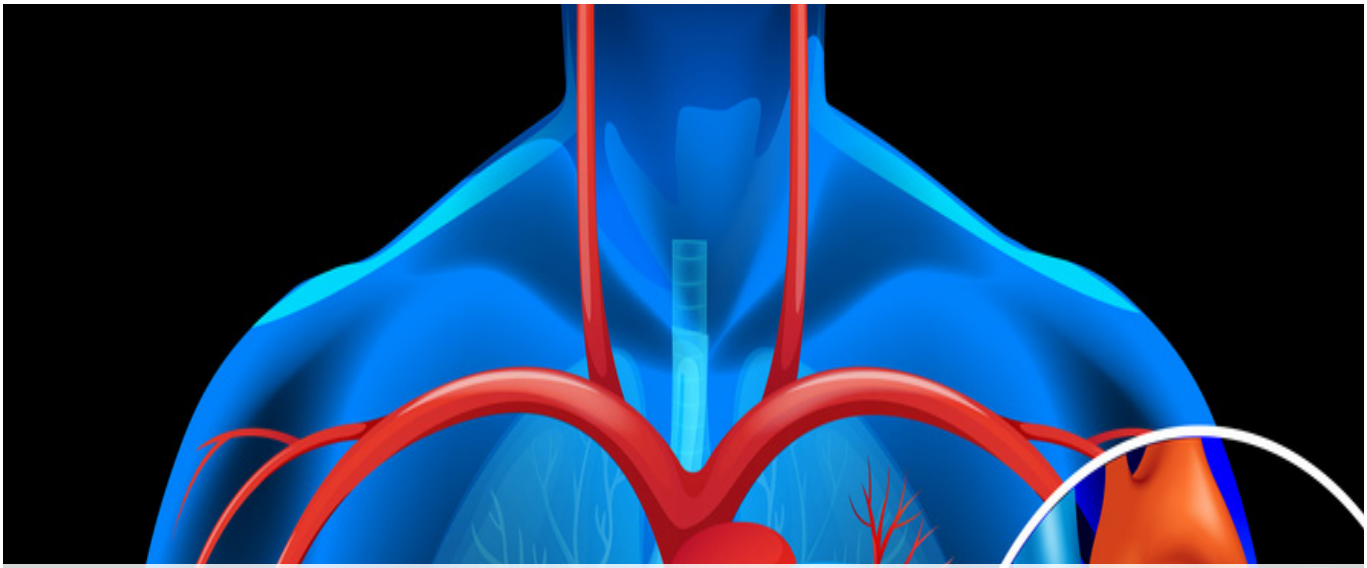
Column I	Column II
1. Small Intestine	a. Transports food from pharynx to the stomach
2. Large Intestine	b. Production of bile
3. Stomach	c. Absorbs water, minerals and vitamins
4. Oesophagus	d. Maximum chemical digestion takes place
5. Liver	e. Produces gastric juices

F. Answer the following questions

1. What is digestion?
2. What are end-products of digestion of starch, proteins and fats?
3. The human digestive system has many structural adaptations. Describe any three adaptations (*as described in text*) and its functions.
4. Refer the Figure on the right to answer the question 'a' through 'd'.
   a. Label the parts A, B, F and C.
   b. What is the function of part labelled G?
   c. What do you think will happen, if organ labelled C is damaged?
   d. Describe the physiological process that takes place in D.



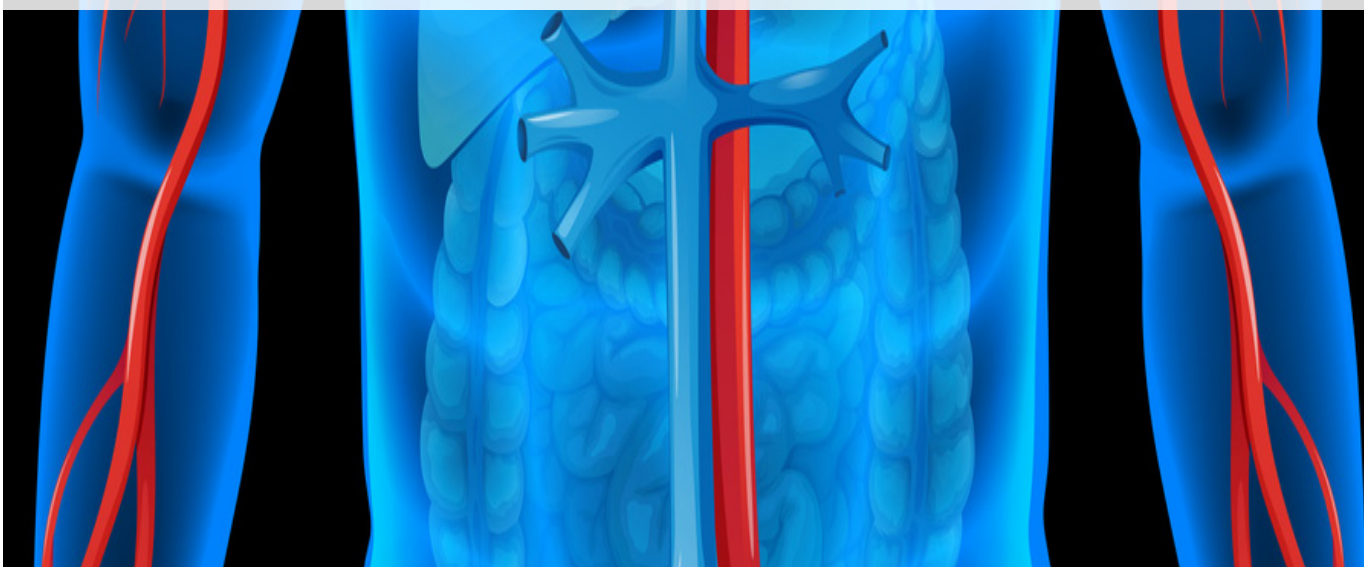
5. Yesterday Tenzin had mix vegetable and eggs for dinner. Describe how potatoes and eggs might have been digested with the help of enzymes.
6. Explain any two disorders that happen in digestive system. List ways to avoid such disorders.
7. List all the accessory organs of digestive system and describe their role in digestion.
8. Construct a flowchart of food from mouth through different disgetive organs to anus.
9. Refer Figure 3.6 to explain the process of digestion.
   a. Why does the chemical digestion cease at the large intestine?
   b. What different gland and hormones are involved in the production of amino acids, peptides, glucose, and fructose?
   c. Why it is important to move and mix food in the alimentary canal?
10. Draw a human digestive system and label all its parts.



4 Human

Circulatory System

Blood is the body's transport system. It carries food, oxygen, hormones, nutrients, heat and other useful materials to every living cell in the body, as well as take away waste materials generated because of metabolic activities of the cells. The heart, blood and blood vessels make up the body's circulatory system. Blood circulates continuously around the body, travelling through thousands of kilometres of tubes called blood vessels. Another fluid that circulates in the human body is lymph. The lymphatic system is an extension of the circulatory system.



A. Components of the Circulatory System

Learning Objectives

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

- identify components of blood and their basic functions.
- differentiate between arteries, veins and capillaries.
- describe the structure of human heart.

The **circulatory system**, also called the cardiovascular system, is an organ system that helps in the **circulation** of blood and the **transportation** of nutrients, oxygen, carbon dioxide and hormones. These substances help to nourish, fight diseases, stabilize temperature and pH, and maintain homeostasis of the body. The **heart**, **blood**, **blood vessels**, **lymph** and **lymph vessels** are important components of circulatory system.

a. Blood

Blood is a **fluid connective tissue**, which is red in colour due to the presence of haemoglobin. It is the medium of transport in the body. The blood volume of a normal adult human is **5-6** litres. The main components of the blood are **plasma** and **blood cells**.

Plasma is the **non-cellular** or **liquid portion** of the blood that makes up about **55%** of the blood's volume. Plasma is a mixture of water, proteins, and dissolved substances. It is light yellow coloured liquid containing water, salts and plasma proteins.

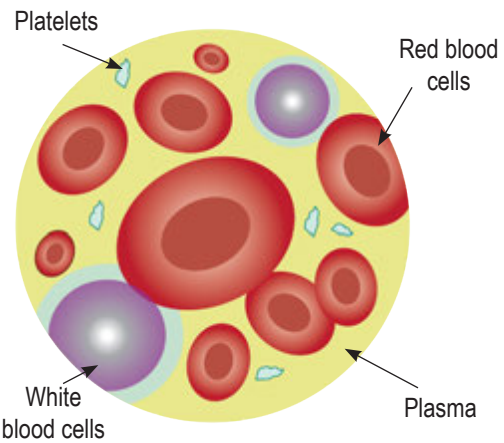


Figure 4.1 Blood composition

Blood cells include **red blood cells, white blood cells** and **platelets** which are suspended in the plasma. The proteins within plasma include **antibodies** and **albumins**. **Antibodies** are part of the immune system that bind to antigens on the surface of pathogens that infect the body. Many different substances can be found dissolved in the plasma, including glucose, oxygen, carbon dioxide, hormones, ions, nutrients, and cellular waste products. The plasma functions as transportation medium for these substances, as they move throughout the body.

Plasma from which the proteins have been removed is called serum. All the important nutrients, hormones, and clotting proteins as well as the waste products are transported in the plasma.

Red blood cells, also known as erythrocytes, are by far the most common type of

blood cells and make up about **45%** of the blood volume. **Erythrocytes** are produced inside the **red bone marrow**. The shape of erythrocytes is **biconcave** so that the centre of an erythrocyte is its thinnest part. The unique shape of erythrocytes gives these cells a **high surface area to volume ratio**, and can fold to fit into thin capillaries. Immature erythrocytes have a nucleus that is ejected from the cell when it reaches maturity to provide it with its unique shape and flexibility. The lack of a nucleus means that red blood cells contain no DNA, and are not able to repair themselves once damaged.

Figure 4.2 Red blood cells

Erythrocytes contain a red pigment called haemoglobin, which helps in transportation of oxygen. Haemoglobin contains **iron** and **proteins** joined to increase the oxygen carrying capacity of erythrocytes. It also binds to **carbon monoxide**, which often leads to **carbon-monoxide poisoning**. Red blood cells live for about **120 days** and they are then destroyed in the spleen.

White blood cells are known as leukocytes. They do not contain haemoglobin, and hence are not red in colour. They are generally larger than red blood cells and have clearly defined nuclei. They are also produced in the bone marrow and have various functions in the body. Their lifespan is about **12 days**. White blood cells are of different types, like **lymphocytes** and **phagocytes**. They attack the microorganisms, which enter our body and protect us from diseases.

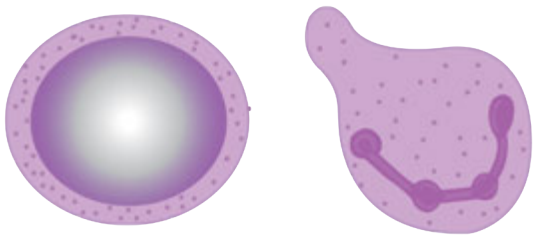


Figure 4.3 White blood cells

Blood platelets are called as thrombocytes, which are small and oval. It is produced in the **bone marrow**. They lack nuclei and are much smaller than erythrocytes. They are white in colour, and their life span is **3** to **10 days**. Platelets normally remain inactive in the blood until they reach the damaged tissue. Once activated, platelets change into a **sticky spiny ball shape** and helps to latch on to the damaged tissues. This serves as a temporary seal to keep the blood in the vessel until the cells of the blood vessel repair the vessel wall.

Figure 4.11 Blood platelet

After the initial response of forming platelet plugs at the site of blood vessel injury, the **clotting mechanism** is activated. **Blood clot** is formed by activation of a plasma protein (**fibrinogen**) to form fibrin that helps to form interlacing strands of fibres over the damaged vessel and the platelet plug.

b. Blood vessels

Blood vessels are thin pipe like structures, which supply the blood to the whole body as well as heart itself and receive **deoxygenated blood** from different parts of the body. All blood vessels are lined with a **thin layer of simple squamous** epithelium tissue called endothelium. There are three major types of blood vessels: **arteries, veins**, and **capillaries**.

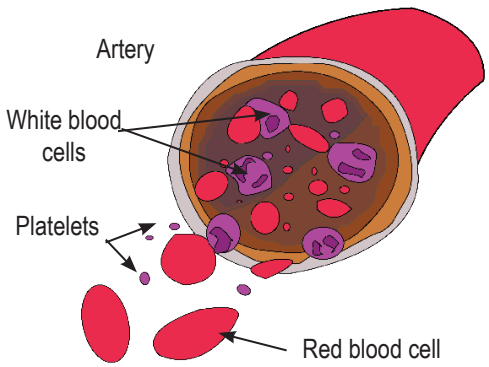


Figure 4.4 Blood vessel

1. **Arteries and arterioles**: Arteries are blood vessels that **carry blood away** from the heart. Blood carried by arteries is usually **oxygenated**, except the blood carried by the **pulmonary artery**. This artery carries deoxygenated blood from the heart to the lungs. Arteries are subjected to high levels of blood pressure because they carry blood being pushed from the heart under great force. To withstand this pressure, the walls of the arteries are **thicker**, **more elastic**, and **more muscular** than that of other vessels. The smooth muscles of the arterial walls contract, or expand to regulate the flow of blood through their lumen to different parts of the body under varying circumstances. The regulation of blood flow affects blood pressure because smaller arteries give blood less area to flow through, which increases the pressure of the blood on the arterial walls. Arterioles are narrower arteries that branch off from the ends of arteries and carry blood to **capillaries**. The walls of arteriole are much **thinner** than that of arteries. Arterioles, like arteries, are able to use smooth muscles to control their apertures and regulate the blood flow and blood pressure.

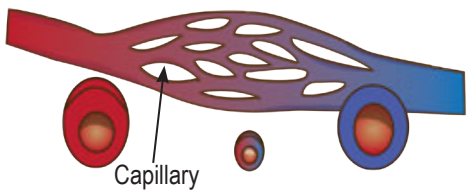


Figure 4.5 Capillary bed

2. **Capillaries**: Capillaries are the smallest and thinnest of the blood vessel in the body, and they are the most common blood vessel. They can be found **running throughout almost every tissue** of the body, and border the edges of the body's vascular tissues. Capillaries are connected to arterioles on one end and **venules** on the other. Capillaries carry blood very **close to the cells** of the tissues of the body in order to exchange gases, nutrients, and waste products. The endothelium acts as a filter to keep blood cells inside of the vessels while allowing liquids, dissolved gases, and other chemicals to diffuse along their concentration gradients into or out of tissues.

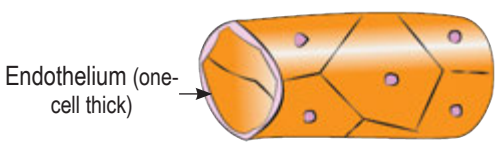


Figure 4.6 Capillaries

3**. Veins and venules**: Veins act as the blood return counterparts of arteries. Veins and venules have low blood pressure as compared to arteries, arterioles, and capillaries. Therefore, the walls of veins are much **thinner, less elastic**, and **less muscular** than the walls of arteries. Veins rely on gravity, inertia, and the force of skeletal muscle contractions to help push blood back to the heart. Some veins contain many valves that prevent the back flow of blood. When the muscle relaxes, valve traps the blood until another contraction pushes the blood closer to the heart. Venules are similar to arterioles as they are small vessels that connect capillaries. They collect blood from many capillaries and convey it into larger veins for transport back to the heart.

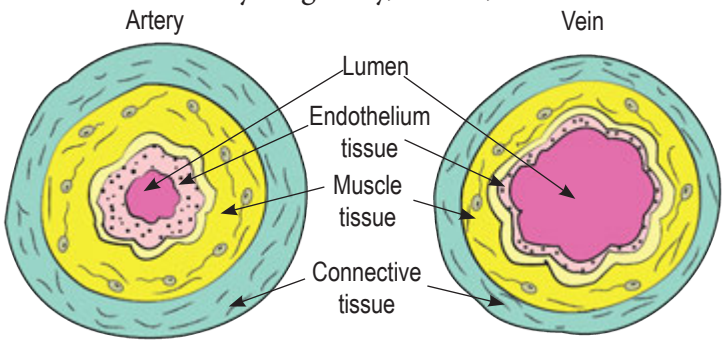


Figure 4.7 Cross section of artery and vein

Table 4.1 Differences among arteries, veins and capillaries

Characteristics	Arteries	Veins	Capillaries
1. Function	To carry blood away from the heart to other parts of the body.	To carry blood to the heart.	To connect the artery and the vein.
2. Wall thickness	Thick, muscular and have elastic fibres.	Thin, less muscular and have less elastic fibres.	Very thin (one-cell in thickness) formed of endothelial cells.
3. Size of lumen	Narrow.	Wide.	Very small.
4. Blood flow	Very fast, high pressure.	Slow, low pressure.	Very slow, very low pressure.
5. Presence of valve	Absent (except pulmonary artery).	Present (except pulmonary vein).	Absent.
6. Nature of blood	Carry oxygenated blood (except pulmonary artery).	Carry deoxygenated blood (except pulmonary vein).	Carry oxygenated blood at arteriole end and deoxygenated at venule end.
7. Position in body	Situated deep to body surface.	Situated near to body surface.	Found inside all body tissues.

c. The heart

Human heart is located in between the lungs in the thoracic cavity. It is a **four-chambered muscular organ** that beats tirelessly to keep blood flowing in the body. It is about the same size as a *man's closed fist*-and just as strong. The narrow end of the heart is pointed to the left side and during the contraction of heart, it gives powerful effect- at the end giving a feeling that the heart is on the left side. The heart is one of the most vital organs in the human body, which pumps blood throughout the body.
The heart is **enclosed and protected** by a **double walled membranous covering** called pericardium. In between the two layers, a space, the pericardial cavity is present which is filled with pericardial fluid. This lubricating fluid protects the heart from shocks and mechanical injuries.
The heart is made up of a special type of muscle called cardiac muscle.

i. Chambers of the heart

The heart consists of **four chambers**. The two upper chambers are the atria (*singular*: **atrium**) and the two lower chambers are the ventricles. The two atria are thin-walled chambers that receive blood from veins and deliver it into the adjacent ventricles. The two thin walled atria are separated from each other by the interatrial septum.

The **two ventricles** are thick-walled chambers that forcefully pump blood out of the heart and deliver to the rest of the body. The left ventricles have **thicker muscular wall** than that of the right because left ventricle pumps blood to greater distances. The right ventricle only pumps blood into the lungs, which are close to it.

ii. Valves present in the heart

The heart has two types of valves with primary function of regulating the blood flow through the heart. They are as follows:

1. The artrio-venticular valves are situated between the atria and ventricles. The right artrio-ventricular valve opens between the right atrium and the right ventricle. This valve has **three triangular flaps** (*cusps*) and is called tricuspid valve. The left artrio-ventricular valve is situated between the left atrium and the left ventricle and is called bicuspid valve or mitral valve (having **two flaps**). Attached to the flaps of the bicuspid and tricuspid valves are special fibrous cords, the chordae tendinae, which are joined to the other ends with the special muscles of the ventricular wall, the papillary muscles. The chordae tendinae prevent the bicuspid and tricuspid valves from collapsing back into the atria during powerful ventricular contraction.
2. Semilunar valves are located at the base of pulmonary artery and aorta. The valve between the right ventricle and pulmonary artery is the pulmonary semilunar valves. The valve between the left ventricle and the aorta is the aortic semilunar valves. Both the valves consist of three half-moon shaped pockets.

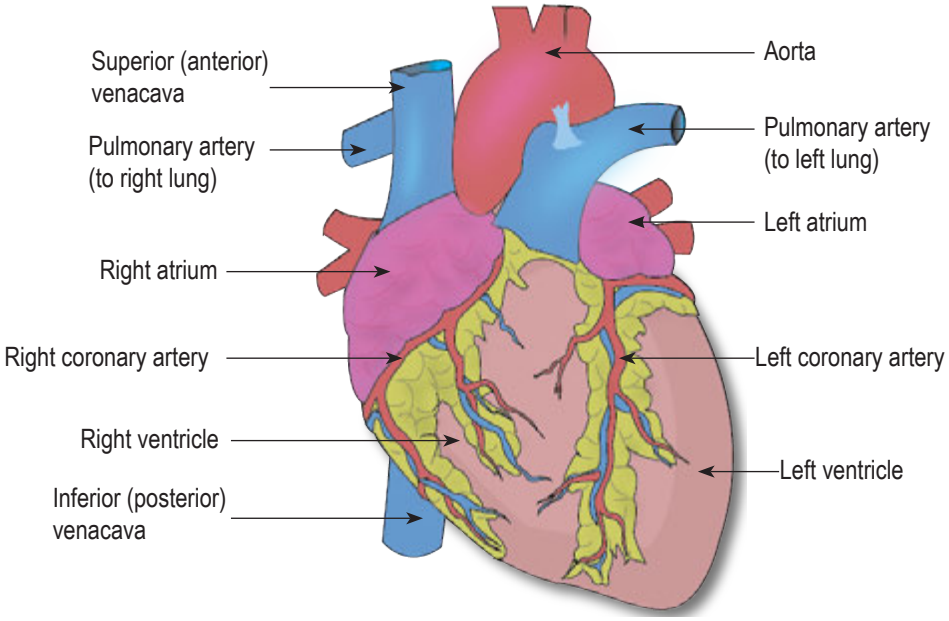


Figure 4.8 External view of human heart

iii. Blood vessels entering and leaving the heart

The superior (**anterior**) vena cava, inferior (**posterior**) vena cava and coronary sinus open into the **right atrium**. The superior vena cava carries deoxygenated blood from the upper region of the body including head, chest and arms. The inferior vena cava is larger than the superior and carries deoxygenated blood from the lower region of the body including abdomen and legs. The coronary sinus carries deoxygenated blood from the heart and delivers it to the right atrium. The **left atrium** receives oxygenated blood from the lungs through two pairs of **pulmonary veins**.
Pulmonary artery that arises from **right ventricle** divides into **left** and **right pulmonary arteries** that carry deoxygenated blood to the lungs. The aorta arises from the left ventricle and carries oxygenated blood to supply to all parts of the body.
Coronary arteries arise from the base of the aorta and supply blood to the heart.

Activity 4.1

Study the internal structure of heart in Figure 4.9 and complete the blanks by choosing right words in the passage that follows.

The human heart is about the size of a closed fist and is built with cardiac muscles. It contains four hollow chambers consisting of two atria and two ventricles. The left and right sides of the heart are separated by a muscular wall of tissue known as the .....1..... of the heart. The slightly pointed apex of the heart is directed towards left side of the chest. The heart is enclosed by a membrane called pericardium.

The wall of the heart has three layers: outer epicardium, middle myocardium, and the innermost endocardium.

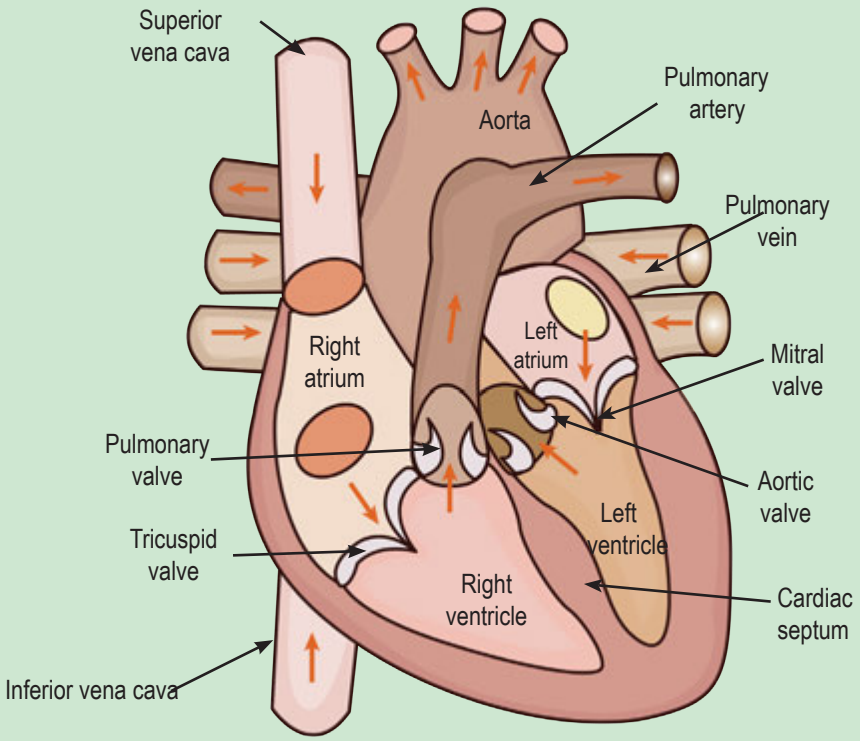


Figure 4.9 Internal structure of human heart

Two atria have thinner muscular walls as compared to two .....2..... The ventricles have thick muscular walls as they have to pump blood to a greater distance away from the heart.

The heart is equipped with .....3..... valves, which allow blood to flow only in one direction through the heart chambers. The atrioventricular valve is present between the atrial and ventricular chambers on each side of the heart. The left atrioventricular valve is called bicuspid or .....4..... valve. The right atrioventricular valve is called .....5.....valve. The second set of valves, the semilunar valves, are present at the base of each blood vessel leaving the ventricular chambers, the pulmonary artery and the .....6.....

Two chambers on each side, the atrium and the ventricle, operate as a single system. Therefore, there are two pump systems in the heart. The right side of the heart receives deoxygenated blood from the systemic veins and pumps it to the lungs for oxygenation. The left side of the heart receives .....7..... blood from the .....8..... and pumps it through the systemic arteries to different tissues of the body. Each .....9..... results from the simultaneous pumping of both sides of the heart.

iv. Heart beat cycle

What is heart beat? Heart beat is the **rhythmic contraction** and **relaxation** of the heart. Each heart beat includes one systole (*contraction phase*) and one diastole (*relaxation phase*) of the heart. The heart of an adult healthy person beats about **72** times per minute at rest. This is called heart rate of that person. The heart rate increases during exercise, fever, fear and anger. Heart rate of smaller animals is higher than larger animals because of their higher **metabolic rate**. For an example, an elephant has normal heart rate of about 25 per minute whereas rat has a heart rate of about 205 per minute.

Steps in heartbeat cycle (*cardiac cycle*)

Each beat of the heart involves carefully timed steps of **contraction** and **relaxation** of atria and ventricles. The **contraction phase** is called the systole while the **relaxation phase** is called the diastole. When both the atria and ventricles are in diastolic and relaxed phase, this is referred to as a joint diastole. Each full heart beat of an adult human lasts for about 0.85 seconds. *The steps of heart beat are briefly described below*.

1. *In the first step*, the atria contract and blood is squeezed out from their cavities into the corresponding ventricles as the **bicuspid** and **tricuspid valves** are open. During this step, atria contract and **ventricles** remain relaxed. This step is therefore called atrial systole or ventricular diastole.

2. *In the second step*, the **auricles relax** (*diastole*). Just as they relax, the atrio-ventricular (*tricuspid and bicuspid*) valves close immediately producing the first heart sound. Once the **atrio-ventricular valves** are closed, the **ventricle contracts** (*systole*). The **semilunar valves** open as the blood rushes into the arteries from the ventricles.

3. *In the final step*, the **ventricles** start to relax (*diastole*). This gradually brings down the pressure and at the same time the **semilunar valves** close to prevent backflow of blood into the heart. This produces the second heart beat sound. With the closure of the semilunar valves the ventricles relax further and the **atrio-ventricular valves** open. Thus, at this stage, both auricles and ventricles are in relaxed phase and hence, the stage is called joint diastole.

The occurrence of the periodic series of events during one heartbeat is called a cardiac cycle.

v. Heart sounds

The heart beat produces characteristic sounds which can be heard by placing the ear against the chest or by using stethoscope. In a normal person, two sounds are

produced per heart beat. *First sound*, '**LUBB**' is produced due to the **partly closure of the bicuspid** and **tricuspid valves** and partly due to the **contraction of the muscles in the ventricles**. The *first sound*, '**LUBB**' is **low pitched**, not **very loud** and of **long duration**.

Second sound, '**DUP**' is produced due the **closure of the semilunar valves** which marks the end of ventricular systole. The *second sound* '**DUP**' is **highly pitched**, **louder**, **sharper** and **shorter in duration**. The two sounds have been described in words as "**LUBB DUP**" and their quality indicates the state of the valves. Damage to the bicuspid or tricuspid valve affects the quality of the first heart sound. When the semilunar valves are injured, a ***soft hissing noise*** "**LUBB SHHH**" is heard in place of the second sound. This is called a heart murmur.

vi. Circulation of blood in the heart

The deoxygenated blood (**blood with low oxygen**) flows from the **superior** and **inferior venae cavae** into the **atria** and from the atria to the respective ventricles through **atrio-ventricular valves**. But there is no flow of blood from the ventricles to the **aorta** and **pulmonary artery** as the **semilunar valves** remain closed. The **right ventricle** opens to a major artery called the **pulmonary artery** which takes the deoxygenated blood to the lungs. The **left atrium** receives oxygenated blood (**blood with high oxygen**) from the left and right pulmonary veins coming from the left and right lung respectively. This blood is then pumped into the **left ventricle** from where it moves into the aorta and then to the different parts of the body. The action of heart includes contractions and relaxations of the atria and ventricles. **Contraction of atria** results in flow of blood from atria into ventricles. When the ventricles contract, the blood from ventricles is pumped into the blood vessels during which the **atrio-ventricular valves** close to **prevent blood from flowing back into the auricles from the ventricles**. When the ventricles relax, **semilunar valves** close to **prevent blood from flowing back into the ventricles**. The atria and ventricles contract alternately. The auricles are the **receiving chambers** and the ventricles are the **pumping chambers**.

vii. Conduction of heart beat

The contraction of heart is initiated and activated by nerves that lie in the wall of the right atrium near the opening of the **superior vena cava** called the sinoatrial (SA) node. This node is called the pacemaker. The electrical impulse generated arrives at the atrioventricular (AV) node, a node which is located in the wall of the **right atrium**. The impulse from the SA node causes the atria to contract, pushing blood through the open valves into the ventricles. From the AV node, **electrical impulse**

travels through a mass of specialized fibres, the bundle of His. It then divides into the **right** and **left bundle branches**, one going to each ventricle called the Purkinje fibres. The bundle of His and the Purkinje fibres convey electrical impulse of contraction from the AV node to the walls of the ventricles. These impulses stimulate the ventricles to contract simultaneously. The ventricles force blood through long system of pulmonary artery and aorta at **greater pressure**.

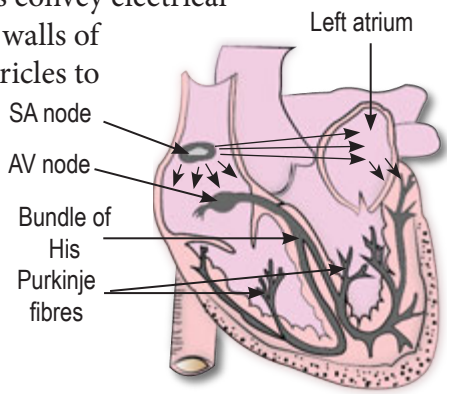


Figure 4.10 Conducting system in human heart

Sometimes, the **SA-node** may become damaged or defective. So the heart does not function properly. This can be remedied by the **surgical grafting** of an artificial pace maker in the chest of the patient. The artificial pace maker stimulates the heart at regular intervals to maintain its beat.

Blood pressure is the pressure exerted by the blood against the walls of the arteries. It is measured by noting the height to which a column of mercury can be pushed by the blood pressing against the arterial walls. A **normal blood pressure** has a height of **120** millimetres of mercury during **heart contraction** (**systole**), and a height of **80** millimetres of mercury during **heart relaxation** (**diastole**). Normal blood pressure in an adult is expressed as **120/ 80 mmHg** *(read as 120 over 80 millimetres of mercury)*. Blood pressure is measured using instruments such as sphygmomanometer, the digital blood pressure meter and the aneroid blood pressure meter.

Brain Snacks

- The average heart rate in human is **70** to **80** beats per minute.
- The total length of blood vessels in the human body is about **100,000** km.
- Blood constitutes **7%** of our body weight.
- A drop of blood contains about **5** million red blood cells.
- The length of time a heart can survive if removed from the body is **5** hours.
- Every day an average of **7,000** litres of blood pass through a person's heart.

B. Physiology of Circulatory System

Learning Objectives

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

- differentiate between systemic circulation and pulmonary circulation.
- describe lymphatic circulation.

The circulatory system permits blood to circulate through a network of vessels throughout the body to provide cells with oxygen and nutrients and helps dispose of metabolic wastes.

a. Circulation of blood

The circulatory system works to transfer oxygenated blood to all the tissues of body. The blood flows twice in the heart before it completes one full cycle. These two main circulatory processes are **systemic circulation** and **pulmonary circulation**. In the systematic circulation, the blood circulates in body and supplies oxygen to organs, tissues, and other structures. In the pulmonary circulation, the blood flows to the lungs to release carbon dioxide and get new oxygen. For this reason, the blood circulation in the human body is also referred as double circulation.

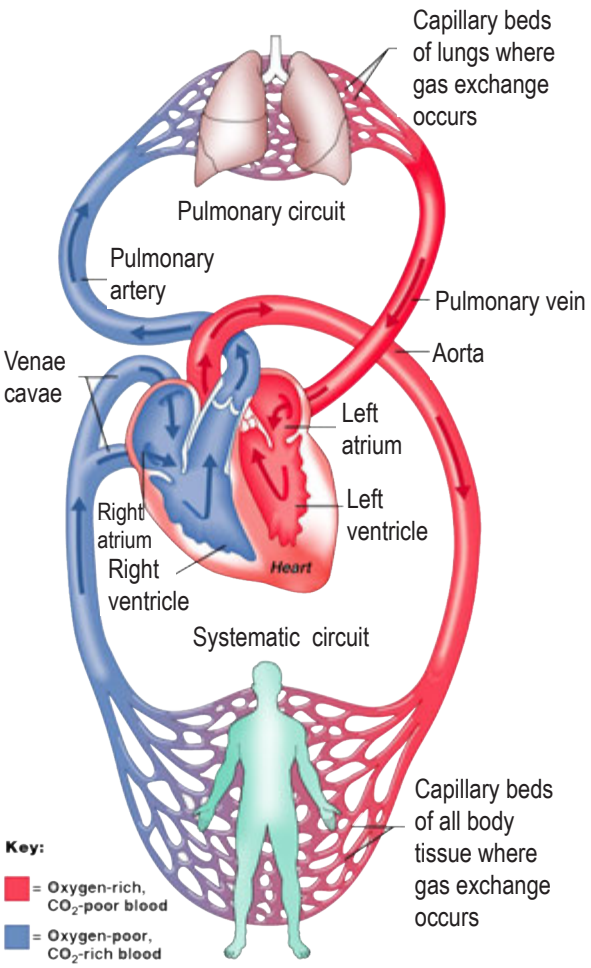


Figure 4.12 Working of circulatory system

i. Systemic circulation

At the start of the blood circulatory cycle, the heart **pumps oxygenated blood** out of the left ventricle through the aorta (*the largest artery in the body*). The aorta divides into smaller arteries, then **arterioles** and finally into microscopic **capillaries**, found deep within muscles and organs. Here, the oxygen and other nutrients passes through the thin capillary walls, into the tissues where it can be used by the cells.

The carbon dioxide produced as the metabolic waste in the cells passes across

the walls of the capillaries into the blood stream for removal from cells. The **oxygen-low blood** flows through venules and veins and, finally enters the heart through the **vena cava** into the **right atrium**.

The **heart** has its own set of blood vessels that provide the cardiac muscular wall with oxygen and nutrients.

Hepatic portal circulation

The veins of the stomach and intestines perform a unique function; instead of carrying blood directly back to the heart, they **carry blood to the liver** through the hepatic portal vein. Blood leaving the digestive organs is rich in nutrients and other chemicals absorbed from the food. The liver removes toxins, stores sugars, and processes the products of digestion before they reach the other body tissues. Blood from the liver then returns to the heart through the **inferior vena cava**.

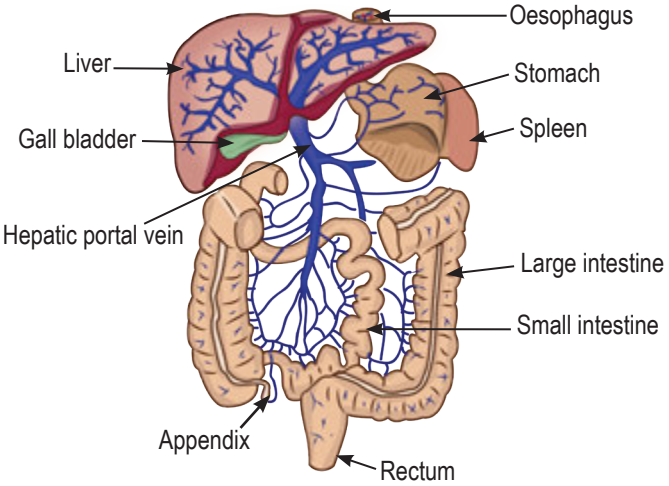


Figure 4.13 Hepatic Portal Circulation

ii. Pulmonary circulation

Once blood returns to the **right atrium,** it passes through the **tricuspid valve** into the **right ventricle**. From the right ventricle, the blood is pumped through the pulmonary artery to the lungs for gaseous exchange. Gaseous exchange takes place in the lungs, where oxygen diffuses into the blood and carbon dioxide is removed from the blood. The **oxygen-rich blood** from the lungs returns to the left atrium via the pulmonary vein.

The oxygen-rich blood flows from left atria through the bicuspid (***mitral***) valve into the left ventricle, from which it is pumped through the **aorta** to other parts of the body again.

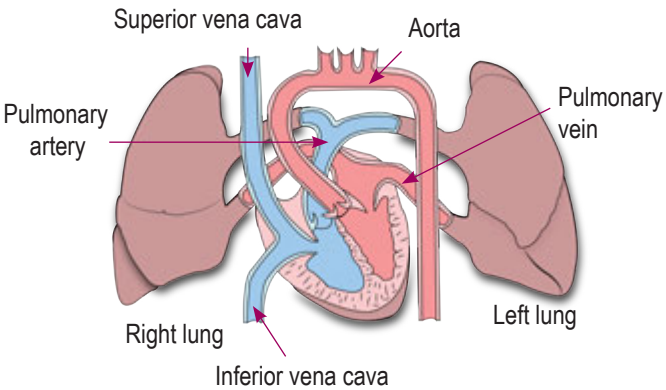


Figure 4.14 Pulmonary Circulation

b. The lymphatic circulation

The lymphatic circulation consists of all **lymphatic vessels** and **lymphoid organs** such as *lymph nodes*, *spleen*, *thymus gland*, and *tonsils*. It is an extension of the circulatory system, consisting of a fluid known as lymph, which circulates through lymphatic vessels and lymph nodes. Lymph is a **watery fluid derived from plasma** that has seeped out of the blood system capillaries and surrounded with body cells. The lymph enters a series of one-way lymphatic vessels and **lymph nodes** that return the fluid to the circulatory system. Many lymph nodes are located in the **neck**, armpits and groin (Figure 4.15). They serve as filter stations for the lymph of a certain body region and contain specials cells of the immune system called lymphocytes, which fight infections attacking the body. So, the lymph nodes clean the lymph and free it from pathogens and infectious bodies.

The spleen is an organ composed primarily of lymph node tissue lying close to the stomach. The spleen is the site where red blood cells are destroyed. The spleen serves as a **reserve blood supply** for the body. The thymus is a gland located behind the breastbone (*sternum*). At birth, the thymus is the largest organ of the lymphatic system. It plays a vital role in building the **immune system**.

The lymphatic system has three main functions:

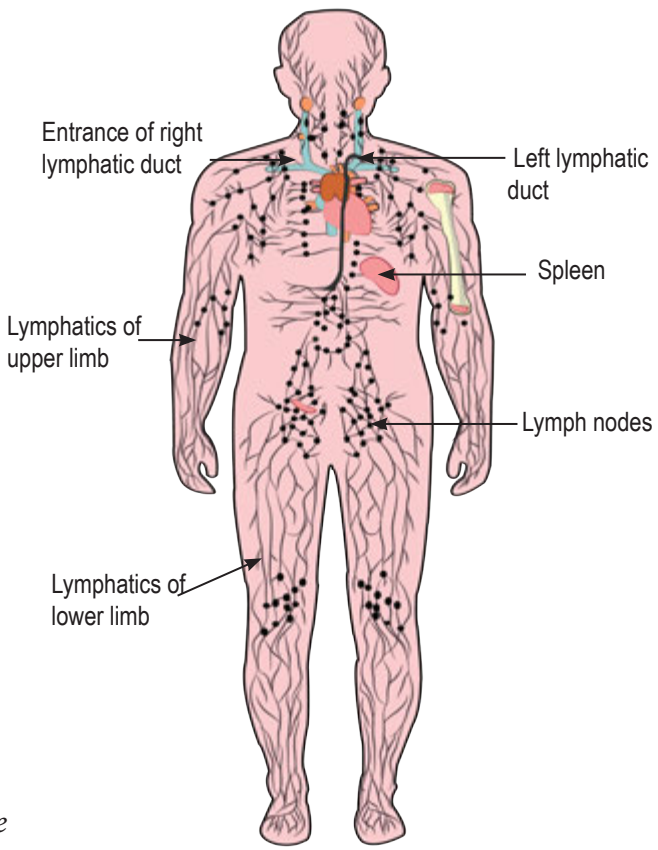


Figure 4.15 Lymphatic circulation

1. Maintains the fluid balance by returning the tissue fluid to the blood. *Tissue fluid* is a fluid surrounding the cells of a tissue.

2. Forms an important part of the body's immune system, which fights foreign bodies such as bacteria by producing **lymphocytes**.

3. Facilitates absorption of fats and fat-soluble nutrients through **lymphatics** (*lacteals*) in the small intestine.

Summary

- Heart contains four chambers- two atria and two ventricles.
- The heart is equipped with four valves, the left atrioventricular valve is called bicuspid or mitral valve, and the right atrioventricular valve is called tricuspid valve.
- Arteries are blood vessels that goes away from the heart and carries oxygenated blood except the pulmonary artery.
- Capillaries are the smallest and thinnest of the blood vessels that carry blood very close to the cells of the tissues of the body in order to exchange gases, nutrients, and waste products.
- Blood is a fluid connective tissue, which is red in colour due to the presence of haemoglobin.
- All the important nutrients, hormones, blood cells and the clotting proteins, as well as the waste products, are transported through the plasma.
- Platelets normally remain inactive in the blood, until they reach the damaged tissue or leak out of the blood vessels through the site of the injured blood vessel.
- The blood delivers essential nutrients and oxygen, and removes wastes like carbon dioxide from the body
- Platelets and red blood cells form layer to seal wounds and prevent pathogens from entering the body.
- Systemic circulation encompasses blood circulation from heart to the body cells and tissues and back to the heart.
- Pulonary circulation encompasses circulation of de-oxygenated blood from right ventricle by the pulmonary artery to lungs and back to left atrium by pulmonary veins.
- Coronary circulation circulates blood to the heart muscle itself.
- Lymphatic circulation carries lymphatic fluid from intercellular space to the heart.

http://www.biologycorner.com/anatomy/chap13.html

http://www.biologycorner.com/anatomy/chap12.html

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. Outline of blood circulation is given below. Identify the correct sequence.

   I. The heart receives oxygen-low blood from the body into the right upper atrium.

   II. As the heart contracts, the left ventricle forces the blood out of the heart through a network of arteries to different parts of the body.

   III. When the heart contracts, the right ventricle pumps the blood into the lungs, where the carbon dioxide is exchanged for oxygen.

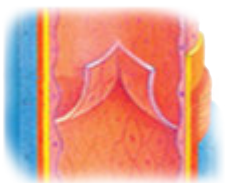
   IV. The blood containing high concentration of oxygen flows into the left atrium. Oxygen-rich blood flows from the left atrium into the left ventricle.

   A. I, II, III and IV C. I, IV, III and II
   B. I, III, IV and II D. I, II, IV and III

2. What happens to blood when it is pumped into the thin-walled blood vessels of the lungs?

   C. Platelets are exchanged for plasma
   D. Platelets are exchanged for carbon dioxide
   E. Carbon dioxide is exchange for oxygen
   F. Replace haemoglobin

3. The Figure on the right shows ..... because it has valve.



   A. vein C. heart
   B. artery D. capillary

4. The nearest organ to which the heart supplies oxygenated blood is

   A. lungs. C. intestine.
   B. stomach. D. heart itself

5. When doctor is recording your pulse, he is pressing on your wrist, exactly on a

   A. vein. C. artery.
   B. nerve. D. capillary.

6. The main function of lymph nodes is to

   A. produce erythrocyte. C. produce hormones.
   B. produce enzymes. D. produce lymphocytes.

7. Which statement is not true?

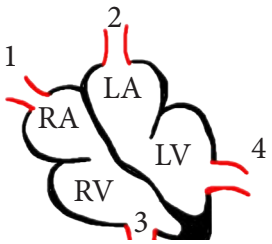
   A. Veins contain valves
   B. All veins carry deoxygenated blood
   C. Veins are thin-walled
   D. Veins return blood from various parts of the body to the heart

8. This component of the blood can be best compared to soldiers of the country.

   A. Lungs C. Red blood cells

B. Capillaries D. White blood cells

9. The valve present between the RA and RV in the Figure on the right is



A. tricuspid valve. C. aortic semilunar valve.
B. bicuspid valve. D. pulmonary semilunar valve.

10. Blood vessel 1 and 4 in the Figure above in question 10 are ..... and ..... respectively.

A. vena cava and pulmonary artery. C. pulmonary vein and aorta.
B. vena cava and aorta. D. aorta and pulmonary artery.

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

1. The network of blood vessels, connecting arteries and veins is .....
2. The back flow of blood in viens are prevented due to presence of .....
3. Heartbeat results from the pumping of blood by atria and ventricles. Contraction of ventricles is known as .....
4. At rest, pulse rate in a healthy adult human is about ..... beats / minute.
5. The contraction of heart muscles is controlled by the conducting system that originates on the upper region of the right atrium called the .....

C. Write TRUE or FALSE against the following statements.

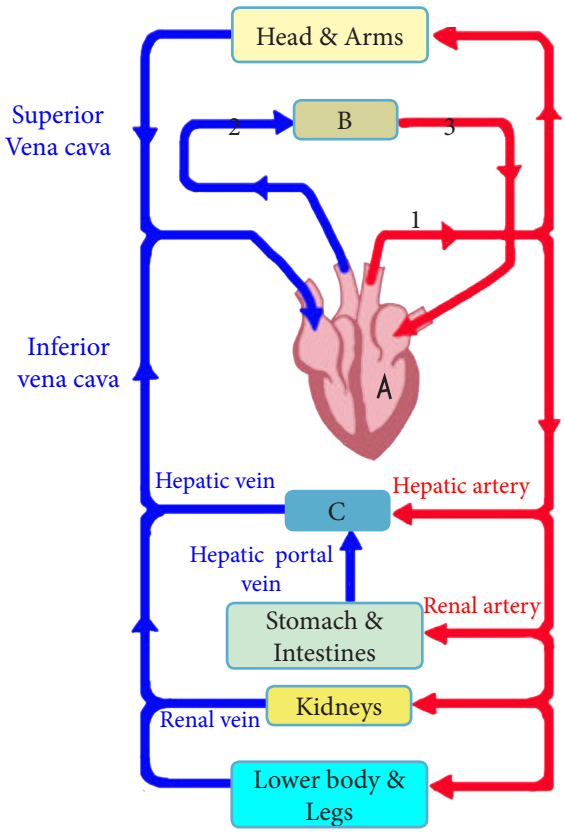
1. Cells and tissues receive their food via blood.
2. The heart receives oxygen rich blood from the lungs into the right atrium.
3. Red blood cells finally get digested in liver.
4. Red blood cells can be compared to the vehicle of the body and white blood cells can be compared to the soldiers of the body.

D. Match the items of Column I with the most appropriate items of Column II. Rewrite the correct matching pairs.

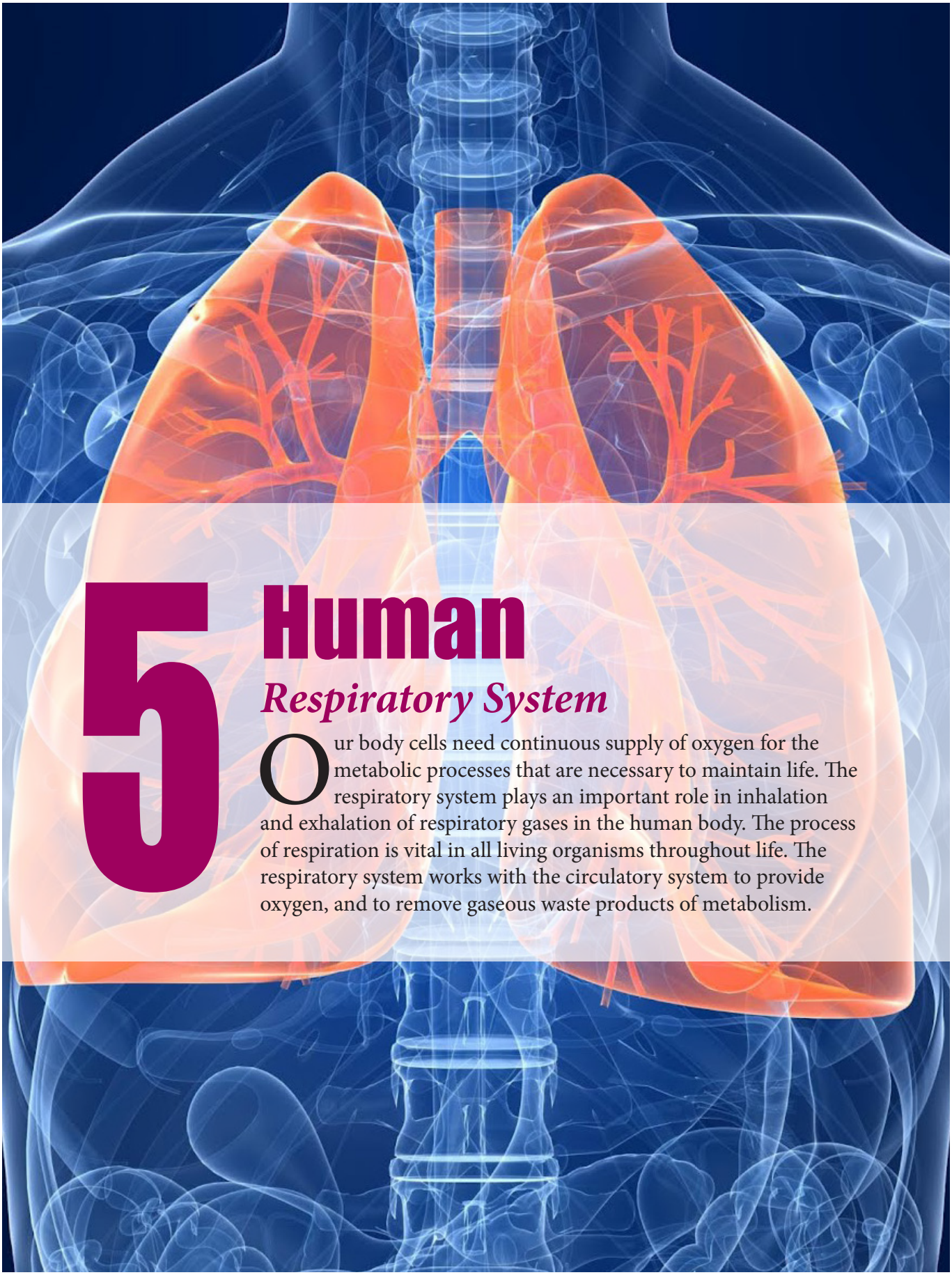
Column I	Column II
1. Erythrocytes	a. clean up cellular debris and fight pathogens that have entered the body.
2. Valve	b. condition in which blood vessels constrict to keep blood flowing only to vital organs in the body.
3. Cardiac arrest	c. transport oxygen in the blood through the red pigment haemoglobin.
4. White blood cells	d. allows unidirectional flow of blood.
5. Hypothermia	e. condition in which heart stops pumping the blood in the body.

E. Answer the following questions.

1. Draw a sketch of human heart.
   a. Label the four chambers. Colour either red or blue in accordance to oxygenated and deoxygenated blood in all the chambers.
   b. Draw arrows to show the direction of blood flow within the heart.
   c. Label the mitral valve, aortic semilunar valve, and septum.
2. The Figure on the right is a schematic diagram of human blood circulatory system.
   a. Name the organ A, B and C.
   b. Name blood vessel 1, 2 and 3.
   c. What is the significance of C.
   d. What is the connotation of red and blue coloured blood vessel?
   e. Explain double circulation?



3. Counting of pulse rate is an indirect method of counting of the heart beat. If the pulse rate of healthy adult human is 80 per minute. Calculate the number of times your cardiac muscles contract in 1 hour.
4. Why do people believe that heart is felt in left side of the chest?
5. Give reasons.
   a. Arteries have thicker muscular wall than veins.
   b. Spleen is a lymphatic organ.
   c. Valves are present in veins, but not in arteries.
   d. Auricles have thinner wall as compared to ventricles.
6. Describe lymph and lymphatic system.
7. Why people living in high altitude have more numbers of red blood cells?
8. When your toe is injured, often your groin is swollen. Explain.
9. How is the *Yoga* related to blood circulation?



5 Human

Respiratory System

Our body cells need continuous supply of oxygen for the metabolic processes that are necessary to maintain life. The respiratory system plays an important role in inhalation and exhalation of respiratory gases in the human body. The process of respiration is vital in all living organisms throughout life. The respiratory system works with the circulatory system to provide oxygen, and to remove gaseous waste products of metabolism.

Human Respiratory System

Learning Objectives

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

- describe the basic structures of the breathing system and their roles in respiration.
- explain gaseous exchange.
- investigate presence of carbon dioxide in the expired air.
- explain respiratory diseases.

Our lungs take in about 15 breaths of air every minute. This vital process of breathing keeps all the cells in the body supplied with the **life-giving gas oxygen**. Without oxygen, the cells in our body would not be able to release energy trapped in food molecules. As we breathe in air, oxygen is channelled through hollow tubes of **respiratory organs** and **structures**.

a. Respiratory organs and their functions

The respiratory system is the group of tissues and organs in the body that enable us to breathe. This system includes airways (**nose**, **mouth**, **pharynx**, **trachea**, **bronchial tubes**), **lungs** and the **blood vessels** and **muscles** attached to them that work together so we can breathe. The **primary function** of respiratory system is to supply oxygen to all the parts of the body through **inhaling air** rich in oxygen and **exhaling** air

The organs of the respiratory system are shown in Figure 5.1.

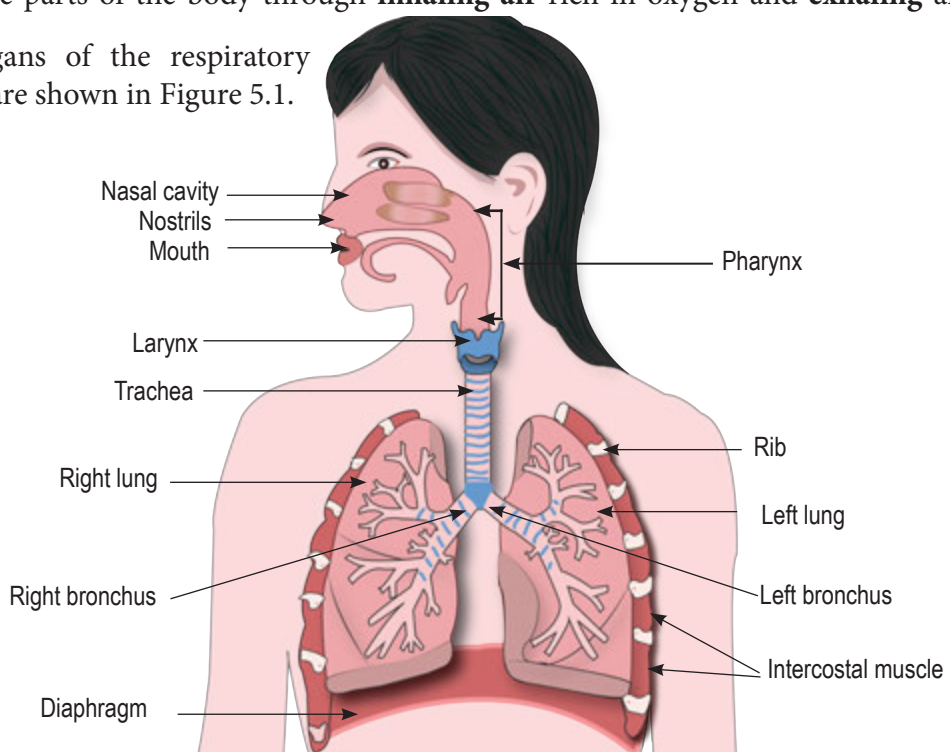
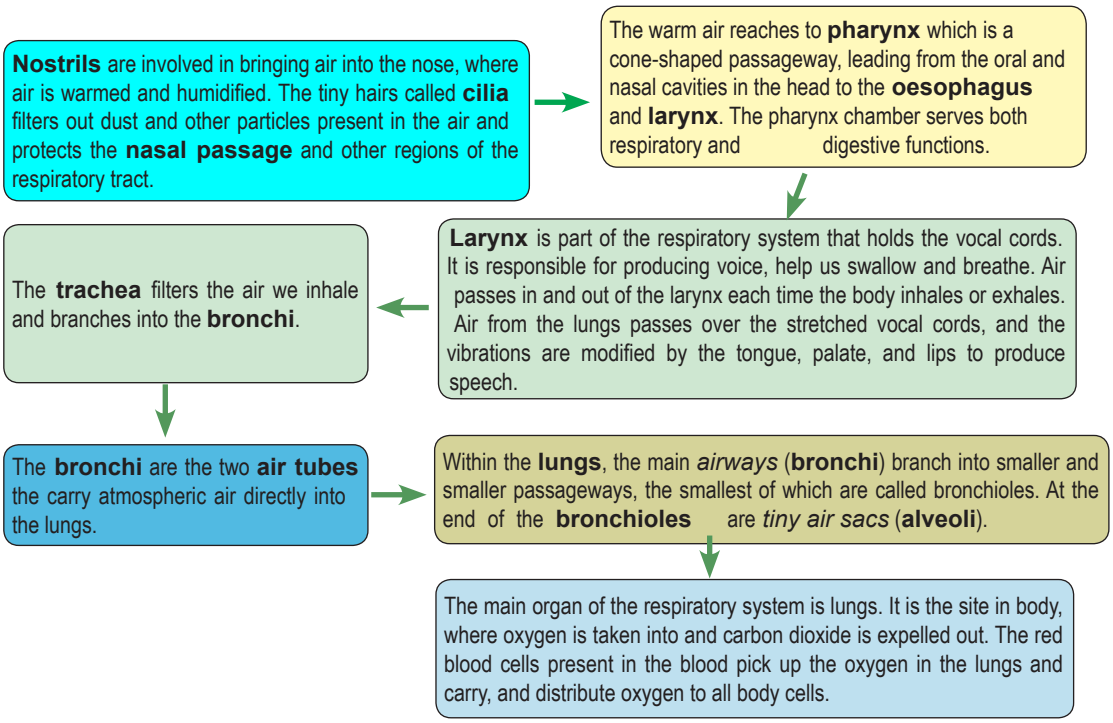


Figure 5.1 Human Respiratory system

filled with carbon dioxide. The respiratory system is divided into **upper** and **lower respiratory tracts**. The upper respiratory tract consists of **nose** and **pharynx**. The lower respiratory tract includes the **larynx**, **trachea**, **bronchus** and **bronchioles**. The trachea splits into two main branches, the **left** and **right bronchus**, each bronchus divides many times into smaller branches called bronchioles. Each bronchiole finally leads to a bunch of **tiny air sacs**, called alveoli, where gas exchange takes place.

The passage of air



i. Lungs

The lungs are a **pair of spongy** and **elastic air-filled sacs**, formed of millions of tiny pockets called alveoli. Lungs occupy the greater portion of **thoracic cavity** which is formed of **vertebrate**, **ribs sternum** and **muscular diaphragm**. Each **alveolus** is just a fraction of a millimetre across and has a network of blood vessels wrapped around it. The walls of the alveoli and blood vessels are so thin that oxygen can pass freely across to enter the blood.

The **right lung** is slightly larger than the **left lung**. It has **three lobes,** while left lung has only **two lobes**. The left lung is smaller in size to accommodate the heart in between. Each lung is covered by two protective membrane called parietal (**outer**) pleura and the visceral (**inner**) pleura. The cavity between the two membranes is called pleural cavity or pueral space, and is filled with pleural fluid. This fluid **provides lubrication** for the free movement of lungs during expansion and contraction.

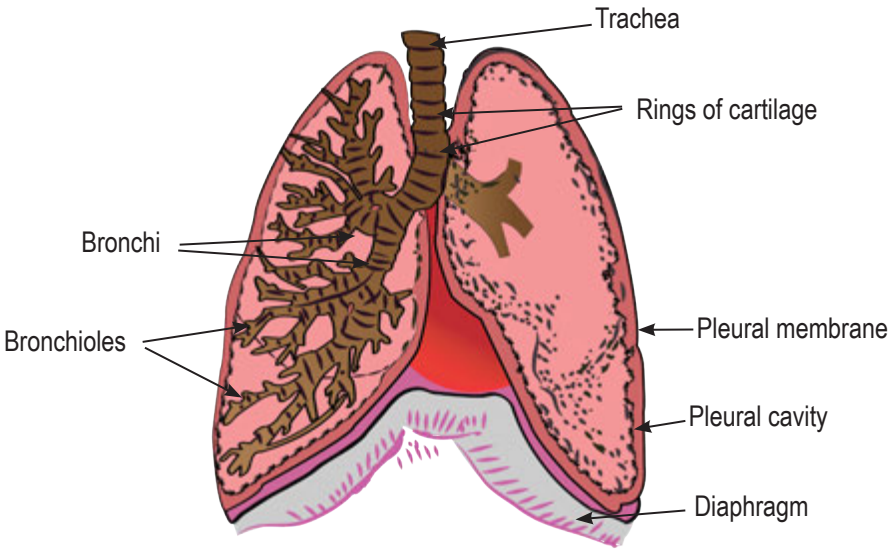


Figure 5.2 Human respiratory system

Functions of lungs

The lungs provides a very **large surface area for the exchange of gases**. The oxygen from the air is inhaled through the process of inhalation, the lungs bring oxygen into the bloodstream, which carries oxygen to the rest of the body. The cells of the body produce carbon dioxide as they use oxygen. This is carried back to the lungs by the blood vessels. The carbon dioxide leaves the lungs through the process of exhalation.

b. Breathing cycle

Breathing cycle includes three stages of inspiration (or **inhalation**), expiration (or **exhalation**) and short pause (or **relaxed state**). The lungs have no muscles. To suck in air and push it out again, they rely on the msucles around them. The **diaphragm muscle** and **rib muscles** help in the breathing cycle (Figure 5.3 & 5.4).

Control of breathing movements

All our breathing movements such as inspiration and expiration are regulated by respiratory centre, located in the **medulla oblongata** of the brain. This centre sends the nerve impulse to the **diaphragm** and **intercostal muscles** to contract or expand the **muscles in the rib cage**. In normal adults, breathing rate is 14-18 breaths per minute. However, a new born breathes about 60 times per minute. The breathing rate increases with increased physical activity. For example, if we do some physical exercise, our breathing rate increases considerably. The body automatically regulates the breathing to maintain the **body homeostasis**.

Inspiration

During inspiration, the **diaphragm muscle** starts to contract, pulling the diaphragm downward and **becomes flatten**.

The **external intercostal muscles contracts**, pulling the sternum and ribs up and outward.

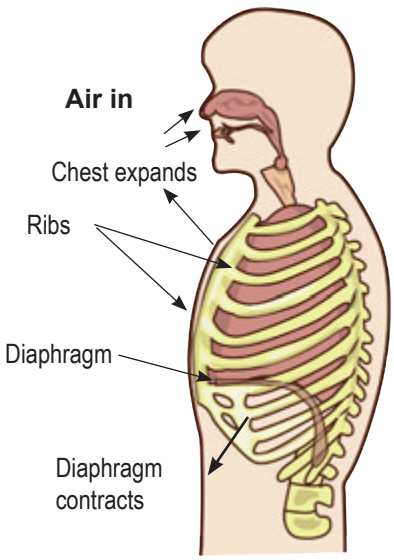


Figure 5.3 Inhalation

The volume of t**horacic** (chest) **cavity** increases, the pressure in the lungs is lowered below the atmospheric pressure, due to which, the air from outside flows in.

Expiration

Expiration (or **exhalation**) is the result of reverse movements of ribs and diaphragm. During expiration, the diaphragm muscle relaxes and becomes **dome-shaped**.

The **external intercostal muscles relax**, pulling the ribs down and inward.

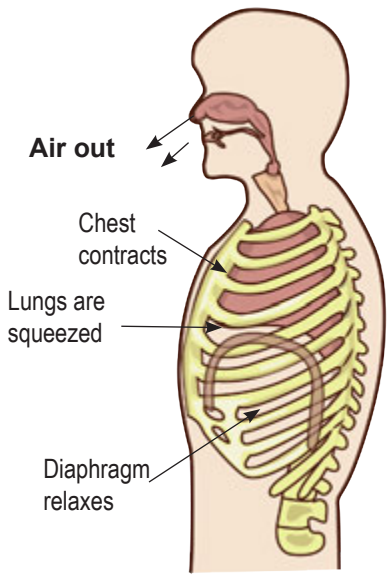


Figure 5.4 Exhalation

The volume of the **thoracic cavity** is decreased, the pressure in the lungs increased above the atmospheric pressure, and **air flows out**.

Yawn: When you are sleepy or drowsy, the lungs do not take enough oxygen from the air. This causes a shortage of oxygen in our bodies. The brain senses this shortage of oxygen and sends a message that causes you to take a deep long breath-a yawn.

Sneeze: Sneezing is like a cough in the upper breathing passages. It is the body's way of removing an irritant from the sensitive mucous membranes of the nose. Many things can irritate the mucous membranes. Dust, pollen, pepper or even a cold blast of air are just some of the many things that may cause you to sneeze.

Hiccups: Hiccups are the sudden movements of the diaphragm. There are many causes of hiccups. The diaphragm may get irritated, you may have eaten to fast, or maybe some substances in the blood could cause hiccups.

Activity 5.1

Effect of activity on breathing rate

Materials required: stop watch

Procedure

1. Count the breathing rate in one minute.
2. Stand up and step-march to a rhythm set by the teacher or timekeeper, for duration of two minutes.

Activity	Make prediction of breathing rate per minute	No. of breathing rate per minute	Time taken to return to resting breathing rate (min)
At rest			
Walk slowly			
Walk fast			
Run			

3. Analyze the results.

Questions

i. Predict the time taken to return to rate of breathing at rest for different physical activities.
ii. Draw a graph to show the patterns.
iii. List at least two precautions that need to be taken care during the investigation.
iv. Which physical activity act as a control in this investigation?
v. What can you conclude from the experiment?

Activity 5.2

Action of diaphragm during breathing

Materials required: plastic bottle, rubber sheet, strings, cork, tube, balloon

Procedure

1. Set up an experiment as shown in Figure 5.5.
2. Predict what will be the change in the balloons when the rubber sheet is pulled downward and released. Observe to the changes in the balloons.
3. Predict what will be the change in the balloons when the rubber sheet is released.
4. Next, push the rubber sheet upward and write your observations.

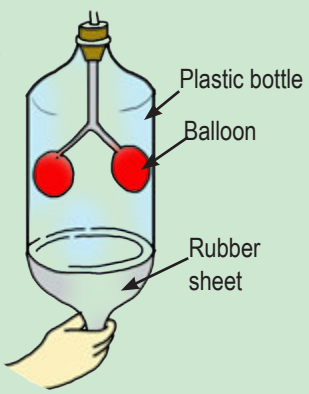


Figure 5.5

Questions

i. Identify the part that represents the diaphragm?
ii. Explain your observation in step 2.

iii. What can you conclude from step 3?
iv. Which stages of breathing cycle is represented by processes in steps 2 and 4?
v. What is the main precaution that one must take for the set up to function correctly?
vi. Relate Boyle's law and the human breathing cycle.

c. Gaseous exchange

Respiration involves sequence of events that results in the exchange of oxygen and carbon dioxide between the atmosphere and the body cells. Every few seconds, nerve impulses stimulate the breathing process, which moves air through a series of passages into and out of the lungs. After this, there is an **exchange of gases** between the lungs and the blood. This is called external respiration. The blood transports the gases to and from the **tissue cells**. The exchange of gases between the blood and the tissue cells is internal respiration. Finally, the cells utilize the oxygen for their specific activities, such as oxidation of food. The carbon dioxide is transported back to the blood.

In respiring cells or tissues, **concentration difference of oxygen and the waste products** such as carbon dioxide are created between the **cells and the tissue environment and capillaries**. This concentration difference leads to the movement of molecules from the regions of high concentration to the regions of low concentration by diffusion. As a result, oxygen is transported towards the cells and the carbon dioxide is transported back to the environment.

The **site of gases exchange** is referred to as the respiratory surface. In single-celled organisms, gas exchange occurs directly between the cell and the environment, i.e., at the cell membrane. In plants, gas exchange with the environment occurs in special organs, the **stomata**, found mostly in the leaves.

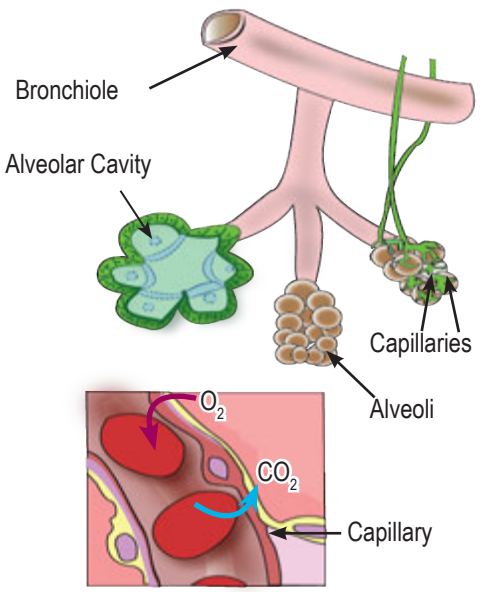


Figure 5.6 Exchange of gases

Transport of oxygen and carbon dioxide

In the blood, **oxygen combines with haemoglobin** to form an unstable compound called oxyhaemoglobin. It is carried by the red blood cells to the tissues. Once it reaches to the tissue cells where oxygen concentration is low, oxyhaemoglobin breaks down and release oxygen by diffusing through the capillaries.

The end products of cellular respiration,

carbon dioxide and water diffuse back out of the tissue cells into the blood where the carbon dioxide concentration is low. **Carbon dioxide** is carried in the blood plasma in the form of bicarbonate ion. In lungs, bicarbonate releases carbon dioxide which diffuses into the **alveolar air**.

Activity 5.3

Investigate the presence of CO_2 in expired air.

Materials required: test tubes, lime water, glass tubes and cork.

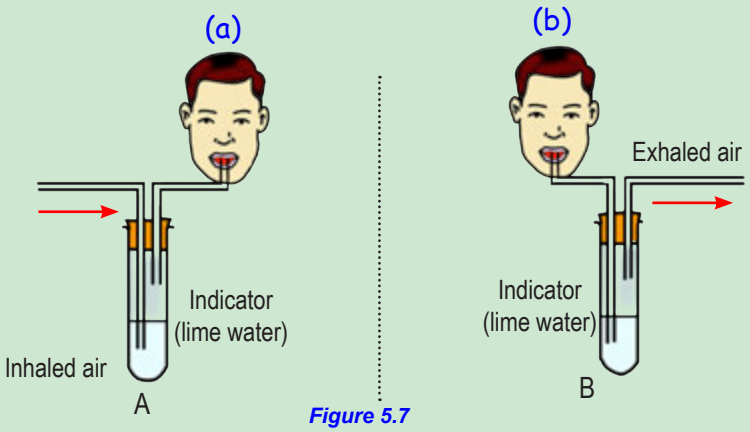


Figure 5.7

Procedure

1. Get the help of your laboratory assistant or teacher and set up an apparatus as Figure 5.7.
2. Copy and complete the table 5.1.
3. Do not suck in or blow out the air forcefully.

Table 5.1

Sl.No.	Procedure	Observation	Inference
1	Suck in air with the help of a delivery tube as shown in the set up (a) for few minutes. Observe what happens to lime water in test tube A.		
2	Blow the air through the tube as shown in set up (b) for few minutes. Observe what happens to the lime water in the test tube B.		

Questions

i. What is the most probable hypothesis for this experiment?
ii. What is the role of lime water in the experiment?
iii. Explain your observations about the lime water in test tube A and B.
iv. List down two precautions, you would take in while conducting the experiment.
v. What can you conclude from the above experiment?
vi. Design another experiment as an extension of the above experimental set-up.

d. Lung volumes and capacities

A doctor can measure your lung capacity using a device called a spirometer. In Bhutan, the facility to perform spirometry was introduced in 2016 at the **Khesar**

Figure 5.8 Spirometer

Gyalpo University of Medical Sciences of Bhutan (KGUMSB), Thimphu. The amount of air in the lungs can be subdivided into **four volumes** and **four capacities**.

1. **Tidal volume (TV)** is the amount of air that can be inhaled and exhaled during one normal (quiet) breathing cycle, which is about **500 mL** for an humans. Some tidal air is left in respiratory passages, such as trachea and bronchi, where no diffusion of gases can occur (about **150 mL**). This is called dead air space.
2. **Inspiratory reserve volume (IRV)** is the amount of air that can be forcibly inhaled beyond the tidal volume (about **3000 mL** for men and **2000 mL** for women).
3. **Expiratory reserve volume (ERV)** is the amount of air that can be forcibly exhaled after normal exhalation (about **1200 mL** for men and **700 mL** for women).
4. **Residual volume (RV)** is the amount of air remaining in the lungs after an expiratory reserve volume (about **1500 mL** in men and women).

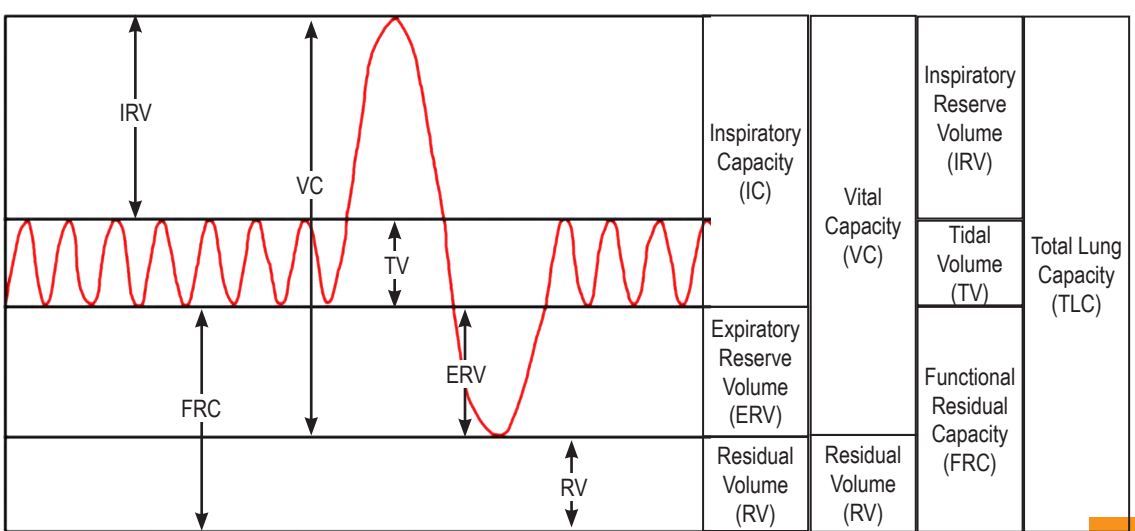


Figure 5.9 Graph showing lung volumes and capacities

5.4 Activity

Calculating four lung capacities

Using the graph in Figure 5.9 and the lung volumes and capacities for men and women, calculate the following.

1. The inspiratory capacity (**IC**), is the maximum amount of air that can be inspired after a normal expiration (**IC = TV + IRV**). Calculate the inspiratory capacity in human.
2. The functional residual capacity (**FRC**), is the amount of air remaining in the lungs after a normal expiration (**FRC = RV + ERV**). Calculate the functional residual capacity in human.
3. The vital capacity (**VC**), is the total amount of air that can be taken in and expelled out by maximum inspiration and expiration (**VC = TV + IRV + ERV**). Calculate the vital capacity in human.
4. The total lung capacity (**TLC**), is the maximum amount of air that can at any time held in two lungs (**TLC = RV + VC**). Calculate the total lung capacity in human.

e. Respiratory diseases

Respiratory diseases are the diseases that affect the tissues and cells of respiratory tracts and organs. It is mainly caused by **smoking**, **air pollutants**, **industrial smokes**, etc,. Severe respiratory diseases greatly increase the risk of illness, disability and death from **bronchitis**, **emphysema** and **lung cancer**.

i. Bronchitis

Bronchitis is an **inflammation of the bronchi** caused by irritants, such as tar in the cigarette smoke, air pollution, or infections. The inflammation in bronchi results in

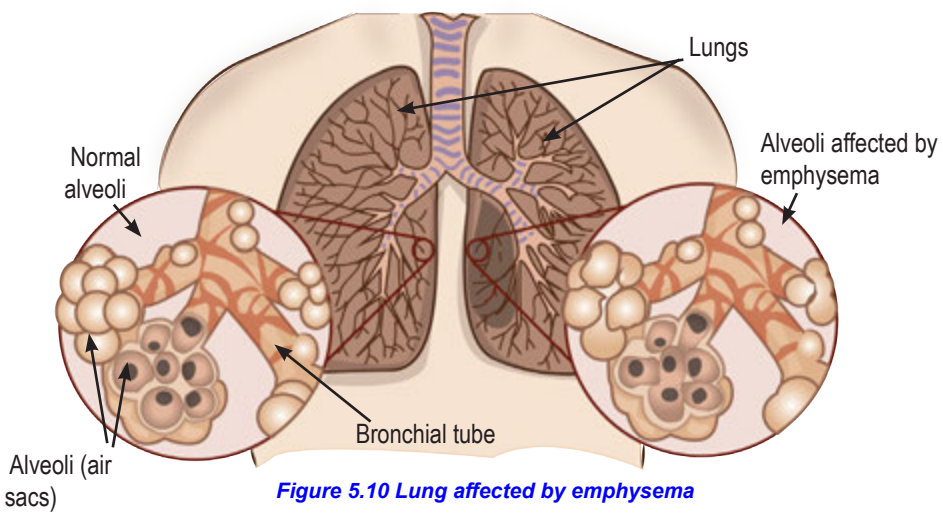


Figure 5.10 Lung affected by emphysema

swelling of the mucous membrane lining of the bronchi, increased mucus production, and decreased movement of mucus by cilia resulting into coughing. As the disease progresses, the bronchioles narrow, and breathing becomes difficult. It can progress to **emphysema**.

ii. Emphysema

Emphysema is caused by chemicals in **cigarette smoke**, **industrial dust** or other **air pollutants**, which harm the cells of the alveolar walls. The accumulation of mucus increases pressure in the alveoli, resulting in rupture and destruction of alveolar walls. **Symptoms of emphysema** include shortness of breath, cough and recurrent chest infections. The progress of emphysema can be slowed by stopping smoking, but there is no cure.

iii. Carbon monoxide poisoning

Carbon monoxide poisoning is caused by **inhaling carbon monoxide** while smoking tobacco or burning fire wood and charcoal, or inhalation during fire outbreak. This gas when inhaled combines irreversibly with haemoglobin and impair the transportation of oxygen in blood. This prevents oxygen from reaching body tissues and organs.

ii. Asthma

Asthma is a disease involving our immune systems. The airways in lungs become narrow due to contraction of smooth muscle in the walls of the bronchioles. Breathing becomes difficult. Asthma attack is mainly triggered by **irritants** like **pollen**, **dust** from pets, **droppings** of house mites, or other substances. People diagnosed as susceptible to an asthma attack carry inhaler to treat themselves (Figure 5.11). Treatment includes the use of drugs that relax the bronchiole smooth muscles and reduce the inflammation.

Figure 5.11 Inhaler

v. Lung cancer

Lung cancer is characterized by **uncontrolled cell growth** in tissues of the lung that grows into a **tumour**. It arises from **continual exposure to cigarette smoke**. It is the most common cause of cancer death among the smokers. Because of the rich lymph and blood supply in the lungs, cancer in the lung can easily spread to other organs. Typical **symptoms** include **coughing**, **sputum production**, and **blockage of the airways**.

Summary

- Respiration is the breakdown and oxidation of sugars and other substances, by which energy (ATP) is released.
- The order of air passage in human is from nostril, pharynx, larynx, trachea, bronchus, bronchiole, alveolus in lung, blood, tissue and the cell.
- Lungs have two protective membranes called visceral membrane and parietal membrane.
- All breathing movements are controlled by respiratory centre, located in medulla oblongata of the brain.
- Respiration cycle includes three stages namely, inspiration, expiration and respiratory pause.
- All events occuring during diffusion of oxygen and carbondioxide between the alveoli and the blood capillaries are called gaseous exchange.
- Expired air has more CO_2 concentration than inspired air.
- The four volumes are tidal volume (TV), inspiratory reserve volume (IRV), expiratory reserve volume (ERV) and residual volume (RV) and four capacities are inspiratory capacity (IC), functional residual capacity (FRC), vital capacity (VC) and total lung capacity (TLC).
- Respiratory diseases affect the tissues and cells of respiratory organs and respiratory tracts.
- Smoking tobacco causes several respiratory diseases like bronchitis, emphysema, carbon monoxide poisoning, lung cancer, etc.

http://www.biologycorner.com/anatomy/chap16.html

http://www.innerbody.com/anatomy/respiratory

http://www.healthline.com/human-body-maps/respiratory-system

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer

1. After working outdoors in the garden, you come indoors and blow your nose to find dirt in the mucus. What function of the respiratory system is carried out by your nose?

   A. Warming the air
   C. Adding moisture to the air
   B. Filtering the air
   D. Causing an allergic reaction

2. Contraction of the external intercostal muscles and diaphragm cause the thoracic cavity to _____ and the air pressure in the lungs to _____.

   A. contract; increase
   C. expand; increase
   B. expand; decrease
   D. contract; decrease

3. Which of the following best describes the vital capacity?

   A. Inspiratory reserve plus expiratory reserve plus tidal volume.
   B. Expiratory reserve plus residual volume.
   C. Tidal capacity plus inspiratory capacity.
   D. Total lung capacity

4. Which of the following is a respiratory disorder that results in permanent damage to the alveoli?

   A. Influenza.
   C. Emphysema.
   B. SARS.
   D. Common cold

5. The function of the respiratory system is to provide the body with

   A. essential nutrients.
   B. oxygen and dispose of carbon dioxide.
   C. enzymes and hormones needed to function.
   D. Vitamins for cellular activities.

6. The gas that travels the opposite direction, from the blood to alveoli to be breathed back out.

   A. Carbon monoxide
   C. Carbon dioxide
   B. Oxygen
   D. Hydrogen

7. The adult lungs are

   A. covered with a tough membrane called the parietal pluera.
   B. covered with thin mucous membrane.

C. spongy, air-filled sacs, located inferior to the diaphragm.

D. lobulated, the right lung has 2 lobes and the left has 3 lobes.

8. A patient exhales normally, then, using forced ventilation, the patient blows as much air as possible into a spirometer. This would measure

A. inspiratory reserve volume. C. vital capacity.

B. expiratory reserve volume. D. tidal volume.

9. Oxygen and carbon dioxide are exchanged in the alveoli by

A. osmosis. C. filtration.

B. active transport. D. diffusion.

10. The total amount of air that cannot be exchanged either because of disease or because it cannot reach an exchange site is termed as the

A. dead air space. C. functional reserve capacity.

B. residual volume. D. vital capacity.

B. Write TRUE or FALSE against the following statements.

1. Exhalation and inhalation of air is known as "cellular respiration".
2. The correct sequence of airflow during inhalation is nasal cavity, pharynx, larynx, trachea, bronchi and bronchioles.
3. If Sonam had an upper-respiratory infection, it might be located in bronchioles.
4. Pleural fluid helps in lubrication and absorbs mechanical shocks.
5. Breathing through the mouth is considered as good as breathing through the nose.

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

E.g. Small intestine is for <u>digestion</u>

1. Epiglottis is for.....
2. Cilia is for.....
3. Pleural membrane is for.....
4. Vocal code is for .....
5. Nostrils is for.....

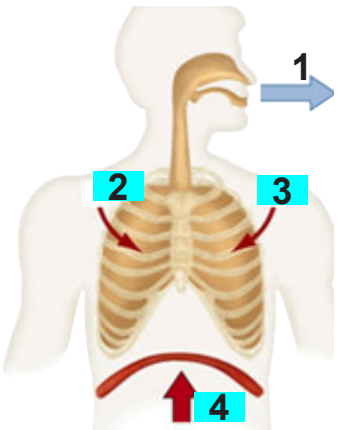
D. Choose the 'odd' one in each case.

1. Oxyhaemoglobin, bicarbonate ion, pneumonia, carbaminohaemoglobin
2. Nostril, trachea, esophagus, alveolus

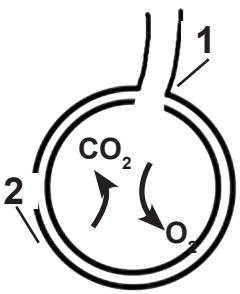
3. Bronchitis, emphysema, asthma, fever
4. Nostril, external intercostal muscle, diaphragm, lungs
5. Tidal volume, inspiratory reserve volume, vital capacity, residual volume

E. Answer the following questions.

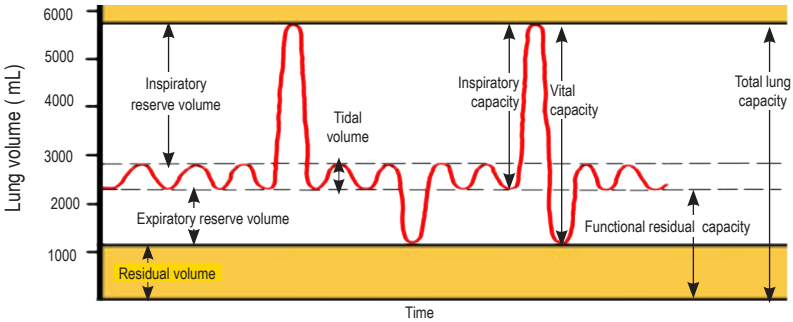
1. The major organs and tissues of the human respiratory system are *nostrils, lungs, trachea, alveoli, bronchioles, bronchi and pharynx.*
   a. Sequence these seven organs and tissues in order of air passage through them.
   b. Identify which tissue is primarily responsible for gaseous exchange between lungs and blood.
   c. Describe the functions of two organs listed, other than the one you identified.



2. The Figure on the right shows one of the three stages of human breathing cycle. Study and answer the questions a through d.
   a. What does 1 indicate?
   b. Describe the significance of 2.
   c. Illustrate the movement of diaphragm during inspiration and expiration.
   d. During the respiratory cycle, the pressure in the lungs and atmosphere varies in a regular pattern. Describe how pressure varies.



3. The Figure on the right shows the part of respiratory system. Answer the questions a through d.
   a. Identify the phenomenon.
   b. Name part of the respiratory organ.
   c. Name the parts labelled 1 and 2.
   d. What do the arrows signify?
4. Design one experimental method to show that water is lost while breathing.
5. Study the graph below and answer the questions a through d.
   a. Explain vital capacity using the graph.
   b. Calculate the total lung capacity in mL.
   c. Derive the relationship between inspiratory reserve volume (IRV) and the inspiratory capacity (IC).



d. Calculate the tidal volume and the residual volume.

6. Read the following passage and answer the questions a through d.

Breathing problems

When you are short of breath, it is hard or uncomfortable for you to take in the oxygen your body needs. You may feel as if you are not getting enough air. Sometimes mild breathing problems are from a stuffy nose or hard exercise. But shortness of breath can also be a sign of a serious disease.

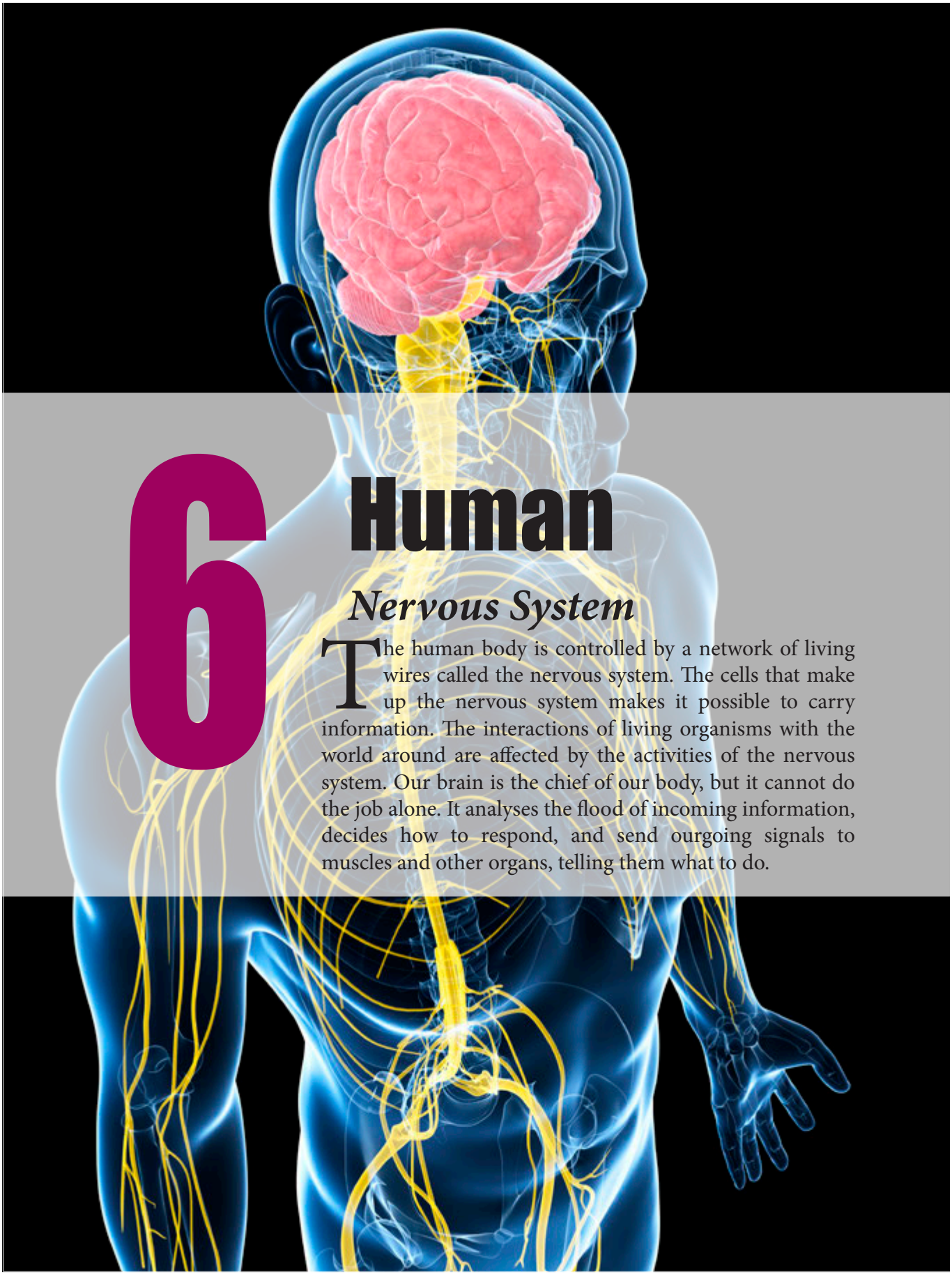
Many conditions can make you feel short of breath. Lung conditions such as asthma, emphysema or pneumonia cause breathing difficulties. Likewise, if there are problems with your trachea or bronchi, you will have breathing difficulties. Heart disease can also make you feel breathless if your heart cannot pump enough blood to supply oxygen to your body. Stress caused by anxiety can also make it hard for you to breathe. If you often have trouble breathing, it is important to find out the cause.

a. What are some of the causes of breathing problems?

b. How is a heart disease associated with breathing problems?

c. List down possible causes of breathing problem in your classroom?

d. Suggest two preventive measures for reducing the occurrence of breathing problems at your home.



6 Human

Nervous System

The human body is controlled by a network of living wires called the nervous system. The cells that make up the nervous system makes it possible to carry information. The interactions of living organisms with the world around are affected by the activities of the nervous system. Our brain is the chief of our body, but it cannot do the job alone. It analyses the flood of incoming information, decides how to respond, and send ourgoing signals to muscles and other organs, telling them what to do.

The Human Nervous System

Learning Objectives

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

- draw the structure of neuron and label its parts.
- explain the role of neurons in transmitting electrochemical impulses.
- describe the two major division of the nervous system.
- explain the structure and functions of human brain and spinal cord.
- identify the specialized structures that allow neurons to carry out their functions

The nervous system is made up of billions of cells called neurons (**nerve cells**). These cells have many finely branched fibres extending from the main cell body. It provides the fastest means of **communication** between different parts of the body.

a. Nervous system

The nervous system has two major divisions:

i. the central nervous system (CNS), which consists of the brain and spinal cord. Together, these process incoming signals and decide how the body should react.

ii. the peripheral nervous system (PNS), which is composed of cranial nerves and spinal nerves carries signals around the rest of the body.

The nervous system controls and correlates basic bodily functions and behaviour. The body responds to stimuli of surroundings through receptors. Receptors are nerve endings, **specialized in registering specific stimuli**. Changes inside the body are detected by interoceptors. Stimuli from outside the body are detected by receptors called exteroceptors, which are concentrated in the **sense organs**; skin, eyes, nose, tongue, and ears. They detect changes in contact, pressure, pain, heat, cold, light, scent, taste, and sound.

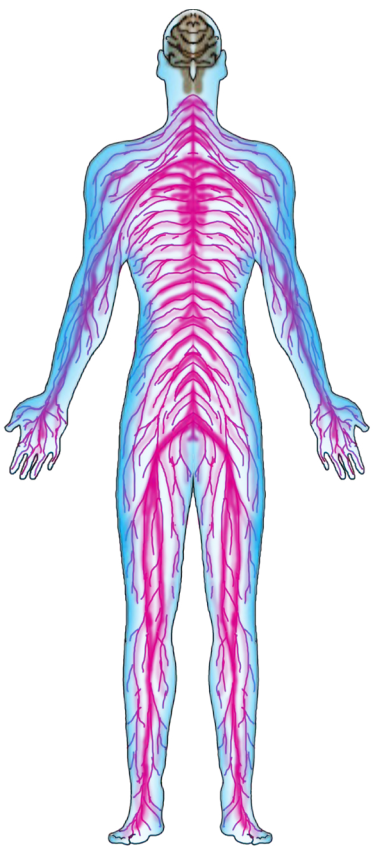


Figure 6. 1 Nervous system: the brain and spinal cord are connected to the rest of the body by a network of nerves.

The major functions of nervous system are to:

1. *sense changes, both outside and within the body.* It keeps us informed about the changes occurring within and around our body.
2. *transmit information to the brain.* It helps us to think, remember and reason out.
3. *make changes to the functioning of muscles and glands.* It controls voluntary and involuntary muscular activities. Voluntary muscular movements, such as running, chewing, hand movements, etc. are under the control of our will. However, involuntary muscular activities, like heart beat and breathing cannot be controlled by our will.

b. Neuron -The unit of the nervous system

Nerve cells or neurons are the **structural** and **functional unit** of nervous system. It consist of one large fibre, an axon, that carries outgoing electrical signals, and many smaller fibres called dendrites that carry incoming signals. Neurons carry signals in the form of **electric impulse**. The **impulses** are **electrochemical** generated by the movement of ions across the membranes of nerve cells. All neurons contain the following components.

Cell body: This includes a nucleus and cytoplasm. It has all other cell organelles, except **centrosome**, thus the nerve cell has **lost the ability to divide**.

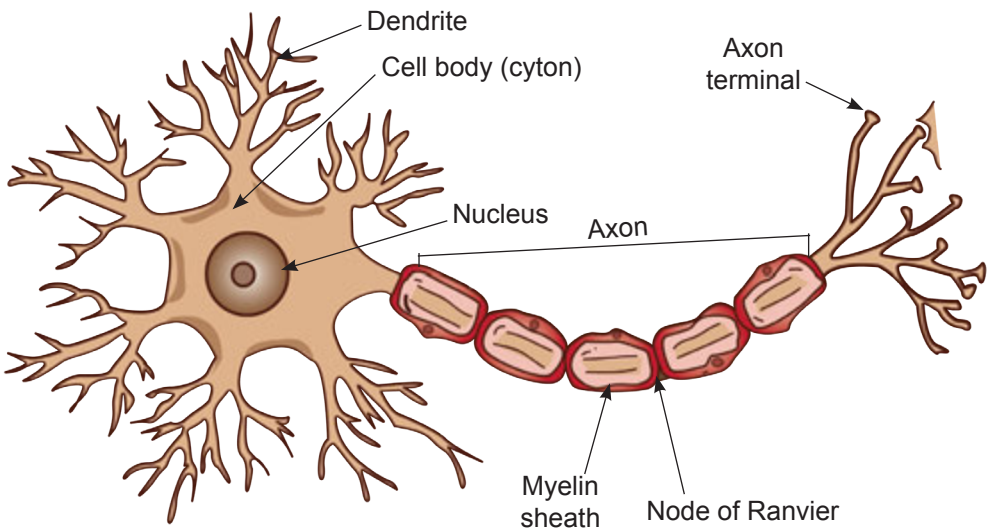


Figure 6.2 Neuron, the nerve cell

Axon: Axons vary in length from a few millimetre to even more than a metre that carry outgoing electricals signals. Most axons are covered with a fatty substance called myelin sheath, which provide **protection** and **insulation**. Constrictions at regular intervals along the axon are called the nodes of Ranvier (Figure 6.2).

Dendrites: These are networks of short fibres that branch out from the **axon** or **cell body** and link the ends of axons from other neurons. Dendrites are the **cell receivers of information** that brings signals to the cell body. Each neuron might have hundreds of dendrites.

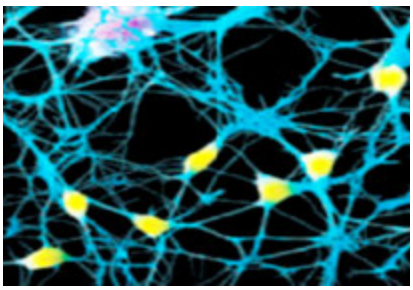


Figure 6.3 The electron micrograph of interconnecting neurons with their cell bodies (yellow) and a supporting glial cell (purple).

Table 6.1 Main structure and function (s) of the neuron.

Term	Function(s)
Cell body	is the factory in the neuron that produces all the *proteins* to *provide energy* to the dendrites, axons and synaptic terminals and contains specialized organelles.
Axon	carries nerve impulses *away* from the cell body.
Dendrite	a network of nerve processes that carries nerve impulses from the adjacent neurons *into* the cell body.
Node of Ranvier	allows nerve impulses to move along the neuron through a process of *de-polarisation* and *re-polarisation* of the nerve membrane.
Schwann cells	produce the *protective myelin sheath* around the axon of medullated nerve fibres.
Sensory neuron	transmit impulses *inwards* from sense organs to the *central nervous system* (CNS).

c. Nerve and nerve impulse

Nerve is a thin **thread like structures**, consisting of nerve fibres that run throughout the body as shown in Figure 6.1. Bundled together, they carry messages back and forth just the way that telephone wires do. Sensory nerves send messages **to the**

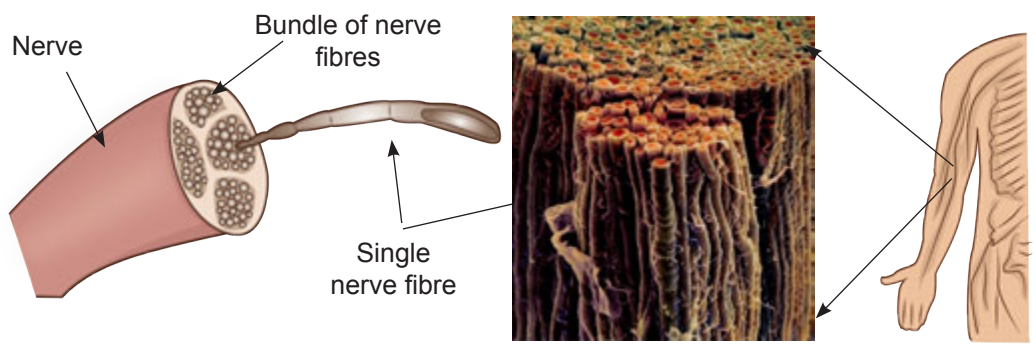


Figure 6.4 A nerve, constituting a bundle of neurons.

brain, and generally connect to the brain through the spinal cord. Motor nerves carry messages back from the **brain to all the muscles and glands** in the body.

A neuron connects to other neuron at junction called synapse. At the synapse, there is a **small gap** between the two neurons called synaptic cleft (Fig. 6.5). Inside the terminal knobs of axon, there are many synaptic vesicles. These are **membrane-bound spheres** filled with neurotransmitter molecules such as acetylcholine.

Nerve impulse is a signal that travels along the nerve fibres as a **wave of electric**

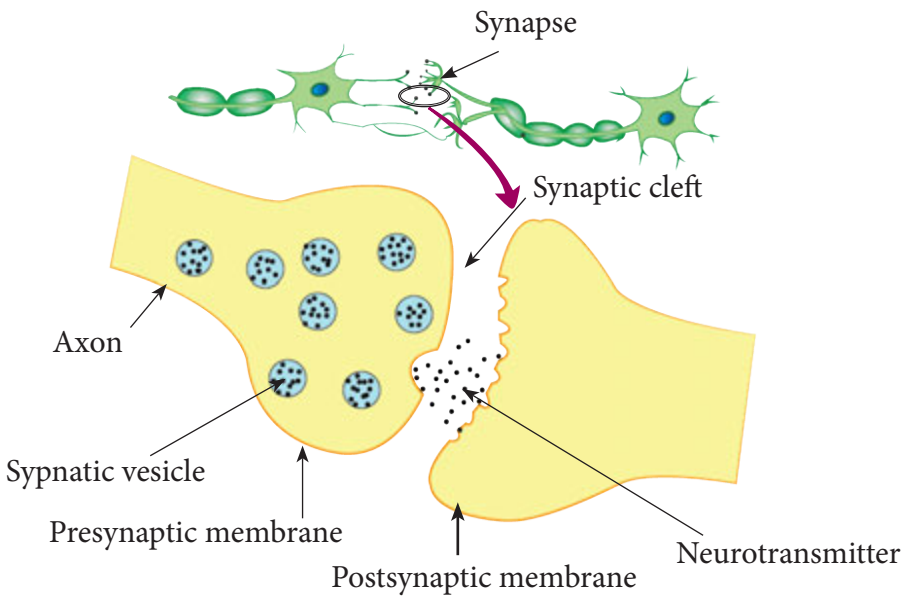


Figure 6.5 Synapse between two successive neurons

charge just like the conduction of electric current through a copper wire. When the charge reaches the **end of a neuron** (*terminal knob*), a ting gap called **synapse** prevents it from jumping across. Instead, chemicals called neurotransmitters flow into the gap and trigger a new signal in the next neuron.
The impulse arises at the **end of a receptor cell** of sense organ and travel along the **axon to dendrites of sensory neron** and from there to the **target organ**. Nerves generate impulses when stimulated by a physical, chemical, or electrical event that alters the cell membrane.

Most of the signals from **sense organs** are processed by our **brain** before body reacts. However, some signals are processed through our **spinal cord** by taking a shortcut. This is termed as reflex action.

The electrical events that occur along the axon of the nerve cell is discussed below.

1) Resting neuron

A resting neuron is **negatively charged** inside the cell membrane of axon, and **positively charged** outside due to more sodium ion (Na^+) concentration, as shown in Figure 6.6. This is called the resting membrane potential.

2) Stimulated neuron

When a neuron is stimulated, **permeability** on the cell membrane alters. Positively charged sodium ions begin to enter the cell more quickly than during the resting state, making the **inside of the nerve membrane positive**. This is called depolarization.

3) The nerve impulse

Depolarization spreads along the cell membrane. Eventually, the charge on either side of the cell membrane is **temporarily reversed**. This is called reverse polarization. It is, in fact, the nerve impulse traveling along the nerve's cell membrane.

4) Repolarization

The cell membrane **alters its permeability** again. Positively charged **sodium ion**s begin to pass out of the cell. Finally, the **outside of the cell** is again positively charged, and the **inside of the cell is negatively charged**. This process is called repolarization.

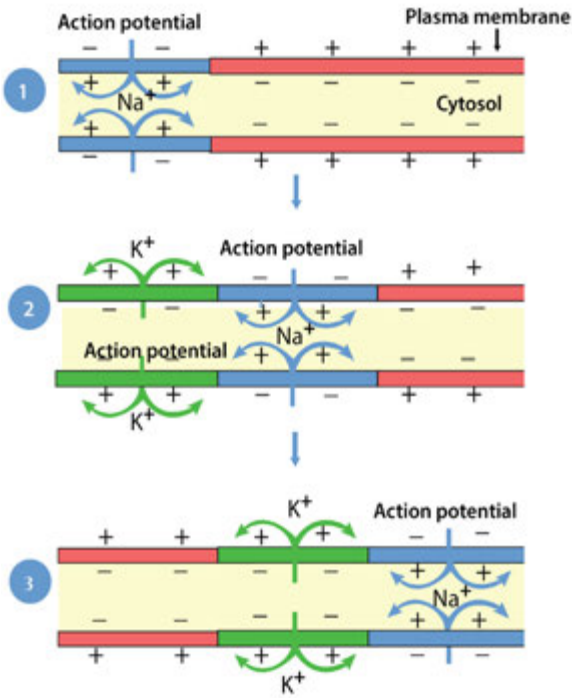


Figure 6.6 Conduction of nerve impulse

d. The central nervous system

The central nervous system (**CNS**), consisting of the **brain** and the **spinal cord**. It is the **structural and functional centre** for the entire nervous system. The central nervous system receives information from the **sense organs**. Damage to the central nervous system can, therefore, affects temperament, motor control, and homeostasis. The CNS is composed of **two types** of nervous tissue: **gray matter** and the **white matter**. Gray matter contains mostly **cell bodies**, found around the outside areas of the brain. White matter contains **myelinated axons** that run together in tracts. The white matter occupies the inner region in the brain, and it occupies outer area in the spinal cord.

i. The brain

The human brain is the most poorly understood organ in the body. Last two centuries, scientists have begun to unravel the complex working of the human brain. As shown in Figure 6.7, the brain

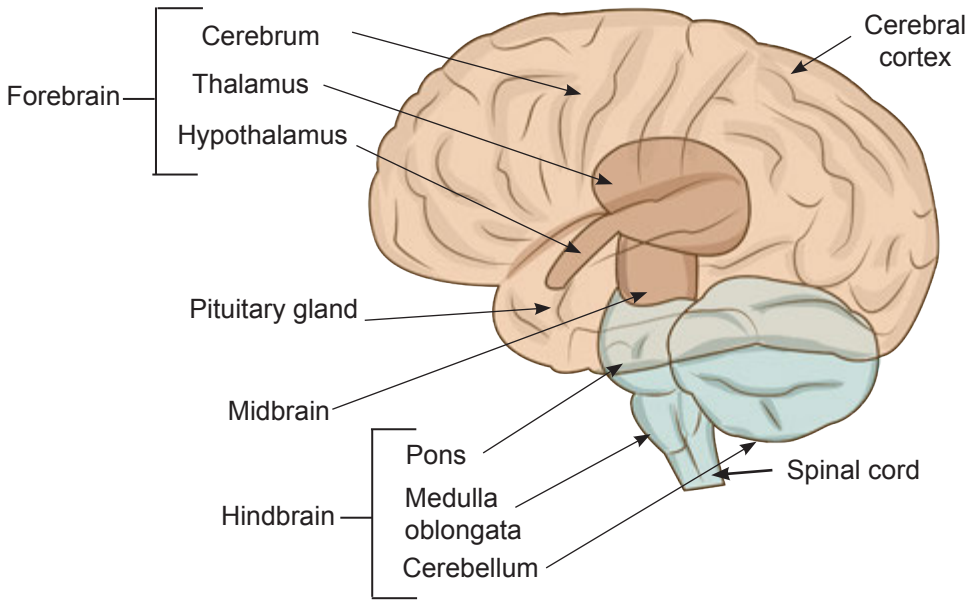


Figure 6.7 Structure of the human brain.

can be subdivided into **three general regions**: the forebrain, midbrain and the hindbrain. The brain is protected by a bony armour called skull. In addition, brain and spinal cord are covered with three layers of **tough**, **elastic membrane** called meninges.

1. Forebrain

The cerebrum is the largest part of the brain, and accounts for more than four fifths of the total weight of the brain. The cerebrum is divided into right and left cerebral hemispheres, which are linked by a bundle of white matter called the corpus callosum. The corpus callosum **sends messages from one cerebral hemisphere to the other**. The cerebrum is the *centre for intellect, memory, consciousness, and language.* The meninges protect the central nervous system.

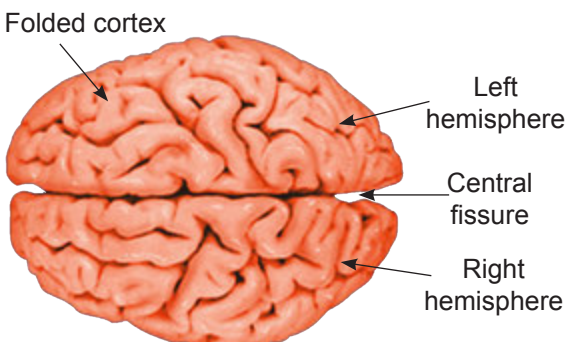


Figure 6.8 Superior view of human brain.

The thalamus is situated at the base of the **forebrain**. It consists of neurons that provide *connections* between various parts of the brain.

The hypothalamus lies just below the **thalamus**, and regulates the body's internal environment, as well as, certain aspects of behaviour. It also helps to coordinate the actions of the **pituitary gland**. Hypothalamus contains neurons that control blood pressure, heart rate, body temperature, thirst and hunger, and emotions. Any damage to it can cause a person to display unusual behaviours.

6.1 Activity

Brain parts and functions

Draw the Figure 6.9 and complete the boxes with their definitions. Use reference books.

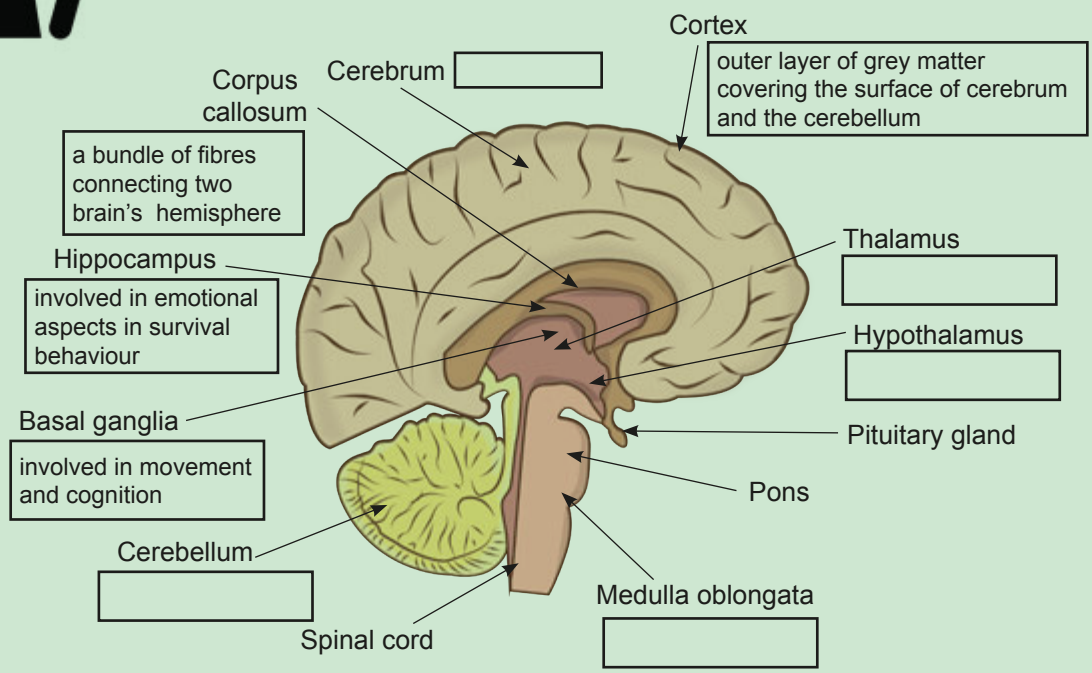


Figure 6.9 Cross section of the human brain.

2. **Midbrain**

It is found above the pons in the **brainstem**. It plays an important role in **eye movement**, and **control of skeletal muscles**.

3. **Hindbrain**

The cerebellum is a walnut-shaped structure, located behind the **cerebrum**. This part of the brain is involved in the **unconscious coordination** of posture, **reflexes**,

and **body movements**, as well as, fine voluntary motor skills, such as those used to hit a ball, ride a bicycle, or write.

The medulla oblongata is located at the base of the **brainstem**, and **connects the brain with the spinal cord**. The medulla oblongata contains centres that **control automatic, involuntary responses**, such as heart rate, constriction or dilation of blood vessels to control blood pressure, and the rate and depth of breathing, swallowing, and coughing.

The pons is found in front of the **medulla oblongata** in the **brainstem**. The pons **carries impulses** from one hemisphere of the cerebellum to the other and coordinates muscular movement on both sides of the body.

Table 6.2 Major structures and their functions of the human brain.

Structure	Major Functions
Forebrain	
Cerebrum	Associated with *conscious thought, intelligence, memory, and personality;* and *control voluntary muscle movements.*
Thalamus	Connects various parts of the brain; and *communicate information* from the senses.
Hypothalamus	*Regulates* the pituitary gland, heart rate, blood pressure, and temperature; and controls drives such as hunger, thirst, and sexual desire.
Corpus callosum	*Connects* the right and left cerebral hemispheres through nerve tracts.
Midbrain	*Receives* specific sensory input; and *connects* the hindbrain to the forebrain.
Hindbrain	
Cerebellum	Controls *muscle coordination* and *balance*.
Medulla oblongata	*Controls subconscious activities*, such as heart rate, blood pressure, breathing, swallowing, and vomiting
Pons	*Relays information* between the cerebellum and the cerebral cortex.

ii. The spinal cord

The spinal cord is a **column of nerve tissue** that extends from the lower end of the **medulla oblongata** and passes downward through a canal within the **backbone** as shown in figure 6.10. The spinal cord is a vital **communication link**

Figure 6.10 Spinal cord

between the **brain** and the **peripheral nervous system**. The spinal cord is also the **primary reflex centre** that coordinates involuntary and instantaneous movement in response to stimuli.

The **butterfly-shaped core** of spinal cord is made up of **gray matter**, which contains unmyelinated neurons, as well as the cell bodies and dendrites of many spinal neurons. The outer white matter consists of **myelinated nerve fibres**. The spinal nerves divides to form **two branches** called the dorsal root and ventral root. Sensory neurons enter the **dorsal root** and have cell bodies outside the central nervous system called dorsal root ganglion. Similarly motor neurons also have cell bodies outside the CNS called ventral root ganglion.

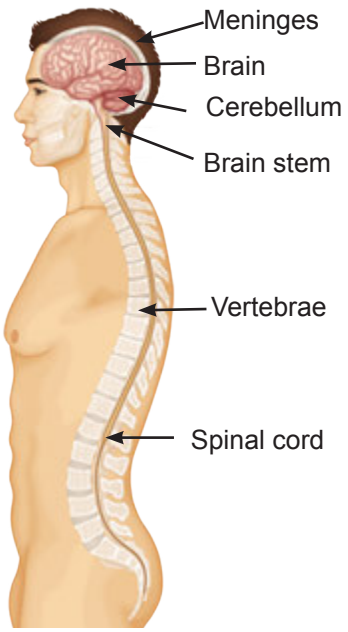


Figure 6.11 The central nervous system

The connection between sensory and motor neuron in **gray matter** is brought about by interneuron. Sensory neuron carries sensory impulse from the receptor organs of body to the brain via spinal cord. In turn, motor impulse is relayed from brain to the effector organs for necessary response. Any *injury* to the **spinal column** can also damage the spinal cord, resulting in **paralysis**.

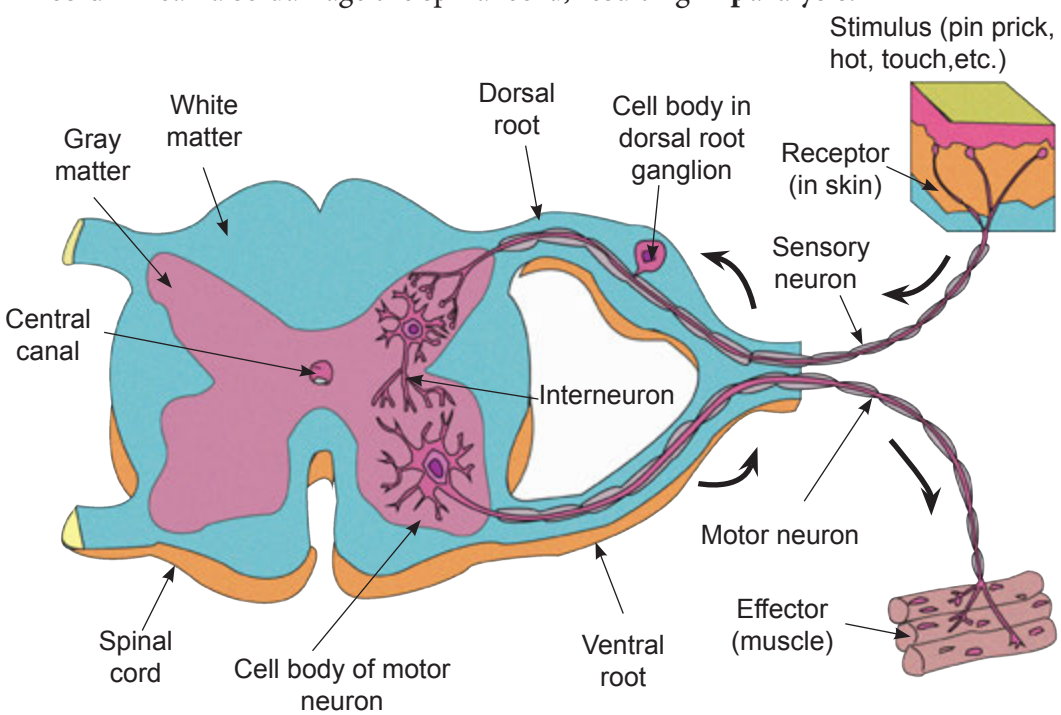


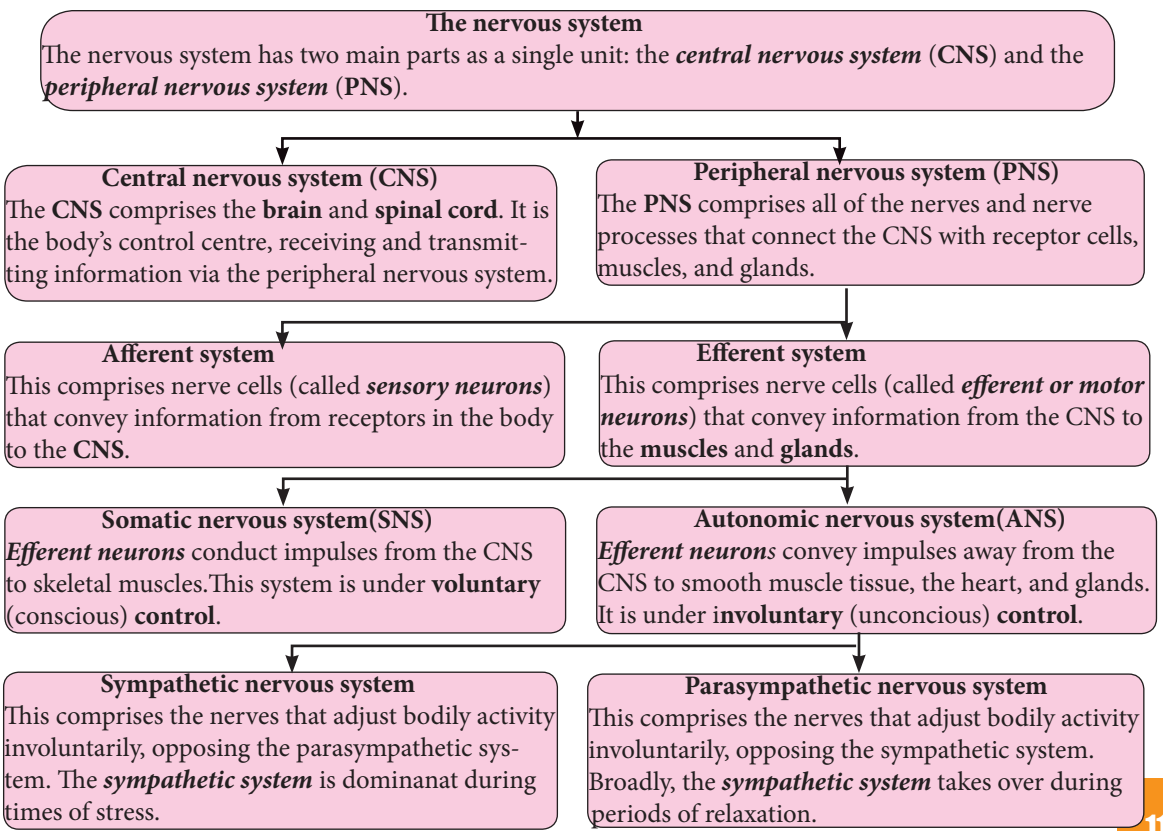
Figure 6.12 Cross section of spinal cord.

e. Peripheral nervous system (PNS)

The peripheral nervous system (**PNS**) includes **cranial** and **spinal nerves** that connect with the central nervous system (**CNS**). Nerves that arise from brain are called cranial nerves. There are **twelve pairs** of cranial nerves in our body. Nerves that arise from the spinal cord are called spinal nerves. There are **thirty one pairs** of spinal nerves in the body. This nervous system is divided into **two** subdivision; ***somatic nervous system*** and **autonomic nervous system**.

Somatic nervous system (**SNS**) is associated with voluntary movement and is composed of nerves that *sends sensory signal from the body to the CNS and nerves* that carries motor signal from CNS to the **skeletal muscles**.

The autonomic nervous system (**ANS**) which is sometimes known as **involuntary nervous system** is involved in regulating the internal environment of our body. It carries *signal from the internal organ to the CNS and from CNS to the internal organs* including glands. The **autonomic nervous system** can be further subdivided into sympathetic and parasympathetic nervous system. These two systems have opposing effects. ***Sympathetic nervous system*** prepares our body to respond to unusual situation or during emergency, whereas ***parasympathetic nervous system*** brings back our body to normal functioning. For example, sympathetic nervous system increases the heart rate and blood pressure whereas the other reduces them to normal.



Activity 6.2

Observing neural tissue

In this investigation, you will examine micrographs of neural tissue. As you observe the tissues and draw sketches, identify the specialized structures that allow neurons to carry out their functions.

Materials required: micrographs.

Procedure

1. Observe the micrographs provided by your teacher.
   b. Micrograph 1 shows a cross-section of the brain. Sketch your observations, and label the white and gray matter.
   c. Micrograph 2 shows a cross-section of the spinal cord. Sketch your observations, and label a sensory neuron, a motor neuron, and an interneuron.

Precautions

Handle the microscope slides with care, to prevent breakages, which may hurt yourself.

1

2

Do you know?

- The brain alone uses a fifth of the oxygen required by the body.
- A human brain grows to full size in six years.
- The brain is the source of moods and emotions, and is the seat of the mind.

Common mental disorders in Bhutan

Study the graphs in Figure 6.13 and Table 6.3, and answer the questions that follow.

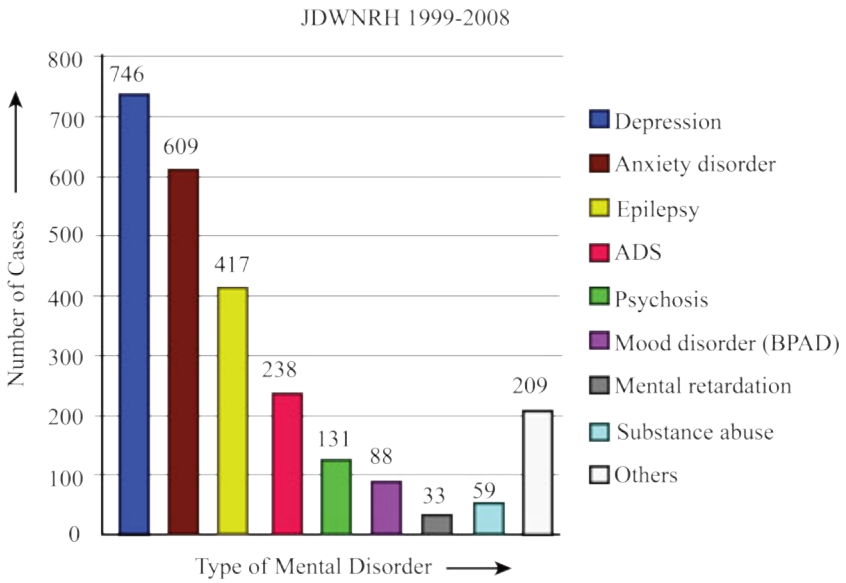


Figure 6.13

Table 6.3 Common mental disorders in Bhutan; common causes and common signs and symptoms.

Mental disorder	Common causes	Common signs and symptoms
Depression	• Certain medication. • Death or loss of loved ones. • Genetics. • Serious illness. • Personal problems. • Substance abuse.	• Sadness or hopelessness. • Irritability, anger, or hostility. • Tearfulness or frequent crying. • Withdrawal from friends and family. • Loss of interest in activities. • Changes in eating and sleeping habits.
Psychosis	• Psychological (mental) conditions. • General medical conditions. • Substances, such as alcohol or drugs.	• Changes in thinking patterns. • Unusual or false beliefs. • Changes in perception. • Changes in feeling and mood. • Changes in behaviour.

Mental disorder	Common causes	Common signs and symptoms
Anxiety Disorder	• Environmental factors. • Medical factors. • Genetics. • Substance abuse. • It is most commonly triggered by the stress in our lives. • Panic disorder. • Phobic disorders. • Stress disorders.	• Feelings of panic, fear, and uneasiness. • Problems sleeping. • Cold or sweaty hands and/or feet. • Shortness of breath. • Heart palpitations. • An inability to be still and calm. • Dry mouth. • Numbness or tingling in the hands or feet. • Nausea. • Muscle tension. • Dizziness.
Epilepsy	• Low oxygen during birth. • Head injuries that occur during birth or from accidents during youth or adulthood. • Brain tumors. • Genetic conditions that result in brain injury, such as tuberous sclerosis. • Infections such as meningitis. • Stroke or any other type of damage to the brain. • Abnormal levels of substances such as sodium or blood sugar.	• **Variety of seizure**: Doctors classify seizures based on history and eye witness observation on the event. • **Partial seizures**: where only a small part of the brain is affected. • **Generalised seizures**: where most or all of the brain is affected.

Questions

i. Name three most common types of mental disorders in Bhutan.

ii. What could be the reasons for the increasing trend of depression cases over the year in Bhutan?

iii. What are common signs and symptoms of depression?

iv. Do you think substance abuse should be included under common mental disorders? Why or why not?

v. Why do you think that cases of epilepsy are high in Bhutan? You as an educated child, what advice would you give to those pregnant women in the villages who have no knowledge on epilepsy?

vi. Suggest some ways on how you can contribute in your own little ways in reducing the mental disorders in the country?

Summary

- The nervous system controls and correlates basic bodily functions and behaviour.
- The neuron is the structural and functional unit of the nervous system.
- All cells have a membrane potential, but the neuron is unique in that it can change the potential of its membrane to generate an impulse.
- Two major divisions of the nervous system are central nervous system (CNS), consisting of the brain and spinal cord, and the peripheral nervous system (PNS), which is made up of cranial nerves, spinal nerves, and the nerves of the autonomic nervous system.
- The cerebrum is divided into two cerebral hemispheres, the right and the left cerebral hemispheres.
- The cerebrum is the centre for intellect, memory and other higher thinking of the brain.
- The brain and spinal cord are protected by three layers of tough, elastic tissue within the skull and spinal column called meninges.
- The hindbrain is composed of the cerebellum, involved in controlling the body movements; medulla oblongata that controls many involuntary responses.
- The forebrain includes the thalamus and hypothalamus, involved in sensing the external and internal environment.
- The outer layer of the cerebrum, called the cerebral cortex, is composed of grey matter.
- The peripheral nervous system contains components that gather sensory information and then relay this information to the muscles and glands for a voluntary (somatic) or involuntary (autonomic) responses.

http://www.biologycorner.com/anatomy/chap9.html
http://www.innerbody.com/image/nervov.html
https://www.khanacademy.org

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. When electric signal reaches end of neuron, a tiny gap prevents it from jumping across. Transmission across a tiny gap is dependent on the release of
   A. neurotransmitters. C. neurons.
   B. synaptic vesicle. D. receptor proteins.
2. The branch of the nervous system controls parts of the body that you control will, such as the muscles you used to kick a ball or swing your arms.
   A. Somatic nervous system C. Autonomic nervous system
   B. Sympathetic nervous system D. Central nervous system
3. Which part of the neuron receives information?
   A. The node of Ranvier C. The axon
   B. The myelin sheath D. The dendrite
4. The diagram on the right shows the right and left sides of the human brain? The part having so many folds is
   A. cerebellum. C. hypothalamus.
   B. cerebrum. D.medulla oblongata.

5. What kind of movement is coordinated by brain and spinal cord, when a person bends his legs to pick a pencil from the floor?
   A. Voluntary C. Spontaneous
   B. Intentional D. Involuntary
6. In the resting stage of the neural membrane, diffusion due to concentration gradient, if allowed would drive
   A. K^+ into the cell. C. Na^+ into the cell.
   B. K^+ and Na^+ out of the cell. D. Na^+ out of the cell.
7. The part of the body that integrates the information it receives from all over the body in order to make decisions.
   A. Central nervous system C. Sympathetic nervous system
   B. Peripheral nervous system D. Parasympathetic nervous system

8. The cerebral hemispheres in mammals are connected by
   A. pons.
   B. hypothalamus.
   C. medulla oblongata.
   D. corpus callosum.
9. Which of the following is the example of the action of the autonomous nervous system?
   A. Kicking a ball
   B. Swinging of arms
   C. Swallowing of food
   D. Movement of food in small intestine
10. A person was referred to a psychiatrist with following signs and symptoms.
   i. Unable to breathe properly.
   ii. Complain of not being able to sleep properly.
   iii. Feeling of dizziness.
   iv. Occurence of frequent muscle cramps.
   v. Feeling of restless and uneasiness.
   What common mental disorder do you think this person is suffering from as per your knowledge and understanding of biology?
   A. Psychosis
   B. Depression
   C. Epilepsy
   D. Anxiety disorder

B. Write TRUE or FALSE for the following statements. Rewrite the false statements in the correct forms.

1. Neurons in the brain and spinal cord regenerate once damaged.
2. The two hemispheres of the cerebrum are connected and share information.
3. If your sense of smell is not working, you will not be able to taste the food you eat.
4. Sensory nerve cells act as the decision-making cells to sum up all signals for certain stimuli.
5. The main component of the white matter of the brain is dendrites.

C. Name the following.

1. The membrane that protects the human brain and spinal cord.
2. Part of the brain that helps coordinate muscles so they work in perfect time.
3. The fatty material sheath in the neuron that helps the signal travel faster.
4. A tiny space across which the signals are sent from one nerve cell to another.
5. The action that happens as a result of signals from sense organs processed by taking shortcut through a spinal cord.

D. Fill in the blanks with the correct form of word/s.

1. The divisions of nervous system consisting of the brain and spinal cord is called the …… nervous system.
2. Your brain has three parts: the ……., the …….. , and the …….
3. Nerve cell has projections attached, which can send messages to other nerve cell. These projections like electrical wires is called …….
4. Impulses of a beautiful red flower are picked up first by your ……. organs.
5. The part of central nervous system that helps to carry nerve impulse back and forth between your body and your brain.

E. Differentiate between the following pairs.

1. Brain and spinal cord.
2. Sympathetic and parasympathetic nervous system.
3. Voluntary and involuntary muscular activity.
4. Central nervous system and peripheral nervous system.
5. Gray matter and white matter.

F. Match the items of Column I with the most appropriate items of Column II. Rewrite the correct matching pairs.

Column I	Column II
1. Nerve cell	a. Body coordination
2. Dilate pupil	b. Body temperature
3. Cerebellum	c. Fatty substance
4. Hypothalamus	d. Conduct impulses
5. Myelin sheath	e. Sympathetic nervous system
	f. Parasympathetic nervous system

G. Extend the abbreviation below.

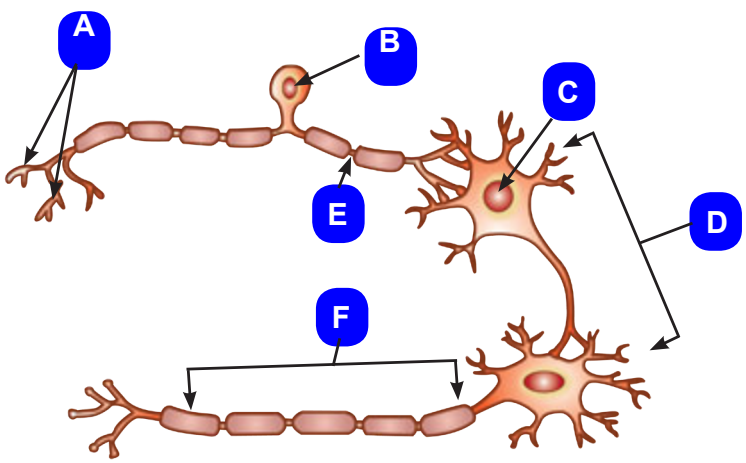
1. ANS
2. CNS
3. PNS
4. SNS
5. ANS

H. Tick the odd one out.

1. Depolarisation, reverse polarisation, repolarisation, membrane potential
2. Pons, medulla, cerebrum, cerebellum
3. Myelin sheath, axon, nerve, dendrite
4. Thalamus, hypothalamus, cerebellum, cerebrum
5. Sensory neuron, gray matter, motor neuron, interneuron

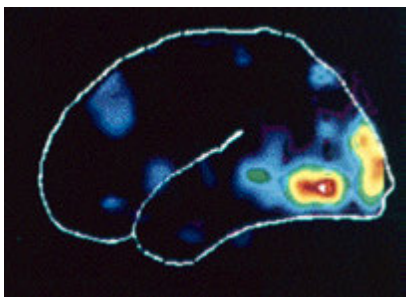
I. Answer the following questions.

1. Imagine that you are hiking in the mountains one afternoon with friends. As you turn a corner, you come across a mother bear and her cubs standing in the middle of the trail.
   a. Identify the specific division of the nervous system that is responsible for the body's response to this situation.
   b. Indicate the division of the nervous system that is responsible for returning the body back to equilibrium, after the event is over.
2. Using a diagram, explain depolarization, action potential, and repolarization of the neuron.
3. Examine the Figure given below and answer the questions 'a' through 'd'.

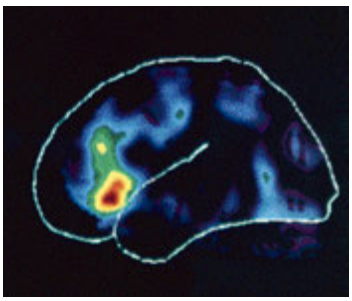


a. Draw and label the structures.
b. Identify type of neuron shown inbetween the other two neurons.
c. Write the function of structure labelled 'E'.
d. Indicate the direction of neuron transmission in the diagram drawn in question '**a**'.

4. The Figure below shows a scan cross section of the cerebrum, revealing the activity levels in different areas when the brain is performing certain tasks. Red, orange, and yellow indicate areas of high, medium, and low activity, respectively.



A

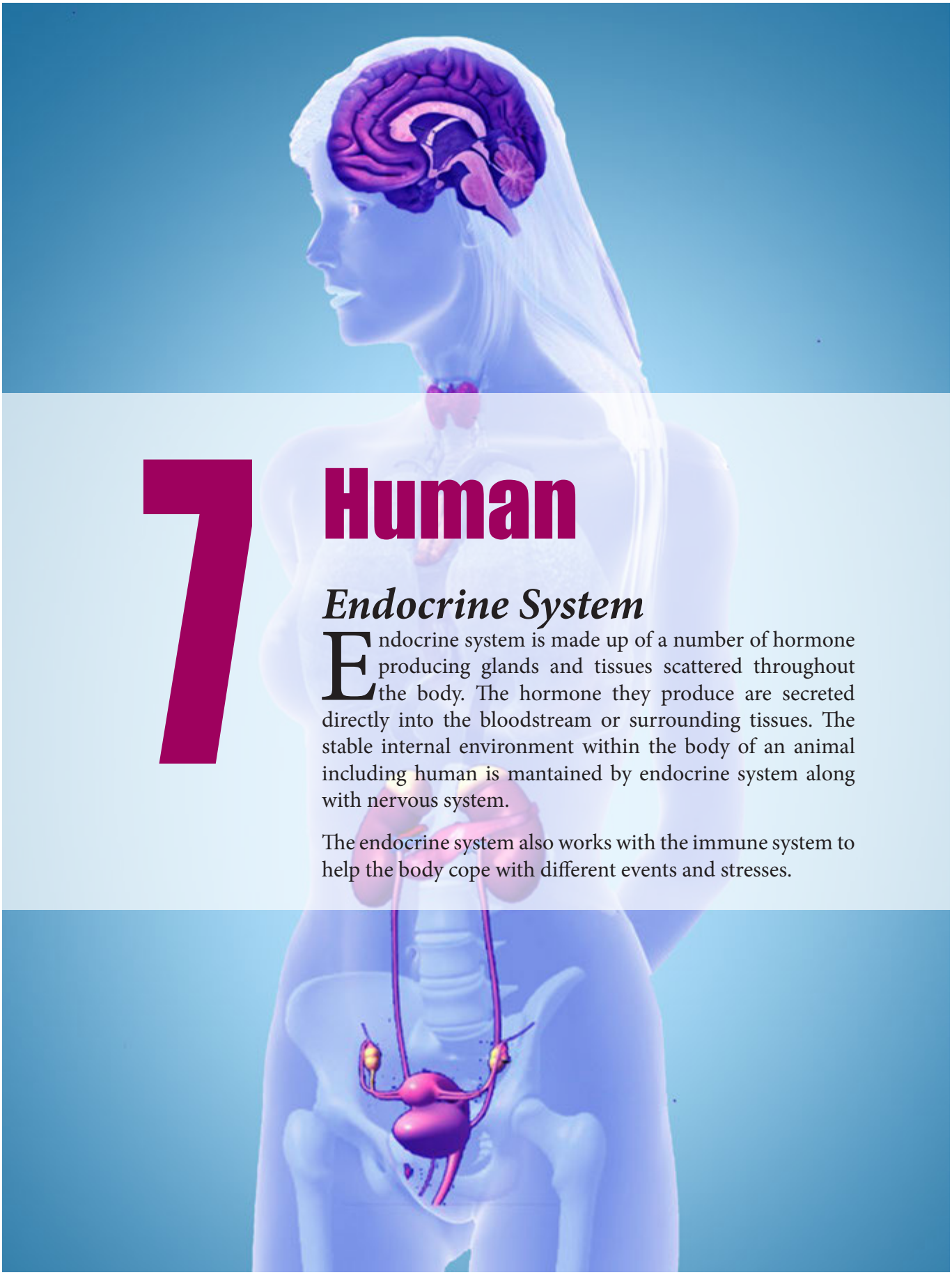


B

a. Predict the activities in each case?

b. Brain in which Figure seems active?

c. What activity might a person do, when the part of the cerebrum is represented with orange colour?



7 Human

Endocrine System

Endocrine system is made up of a number of hormone producing glands and tissues scattered throughout the body. The hormone they produce are secreted directly into the bloodstream or surrounding tissues. The stable internal environment within the body of an animal including human is mantained by endocrine system along with nervous system.

The endocrine system also works with the immune system to help the body cope with different events and stresses.

Endocrine System

Learning Objectives

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

- name glands and the hormones they secrete.
- explain types of hormones and their functions.

Endocrine system, also referred to as hormone system, is found in all mammals, birds, fish, and many other types of living organisms. They are made up of glands that **produce and secrete hormones** into the **bloodstream**. The various hormones present in the body of mammals including humans are produced by endocrine system.

a. What are hormones?

Hormones are **complex chemical substances** that **regulate body functions** such growth, reproduction, water balance, metabolism and sexual development. They are ***made and released into the blood*** to act on an organ in another part of the body by **endocrine glands**. Hormones can reach every part of the body via the **blood**, but they only affect **specific target tissues and organs**. Hormones are secreted in response to changes in environment inside and outside of the body. When they reach their target organ, they trigger major chemical changes inside cells, sometimes switching particular genes on or change how the cell operates.

The release of hormones is **regulated by** the **hpothalamus**, **pituitary gland** and the ***feedback mechanism*** – needs expressed by the body. Many hormones are **controlled by other hormones**, and some hormones **work in pairs** to keep levels of body chemicals such as sugar in balance. For example, two hormones released by the pancreas-**insulin** and **glucagon**-control sugar levels in our blood. Insulin reduces blood glucose levels, while glucagon increases them. If there is **too much glucose in the blood, more insulin is produced; if too lttle glucagon is secreted**.

There are ***over 30 hormones*** and these hormones control many **biological processes** that happen within the body. Examples of such processes include; *blood sugar control; differentiation, growth, and function of reproductive organs and body growth and energy production.*

All hormones have the following basic characteristics:

1. *they are produced in some glands, and influence the functioning of other organ.*
2. *they are transported to other target organ through blood.*
3. *they are required in very small quantities.*
4. *they are very specific in their actions.*

b. Major endocrine glands

The endocrine system of human and higher vertebrates has **two types** of glands namely, **endocrine glands** and **exocrine glands**. Exocrine glands secrete substances **through their ducts** into the body surfaces, or cavities in the body. Sebaceous glands in the skin, salivary glands in the buccal cavity, gastric glands in the stomach wall, liver, etc. are examples of exocrine glands. Endocrine glands are **ductless glands** that **secrete a hormone directly into the bloodstream** and transported all over the body. They act on the specific sites called target organs. The distribution of endocrine glands in human is shown in Figure 7.1. These include other **secondary endocrine organs** and tissues that have other primary functions but release hormones as **secondary functions** like in kidney, liver and tissue hormones of alimentary tract. For example, stomach has a primary function to digest food, but also has a secondary function as it releases **gastrin** and **secretin hormones**. The major glands of the endocrine system are the hypothalamus, pituitary, thyroid gland, parathyroid glands, adrenal glands, pineal gland, pancreas, ovaries and testes.

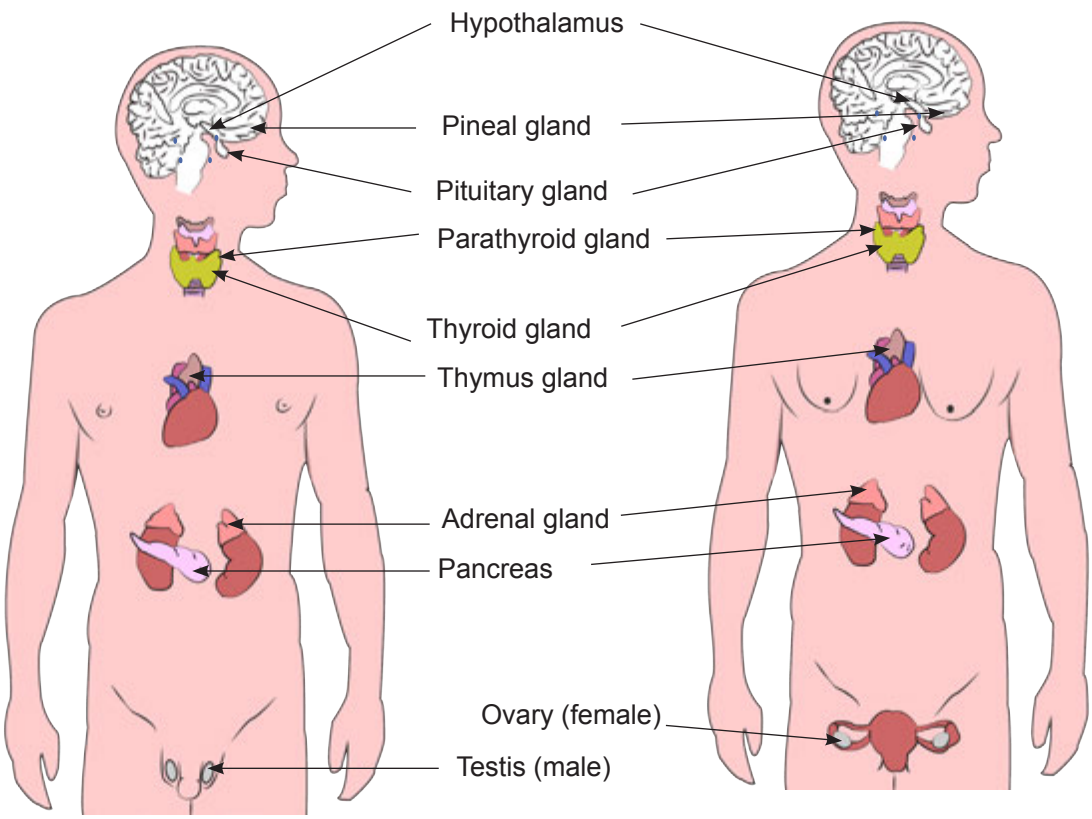


Figure 7.1 Endocrine glands

Activity 7.1

Body Nuggets – library research

Prepare a small and interesting fact about any one of the glands labelled in the Figure 7.1 that you like to know more. Then share your fact file about the glands you have chosen with your group members.

i. Hypothalamus

The hypothalamus is located in the lower central part of the brain. This part of the brain is important in **regulation of satiety**, **metabolism**, and **body temperature**. In addition, it secretes hormones that stimulate or suppress the release of hormones in the **pituitary gland**. The hypothalamus also secretes a hormone called somatostatin, which causes the pituitary gland to stop the release of growth hormone.

ii. Pituitary gland

Pituitary gland is a rounded **gland of pea-nut size**, and weighs about one to half gram. It has many significant functions in **maintaining the homeostasis** of an organism. It makes more than ten hormones, many of which **control** and **regulate other endocrine glands**. Therefore, it is referred as 'master gland'. The pituitary is linked by blood vessels and nerves to hypothalamus and the brain. Using these links, nervous and hormonal systems work together to make the body function normal.

The **pituitary gland** is divided into **two** parts: anterior pituitary and posterior pituitary. The frontal part of the **posterior lobe** is different from rest of the lobe, and

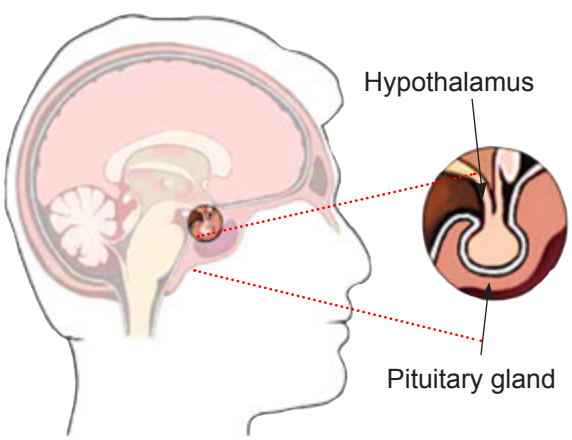


Figure 7.2 The hypothalamus and pituitary gland

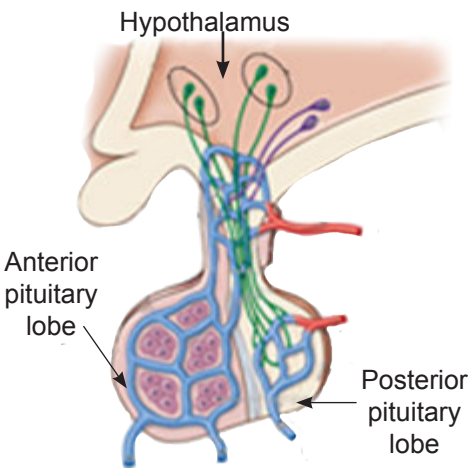


Figure 7.3 Cross-section of pituitary glands and hypothalamus

is called intermediate lobe. Intermediate lobe is almost absent in man, but much larger and more functional in other lower animals.

1. Anterior pituitary

Anterior pituitary forms 3/4th part of the pituitary. It is connected with the hypothalamus by **portal system of veins**. It produces **two types** of hormones such as **tropic hormones** and **gonadotropins**.

i). Tropic hormones

Tropic hormones are hormones that activate other endocrine glands or target organs. Some tropic hormones secreted by ***anterior lobe*** are as follows:

a. Growth hormone (GH). It increases metabolic processes leading to body growth by stimulating cell division, growth of muscles and bones.
b. Thyroid stimulating hormone (TSH). It stimulates thyroid gland to secrete **thyroid hormones**.
c. Adrenocortico tropic hormone (ACTH). It stimulates the adrenal cortex to secrete hormones such as **mineralo-corticoids** and **glucocorticoids**.

ii). The gonadotropins

The gonadotropic hormone controls the normal functioning of gonads and accessory reproductive organs. Some of the hormones secreted by ***anterior lobe*** are as follows:

a. *Follicle stimulating hormone (FSH).* In females, it stimulates the growth of **Graafian follicle** and helps in the secretion of oestrogens by follicle cells. In males, it controls the formation of sperm cells.
b. *Luteinizing hormone (LH).* In female, it stimulates ovulation, and helps in the **secretion of progesterone** and **oestrogen**.
c. *Insterstitial cell stimulating hormone (ICSH).* In male, it causes the **secretion of testosterone**.
d. *Prolactin.* It stimulates the **production of milk** and promotes breast development in females.

2. Intermediate Lobe

This lobe secretes only **one** hormone known as melanocyte stimulating hormone (MSH). It makes skin cells produce melanin, a pigment that darkens the skin.

3. Posterior pituitary

This lobe is connected with hypothalamus by axons. Its secretary cells are called pituicytes. They secrete two hormones.

a. ***Antidiuretic hormone (ADH) or vasopressin.*** It controls the water loss from the body by rapid reabsorption of water by the kidney. The hyposecretion of this hormone leads to diuresis, which causes diabetes insipidus.

b. ***Oxytocin.*** It causes contraction of uterine wall during the child birth, and helps in the ejection of milk from the breast during lactation. In male, it helps in sperm transport and ejection.

iii. Thyroid gland

The thyroid gland is a **bilobed** (butterfly-shaped) structure, as shown in Figure 7.4. It lies in the front region of the neck around larynx and trachea. It is composed of **two lobes**: *right* and *left*, which lay one on either side of the trachea connected by an isthmus.

Thyroid gland needs iodine to produce **thyroid hormones**. Iodine is found in sea food, salt and other foods. Thyroid gland secretes **three** hormones namely, tetra-thyroxine (**thyroxine**), tri-iodothyronine and calcitonin.

Functions of thyroid hormone

1. It controls the rate of metabolic activities and growth.
2. It stimulates absorption of glucose by intestine wall, consumption of glucose inside cells, breaking of glucose in liver and cell nucleus.
3. It controls body weight and also controls the functioning of adrenal cortex and gonads.

Disorder related to thyroid hormone

There are two conditions, which are due to either deficiency, or excessive secretion of the thyroid hormone.

a. Hypothyroidism

Hypothyroidism (***underactive thyroid gland***) is a condition in which thyroid gland **does not produce enough thyroid hormones** to maintain the normal functions of the body. It seldom causes symptoms in the early stages, but over time, untreated hypothyroidism can cause a number of health problems, such as obesity, joint pain, infertility and heart disease. Women older than age 60, are more likely to have hypothyroidism. ***It leads to the following disorders:***

1. Cretinism is due to the **inadequate development of thyroid in infants**. The

symptoms are **retarded physical growth**, **short stature**, **deformed teeth** and **bones**, **protruding tongue**, **retarded sexual characters**, **pot belly**, **wrinkled skin** and **short fee**t.

2. Myxoedema in adults, it is characterized by **mental** and **physical dullness**, degenerated sex organs, loss of memory, **swollen face**, **thick lips** and **eyelids**.
3. Simple goitre is due to the **deficiency of iodine in diet**. This causes the enlargement of thyroid gland referred as **simple goitre**. In olden days, many people in Bhutan suffer from simple goitre due to iodine deficiency in their diet.

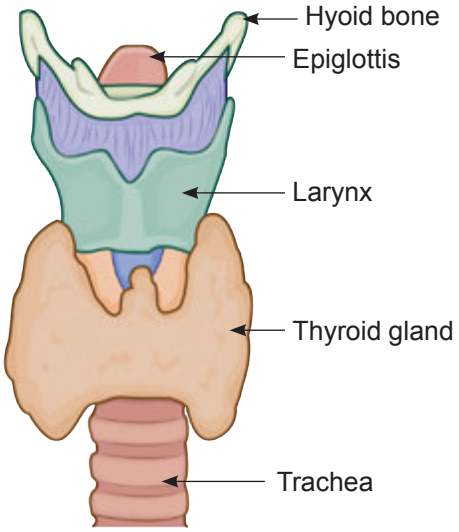


Figure 7.4 Thyroid gland

b. Hyperthyroidism

Hyperthyroidism occurs when the thyroid gland makes **too much thyroid hormones**. ***It leads to the following disorders***.

1. Osteoporosis: Bones become weak and brittle due to excessive loss of calcium and phosphorous from the bone.
2. Exophthalmic goitre: It is **due to increase thyroid hormone** in the blood, which might be due to a hyper-functioning gland or increase in the gland parenchyma.

Dwarfism: hyposecretion of the growth hormone (GH) in child, leads to dwarf or midgets.

Pituitary myxoedema: hyposecretion of GH in adults produces symptoms where person becomes weak with reduced genital organs and reduced fertility.

Gigantism: hypersecretion of the growth hormone during childhood produces long, healthy and .giant size persons.

Acromegaly: hypersecretion of GH in adults produces disproportionate giants with ugly face, long jaws and protruding forehead.

iv. Parathyroid glands

These glands are **size of peas**, which lie embedded in the dorsal surface of the thyroid gland. There are four of them as shown in Figure 7.5.

The hormone secreted by parathyroid glands is parathormone or parathyroid hormone (**PTH**).

Functions of parathormone

1. It regulates calcium-phosphorus balance in the blood.
2. It controls muscular contraction.
3. It increases absorption of calcium by cells.
4. It accelerates the excretion of phosphate.

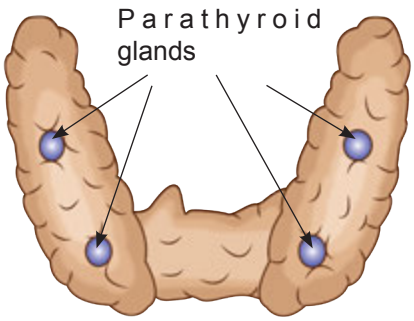


Figure 7.5 Parathyroid glands

The **hypo activity of parathyroid** leads to calcium deficiency called hypocalcemia. This leads to uncontrolled contraction of muscles.

Hyperactivity of parathyroid leads to hypercalcemia. This leads to excessive loss of calcium and phosphate salts into the blood.

v. Adrenal glands

Adrenal glands are like caps on the top of kidney Figure 7.6. Each consists of two distinct parts: outer cortex and inner medulla. This gland helps to **control blood sugar**. In addition, it helps in proper cardiovascular function, and proper utilization of carbohydrates and fats by promoting healthy gastrointestinal functions. Each part secretes independent hormones. Adrenal cortex secretes about 50 steroid hormones.

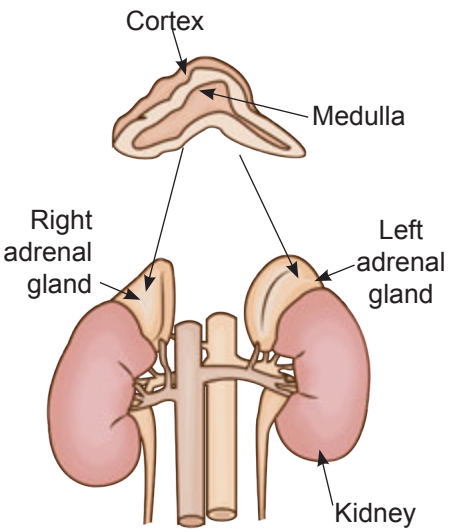


Figure 7.6 Adrenal glands

Adrenal medulla secretes **two types** of hormones: adrenaline and noradrenaline. Both these hormones control contraction of **involuntary muscles** like heart muscle and arteries.

Adrenaline is secreted during the time of **emergency to face physical stress** like fall in blood pressure or blood sugar, cold, pain and injury, and emotional stress like anger, fear and sadness.

Noradrenaline is **secreted under normal conditions** of our body. It regulates blood pressure by constricting the small arteries.

vi. Pancreas

Pancreas lies below the stomach as shown in Figure 7.7. It is elongated and yellowish gland, **composed of exocrine part and endocrine part**. The exocrine pancreas (with blood vessels and ducts) forms about 98-99% of the pancreas as a whole. Exocrine pancreas produce **digestive enzymes** and **alkaline solution**.

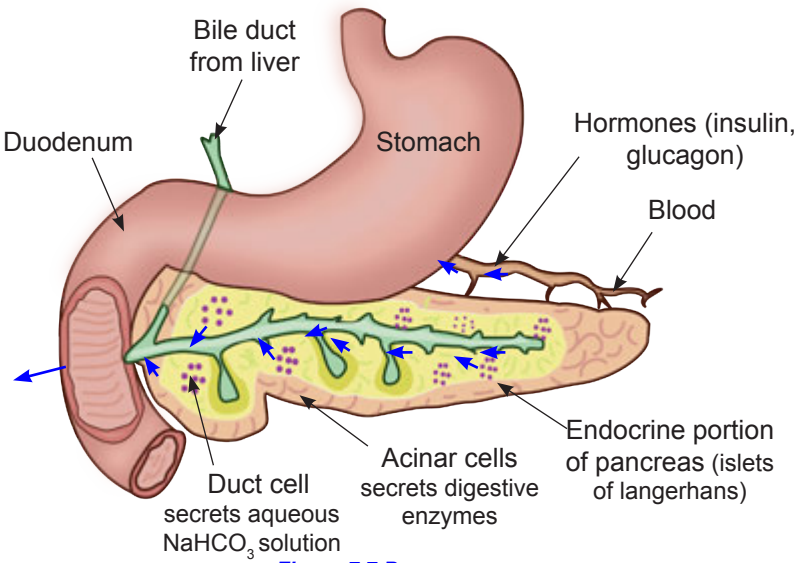


Figure 7.7 Pancreas

Endocrine pancreas forms about 1-2 % of the overall pancreas. It is composed of special group of cells called islets of Langerhans (*islets*: **little islands**), which are large and light staining cells that **produce hormones**.

7.2 Activity

Cells inside pancreas

Observe the transverse section (T.S) of pancreas in the chart. Make a sketch of each type of cells in it.

Questions

i. How the tissues look like?
ii. Name the shapes of cell structures.
iii. Draw a sketch of T.S of pancreas.

Islets cells are of **three types** and they are: alpha cell, beta cell and delta cell. **Alpha cells** produce the hormone glucagon. Glucagon stimulates the breakdown of glycogen in liver to glucose, thus raises the sugar level. Physical exercise and rich protein meal stimulate the secretion of glucagon.

Beta cells produce the major anabolic hormone called insulin in the body. It checks the sugar level in blood.

Deficiency of insulin causes diabetes mellitus. A person with diabetes mellitus will have high concentration of sugar in the blood due to increased concentration of glucose. The kidney functions to get rid of excessive volume of glucose from the blood. **Symptoms** of this deficiency are the **loss in body weight**, **weakness**, **feeling thirsty**, and **increased urination**.

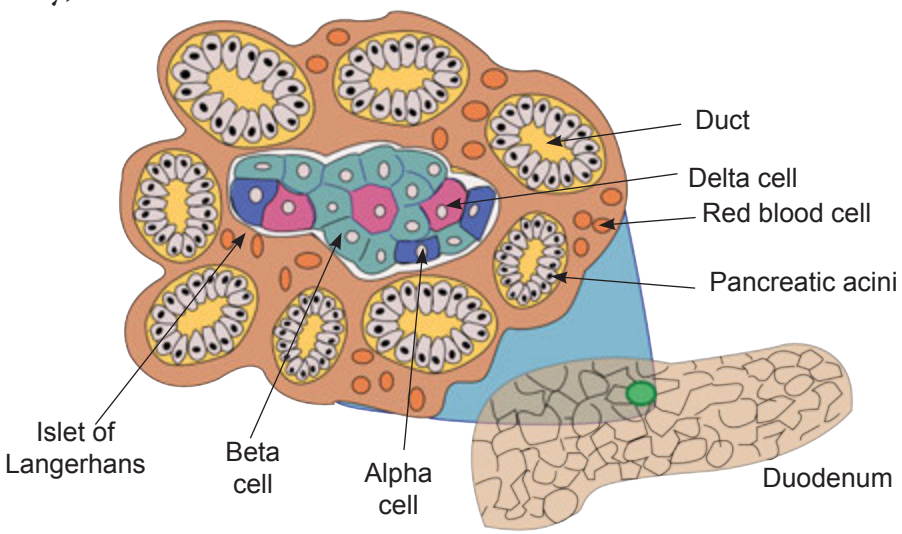


Figure 7.8 Transverse section of pancreas showing various types of cells

Excess of insulin causes hypoglycemia, which is due to fall of sugar level in the blood that may lead to a **state of coma**. The patients suffer from **nervousness** and **sweating**, **hunger** and **mental disturbance** and **feel laziness**. Excess may be also due to overdose of insulin, or taking insulin without eating enough, or due to excessive physical exercises.

Delta cells produce the hormone somatostatin. This hormone **inhibits** both glucagon and insulin secretion. It also **inhibits gastrointestinal secretion**.

Laughter is good for you, because it can reduce the levels of stress hormones, such as cortisol, adrenaline, in your body, making you more relaxed.

vii. Gonads and sex hormones

Gonads are the male and female primary reproductive organs. The **male gonads** are the testes and the **female gonads** are the ovaries. Gonads produce sex hormones needed for the growth and development of **primary** and **secondary reproductive organs** and structures. The primary hormones of the ovaries are estrogens and progesterone. Testosterone is the main hormone secreted by the **testes**.

Estrogens are **group of female sex hormones** important for **reproduction** and the **development of female sex characteristics**. They are **responsible for growth and maturation** of the uterus and vagina; breast development; widening of the pelvis; greater fat distribution in the hips, thighs, and breast; uterus changes during the menstrual cycle; and increased growth of body hair.

Progesterone are the hormone that functions to prepare the uterus for conception; *regulates uterus changes during the menstrual cycle; increases sexual desire; aids in ovulation; and stimulates gland development for milk production during pregnancy*.

Testosterone are male sex hormone important for the **development of male sex organs and sex characteristics**. Testosterone is responsible for *increased muscle and bone mass; increased growth of body hair; development of broad shoulders; deepening of the voice; and growth of the penis.*

Gonadal disorders occur as a result of a disruption in the structure of the function of male or female gonads. Disorders that impact the ovaries include ovarian cancer, ovarian cysts, and ovarian torsion. Female gonadal disorders associated with endocrine system hormones include polycystic ovary syndrome (**results from a hormone imbalance**) and amenorrhea (**no menstrual period**). Disorders of the male testicles include testicular torsion, testicular cancer, epididymitis (**inflammation of the epididymis**), and hypogonadism (**testicles do not produce enough testosterone**).

7.3 Activity

Library research

Go to library and collect information on following endocrine glands.

1. Pineal gland
2. Testes
3. Ovaries

Questions

i. Name the hormones secreted by each of them.
ii. Write the functions of hormones listed in question i.
iii. Write any interesting facts about the three glands.

Brain Snacks

- **Growth hormone levels** in the body rise to peak during the **deep sleep**.
- The height of Robert Wadlow, the tallest person in history was **2.7** metres, who suffered from **gigantism**.

Summary

- Endocrine system forms the second regulatory system in an organism.
- Hormones are the chemical messengers in the body that regulate most activities in an organism.
- Endocrine glands are ductless glands that secrete hormones directly into the bloodstream for their transportation.
- Pituitary gland is referred as master gland, because it controls and regulates most other endocrine glands.
- Anterior pituitary secretes growth hormone, TSH, ACTH, FSH, LH and prolactin. Posterior lobe secretes ADH and oxytocin.
- Hypothyroidism causes disorders such as cretinism, myxoedema and simple goitre.
- Hyperthyroidism causes disorders such as osteoporosis, exophthalmic goitre, etc.
- Under secretion of parathormone causes hypocalcaemia, and over secretion of parathormone causes hypercalcemia.
- Adrenal cortex secretes three groups of hormones namely, mineralocorticoids, sex-steriods and glucocorticoids.
- Adrenal medulla secretes adrenaline and noradrenaline.
- Alpha cells secrete the hormone glucagon, beta cells secrete the hormone insulin, and the delta cells secrete the hormone somatostatin.

http://www.biologycorner.com/anatomy/chap11.html

http://bcs.whfreeman.com/hillis1e/#667501__708874__

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer

1. Male sex hormone is
   A. testosterone. C. progesterone.
   B. oxytocin. D. oestrogen.
2. World's tallest man is the result of
   A. hyposecretion of the growth hormone in childhood.
   D. hyposecretion of the growth hormone in adulthood.
   C. hypersecretion of the growth hormone in childhood.
   D. hypersecretion of the growth hormone in childhood.
3. Substance 'X' is produced in certain glands and transported to its specific target organs through blood. Even at small concentration, it is very effective in influencing the functions of other organs. Identify the substance 'X'.
   A. Neurotransmitter C. Enzymes
   B. Hormones D. Catalysts
4. In females, the two ovaries secrete
   A. Progesterone and oestrogen C. Calcitonin and testosterone
   B. Insulin and glucagon D. None of the above
5. Hormones such as vasopressin and oxytocin is secreted by
   A. hypothalamus. C. posterior pituitary.
   B. anterior pituitary. D. intermediate pituitary.
6. Tashi was diagnosed of having weak and brittle bones. As a doctor, you would recommend his diet to include more
   A. calcium and phosphorus C. iodine and potassium.
   B. sodium and potassium. D. vitamins and roughage.
7. Which of the following pair is incorrect?
   A. Adrenal gland-adrenaline C. Thyroid gland-thyroxine
   B. Pineal gland-melatonin D. Pancreas-prolactin
8. The hormone secreted by alpha cells of pancreas.
   A. Insulin C. Oxytoxin
   B. Glucagon D. Cortisone
9. The hormone that tells the kidneys to reabsorb more water from urine, helping the body retain water.
   A. Noradrenaine C. Antidiuretic hormone
   B. Parathormone D. Melatonin

10. When you are stressful and unhappy, body will secrete more
    A. noradrenaline. C. testosterone.
    B. adrenaline. D. progesterone.

B. Name the following.

1. An organ having both endocrine and exocrine function.
2. A student complains that he feels weak and thirsty. When he visited a hospital, a doctor said that sugar concentration in her blood is very high. This condition caused by under secretion of insulin.
3. The hormone, which is responsible for the contraction of our blood vessels, as per the requirement of the body.
4. A yellow hormone secreting part in the female reproductive system.
5. The hormone known as the 'fight or flight' hormone because it prepares the body for sudden action in emergencies.

C. Expand the abbreviations.

1. TSH 2. GH 3. ADH
4. MSH 5. ADH

D. Differentiate between the following pairs.

1. Endocrine gland and exocrine gland.
2. Adrenaline and noradrenaline.
3. Adrenal cortex and adrenal medulla.
4. Testes and ovaries.
5. Diabetes mellitus and diabetes inspidus.

E. Copy and fill in the blanks with the correct form of word(s).

Glands or gland cells	Hormone produced	Chief function	Effects of over secretion	Effects of under secretion
.....	Growth hormone	Stimulates body growth and cell metabolism.	.....	.....
Thyroid gland	.....	.....	Exophthalmic goitre	Myxoedema
.....	Parathormone	.....	Hypercalcemia	.....
.....	.....	Checks sugar level in blood	.....	Diabetes mellitus

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

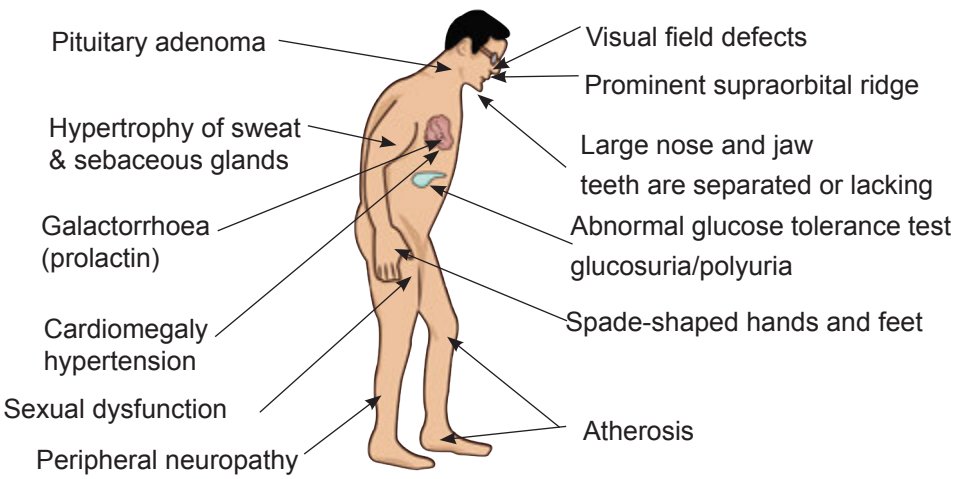
1. The organs influenced by hormones are known as……
2. Oxytocin is the secretion of……..
3. PTH controls calcium and ……balance.
4. Exophthalmic goitre is due to increase in size of the ……..
5. The condition in which there is excessive loss of calcium and phosphate salts into the blood is called.....

G. Give reason.

1. If you stand in front of the large audience to make a speech, your heart rate starts to increase.
2. Pituitary gland, though very small, is often called as the 'master gland.
3. During a bungy jump, the body produces adrenaline.
4. People living in the low himalayan hill regions, often suffer from goitre.
5. Body growth is greatly accelerated at puberty in human.

H. Answer the following questions.

1. How gonads differ from sex hormones?
2. Write three main characteristics of hormone.
3. Study the Figure below and answer the questions 'a' through 'c'.

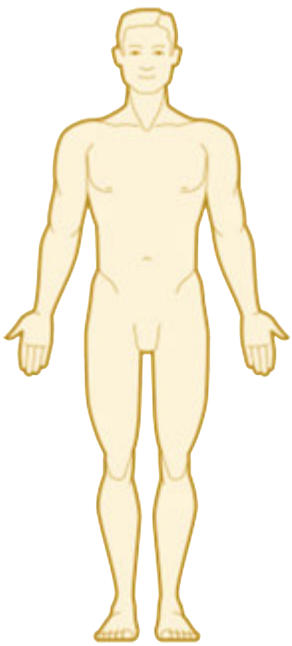


a. Identify the disorder.
b. Name the hormone responsible for this disorder.
c. In what ways, this disorder is different from gigantism.

4. The Figure on the right represents a gland of a human body. Observe and answer the questions 'a' through 'e'.

   a. Identify the gland.
   b. Name any three hormones produced in it.
   c. Why it is called a compound gland?
   d. Write the names of any three endorcrine cells found in it.
   e. If this gland is damaged in our body, what would be the possible consequences?

5. Draw the outline of human body as in the Figure below. Locate and sketch the position of endocrine glands.

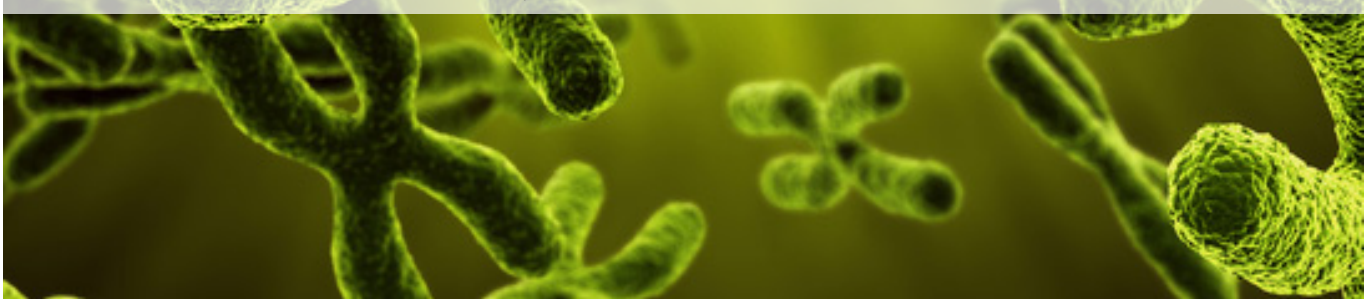


Human body external sketch

8 Variation, Genetics and Evolution

We are all aware that organisms show all sorts of characteristics and variations among themselves. Some of these variations are inherited by their offspring. 'Like begets like,' says the proverb. Modern genetics has expanded beyond the inheritance to studying the functions and behaviours of genes of organisms. Humans have bred selected plants and animals for agriculture, horticulture, sports or security since time immemorial. The application of genetic engineering and cloning in the field of agriculture and other technology have further benefited the mankind.

We find certain groups of organisms, which have ancient body designs have not changed very much. Many other groups of organisms have acquired their particular body designs, relatively recently, as evident from the fossil records. Many evidences supported the evolution of life.



A. Variations in Organisms

Learning Objectives

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

- describe that variation arises from genetic causes, environmental causes, and a combination of both.
- elaborate natural selection as a step to evolution.

Individuals in a population are not exactly the same. Each individual has its **unique set of traits**, such as size, colour, height, body weight, skin colour and even the ability to find food. You can even find that **among three sisters of the same parents**, they differ a lot; one may be very tall, the other may have dark hair and the third may have a rounded face. Such differences in individuals from their parents are called variation.

a. Causes of variations

Variations are brought about by **genetic variation**, or **environment variation** or **both** types. Some variation within a species is **inherited**, and some variations are due to the **environment**. Variation in a characteristic that is a result of genetic inheritance from the parents is called genetic variation. Characteristics of animal and plant species can be also affected by factors such as climate, diet, culture, lifestyle, etc. For example, a plant in the shade of a big tree will grow taller as it tries to reach more light. **Variation caused by the surroundings** is called environmental variation.

i. Genetic variations

They are caused by **differences in number**, or **structure of chromosomes**, or **by differences in the genes** carried by the chromosomes. Eye colour, body form, and disease resistance are genetic variations. It gives rise to differences between individuals and are inherited by offsprings. For example, our eye colour is inherited from our parents, and is different from others.

ii. Variations due to environment

Some other **traits** like **dialect** or **accent**, **scars**, **skin texture**, or **body weight** may be determined by some external or environmental factors. In other words, genetic variation of our **phenotype** is also affected by **environmental variation** such as climate, diet, physical accidents, culture and lifestyle.

For an example, in the **life cycle of honey bee**, **three phenotypes** (*physical appearance*) are present in honey bee colony: **the workers**, **the drones** and **queens**(see Figure 8.1). Males *(the drones)* arise from **unfertilized egg**, and workers and queens (female) from

fertilized egg. The difference between the workers and queens in their phenotypes arises due to **diets** that the larva receives between moults. Sometimes, a person may not have inherited a trait, but some conditions have **modified the individual** to exhibit specific traits.

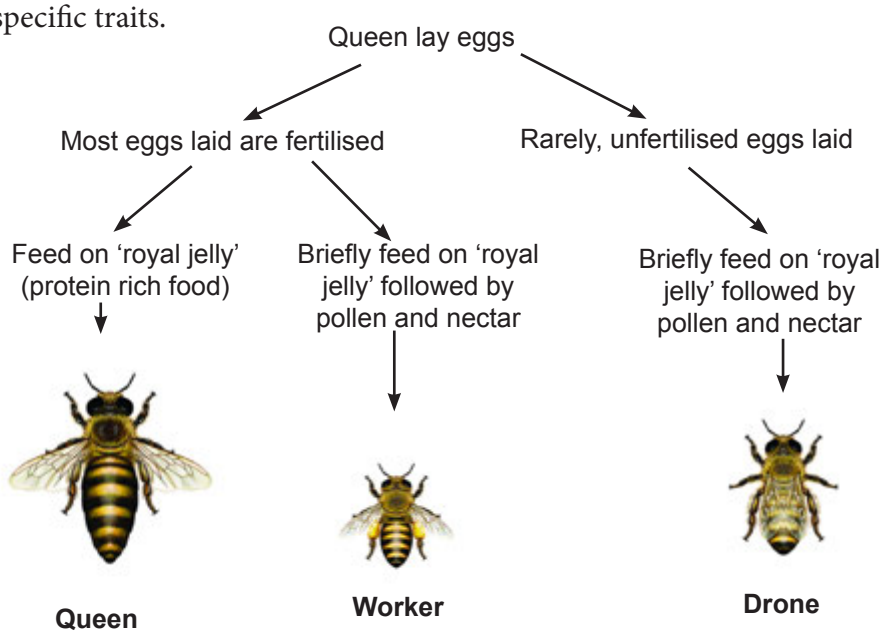


Figure 8.1 An example of environmental variation

Interaction of genetic variations and environment variations

Variation in the physical appearance of offspring may also arise through the **interaction of genotype with the environment**. These variations do not make any hereditary modification; and in general, are **not transmitted to future generations**. Consequently, they are not significant in the process of **evolution**. Here, the influence of particular genes is determined by factors external to the organism. Many variations are influenced by both the environmental and the genetic factors, because although our genes decide what **characteristics we inherit**, our environment affects how these **inherited characteristics develop**. For example:

1. A **person** might inherit a tendency to be tall, but a poor diet during childhood will **cause poor growth**.
2. **Plants** may have the potential for strong growth, but if they do not receive sufficient mineral resources from the soil, they may hardly grow.
3. **Identical twins** are a good example of the interaction between inheritance and the environment. As such, twins are genetically the same. Any difference one may see between them, for example in personality, tastes and particular aptitudes, are due to differences in **their experiences** or **environment**.

B. Genes and DNA

Learning Objectives

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

- describe the relationships between chromosomes and genes.
- explain gene as a section of DNA.

All living cells carry a set of instructions that make each person biologically human and, at the same time unique. These instructions, called genes are stored as a **four-letter code** by the molecule DNA (**deoxyribonucleic acid**). Human cells contain about 20,000 genes.

a. Genes

Take a look at yourself. Is there anyone who looks like you? You are a person with unique physical, mental, emotional make-up. There has never been anyone as you, and never will be. But, a person may look a lot like ones' brother or mother. Probably, that person has similar hair colour or eyes, or smile in a very similar way. This complete **difference** or **similarity** between a person's brother or mother is due to substance in their bodies called genes.

Genes are **specific sequences of nucleotides on a chromosome, that encode for making specific proteins for living cells which express in the form of some particular features in the body**. Proteins are the building blocks for living things. Almost all part of our body including bones, blood and muscles are made up of proteins, and the genes supervise the **protein production**. Genetic code refers to the **plan present** in the gene.

Genes have many functions in an organism.

1. The primary function of the genes is to control characters of an organism.
2. Genes contain the plan for the synthesis of proteins. .
3. Genes are the unit of inheritance. They are transmitted from parents to offspring.

b. Chromosomes

DNA is stored in structures called chromosomes. There are **46 chromosomes** in the nucleus of normal human body cells. Each one contains a single molecule of tightly coiled DNA. Chromosme is simply **a lot of DNA strands folded** and **compacted together**. If you stretched out a DNA molecule, you would observe that it is made of **two strands twisted** together, forming a shaped called a double helix (Fig. 8.2). This structure becomes highly coloured when dyes are applied to it.

Each chromosome contains **one DNA molecule**. The DNA is coiled tightly around proteins called histones. Just before nuclear division takes place, the chromosomes coil up into shorter, thicker and more compact structures called chromatids**.** These structures are much clearly visible under a microscope.

After the completion of cell division, the **chromatids** (*now called chromosomes*) decondense and revert to their very long and fine thread-like chromatin fibres. The chromatin material that constitutes the fibre is formed of two substances:

1. DNA (***deoxyribonucleic acid***): 40%

2. Histones (***a type of protein***): 60%

Figure 8.2 given below is a highly diagrammatic representation of the structure of **chromosome**, the **chromatin fibre** and **DNA**.

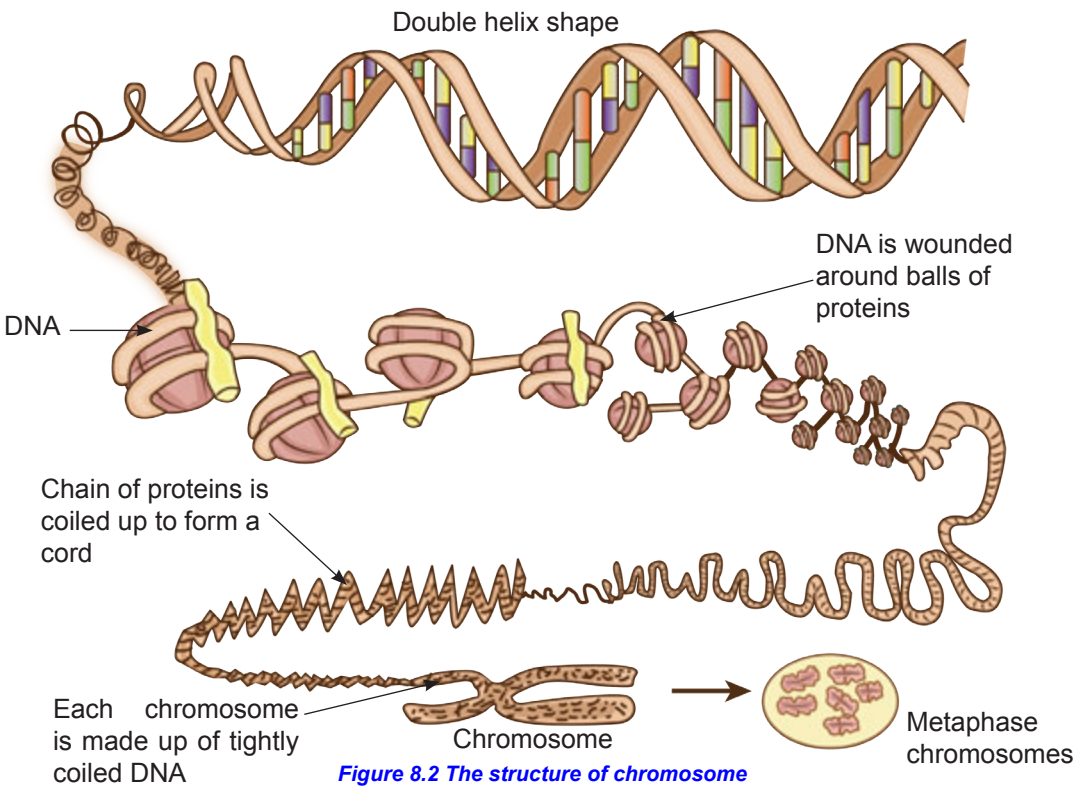


Figure 8.2 The structure of chromosome

Structurally, chromosome is made up of **two chromatids**. These chromatids are **held together at a point** called the centromere. When the sets of chromosomes from a human are lined up according to size, it appears that they exist in pairs. These are called homologous pairs because they are similar in structure.

An image of such an arrangement of chromosomes is called karyogram, and the set of chromosomes is called karyotype.

There are 23 pairs of chromosomes in human beings. The reason the chromosomes are **in pairs** is because one set of chromosomes comes from the **mother via the egg** and the other set of chromosomes comes from the **father via the sperm**. During fertilisation , when the sperm cell fuses with the egg cell, the resulting cell is called a zygote. It contains **two sets of chromosomes** (2n).

c. Nucleic acids

Nucleic acids are complex macromolecules, containing C, H, O, N and P. They were first discovered in **nucleus**; hence, they are named as **nucleic acids**. They are also found in cytoplasm. Nucleic acids are two types, namely,

1. DNA (Deoxyribonucleic acid) and
2. RNA (Ribonucleic acid)

The nucleic acids, **Deoxyribonucleic Acid** (DNA) and **Ribonucleic Acid** (RNA) are common to all living organisms.

i. Deoxyribonucleic acid (DNA)

Deoxyribonucleic acid holds the instructions that make each person biologically human and, at the same time, unique. A DNA molecule is made up of thousands of **building blocks** called nucleotides. Each nucleotide is made up of three parts; **a phosphate group**, **a sugar group** and **a nitrogen bases**.

DNA is found in the chromosomes inside the **nucleus**, **mitochondria**, and **plastids of eukaryotic cells**. The shape of the DNA is double helix in eukaryotic cells.

Figure 8.3 DNA structure

ii. Ribonucleic acid (RNA)

RNA is somewhat similar to DNA; they both are nucleic acids of **nitrogen-containing bases joined by sugar-phosphate**. However, structurally, RNA is a single-stranded, where as DNA is double stranded.

Functions of RNA

1. RNAs play an important role in **protein synthesis**.
2. In many viruses, RNA functions as the **genetic material**.
3. The **rRNA** (*ribosomal RNA*) present in the chromatin fibres **initiates the replication of DNA**.

C. Selective Breeding

Learning Objectives

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

- explain the basic principles of selective breeding.
- discuss the moral and ethical implications of selective breeding.

For thousands of years, people have used different ways of moving genes to **produce desirable traits**. People have **bred plants and animals** for favourable traits-resistance to drought, a tastier fruit, higher milk yielding, etc. by selecting and saving the best plants and animals or by **cross-pollinating plants** and **cross-breeding animals** with different characteristics. For both plants and animals, one of the more traditional ways is through selective breeding.

a. The principles of selective breeding

The **objective** of plant breeding is to **improve crop yields by increasing the size of whole plant**, or by **selectively increasing the edible part** of the plant, or by the **selection and development of disease-resistant varieties**. The principle of plant breeding is based on **combination of the superior genes**. The product must be an organism that is not only superior in identified qualities, but which has a recognized market. Human choice and preference are important factors in the economics of both plant and animal breeding.

Plant breeding is carried out largely by crossing different varieties, and then selecting the progeny with particular characters from which to breed further. Plant breeders are looking for qualities in the progeny such as:

1. *Fast germination and growth.*
2. *Good response to applied fertilizer.*
3. *Dwarfed stem growth and enhanced leaf growth.*
4. *Efficient capture of solar energy.*
5. *Efficient inflorescence and flower formation.*
6. *Tolerance to occasional unfavourable conditions, such as drought.*
7. *Effective resistant to diseases and common pests.*
8. *Superior nutritive value of the grain or fruit.*

The **objective** of animal breeding is to **improve the yield**, or **quality of wool** or **hide**, or to **increase the milk production**, or **increase the meat quality** (more protein than fat), or **litter size**, based on animal species and the local needs.

Animal breeders have been using **artificial insemination techniques**, as well as the newest development of **genetic engineering technologies** for decades. These techniques allow breeders to choose a mother and father, but uncertainties of sexual reproduction remain. ***Which traits will be passed on? Will the offspring be male or female?***

In artificial insemination, semen is collected and then appropriately diluted and stored in an adequate quantity. Sperms stored at **low temperature**, at about -196^{0}C provides viabe sperms over a prolonged period. The diluted semen is injected into the uterus of animals in the oestrus by means of a long, fine tube.

Plant and animal breeding: Some common terms

- **Variety** is a genetically diverse population within the species.
- **Pure line** is a variety produced by intensive selfing, so that the progeny are homozygous.
- **Breed** is a specific group of domestic animals having similar appearance and behaviour, and other characteristics that distinguish it from other organisms of the same species.
- **Inbreeding** occurs when gametes of close relatives (plant or animal fuse). Typically, inbred plants are from species that are naturally self fertile. In animals, inbreeding is achieved by siblings and test-cross mating.
- **Outbreeding** occurs via the crossing (mating) of unrelated varieties.
- **Hybridization** is crossing of carefully selected varieties in order to bring together desirable qualities from both parents in an offspring.
- **Interspecific hybridization** is the crosses between plants of different species.

Activity 8.2

Good and bad of selective breeding

Discuss the advantages and disadvantages of selective breeding. Get additional information from library books and internet. Prepare a chart and display in the classroom.

Questions

i. Write down the advantages of selective breeding.
ii. Write down the disadvantages of selective breeding.
iii. In your opinion, is selective breeding good or bad? Why?

D. Genetic engineering

Learning Objectives

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

- explain the basic principles of genetic engineering.
- discuss the moral and ethical implications of genetic engineering.

You may have heard that many foods (plants and animals) these days have questions around, as to whether they have been **grown naturally** or have been **manipulated** in some way. These are genuine concerns since, a new method has entered on the scene, creating a better specimen by directly inserting genetic material from one plant (or in some cases from a *bacterium* or *virus*) into the genes of another. This is possible due to **genetic engineering**.

a. What is genetic engineering?

Genetic engineering refers to the **artificial synthesis**, **modification**, **removal, addition**, and **repair of genetic material** (DNA) to get a desired and useful character. In this technique, DNA or genes of one organism are fused into the genome of unrelated species to produce **hybrid DNA**, called recombinant DNA. The science of genetic engineering has enormous potential for social and commercial purposes.

For example, a scientist wants to make blue apples: the scientist decides on the reason for making blue apples. He can get a plant with **blue fruits** (say blue berries). He cuts out a piece of blueberry DNA that codes for blue colour and inserts it into the apple's DNA. He plants the new apple seed and the apple tree produces **blue apples** instead of *red*. Similarly, if he wants a cow to have some desired traits such as **high milk production**, he gets the DNA of a cow with that trait and fix its DNA into the new cow, so that the **recipient cow** will yield high amount of milk.

Genetic engineering or biotechnology also has the capacity to manufacture entirely new animals or plants by merging cells from different sources.

Basic steps in genetic engineering

The process of genetic engineering can be studied by taking an example of how a rice seed with **higher protein content** is produced. *The following common steps are followed in genetic engineering.*

Step 1. A plant with a **high protein content** characteristic, such as a bean is identified.

The bean seed is called donor organism. Then the genetic make-up of the donor organism is carefully studied.

Step 2. Next, a viable rice seed, referred as recipient organism, is identified and DNA carefully studied to understand how a segment of DNA from the bean seed can be inserted into the rice seed.

Step 3. The genes from the **donor organism** is isolated by the process called mapping. This genetic isolation is done to take out only the **desired protein-making trait** (or DNA).

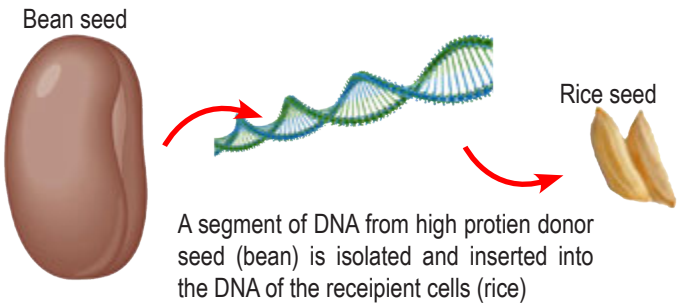


Figure 8.4 Mechanism of genetic engineering

Step 4. A several copies of the gene of **donor organism** (bean) is extracted and inserted into the gene structures of the **recipient organism** (rice). This is a carefully devised in the laboratory process. This process is called transformation. A new gene called transgene is obtained.

Step 5. The **new gene** (now called a *transgene*), with the desired trait, is transferred into the **recipient cells** (rice cells). This process is aided by some special **bacterium** and equipment. It must be ensured that the new genes are properly fixed in the cell structure of the seed.

Once genetic engineering is **complete**, traditional breeding can continue normally, and the new seeds from the parent plant will have the new gene or DNA structure. This means **traditional breeding will continue**, and the genetic engineering only added some new or desirable traits to the collection.

b. Genetically modified organisms

Genetic modification involves the addition of *new DNA* to an organism, thereby modifying its genetic make-up. It is the use of a new method (**biotechnology**) tools to introduce **new traits** (characteristics) into organisms, either from related and non-related organisms. Plants produced with such techniques are called transgenic, or generally referred to as Genetically Modified Crops **(GM crops).** *Genetic*

modification techniques typically aim to boost a **crop's resistance to disease**, **insects, pesticides or weed killers**. **GM foods** that are genetically modified organisms have **lower prices**, **higher nutritional value and taste**, and **durable in terms of produce quality**. More importantly, they are generally **more resistant to droughts**, **pests** and **weeds**. Among the most common genetically modified crops are maize, soyabeans, cotton, canola and potatoes.

For example, a DNA from a plant (**Plant X**) that has high resistance to pests can be copied and introduced into another plant (**Plant Y**), so that, the **Plant Y** will have the pest resistant trait. The Figure 8.5 shows, how the DNA of a *potato* (plant) can be modified by a DNA from a *fish* (animal), which is a completely **non-related organism** to produce frost resistant potato.

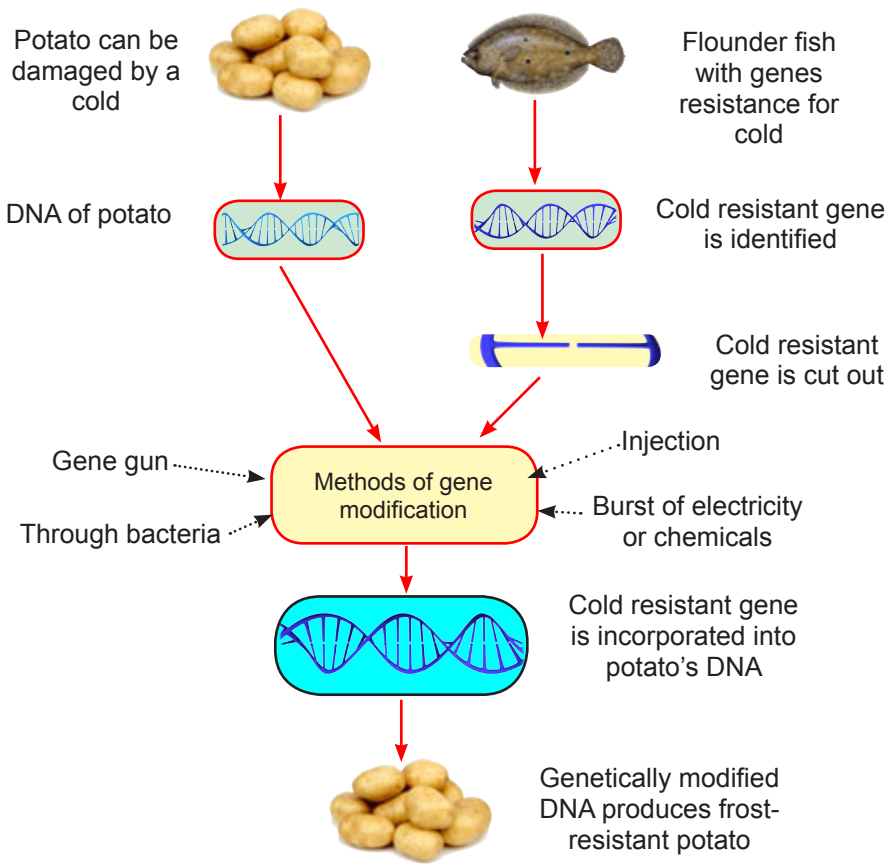


Figure 8.5 Genetically modified potato

The terms *genetically modified organisms* (**GMO**), *genetically engineered* (**GE**) and *biotechnology* are often used interchangeably.

Application of genetic engineering

Genetic engineering is important because of its use in different fields such as *horticulture*, *agriculture* and *medicine*.

1. In medicine genetic engineering has been used in the production of **insulin**, **human growth hormones** (**hGHs**), **albumin**, **antibodies**, **vaccines**, and many other drugs.

2. In agriculture, it helps to produce **genetically modified food** (**GM**), which possesses specific traits such as tolerance to herbicides or resistance to insects or viruses. It also helps to produce **genetically modified organisms** (**GMOs**), which are disease and drought resistant and give high quality yields.

c. Ethical and safety concerns

There are several issues and concerns related to genetic engineering.

1. *Genetically modified foods have implications on human health, as some people are allergic to some food types.*
2. *Genetic engineering often produces new organisms, when genes are transferred between organisms. Consequently, these are potential sources of hazards for human.*
3. *Use of heavy chemicals on crops, post a threat to soils, living organism and environment.*
4. *Ethical concerns involve religious issues, social and cultural practices, food supply regulations and intellectual property rights.*

Tools commonly used in genetic engineering

Host: It is a cell where the recombinant DNA is allowed to multiply to produce thousands of copies. Bacteria like *Escherichia coli* and yeasts are commonly used as the host.

Vector: It is the carrier, which is used to transfer the foreign DNA from one cell to another. The commonly used vector is the plasmid. It is an extra extra-chromosomal, circular, double stranded DNA present in bacteria.

Desired genes: It is the DNA to be cloned and transferred. It can be synthesized artificially, or be obtained from other cells.

Enzymes: They are used in genetic engineering as chemical knives and sutures. They are used to cut and link DNA molecules. There are two types of enzymes:

Restriction endonucleases: These enzymes are used as chemical knives. They cut DNA strands.

Ligase: These are used as chemical sutures to join cut DNA sections.

8.2 Activity

The Biosafety Bill of Bhutan

Study the article given below and discuss about it in groups.

Under the National Biosafety Framework Project (NBFP), Bhutan has drafted Biosafety Bill of Kingdom of Bhutan 2013. The Biosafety Bill of Bhutan was prepared in alignment with the existing government policies and regulations; to impose consequent ban on practices with GMOs and to regulate products derived from GMOs. The Bill extends to all GMOs and import, export and direct use of products having GM content within the country. The prohibitions and exemptions described in the Bill are:

The prohibitions laid out in the Bill:

1. Import of any GMOs and any other genetically modified biological material capable of reproducing;
2. Transit of GMOs capable of reproducing;
3. Intentional introduction of GMOs capable of reproducing into the environment;
4. Any use, including contained use of GMOs capable of reproducing; and
5. Research and development that involves GMOs capable of reproducing.

The exemptions laid out in the Bill:

1. Traditional and domestic methods of animal and plant breeding;
2. Traditional and domestic exchange and sale of local seeds, plants and livestock;
3. Gene sequencing, tissue culture, and other similar methods, which do not involve the use of modern biotechnology;and
4. Products derived from genetically modified organisms for pharmaceuticals for human and veterinary use.

Source: The Biosafety Bill of Bhutan 2013

Questions

i. What is the main objective of the biosafety bill?
ii. Which prohibitions laid out in the bill is relevant to your community? Support your answer.
iii. How can Bhutan benefit from the adoption of this bill?
iv. What are the possible intentions behind, for allowing traditional and domestic methods of animal and plant breeding for import and export? .
v. If Bhutan do not adopted this bill at the earliest, what are the possible implications of GMOs to our environment?
vi. By laying out exemptions in this bill, how community people could benefit in the long run?

E. Cloning

Learning Objectives

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

- explain the basic principles of cloning.
- discuss the moral and ethical implications of cloning.
- explain that cloning can reduce variation within a population.

One of the most incredible developments of genetic science is the ability to **clone animals and plants**. It has been used for many years to produce plants by cutting, which is a type of cloning. Geneticists have already **cloned human embryos** for medical research. If their techniques are perfected, it may soon be possible to clone human organs and tissue for transplant. However, many people have concern about cloning the whole human beings.

a. What is cloning?

Genetically, cloning is the **creation of an exact genetic copy of an organism**. This means that the DNA or genes of the cloned organism is the **same** as that of the parent or the donor. In 1997, the world was introduced to **Dolly** the sheep, the first mammal to be cloned from a cell of another adult sheep. Cloning is a very common process in plants too. For example, if you plant from the cuttings of a crop, you are reproducing by **asexual means**. With cloning, **no new genes** are added. It is important to remember that a cloned animal is born by asexual reproduction, not by sexual reproduction.

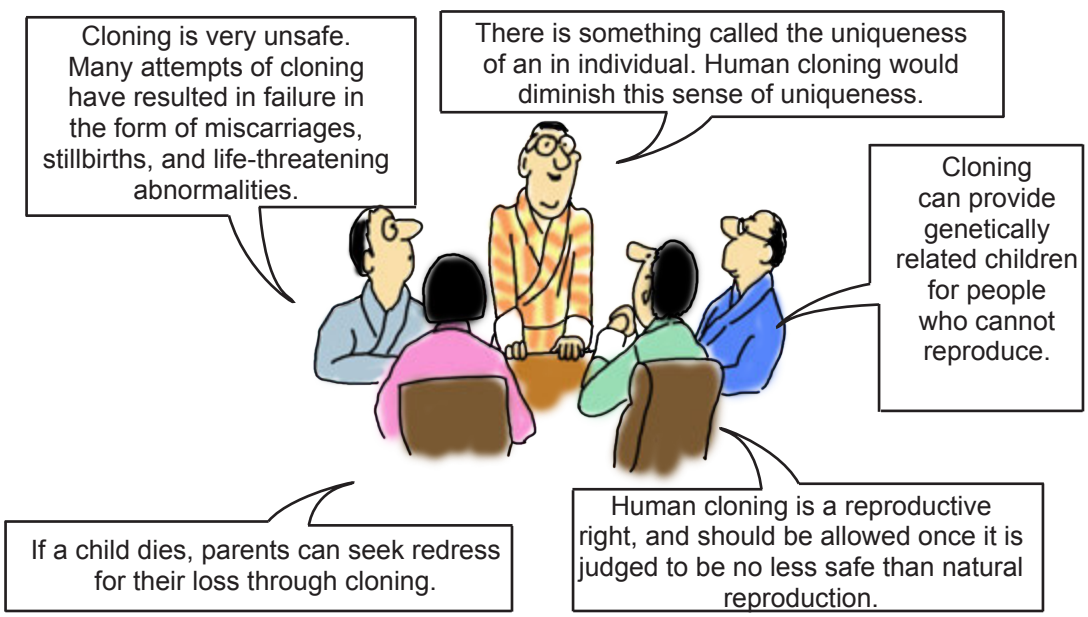


Figure 8.6 Different views about cloning

b. Methods of cloning

Animals are cloned either by i. somatic cell nuclear transfer (**SCNT**), also called **nuclear transfer method** or ii. embryo splitting.

i. Somatic cell nuclear transfer

In somatic nuclear transfer, scientists **remove the DNA** containing nucleus from immature egg (ovum) and **replace it with a nucleus** from the cell of a donor animal. If the fused cell survives and divides, the resultant embryo is implanted in a surrogate mother. *Study Figure 8.7 for better understanding.*

In SCNT, the nucleus which contains the **organism's DNA of a somatic cell is removed** and rest of the cell parts are discarded. At the same time, the **nucleus of the egg is removed**. Then the nucleus of the donor cell is inserted to the **enucleated egg cell**. The egg, now containing the nucleus of a somatic cell is stimulated with an electric shock and will begin to divide. After many mitotic divisions in culture medium, this single cell forms a **blastocyst** with almost identical DNA of the donor organism. Blastocyst is an early embryo stage with about 100 cells.

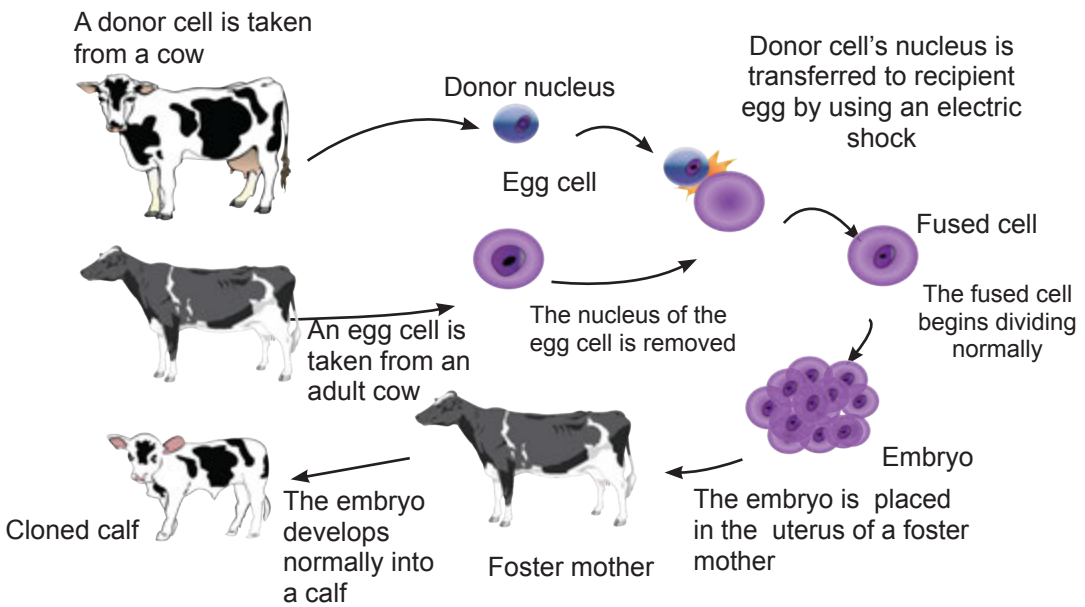


Figure 8.7 Cloning by nuclear transfer

ii. Embryo splitting

Embryo splitting technique **mimics the natural process** that creates identical twins.

In nature, twins form very early in the development stage, when the **embryo splits into two**. Splitting happens in the first few days, after the fusion of egg and sperm. Each half of the embryo continues dividing on its own, ultimately developing into

separate, complete individuals. Since they are developed from the same fertilized egg, the resulting individuals are genetically identical.

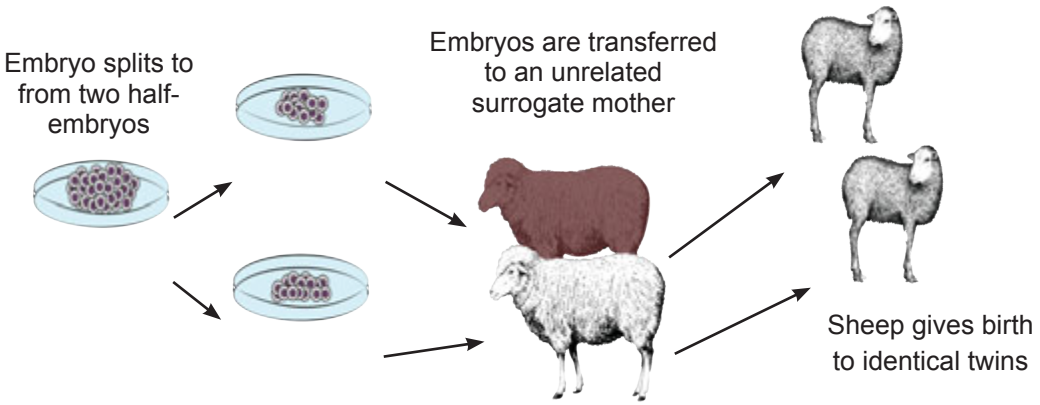


Figure 8.8 Cloning by embryo splitting

Embryo splitting uses the same approach, but it is carried out in a **petri dish**, instead of inside the mother. A very early embryo is separated into individual cells, which are allowed to divide and develop for a short time in the petri dish. The embryos are then placed into a **surrogate mother**, where they complete the development. Again, since all the embryos come from the same fertilized egg, they are **genetically identical** (Figure 8.8). The study found that compared to conventionally bred livestock, cloned animals have **more health problems** and are more likely to die early in life, and their surrogate mothers are more likely to **suffer complications**.

Animal clones

Cattle have been successfully cloned in the United States, permitting a mass **reproduction of unlimited numbers of identical cows**. Cloning cattle would enable farmers to maximize the benefits of desirable traits, such as **high milk yields** and **tender meat**. Cows are also being genetically engineered to produce special proteins in their milk for people with specific dietary needs.


Figure 8.9 Cloned animals

c. Plant tissue culture or micro propagation

Plant tissue culture is the process by which entire plants are formed from the s**ingle cel**l or **tissue** of another plant. The cells or tissue collected from the leaf, buds, shoot apex or roots are used for **micro propagation**. This excised cells or tissue from plant parts is called explants.

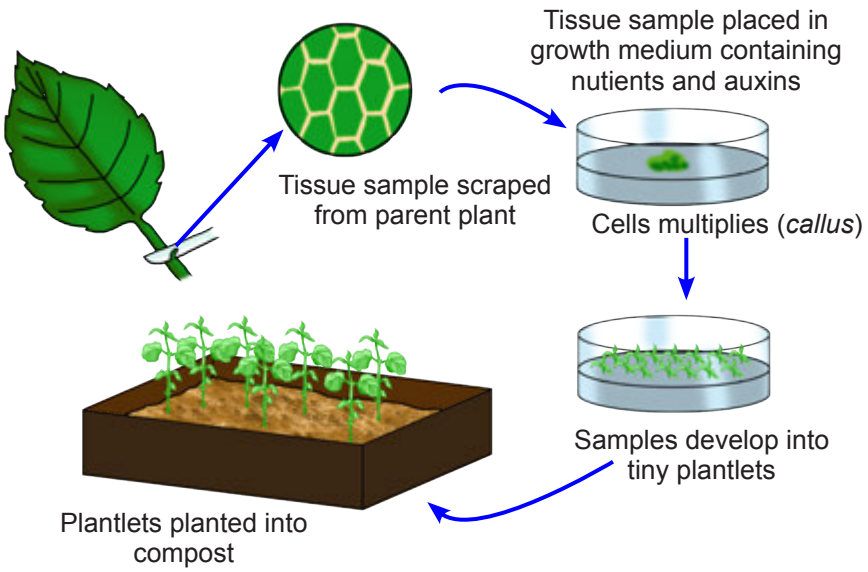


Figure 8.10 Tissue culture

Steps in tissue culture

1. The **cells** or **tissue** collected from the leaf, shoot, bud or root of the parent plant is sterilized and cultured in an **aseptic nutrient-rich medium**.
2. The cells begin to **divide by mitosis**, until there are sufficient cells to develop into roots and shoots of new plantlets. These cells are **undifferentiated** and are known as a callus.
3. The **callus cells differentiate**, forming the different organs of the plantlets with the help of specific plant growth hormone.
4. After 4 to 6 weeks, **plantlet** will developed roots and shoots. It is, then removed from the medium and is transplanted into soil or pots.

Benefits of tissue culture

1. Infinite number of identical individual plants will be produced with very small explants.
2. This process can be carried out throughout the year.
3. Usually, the plantlets obtained will be disease free.

8.3 Activity

Cloning ethics

Most people agree that human cloning is not morally and ethically acceptable due to religious issues and health concerns. The process of cloning organisms has always created unforeseen and serious consequences. An example of these consequences is the premature death of the first cloned sheep named Dolly. Dolly suffered many health problems, including but not limited to DNA degradation, lung disease, arthritis and premature aging. Dolly's health problems became so severe that scientists decided to end her life at the age of six. Consequently, cloning experiments have provoked intense debate and controversy.

Procedure

1. Use any form of resources to discuss some of the pertinent ethical issues related to "cloning".
2. Deliberate these ethical issues from the perspectives of Gross national Happiness (GNH).
3. Prepare a presentation for the class.

Questions

i. What are your perspectives about 'cloning'?
ii. What are good and bad aspects of cloning as per the global perspectives?
iii. Human cloning is against the law of nature'. Justify with reasons.
iv. Describe life on the Earth with full of clones.

F. Evolution

Learning Objectives

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

- state the theory of evolution.
- explain fossil record as an evidence for evolution.

The term evolution comes from the Latin word '*evolvere*', meaning to '*unroll*'. Today, the word evolution implies '*origin from earlier forms*' and is used widely in the English language. The idea of **biological evolution** is one of the greatest contributions of **Charles Darwin**, a British naturalist. Many evidences support evolution principles and ideas and accordingly several theories were proposed. Theory of evolution does not exactly tell how life began on the Earth, but it helps to understand how life existed, diversify in many different life forms, we know of today.

a. What is evolution?

During 1830s, **Charles Darwin** travelled to the Galapagos Islands of South America to study about living things. On his voyage, Darwin made some of his most **important observations**. He saw finches with a **variety of beaks**, tortoises with **different shaped shells** and iguanas with **different claws**. Darwin saw that **finches of Galapagos were very different from one island to the next**. Their beaks varied in shapes and sizes. He noticed that each species is well suited to the life it led. For example, insect eaters were observed with sharp needle like beaks and seed eaters with strong and wide beaks. Darwin **reasoned** that the finches on each of the Galapagos Islands must face conditions that are different from each other. He came up with the **conclusion** that **species must gradually change over many generations**, **becoming better adapted to their environment**. This gradual change in a species over time is described as evolution. 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**. A group made up members of same species is called population.

In biology, evolution is the process that results in the heritable traits within a population across generation. Heritable traits can be any **physical traits** like fur colour of mice, spots in wings of butterfly and distinctive behaviours like dogs able to sniff. These heritable traits spread over many generations leading to diversity of organisms on earth. All living forms like *single celled amoeba* and complex life forms like plants and whales are capable of reproduction. The heritable traits present in living organisms can be **inherited to their offspring through the reproduction**.

b. Evidences of evolution

Scientists have collected **evidences of evolution** from different branches of biology. Some of the evidences are discussed below.

i. Evidence from fossil records

Fossils are the **dead remains of plants and animals**, preserved in sedimentary rocks. Different-aged rock sediments contain fossils of different life-forms. Hence new lives have arisen at different times in the history of the Earth. Fossils are normally formed from the hard parts of an organism, which typically make up 5-20% of most organisms. Therefore, fossils parts are the **exoskeletons of arthropods**, **molluscus or echinoderms**, or **the endoskeletons and teeth of vertebrates**. In plants, it is the hardened parts or organs, such as the **woody tissues**, **seeds**, **spores**, and **pollen grains**. The study of plants and animals of the geological past, as represented by their fossil remains is called palaeontology.

Table 8.1 Examples of fossils

			
Archaeopteryx lithographica, a bird with reptilian feature.	**Fossil leave**, a key evidences for understanding the climate of the past environments	*Eurypterid*, a fearsome predator.	*Eohippus*, resembled a modern horse

Significance of fossil records in evolution

The study of fossil reveals existence of life in the past, and illustrates the course of evolution of plants and animals. Fossil records establish the following facts.

1. A few fossils are found to be intermediate in their structure, showing the features of **two groups of living animals**. For example, *Archaeopteryx* (Table 8.1), a fossil bird, has retained certain reptilian features. Thus, it is the '*missing link between reptiles and birds*', and suggests that birds have evolved from reptiles.
2. With the help of fossil records, palaeontologists have **traced out the complete evolutionary history** of some animals such as horse, elephant, camel, and man.
3. By studying the fossil records, palaeontologist had explained the **gradual changes in earth's land pattern**.

4. The distribution pattern of fossils in rocks shows that ancient fossils present in the bottom rocks are simple compared to most recent fossils. This means that fossil forms become more complex as we move from earliest to the recent rocks. The fossils of man, the most highly evolved animal, are found only in the recent rocks.

ii. Comparative anatomy and morphological

The comparison of body structures among different species shows **similarities** and **differences** among organisms of today and those that existed years ago. Certain **anatomical similarities among species are the same**. For example, ex-skeletal elements make up the forelimbs of man, cheetah, whale and bat are same. All of them have humerus, radius, ulna, carpals, metacarpals and phalanges in their forelimbs. But each of them **performs different functions**. Homologous organs are **the organs having same basic structure but different function**. Thorn of *Bougainvillea* and tendrils of *Cucurbita* represent homologous organs. These homologous organs indicate that there is a relationship between the organisms.

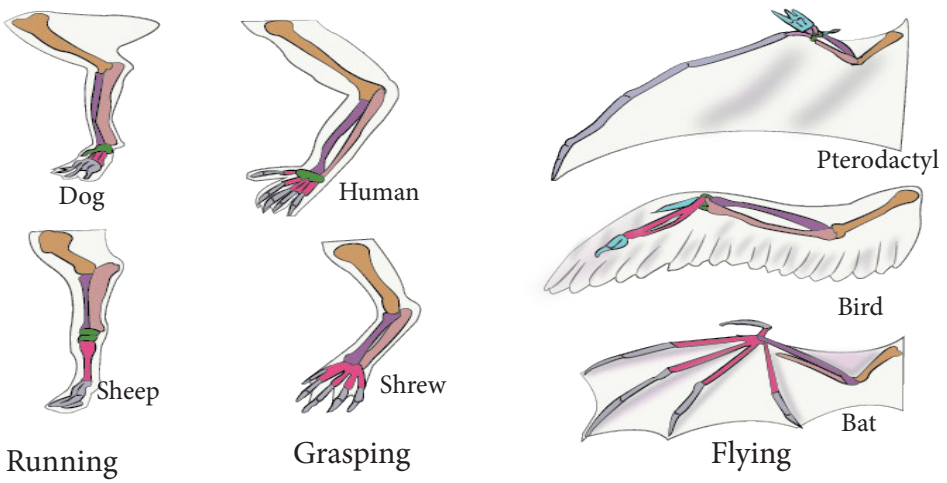


Figure 8.11 Homologous organs and analogous organs

The **organs which have common form and function** are called analogous organs. But they differ in origin and structure. For example, the wings of insects, bats and birds. In all these animals, the wings perform the function of flying. But the wing of insect is derived from **ectoderm** and it is **supported by chitinous nervures**. Whereas the wing of bird is derived from **mesoderm** and it is **supported by bones**. This indicates that the insects, bats and bird had different ancestors.

iii. Embryology

The study of the developmental stages of an organism is called embryology. If we observe the embryos of different animals, there is a similarity. This similarity tells us

that there is a relationship between the animals. The **embryological evidences** show support to evolution. The **early embryos of shark, lizard, chicken, chimpanzee and human resemble with each other closely**. That it is impossible to separate if the embryos were mixed. But the embryos differ in the final stages due to the formation of specialized characters. The **similarity of early embryos** indicate that the above animals have common ancestors.

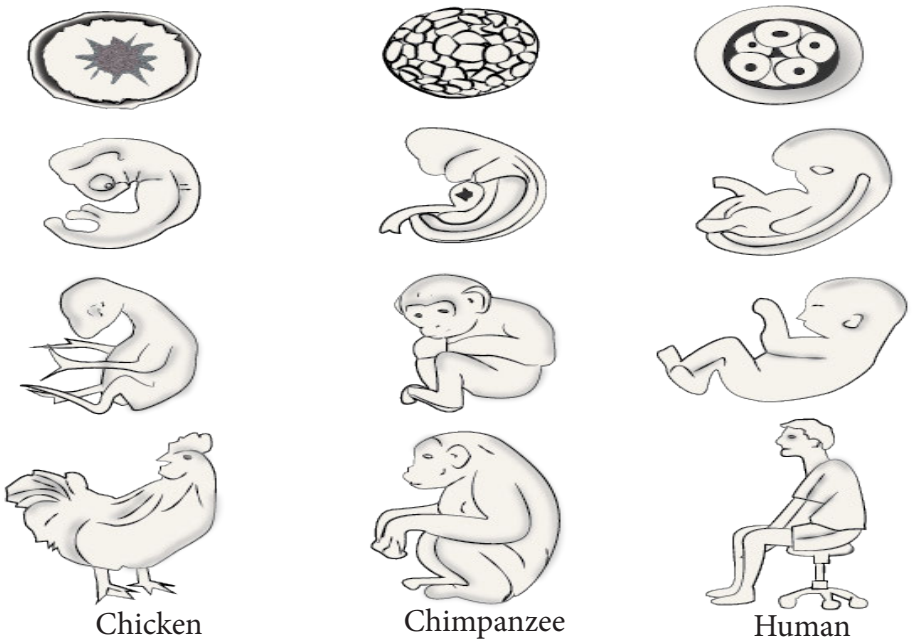


Figure 8.12 Different embryos share certain characteristics indicating that they may share a common ancestor.

c. Theory of evolution

The theory of evolution states that as living organism exist on our planet, they adapt and change to existing conditions. In order to survive to the constant changing environment, living organism must change gradually over time in order to continue their own existence. For instance, it is generally accepted that the present-day flora and fauna evolved by **gradual change from the pre-existing forms of life**. This is termed as organic evolution. Many theories have been proposed by different evolutionists. Most important four theories are:

1. ***Lamarck's theory of inheritance of acquired characters*** *(Lamarckism).*
2. ***Theory of continuity of Germplasm.***
3. ***Darwins' theory of natural selection*** *(Darwinism).*
4. ***Modern concept of evolution*** *(Neo-Darwinism).*

i. Lamarck's theory of inheritance of acquired characters

This idea was developed by Jean Baptiste de Lamarck (1744-1829), a French biologist. From 1800 onwards, **Lamarck** explained the theory of change in his '***law of use and disuse***'. Since changes in the environment made special demands on certain organs, these organs became **especially well-developed**. At the same time, disuse of other organs caused them **atrophy**. These developments of body parts in organisms were **transmitted to the offspring**. He suggested that the **giraffe evolved** from ground feeding herbivores that experienced shortage of ground-level vegetation to feeding from trees. The **constant stretching of the neck** over generations resulted, in the **accumulation** of this feature and **its inheritance by the progeny**.

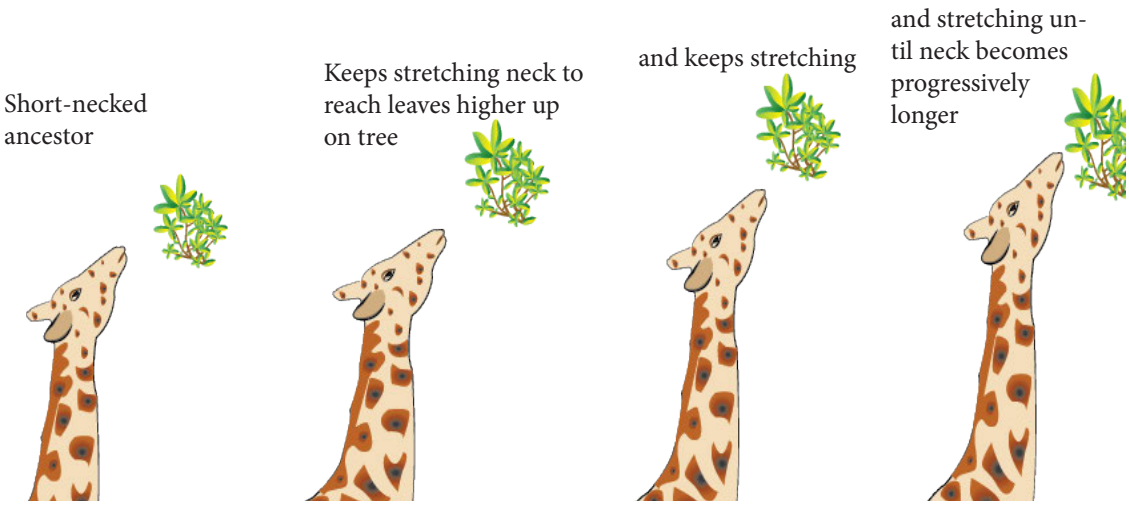


Figure 8.13 Giraffe evolution according to Lamarck

'The inheritance of acquired characters in organisms' comprises of four main assumptions.

1. Organisms tend to increase in size and complexity with time.
2. New organs develop in response to an organism's specific need for them.
3. Organs vary in size and efficiency in direct proportion to use.
4. All that is acquired in an organism's lifetime may be transmitted to the offspring in reproduction.

ii. Theory of continuity of germplasm

The **theory of germplasm** was put forward by the German biologist, August Weismann (1834-1914). According to his theory, multicellular organisms consist of **germ cells** and **somatic cells**. The inheritance from parents to offspring only takes place by means of the germ cells called 'gametes' such as egg cells and sperm cells. Other cells of the body (**somatic**) do not function as agents of heredity. This idea

rejected the idea of inheritance of acquired characteristics as proposed by **Lamarck**.

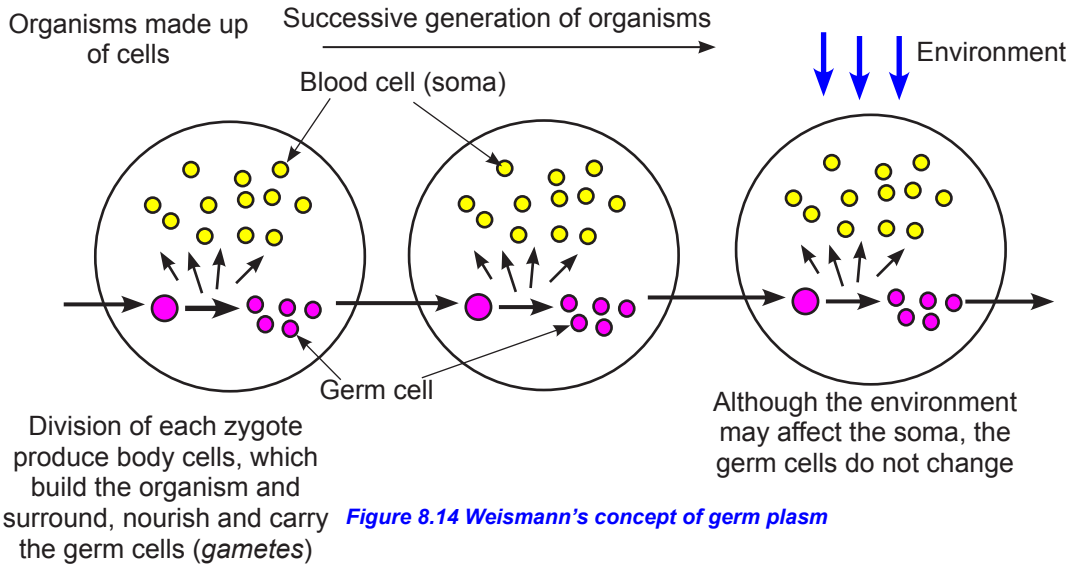


Figure 8.14 Weismann's concept of germ plasm

iii. Theory of natural selection

The **theory of natural selection** is the most famous theory of Charles Darwin (1809-1882). It is also referred as Darwinism. Darwin explained that **species must change over time as a result of natural selection**. Just like the selective breeding done by humans, environment also selects the **most well adapted organism** for reproduction. Individuals that are better adapted to their environment are most likely to **survive and reproduce than other members of the same species**. Thus natural selection (also known as '***survival of fittest***') can be defined as the **process by which environments, '*selects*' the most well adapted organism for reproduction**. He further explained that the species that have more opportunities to reproduce their offspring will have a greater probability of survival, which in turn, helps the offspring acquire these similar traits. Therefore, over the time, these variants will spread through the population.

Charles Darwin, along with biologist **Alfred Russel Wallace**, published his explanation in a book called '***The Origin of Species***' (*by Means of Natural Selection*).

Factors that affect the process of natural selection

1. **Overproduction**: *Organisms produce a far greater number of offspring than that can possibly survive*. For example, sea turtles lay more than100 eggs in a season. If all of the young turtles survived, the sea would be full of turtles. But it is not the case because not all of the offspring will survive.
Overproduction leads to competition, making it more likely than only the members with the best adaptation survive.

2. **Competition**: *Organisms utilize the same resources* such as food, water, living space, mates, etc. For example, sea turtle hatchlings compete for space. Offspring must compete with each other and with other organisms to survive. *Most well-adapted organism are most likely to survive and reproduce*, passing those beneficial traits on to the next generation. Adaptations are traits that help organisms survive and reproduce.

3. **Genetic variation**: Any difference between individuals in the same species is called a variation, which are the results of genes. A **strong species** is one in which there are many differences between individuals. *Variations increase the chances of some individuals to survive, despite changes in environment*. For example, sea turtles are borne with various traits such as size, speed, colour, etc. Some turtles are fast on land, others are fast swimmers.

The **individuals best fit** for the environmental conditions survive and pass their traits to the next generation.

Darwinism theory criticisms

Many objections were proposed by scientists to Darwinism. They are,

i. **Natural selection does not explain the origin of variations** (arrival of the fittest). It explains only the **presence of variations** (survival of the fittest). Why Darwin was unable to explain the origin of variations?
ii. **Darwin believed that the variations help in competition**. At the beginning the wings in birds are in primordial state. Then how they fly to protect from enemies?
iii. **Darwin was unable to explain the presence of vestigial organs**.
iv. **Darwin did not explain the overgrowth of antlers in deer and tusks in Mammoths**.

iv. Modern concept of evolution

Neo-Darwinism is the statement of the concept of evolution by natural selection in terms of Mendelian genetics. It was elaborated by Huxley (1942), Dobzhansky (1937), Muller (1949), Fisher (1958) and Wright (1968). The fundamental origins of genetic variation are **mutations** and **random assortment** and r**ecombination of parental homologous chromosome during crossing over**. Once the genetic differences are established in an organism, they are likely to be expressed as **phenotypic variations**. Some phenotypes may be better adapted than others to survive and reproduce in a particular environment. When natural selection operates, there is a change in the proportion of genetic variation in a population of species. This may lead to **formation of new varieties and species**. Neo-Darwinism differs from Lamarckism in its view that **variations arise spontaneously**, and are selected by **environmental pressure**, rather than arising in response to environmental pressure.

Ideas of Neo-Darwinism

Genetic variations arise through

1. ***Mutations (chromosome and gene mutations)***. Mutation is a change in the amount, arrangement and structure of the DNA of an organism. It results in a change in genetic make up of an organism resulting in a **new gene**. Mutation is caused by **radiations**, X-rays, ultra violet rays from the sun and toxic chemicals.
2. ***Random assortment of parental chromosomes during cell division***. During the formation of gamete cells, there is the **random or independent assortment of chromosomes** which result in genetically unique individual gametes.
3. ***Recombination of segments of parental homologous chromosome during crossing over during meiotic cell division***. During the meiosis, the homologous chromosome line up and **parts of one chromosome are crossed over with the corresponding parts** of the other chromosome. This results in mixing of genetic materials in the gametes produced.
4. ***Random fusion of male and female gametes in sexual reproduction***. This takes place when **male and female gametes fuse to form zygote**. Each gamete has a unique combination of genes.

8.4 Activity

Library Research

Procedure

Discus in groups and critically analyse the four evolution theories based on the following areas:

1. Criticisms on each theory of evolution.
2. Strengths of each of the theory of evolution.

Questions

i. What evolutionary theory best explains the presence of mammary glands in male?
ii. Relate the presence of woolly hair on yaks with one of the evolution theory.
iii. Why are four evolution theories important to one another?

Summary

- Genetics is the study of hereditary and variation of inherited characteristics.
- An organism may have numerous genes for its various characters. The number of genes of an organism exceeds the number of its chromosomes, because most organisms contain limited number of chromosomes. Hence, a single chromosome carries a large number of genes.
- Nucleic acids such as DNA and RNA are common to all living organisms.
- Variations can arise from genetic causes, environmental causes, and a combination of both.
- Genetic variations give rise to differences between individuals that are inherited and have significance in evolution. Genetic variations are caused by mutation, hybridization, recombination, etc.
- The objective of selective breeding is to improve the yield, or quality of plants and animal products.
- Genetic engineering involves the manipulation of genes in improving crops and animals. It is widely applied in horticulture, agriculture, and in medicine.
- Cloning has been applied in the improvement of crops and animal products.
- The genetic engineering, selective breeding, and cloning have moral and ethical implications.
- Evidence of evolution is supported by discovery of fossil records, by comparative anatomy, morphological and embryology studies.
- *Archaeopteryx* is considered as the missing link between reptiles and birds.
- The most important theories of evolution are Lamarckism, Germplasm theory, Darwinism and Neo-Darwinsim.

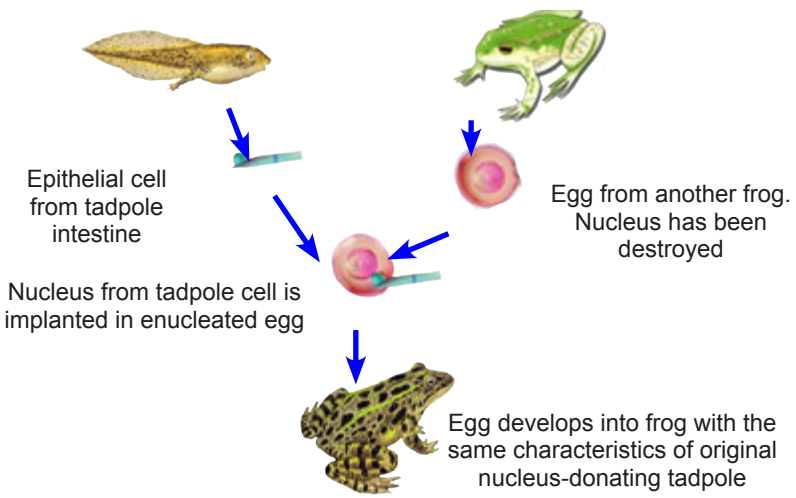
http://ecsd-fl.schoolloop.com/L.15.1

http://ecsd-fl.schoolloop.com/L.16.1

Review questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. Which one of these following statements best illustrates natural selection?
   A. A community, whose members work together, utilizes all existing resources
   B. The largest organisms in a species, receive the only breeding opportunities
   C. A population monopolizes all of the resources in its habitat, forcing other species to migrate
   D. An organism with favourable genetic variations will tend to survive and breed successfully
2. Which of the following best demonstrated by the experiment in the Figure below?



   A. All frogs are genetically identical
   B. The nucleus of a tadpole cell is unspecialized
   C. Differentiated cells contain a complete set of genes
   D. Retains the physical characteristics
3. Which of the following best describes how DNA and RNA are similar?
   A. They both are formed in a double-helix structure
   B. They both are composed of five different nucleotides
   C. They both contain the nitrogen bases cytosine and guanine
   D. They both contain the nitrogen bases thymine and adenine

4. If a set of instructions that determines all of the characteristics of an organism is compared to a book, and a chromosome is compared to a chapter in the book, then what might be compared to a paragraph in the book?

   A. An egg
   B. An amino acid
   C. A DNA molecule
   D. A starch molecule

5. Research applications of the basic principles of genetics have contributed greatly to the rapid production of new varieties of plants and animals. Which activity is an example of such an application?

   A. Testing new fertilizers on food crops
   B. Using natural predators to control insect pests
   C. Developing new irrigation methods to conserve water
   D. Selective breeding of plants and animals that exhibit high resistance to disease

6. Which process is correctly matched with its explanation?

Sl. No.	Process	Explanation
1	Natural selection	The most complex organisms survive.
2	Gene recombination	Genes are copied as a part of cell division.
3	Extinction	Adaptive characteristics of species are not adequate.
4	Mutation	Overproduction of offspring takes place within a certain population.

   A. 1
   B. 2
   C. 3
   D. 4

7. Darwin published '*On the Origin of Species by Natural Selection*.' This information is most closely associated with

   A. the effect of carrying capacity on the size of populations.
   B. the reasons for the loss of biodiversity in all habitats on the Earth.
   C. an attempt to explain the structural similarities observed among diverse living organisms.
   D. an explanation for the change in types of minerals in an area through ecological succession.

8. Genes are inherited, but their expressions can be modified by the environment. This statement explains why

   A. animals can be cloned, but plants cannot.
   B. identical twins, who grow up in different homes have the same characteristics.

C. some animals have dark fur only, when the temperature is within a certain range.

D. offspring produced by means of sexual reproduction look exactly like their parents.

9. Which one among the four theories is considered as the most accepted and relevant theory in the 21st century that supported evolution?

A. Lamarckism C. Neo-Darwinism

B. Darwinism D. Germplasm

10. How is natural selection in the evolution of long necks in giraffes, best explained?

A. Shorter-necked giraffes were killed by long-necked giraffes

B. Giraffe necks grew longer because of the bone structure of the animals

C. Giraffes with longer necks survived because they were better suited to the environment

D. Long-necked giraffes mated only with other long-necked giraffes

B. Explain the following terms.

1. Variation
2. Clone
3. Evolution
4. Genetically modified organism
5. Natural selection

C. Name the following.

1. The fundamental hereditary unit of an organism.
2. A farmer selects certain parental characters and crosses to produce offspring with specific qualities.
3. The technique of manipulation of genes to obtain the desired useful characters.
4. Numerous identical molecules were produced in a laboratory by copying individual DNA molecule.
5. The organs having same basic structure but have different functions.

D. Differentiate between the following pair of words.

1. Gene and chromosome.
2. DNA and RNA.
3. Genetic engineering and selective breeding.

4. Somatic cell nuclear transfer and embryo splitting.
5. Genetic variation and environmental variation.

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

Column I	Column II
1. Lamarckism	a. Like begets like, but not always.
2. Germ cells	b. The variations arise spontaneously and are selected by environmental pressure.
3. Darwinism	c. All that is acquired in an organism's lifetime may be transmitted to the offspring in reproduction.
4. Neo-Darwinism	d. The substances called 'gametes' passed from parents to offspring were not changed by surrounding body cells.

F. Give reasons for the following statements.

1. Genetic engineering is simply an extension of traditional breeding practices.
2. All human beings are all related, but we don't look the same.
3. Species that are less adapted to environmental conditions are eliminated.
4. Genes are instruction manuals in our body.

G. Answer the following questions.

1. Write two functions of RNA.
2. Explain, how discovery of fossils provide the evidence for evolution.
3. Genes are inherited, but their expressions can be modified by the environment. Explain this statement.
4. If evolution is true, then why are there so many gaps in the fossil records? Explain.
5. A farmer allows his cow to breed with a 'mithun' to produce an offspring. What could be the main objectives of her selective breeding?
6. Justify the statement that 'human cloning is not morally and ethically right'.
7. State any two evidences that support evolution of animals and plants on earth.
8. Explain how analogous organs support evolution?
9. If a father is a body builder who has huge mass of muscles in his body, will his son inherit it or not? Justify.

10. Lists the factors that affect the natural selection processes as per Charles Darwin.
11. Observe the Figure on the right and answer the questions 'a' through 'c'.

    a. Name the theory that explains why a giraffe has long neck.

    b. How does this theory contradict with the theory of Neo-Darwinism.

    c. In what ways, this theory is similar to the theory of natural selection.

12. You may not be able to tell a genetically modified fruit (e.g. strawberry) from its natural counterpart. They may look the same. Based on this statement and the figure below, answer the questions 'a' through 'd'.

    a. Name the method used to produce genetically modified fruit.

    b. What makes the strawberries different?

    c. What advantage does the genetically modified fruit have over its natural counterparts?

    d. "Bhutan will immensely benefit by adopting the production of GM foods". Justify for or against the statement.

Natural strawberry

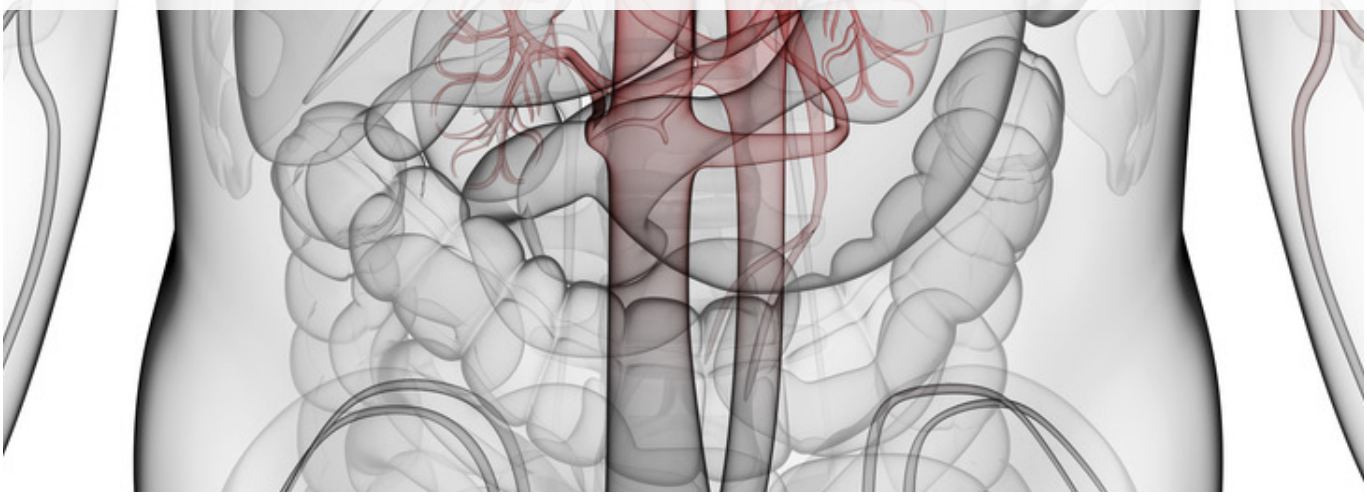
Genetically modified strawberry

9 Health and Harmful Substances

Good health is essential for all living organisms. There are several natural self-regulating chemical processes that take place in the body of organisms. These processes tend to maintain a steady state within an external environment which is likely to change. Our body is under constant attack. Microorganisms are continually trying to get inside our body and multiply. Fortuntely, our body has a powerful immune system to repel the invaders.

There are several substances which are harmful that affect our health by altering the natural feedback mechanisms of our body.

Substance abuse is common phenomenon that affects our health and the consequences are sometimes fatal.



A. Homeostasis and Body Control System

Learning Objectives

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

- explain homeostasis.
- express the importance of human body to maintain a constant internal environment.
- explain how human body maintains constant body temperature.
- describe the roles of the skin, blood and mucous membranes of the respiratory tract for the defense mechanisms of our body.

All biological systems tend to **maintain stability**, while adjusting to conditions that are optimal for survival. Our body functions best on a relatively stable external and **internal environment**. We are often exposed to varying external environments like heat, pressure, light intensity etc., that influence our internal environments, such as body temperature, blood pressure, and the composition of body fluids. However, **our body self-regulates to maintain a stable internal environment** by adjusting to the change.

a. Homeostasis

The **ability of a body system to regulate or maintain a constant internal environment in response to the changes in the external environment**s is called homeostasis. It is often stated as the maintenance of a steady state within an organism. There are a variety of mechanisms and vital functions that are maintained through homeostasis; such as **blood glucose**, **blood pH**, **blood pressure**, **body temperature**, **oxygen** and **carbon dioxide** levels, etc. An advantage of homeostatic regulation is that it **allows the organism to function effectively** in a wide variety of **environmental conditions**. For example, **when the concentration of carbon dioxide** in the human body increases, lungs are signaled to increase their activity and expel more carbon dioxide. If we get hot, our body sweats; if we are cold, the body shivers; if we are hungry, we have an urge to eat; if thirsty, we get an urge to drink, and so on.

9.1 Activity

Standing on your foot

Stand up and balance yourselves on one foot for several minutes, and note the changes you feel as the time passes. Stop as you feel tired, go to your sit and answer the following questions.

1. What happened to your body balancing, over the period of time during this activity?

2. What do you think would happen to your body, if you keep standing on one foot for long time?
3. Why do you think you feel like using other foot to stand, or feel like resting after some time?
4. What happens to your body on resting after the activity?
5. Relate your experiences of this activity with that of homeostasis.

Homeostatic regulation involves the receptor, the control centre and the effector. The **receptor receives information** that something in the environment is changing. The control centre receives and processes information from the receptor. The **effector**, then **responds** to the commands of the control centre. This is a continuous process, spontaneously working to **restore and maintain the homeostasis** in the body. For example, **in regulating the body temperature**, the temperature receptors in the skin communicate information about the changing temperature to the brain, which is the control centre; the effector finally influences **blood vessels** and **sweat glands** to bring back the body temperature to normal.

b. Positive and negative feedback

The body system responds to changing environment through **two** types of **feedbacks mechanisms**– positive and negative feedback mechanisms.

i. Negative feedback mechanism

The **body system responds to the change in external environment**, in such a way as to reverse the direction of the change. For instance, **if we eat lots of food containing high sugar**, the glucose concentration in our body rises above the normal range. The body then activates pancreas to release a hormone called insulin, which stimulates the absorption of glucose to help return the blood sugar level to normal. Thermoregulation is another example of *negative feedback*. The main organ involved in the the regulation of body temeprature (thermoregulation) is the skin which accounts for about 80% of total heat loss in the body. The **temperature receptors** in the skin communicates information about changing temperature to the **hypothalamus** in the brain, which is the **control centre**. The body then **stimulates heart** to pump more blood to increase the temperature to normal. The changes in atmospheric temperature do not affect our body temperature because **our body maintains its temperature at a constant** by losing excess heat or conserving and gaining the required heat from the surroundings. Most control systems in our body works through **negative feedback mechanism**.

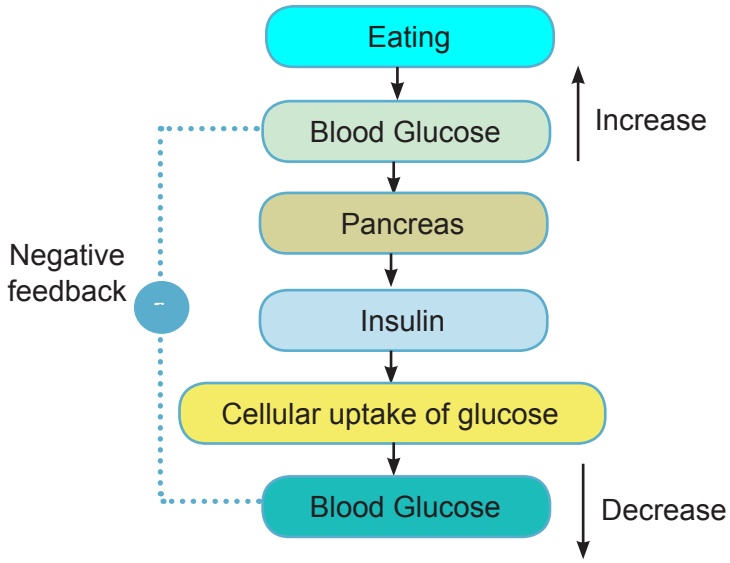


Figure 9.1. Negative feedback mechanism in maintaining blood glucose level

ii. Positive feedback mechanism

Positive feedback mechanism works in opposite to **negative feedback mechanism**. Instead of restoring the body to a normal state, positive feedback mechanism **increases the change**. For example, **during childbirth**, as the baby's head is ready to move out of the mother's body, the release of an oxytocin hormone intensifies the contractions, thus pushing the baby out. In this instance, the body responds to an event to amplify the change. **Positive feedback mechanism** is less common in naturally occurring systems than negative feedback mechanism, but it has its applications. **Lactation** involves positive feedback mechanism, so that more the baby suckles, the more milk is produced.

Positive feedback mechanism can be harmful at times. For example, **when you are suffering from a high fever**, it causes a metabolic change that can push the fever even higher, which may lead to death in extreme cases.

9.2 Activity

Researching your exercise

Materials required: Pencil, stopwatch, handouts.

Procedure

1. Take your pulse and the number of breath for 60 seconds to get your resting pulse rate and respiratory rate. Copy the given Table 9.1, and record the value obtained in it.
2. Do jumping jacks for one minute.

3. Take your pulse immediately after exercises by repeating the Step 1 to measure pulse rate and respiratory (breathing) rate. Record your reading in the table.
4. Repeat steps 1 to 3 with other group members in your group.
5. Calculate the increased rates of your pulse and breathe.
6. Take your pulse rate after 2 minutes, 3 minutes, etc. until pulse rate returns to normal.

Table 9.1

Sl. No.	Pulse rate (1 minute)		Pulse rate (1 minute)	
	During resting	During exercise	During resting	During exercise
1				
2				
3				
Average				

Questions

i. What is the difference in pulse rates at resting and right after the exercise?
ii. Why do you think that heart beats increased during exercise?
iii. Why do you think that changes occurred in our body during the exercise?
iv. Name the mechanism that makes the pulse rate and respiratory rate to come back to normal levels after exercises?
v. Draw a sketch of the feedback loop of the given activity.

c. Maintenance of a constant body temperature

Humans are endothermic, who can **maintain relatively constant body temperatures independent** of the environmental temperature. The normal internal temperature for the human body is **37°C** (98.6°F). Fluctuations of body temperature from the normal range results in abnormal body functioning. At extremes of 45°C, c**ellular proteins denature**, **causing metabolism to stop**, and **ultimately death of cells**. At temperatures lower than the normal, the enzymes in our body would not be activated.

The nerve endings in the skin are **receptors**, which sense the change in external temperatures and transmit the message to temperature receptor in an area of the brain called hypothalamus. The hypothalamus, on receiving the information from the **temperature receptors**, triggers the **effectors** automatically. The effectors include **sweat glands** and **muscles**. At temperature higher than the normal, more sweat is produced by sweat glands, **which cool the body on evaporation**. The **blood vessels** supplying to the skin **dilate** allowing more blood to flow through, which increases the heat loss. This process is called vasodilation.

If the body temperature decreases below the normal level, the increased rate of

respiration **stimulate muscles to contract** rapidly, resulting in shivering and warming of the surrounding tissues. **Blood vessels** supplying to the skin also **constrict**, restricting the blood flow through skin **capillaries**, which reduces heat loss. This is called vasoconstriction.

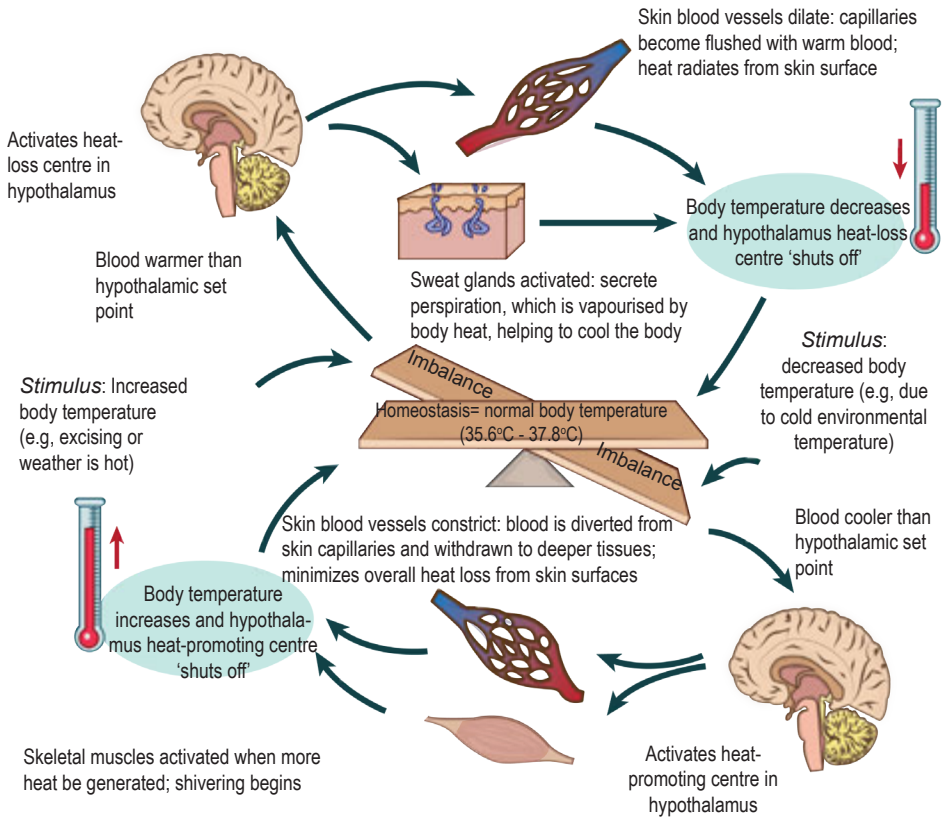


Figure 9.2 Body temperature is regulated by a negative feedback mechanism.

Activity 9.3

Investigating fluctuations in human body temperature

Materials required: clinical thermometer, stop watch, graph papers.

Procedure

1. Sit still. Record your body temperature after every 2 minutes for a period of 6 minutes.
2. For accuracy, standardize your method: shake the thermometer each time until the fluid reaches the same low point on the scale; then place the bulb of the thermometer under your armpit in exactly the same position for exactly 60 seconds; then wait exactly 60 seconds, before inserting the thermometer again.
3. Exercise moderately for 2 minutes by jogging, and record your temperature immediately, and then again, after 2 and 5 minutes. Plot these temperatures on a graph.
4. Exercise vigorously for 2 minutes by running up and down the stairs, and record your temperature immediately, and again, after 2 and 5 minutes. Plot these temperatures on a graph.

Questions

i. What hypothesis can you suggest to explain your observations?
ii. What differences can you observe in the body temperature, while you are resting, and during the mild and vigorous exercising?
iii. What are the immediate and long-term results of moderate and vigorous exercises?
iv. Are these results consistent with those of other members of the class?
v. Suggest what is happening in your body that would explain your observations.
vi. What do you think would be the type of feedback mechanism involved in this activity?

d. Defence mechanisms of our body

Our body is constantly in contact with harmful germs like bacteria, viruses, fungi, etc., yet we survive because our body's immune system defends against these pathogens. A pathogen is a disease-causing germ. Human body has two lines of non-specific defence mechanism against pathogens: **first line of non-specific defence mechanism** and **second line of non-specific defence mechanism**. **Third line of defence mechanism** is the immune response which is specific.

i. First line of non-specific defence mechanism.

This mechanism works against most infections. It involves blocking of entry of pathogens in the body or destroying them in case they manage to enter the body. This includes:

1. Skin: The skin forms human body's first defence against infection, which is non-specific, meaning they do not target specific pathogens.

Skin acts as a nearly **impenetrable barrier** to invading pathogens. Its defensive capacity is enhanced by **acidic surface** formed by **oil** and **sweat**, which inhibit the growth of pathogens. Sweat also contains the enzyme called lysozyme, which digests cell walls of bacteria.

2. Mucous membranes: The inner-linings of the body through which pathogens can pass are covered by **mucous membranes**. Mucous membranes line digestive system, nasal passages, lungs, respiratory passages, and the reproductive tract and produce **sticky**, **viscous fluid** called mucus. Mucous membranes line the digestive system, Like the skin, mucous membranes serve as a **barrier to pathogens** and produce **chemical defences**.

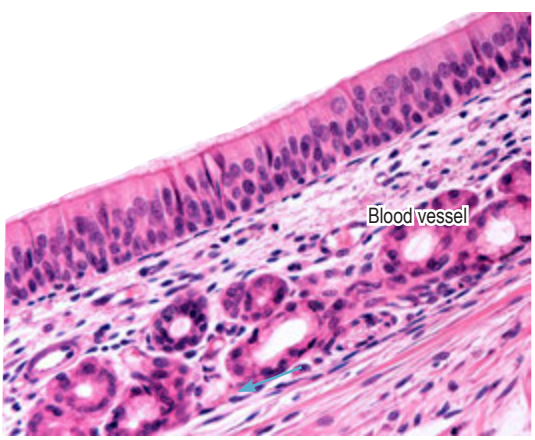


Figure 9.3 Mucous layer of trachea wall

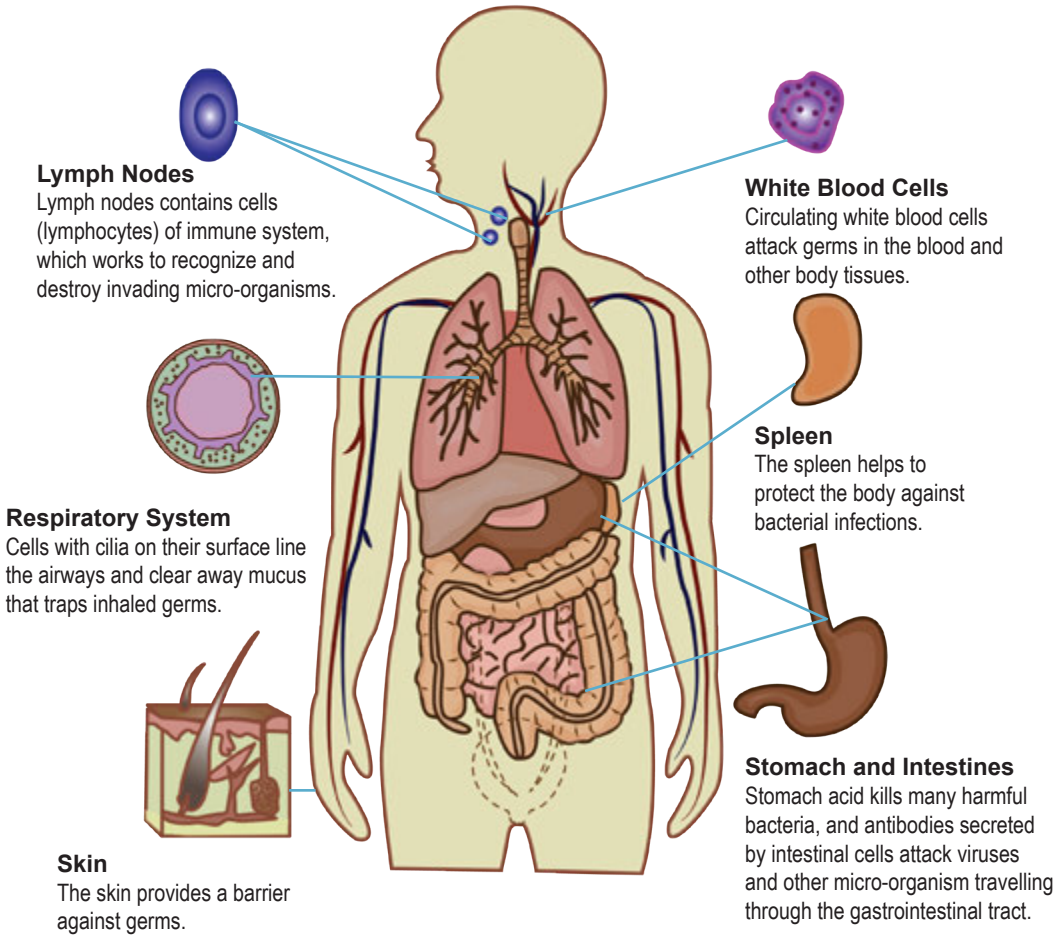


Figure 9.4 Human body defence against infection

Cells lining the **bronchi** and **bronchioles** in the **respiratory tract** secrete a layer of mucus that traps pathogens before they can reach the warm, moist lungs, which are an ideal breeding ground for **microorganisms**. Cilia of the respiratory tract, shown in Figure 9.5, continually sweep mucus towards the opening of the **esophagus**. Mucus is swallowed along with pathogens and reaches the **stomach**. **Acids** and **enzymes** in the stomach **digest the pathogens**.

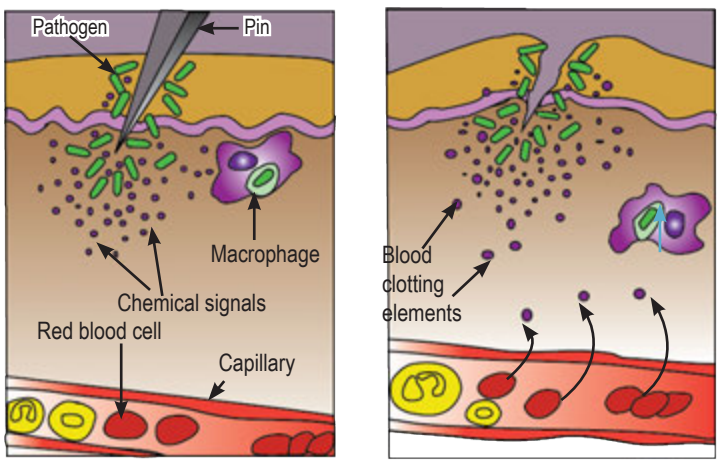
Figure 9.5 Cilia of respiratory tract

Therefore, **skin** and **mucous membranes** work to prevent any **pathogens** from entering the body. Occasionally these defences are penetrated and reach deeper tissues, the **second line of nonspecific defences** takes over. Pathogens enter our body through breathing, food we eat or through wounds or open sores.

ii. Second line of nonspecific defences

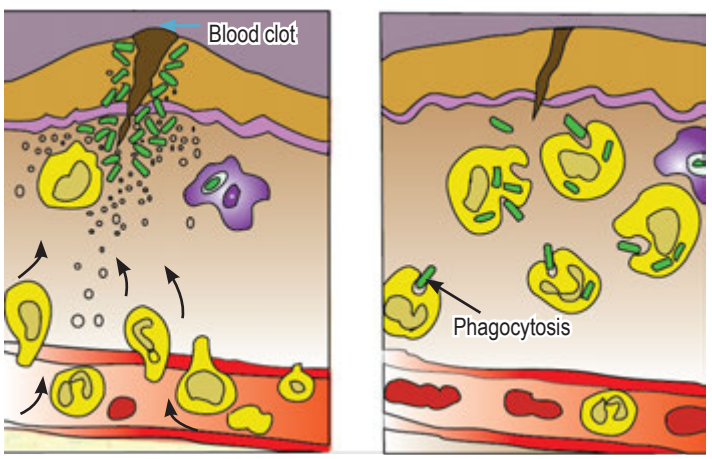
The inner non-specific defence is activated, when pathogens break through the first defence of the body. It may be through *inflammatory response*, *temperature response*, and attack and killing of pathogens by **white blood cells**. *This includes as follows*:

1. Inflammatory response: Injury or local infection, such as a cut or a scrape, causes an inflammatory response. It suppresses infection and speeds the recovery. The cut or punctured skin creates an entrance for pathogens. Infected or injured cells in your skin release chemicals, including **histamine**, which causes local blood vessels to dilate, increasing the blood flow to the area. Increased blood flow brings more white



❶ Chemical signals released by activated macrophages and mast cells at the injury site cause nearby capillaries to widen and become more permeable.

❷ Fluid, antimicrobial proteins and clotting elements move from the blood to the site. Clotting begins.



❸ Chemokines released by various kinds of cells attract more phagocytic cells from the blood to injury site

❹ Neutrophils and macrophages phagocytose pathogens and cell debris at the site, and the tissue heals.

Figure 9.6 Inflammatory response

blood cells to the infected site, where they attack pathogens. This causes swelling and redness in the infected area. The **whitish liquid** or **pus**, associated with some infections, contains **white blood cells**, **dead cells**, and the **dead pathogens**.

2. Temperature response: When the body begins its fight against pathogens, body temperature increases several degrees above the normal value. This higher body temperature is called fever, which is a common symptom of illness, and it indicates that the body is responding to an infection. The fever does not support the growth of many disease-causing bacteria, as they do not grow well at high temperatures. Although fever may slow the growth of bacteria, very high fever is dangerous because extreme heat can **destroy important cellular enzymes**. Temperatures greater than 39°C are considered dangerous, and those greater than 41°C can be fatal.

3. White blood cells: The most important counterattacks in the second line of nonspecific defences are the actions of **three kinds** of white blood cells: neutrophils, macrophages, and natural killer cells. These cells patrol the bloodstream and attack the pathogens if any in the blood. Each kind of cell uses a different mechanism to kill pathogens.

Figure 9.7 Macrophage. Cytoplasmic extensions of this macrophage capturing bacteria.

Neutrophils: A neutrophil is the most abundant type of white blood cells. Neutrophils **engulf pathogens** and **release chemicals** that kill the bacteria and themselves, thus, sacrificing themselves to defend the body. Neutrophils have the **abilities to squeeze between cells in the walls of capillaries** to attack pathogens at the site of an infection.

Macrophages: A type of white blood cells called macrophages, shown in Figure 9.7, **ingest** and **kill** pathogens they encounter. They also clear dead cells and other debris from the body. Most macrophages travel through the body in **blood**, **lymph**, and

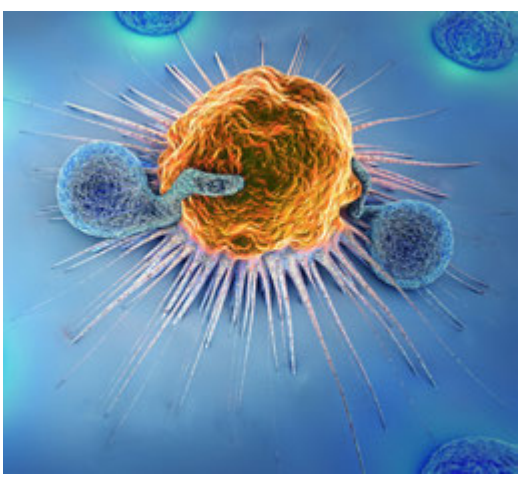


***Figure 9.8 Natural killer cell** (yellow) **attacking a cancer cell** (pink).*

fluid between cells. **Macrophage**s are concentrated in particular organs, especially the **spleen** and **lungs**.

Natural killer cells: A natural killer cell is a large white blood cell that attacks cells infected with pathogens. Natural killer cells **destroy** an infected cell by puncturing its cell membrane. Water then rushes into the infected cell, causing the cell to swell and burst. Natural killer cells can **detect and kill cancer cells** before a tumor can develop, as shown in Figure 9.8. They also attack body cells infected with viruses.

iii. Immune response: The third line of defence mechanism

When pathogens survive the first and second lines of non-specific defences, a **third line of specific defence mechanism** called immune response comes into effect. The immune response consists of an army of individual cells called antibodies that move throughout the body. Antibodies are c**hemicals that stick to specific kinds of germs, weakening 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**.

The immune system consists of cells and tissues found throughout the body. The most important characteristic of this system is its ability to recognise its own cells and **macromolecules** from **invaders** and **non-self**. The **foreign molecules** that enter the body are called antigens. They are large molecules found on the cell wall of **bacteria** and coats of **viruses**.

During the immune response, **the antibodies react with the invading germs** (**pathogens**) to destroy them, thus they provide protection against diseases (immunity). Immunity is the **ability of an organism to produce resistance** against infection of some specific disease. It can be categorised into two: natural or innate and acquired or artificial.

1. Natural or inborn immunity is also known as innate immunity. This type of immunity is due to genetic composition of the body. It is there in the body without any external stimulation or a previous infection. This type of immunity is of two types: non-specific innate immunity and specific innate immunity.

2. Acquired or artificial immunity is **resitance** or **immunity** to a disease acquired by an individual during lifetime due to external stimulation or previous infection. This type of immunity is **usually long lasting** because once a person acquires immunity against particular pathogen or disease, one normally does not get it agian. For example, if one gets infected with **polio** or **measles** once, one normally does not get infected later in ones life with the same disease. This type of immunity is also of two types: active immunity and passive immunity.

B. Harmful Substances

Learning Objectives

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

- define harmful substances with examples.
- explain the effects of substance abuse on human.
- explain the effect of solvents on humans.

Substance is a matter with a definite chemical composition. **Harmful chemical substance** are a solid, liquid, or gas that through its chemical or physical properties, **alone or in combination with one or more other chemical substances**, can be used to **cause death**, **injury** or **disease** in humans, animals or plants. The legal use of drugs and substances are **indispensable for medical**, **veterinary** and **scientific purposes**. However, illegal use of drugs and substances can ultimately lead to a serious threat to individuals and to the community. Some of the pertinent effects of harmful substances are *discussed in this chapter*.

a. Drugs

A drug is a chemical substance, other than food that has **known biological effects** on humans or other animals. It changes the way we think, feel and behave. It also effect on how our body works. For example, as a person contnues to take drugs the body becomes more tolerant of them and larger amounts of the drug have to be taken for the person to feel its effects. A **drug-taker**' s brain or body generally gets used to the drug that it **becomes physically dependent** on the drug. This is known as addiction. If a person stops taking drugs the body reacts in a range of harmful, often self-destructive, behaviours and sickness. These reactions are referred to as withdrawal symptoms. The drug addicts become **psychologically dependent** on it. They become upset if they are not taking it and develop the irrational fear that they cannot cope with life without the drug.

Substance abuse

Drugs are used to **treat** an illness, **prevent** a disease and **improve health** condition. However, the use of a substance in which the user consumes the substance in amounts or with methods which are **harmful** to themselves or others is called substance abuse or drug abuse.

Any abuse can lead to **addiction**, and affect our health in many ways. Drug addiction is the *continued compulsive use of drugs*, despite adverse health or social consequences. The consequences of drug abuse are vast and varied and affect people of all ages.

b. Effects of substance abuse

Some of the effects of drugs and its substances are *discussed* below.

Alcohol: Consumption of alcohol can **damage the brain** and most body organs. Areas of the brain that are impacted by alcohol are responsible for our higher brain functions, including problem solving, decision making, memory, learning, and movement coordination. Some important effects of alcohol are given in Figure 9.9.

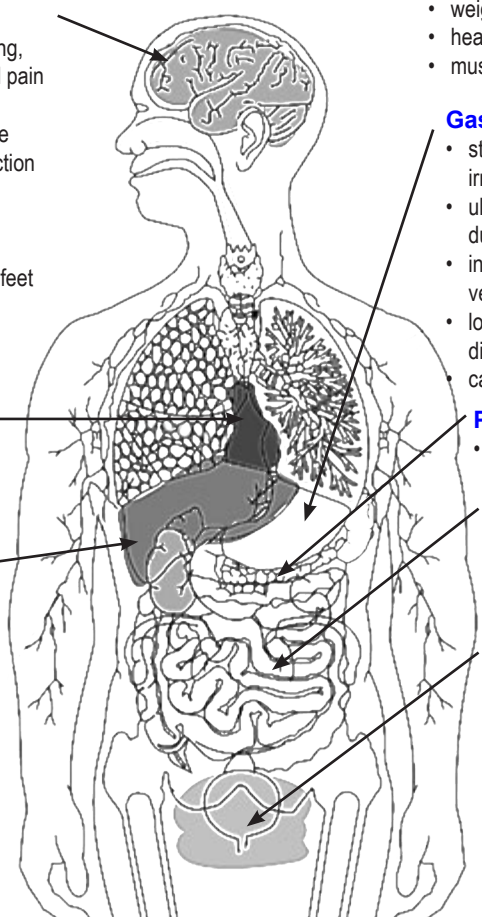


Figure 9.9 The long term effects of alcohol

Nicotine: It is an addictive substance found in **cigarettes**, and other forms of **tobacco** use. **Tobacco smoke** increases the *risk of cancer*, *emphysema*, *bronchial disorders*, and *heart diseases*. Tobacco use killed approximately 100 million people during the 20th century and, if the current smoking trend continues, the cumulative death toll for 21st century has been projected to reach 1 billion. The most damaging components of tobacco smoke are:

Tar: It is a sticky and brown chemical, which stains teeth, fingernails and lung tissues. Tar contains several **cancer-causing substances** called carcinogens.

Carbon monoxide: This odourless gas is fatal in large doses, because it takes the place of oxygen in the blood. Each **red blood cell** contains a protein called haemoglobin, which absorbs and transports oxygen molecules around the body. However, **carbon monoxide binds with haemoglobin better than oxygen**. This means that less oxygen reaches the brain, heart, muscles and other organs.

Do you know?

Recent discoveries in neuroscience and child psychiatry show that the brain is not really fully developed until after age 20 years. The brains of adolescents are therefore, more vulnerable to alcohol related damage than adult brains.

Hydrogen cyanide: The lungs contain tiny hairs called cilia that help to clean the lungs by removing foreign substances. **Hydrogen cyanide** stops this lung clearance system from working properly, which means, poisonous chemicals in tobacco smoke can build up inside the lungs. Other chemicals in smoke that damage the lungs include *hydrocarbons*, *nitrous oxides*, *organic acids*, *phenols* and *oxidising agents*.

Metals: Tobacco smoke contains dangerous metals including **arsenic**, **cadmium** and **lead**. Several of these metals are *carcinogenic*.

Marijuana: It is one of the most commonly abused substances. This drug effects **short-term memory** and **learning**, **reducing ability** to f**ocus attention**, and **coordination**. It also increases heart rate, can harm the lungs, and can increase the **risk of psychosis** in severe long cases.

Figure 9.10 Marijuana plant uprooting

Inhalants: These are **volatile substances** found in many household products, such as **oven cleaners**, **gasoline**, **spray paints**, **correction fluids**, **petroleum products**, and other **aerosols**. Inhalants are extremely toxic and can **damage the heart**, **kidneys**, **lungs**, and **brain**. Even a healthy person can suffer heart failure and death within a minute of a single session of prolonged sniffing of an inhalant.

Impact of addiction

- Cardiovascular disease
- Stroke
- Cancer
- HIV/AIDS
- Hepatitis B and C
- Lung disease
- Mental disorders

Do you know?

Can addiction be treated successfully?

YES. Addiction is a treatable health problem. Discoveries in the science of addiction have led to advances in drug abuse treatment that help people stop abusing drugs and resume their productive lives.

Cocaine: It is a short-acting stimulant, which can lead abusers to take the drug many times in a single session. **Cocaine abuse** can lead to severe medical consequences related to the **heart** and the **respiratory**, **nervous**, and **digestive systems**.

Prescription medications: If you take a medicine in a way that is different from what the doctor prescribed, it is called prescription drug abuse. Commonly abused classes of prescription drugs include **painkillers**, **sedatives**, and **stimulants**.

Every medicine has some **risk of side effects**. Doctors take this into account when prescribing medicines. People who abuse these drugs may not understand the risks. The medicines may not be safe for them, especially at higher doses or when taken with other medicines.

Drug combination: A particularly dangerous common practice is the c**ombining of two or more drugs without the advice from physician**. For instance, practice of taking drugs together, like **alcohol and nicotine**, or random mixing of prescription drugs. Such practices often pose significantly **higher risks** than the already harmful individual drugs.

Using alcohol with other drugs can magnify the effects of each drug and increase the harmful consequences. The results can be deadly. For example, alcohol combined with cocaine can **increase blood pressure** to dangerous levels.

Activity 9.4

Drug and Substance Abuse Acts of Bhutan

Following are some of the Drug and Substance abuse Acts of Bhutan. Read through it and answer the questions that follow:

1. *The Royal Government shall constitute a "Narcotics Control Board" to take all such measures for the purpose of preventing and combating the abuse and illicit trafficking, and to regulate the use of narcotic drugs, psychotropic substances and other controlled substances.*
2. *Advertisement of controlled drugs to the public without authorization shall be an offence. A defendant shall be guilty of the offence of illegal transaction of controlled substances, if the defendant unlawfully, imports, exports, sells, purchases or transports any precursor.*
3. *Cultivation of opium poppy and coca bush shall be an offence.*
4. *Cultivation and domestication of cannabis shall be an offence.*
5. *Harvesting or collection of cannabis shall be prohibited, except for production of fibre and animal feed.*
6. *The owner, operator, or occupier, under whatever title, of land for agricultural or other use shall be required to destroy any opium poppies, coca bushes or cannabis plants found growing there.*
7. *Anyone who informs the authorized agency of the transaction or use of narcotic drugs which leads to the proving of a criminal offence and of the offender the informant shall be rewarded as specified in the Rules and Regulations.*

Questions

i. Why do you think there is a need for the Bhutan government to set up Narcotics Control Board?

ii. What would be the implications to people, community and to the country if Bhutan government allows farmers to grow *Cannabis* plants? Discuss both its pros and cons.

iii. Why do you think would happen if there are lots of drugs transactions in the country?

iv. How would you as a good citizen play role in making a 'drugs free country'?

c. How can addiction harm other people?

Besides the harmful consequences for the addicted individual, **drug abuse** can cause serious health problems to others. Three of the more devastating and troubling **consequences of addiction** are:

a. Prenatal drug exposure on infants and children

The consumption of drugs or abuse of substances **during the pregnancy** is likely to **transmit the effects to their offspring**. Children may also adopt the habits of drugs abuse from adults, parents, and friends. It is likely that some **drug-exposed children** will have **poor memory**, **behavioural problem**, and **cognitive abilities**, and therefore, will need educational support to help them overcome learning difficulties.

a. Effects of second-hand smoke

Second-hand smoke, also referred to as environmental tobacco smoke is smoke from burning tobacco products, such as **cigarettes**, **cigars**, or **pipes** and is also smoke that has been exhaled, or breathed out, by the person smoking. It contains over a thousand different chemicals, including highly **addictive substances nicotine** that pollutes the environment and the surroundings. This has a significant effect on the health of the people in the surrounding. It increases the **risk of heart diseases** and **lung cancers** for the people in the surrounding. The risk is more for infant children that causes damage to their **respiratory system** leading to **respiratory infections**, **ear infections**, etc.

c. Increased spread of infectious diseases

Injection of drugs such as **heroin**, **cocaine**, and **methamphetamine** accounts for more than a third of new AIDS cases. Injection drug use is also a major factor in the spread of **hepatitis B**, a serious, potentially fatal liver disease. Besides, all drugs intoxication interferes with judgement and increases the likelihood of risky sexual behaviours. This, in turn, contributes to the spread of **HIV/AIDS**, **hepatitis B** and **C**, and other **sexually transmitted diseases**.

Activity 9.5

Into The Dark World

Read the following story and answer the questions that follow.

For most of his 19 years of life, he was a "normal kid", who enjoyed the school days very much and participated in every activity. Every winter vacation, he looked forward for the trip to *Bodha Gaya* with his lone mother. He was the youngest of the siblings, and dearest to his mother. Drugs and alcohol had never been a problem in their family. "I didn't drink, smoke or chew tobacco," he said. But, after his mother's sudden demise, everything was changed in his life.

He seems stressed all the time, and has grown very weak within a few months. His friends are shocked to see him abusing substances. He now hardly attends classes or participates in any of the school activities. Recently, he was also blamed for gang fights and robbery cases. He never seeks advice from his friends and teachers but he keeps on saying, "I have lost everything in my life, and I am left with no reason to live'.

Questions

i. Identify the reasons that have driven him into drug?
ii. Do you think he has taken right ways to get relieved from his stress?
iii. Do you think that he is an addict? Support your answer.
iv. What could be the possible impacts of his condition to the surrounding community?
v. You as a very good friend, suggest some ways to him on how to break away from this serious situation.

d. Effects of solvents

Solvents are chemicals found in **glue**, **paint**, **nail varnish**, **gas canisters**, **lighter fuel** and some **cleaning fluids** and can cause changes in the body if inhaled in significant amounts. When solvents are **sniffed**, the chemicals produce an effect similar to drunkenness as it affects the **central nervous system** and **muscles**. The sniffer has a weird short-term effects such as **distorted perceptions**, **hallucination** and **personality changes**. Long-term effects of solvent abuse include *damage to the brain*, *lungs*, *liver* and *kidneys*. It can also lead to heart attack and sudden death. All solvents, natural or synthetic, are toxic and they affect our body in following ways.

1. **Skin contact**: All solvents can dissolve the skin's protective barrier of oils, drying and chapping the skin and causing a kind of **dermatitis**. In addition, some solvents can cause severe burns and irritation of the skin.
2. **The eyes and respiratory tract**: All solvent vapours can irritate and damage the **sensitive membranes** of the eyes, nose, and throat.
3. **The nervous system**: All solvents can affect the **brain** or **central nervous system** (**CNS**) causing '*narcosis*.'
4. **Damage to internal organs**: There is considerable variation in the kinds and degrees of damage different solvents can do to internal organs such as the liver and kidneys.

Summary

- The ability of a body system to regulate or maintain a constant internal environment, despite the changes in the external environments is called homeostasis.
- Homeostatic regulation involves receptor, control centre and effectors.
- The body systems maintain homeostasis by positive or negative feedback mechanisms.
- The body system responds to the change in external environment, in such a way as to reverse the direction of change is called negative feedback mechanisms.
- Instead of restoring the body to a normal state, positive feedback mechanism increases the change.
- Humans are endothermic and maintain relatively constant body temperatures of 37°C.
- Disease-causing germ is called a pathogen.
- The body has nonspecific and specific defense mechanisms to prevent infection and to destroy pathogens.
- Skin and mucous membranes work to prevent any pathogens from entering the body.
- Three kinds of white blood cells are neutrophils, macrophages, and natural killer cells.
- A drug is a substance, other than food, which is taken to change the way the body or the mind functions.
- Intake of drugs for reasons other than medical in a manner that affects themselves or others is termed as drug abuse or substance abuse.
- Substance abuse can cause cardiovascular disease, brain stroke, cancer, HIV/AIDS, hepatitis B and C, lung disease and mental disorders.
- If any medicine is taken in a way that is different from what the doctor prescribed, it is called prescription drug abuse.
- A particularly dangerous common practice is the combining of two or more drugs without the advice from physician.
- Drug abuse can cause serious health problems for self, and affect the lives of others around.

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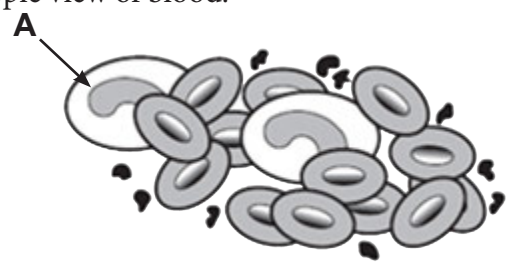
Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. Homeostasis is also termed a dynamic equilibrium because
   A. the body maintains an internal balance within fluctuating limits.
   B. in homeostasis, parts of the system change but the overall system stays constant.
   C. it involves balancing between internal and external temperature.
   D. the body recovers itself from the sickness and injures.
2. How would the body respond to an increased environmental temperature?
   A. Hairs on body erect
   B. Shivering
   C. Redness in face
   D. Sweating
3. The continued compulsive use of addictive substance, despite adverse health or social consequences, is
   A. substance abuse.
   B. drug abuse.
   C. drug addict.
   D. medication.
4. When a person does strenuous exercise, small blood vessels (capillaries) near the surface of the skin increase in diameter. This change allows the body to be cooled. These statements best illustrate
   A. synthesis.
   B. excretion.
   C.homeostasis.
   D. locomotion.
5. Increased blood flow to the infection site, brings
   A. pathogens.
   B. fever.
   C. white blood cells.
   D.pain.
6. The diagram below represents a microscopic view of blood.

   Cell A protects the body by producing specific chemicals in response to pathogens. Cell A is

   A. a red blood cell.
   B. a white blood cell.
   C. an insulin-producing cell.
   D. a bacteria cell.

7. pH balance of the body is regulated by
   A. kidneys.
   C. hypothalamus.
   B. liver.
   D. heart.
8. When you smoke a cigarette or chew tobacco, you ingest or absorb which of the following harmful chemicals?
   A. Cyanide (a poison)
   B. Benzene (a toxic liquid, sometimes used as motor fuel)
   C. Formaldehyde (a substance used to preserve dead things)
   D. All of the above
9. This drug, which is used as an animal tranquilizer, can cause users to hallucinate, vomit, lose their sense of time, and even stop breathing.
   A. Cocaine
   C. Ketamine
   B. Ecstasy
   D. Painkiller
10. When a person gradually needs a larger dose of s drug to get the same effects, it is referred to as
   A. relapsing.
   C. addiction.
   B. withdrawal.
   D. tolerance.

B. Write TRUE or FALSE for the following statements.

1. Maintaining blood glucose level in human is an example of homeostasis.
2. When our body temperature become higher than the normal, more sweat is produced by skin glands.
3. Cytotoxic T cells attack and kill infected cells in the body.
4. Inflammatory response increases infection and reduces recovery.
5. Sweat contains an enzyme called lysozyme, which digests cell walls of bacteria.

C. Name the following.

1. Body system, which defends against disease causing germs.
2. Inner-linings layers of epithelial tissue that produces sticky, viscous fluid.
3. The organic liquids used to dissolve solid materials.
4. Substance, other than food, which is taken to change the way the body or the mind functions.

5. The causes of swelling and redness in the infected area.

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

1. Humans are endothermic who can maintain relatively constant body …….
2. At temperatures lower than the normal body temperature, the ……. in our body would not be activated.
3. The part of brain where temperature receptors are present is called …….
4. The …….. forms human body's first defense against infection.
5. The white blood cells are produced in ……. and circulate in blood and lymph.

E. Differentiate between the following pairs.

1. Positive and negative feedback mechanisms.
2. Specific and non-specific defense system.
3. Receptor and effector.

F. Answer the following questions.

1. Explain, why taking a drug that reduces fever might slow rather than hasten your recovery from an infection.
2. How does temperature response of the body help in homeostasis?
3. What are the impacts of addiction on other people?
4. Why is taking a prescription drug in a manner different from the way it was prescribed so dangerous?
5. What do you think are two significant challenges the human body faces at very high altitude? Explain.
6. Study the table given below and answer the questions that follow.

   Number of admission and death in Jigme Dorji Wangchuck National Referral (JDWNR) Hospital in 2005-2010 by liver diseases due to alcohol consumption.

Year		2005	2006	2007	2008	2009	2010	Total
Alcohol liver disease	Admission	1217	1531	1471	1329	1602	1943	9093
	Death	92	104	98	98	133	122	647

a. Plot a point graph using the above data.

b. Explain the trend of the number of liver diseases and the number of death cases.

C. How will you play your role to reduce this trend?

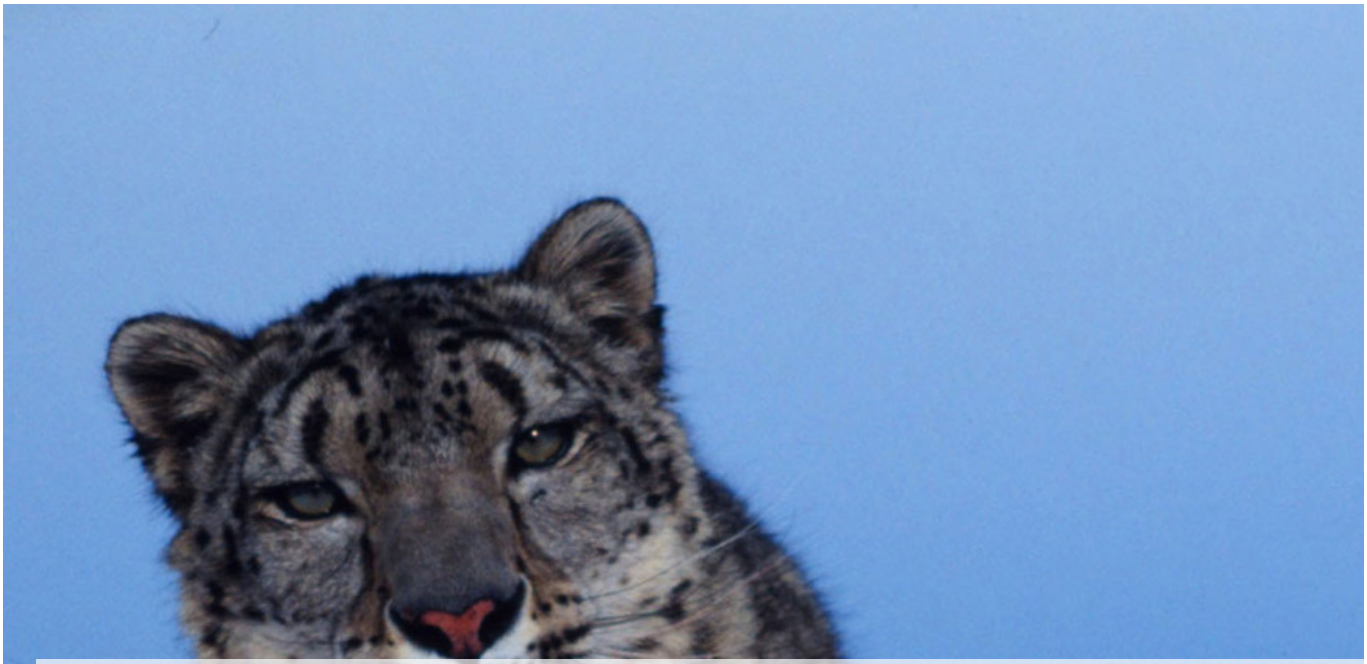
7. Answer the questions by referring the table given below.

Year	Supply of hard drinks in the capital from the distilleries in Gelephu, Samtse and Samdrup Jongkhar
2003 - 2004	63,000 cases
2005 - 2006	67,000 cases

a. What would be the possible impacts of increased supply of alcohol in Thimphu?

b. How will this impact on the health of customers?

8. Impaired thinking and coordination are dangerous side effects that result from mixing marijuana and alcohol. What are some harmful consequences that might result from this combination?



10 Organisms in Its Environment

We see diverse and wonderful organisms in our environment. All organisms do not thrive well in all places. They live in a specific habitat in an ecosystem and interact with other living organisms and abiotic world for their survival. Microbes, producers and consumers interact with each other in different ways to maintain the equilibrium of the environment. All organisms need certain elements such as carbon, nitrogen and phosphorus to build and regenerate their tissues. Decomposers replenish these nutrients and maintain the nutrients cycles. Food chains, food webs, competitions, predation and biochemical cycles represent the interaction between biotic and abiotic components of an ecosystem.

Humans are part of an ecosystem. Ever since the human civilization, human and environment interaction has lead to decline of natural environment through industrialization, settlements and transportation. Some organisms even got extinct over the time

CHAPTER 10

A. Interactions and Adaptations in Its Environment

Learning Objectives

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

- explain various ecological interactions.
- explain adaptation and different adaptive features of organisms.
- explain decomposers, and their economic importance.

In the natural world, an organism cannot exist on its own. Every organism must **interact** with the **environment** and other organisms. An **organism's interactions** with its environment are essential to the survival of that organism and the functioning of the **ecosystem** as a whole.

Every organism has certain features or characteristics that allow it to live successfully in its **habitat**. These features are called adaptations. Organisms living in different habitats need different adaptations. For an example, **polar bears** and **arctic foxes** are adapted to survive in the Arctic region and a **camel** and the **fennec fox** are adapted to live in hot arid conditions.

a. Ecological interaction

Ecological interactions are the effects that the organisms in a community have on one another. It involves individuals of the same species or individuals of different species. Organisms living in an ecosystem have different types of interactions with each other that affect one another. In many cases, two species will interact differently under different conditions.

i. Predator and prey relationship

A predator is an organism that eats another organism. The prey is the organism which the predator eats. Some examples of **predator and prey relationship** are lion and zebra, bear and fish, and fox and rabbit. The words '*predator*' and '*prey*' are almost always used to mean only animals that eat animals, but the same concept also applies to plants: *bear and berry*, *rabbit and lettuce*, *grasshopper and leaf*.

Predator and prey evolve together. The prey is part of the predator's environment, and the predator dies if it does not get food. So, it evolves whatever is necessary in order to eat the prey: **speed**, **camouflage**, a **good sense of smell**, **sight**, or **hearing**, **immunity to the prey's poison**, etc. Likewise, the predator is part of the prey's environment, and the prey dies if it is eaten by the predator, so it evolves whatever is necessary to avoid being eaten.

The fastest lions are able to catch food and eat, so they **survive and reproduce**, and

gradually, faster lions make up more and more of the population. The **fastest zebras** are able to escape the lions, so they **survive and reproduce**, and gradually, faster zebras make up more and more of the population.

ii. Competition

Competition is a mutually harmful interaction between individuals, populations or species. It is a **negative interaction** that occurs among organisms, whenever two or more organisms **require the same limited resource**. All organisms require resources to grow, reproduce, and survive. For example, animals require food and water, whereas plants require soil nutrients, light, and water. Organisms, however, cannot acquire a resource when other organisms consume or defend that resource. Therefore, competitors reduce each other's **growth**, **reproduction**, or **survival**.

iii. Symbiosis

Symbiosis is an interaction between individuals of different **biological species**. A symbiotic interaction involves a **close relationship** between the two organisms. The **impacts of symbiosis** can be positive, negative, or neutral for the individuals involved. There are three main kinds of symbiotic relationships: mutualism, parasitism and commensalism.

Activity 10.1

Identifying the types of symbiotic relationships

Work in groups or individually to identify the types of symbiotic relationships. Copy and complete Table 10.1 with the clues provided in it.

Table 10.1

Interactions	Example of interaction	Nature of impact on each organism	Type of interactions
Mutualism is a kind of symbiotic relationship in which both organisms involved receive benefits. Parasitism is a kind of symbiotic relationship in which one organism receives a benefit and the other organism is harmed by the interaction. Commensalism is a type of symbiotic relationship between two organisms, in which one of the organism benefits and the other is neither benefited nor harmed in any way.	Tick sucking blood out of a cow for food.		
	Many flowering plants depend on insects to perform pollination.		
	Orchid, an epiphytic plant grows attachment on the branches of trees to get adequate sunlight, and nutrition that flows on the surface down the branches.		

Questions

i. Give one other example each for each type of the symbiotic relationships.
ii. Of the three, which one has the potential to eliminate any species from the ecosystem?
iii. List two scientific significances of the symbiotic relationship.

b. Micro-organisms interaction

i. Decomposition

Biochemical cycles are important part of a dynamic ecosystem. Many **microbes** play a vital role in the biochemical cycles. A biogeochemical cycle is a **pathway** by which a chemical substance moves through both **biotic** (biosphere) and **abiotic** (lithosphere, atmosphere, and hydrosphere) components of the earth in an ecosystem. These cycles of chemical elements in an ecosystem are known as nutrient cycles. While **photosynthesis** prepares **organic biomass**, **decomposition** involves conversion of **organic material into inorganic forms**. Therefore, decomposition is the breakdown of chemical bonds of plant and animal tissue, thereby converting organic into inorganic nutrients. Although main **decomposers** are bacteria and fungi, the process of decomposition is accomplished by a variety of decomposer organisms called detritivores.

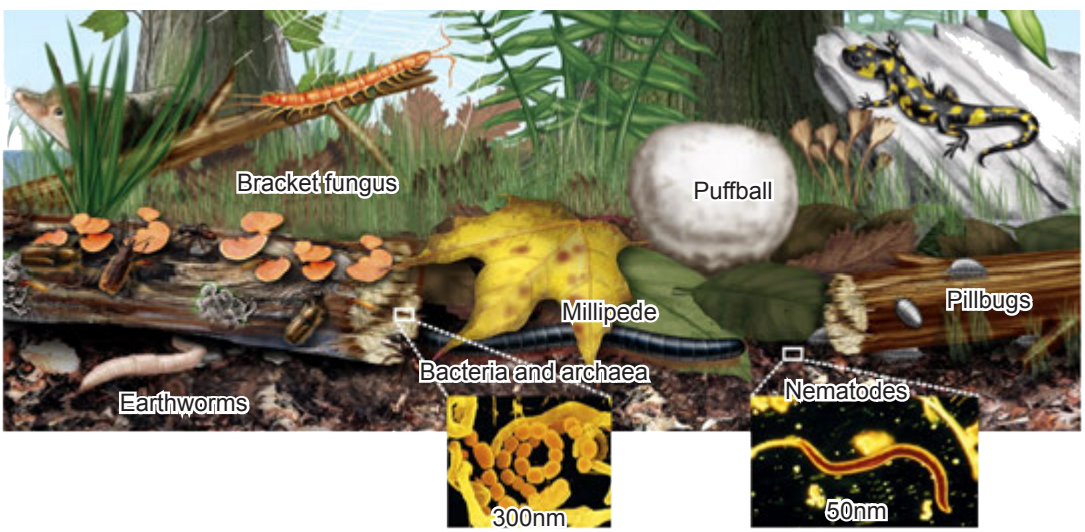


Figure 10.1 Detritivores

A mixed population of **microorganisms** is present in any environment. Some species are active, while others are dormant based on the environmental conditions. The availability and quality of dead organic matter as a **food source** and **physical environment**, particularly, temperature and moisture, are important for microbial activity. Low temperature and dry condition inhibit microbial activities. Many of the natural environmental cycles operating within the earth's environment have key

links that are controlled in larger parts by microorganisms. Carbon and nitrogen cycles largely affect all forms of life and their interactions within the earths environment.

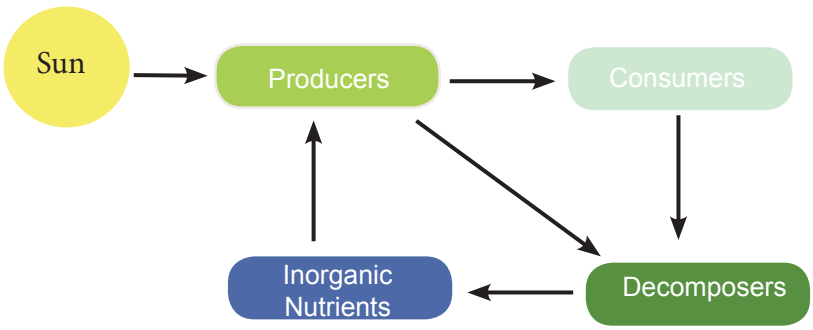


Figure 10.2 Decomposition relations

c. Feeding interaction

Energy pyramids, food chains and food webs represents the feeding interaction of organisms in an ecosystem. It is the process that helps in the **transfer of energy** from one system to another.

i. Energy pyramids, food chains and food webs.

Energy enters the biological system as **light energy** and it is transformed into **chemical energy** in the form of organic molecules by **photosynthesis**. All green plants produce carbon based molecules, usually carbohydrates, and are thus called producers. Producers form the base for all trophic levels and food chains, because rest of the organisms in the ecosystem directly or indirectly, depends on producers.

Organisms which feed on producers directly are called primary consumers. Primary consumers *exclusively feed on producers*. Cow, horse and sheep are example of primary consumer and are also called herbivores.

Primary consumers are consumed by **secondary consumers**. Bird that eats bugs which feeds on

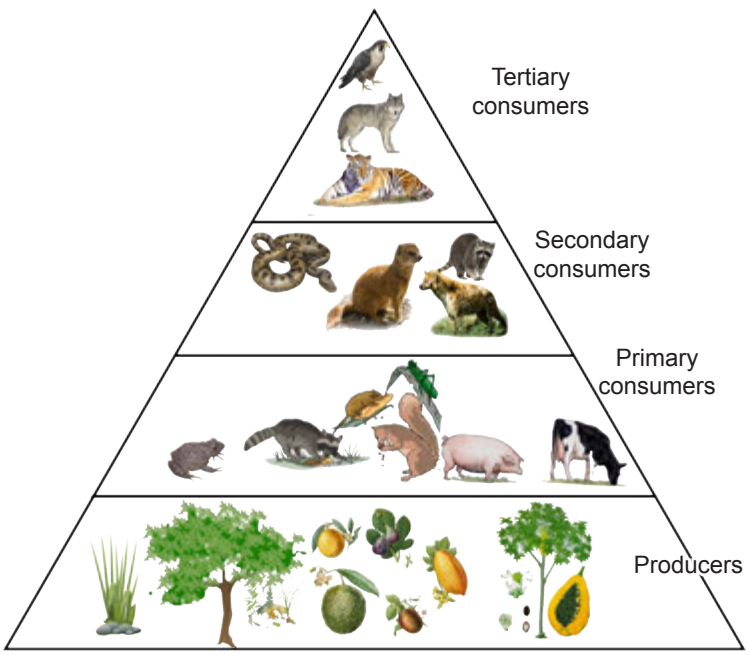


Figure 10.3 Food pyramids

leaves is secondary consumer. Secondary consumers are consumed by tertiary consumers. Cats, dogs, tiger are tertiary consumers.

The *relationships among producers, primary consumers, secondary consumers, and tertiary consumers* are usually illustrated as a pyramid, which is known as an energy pyramid, with producers at the base and tertiary consumers at the **apex of the pyramid**.

c. Adaptation

Some interactions take place among individual organisms responding to their environment. It is mostly about the **study** of physiology, reproduction, development or behaviour of organisms. Under a given set of environmental conditions, organisms that are able to cope with the environmental situations, survive. All animals and plants have **limits of tolerance** to temperature, humidity and intensity of light. As environmental conditions change, set of characteristics that allow an organism to survive, grow and reproduce will vary. They develop new traits that enable them to survive through **adaptation** and **evolution**.

Adaptation is **any heritable**, **behavioural**, **morphological**, or **physical change** that enhances an organism's ability to survive and reproduce in a given environment. An adaptation can be change of physical parts of the organism called structural adaptation. An example of a structural adaptation is the way some plants have adapted to life in the desert. Desert is hot and dry place. Plants called succulents have adapted to this climate by storing water in their thick stems and leaves. Colouration is thought to be an important factor in the reduction of heat absorption in animals. That is, a lighter coloured coat reflects more light relative to a darker coat, which absorbs less heat. This reduces the body temperatures and conserves water. Some animals have **enlarged appendages** in order to increase surface area for greater heat loss. **Insulation** in the form of feathers, hair, or body fat help animals to adapt to varying thermal conditions.

Figure 10.4 Cactus

An adaptation can also be **behavioural**, affecting the way an organism acts. Animal migration is an example of a behavioural adaptation. Black necked crane migrates to warmer places to escape the cold during winter and vice versa. For example, *black necked crane* migrate to Bhutan from Tibet in winter. The use of burrows or nocturnal activity is very common to many different animals, so that the organisms are exposed to little or no sunlight.

Hibernation or aestivation during the cooler or hotter times of the seasons are also **behavioral adaptations**. Organisms develop adaptations usually in response to changes in organism's habitat. **Reproductive success** of organisms depends heavily on the choice of habitat. Therefore, habitat selection is a common behavioural characteristic of organisms.

Figure 10.5 Black-necked cranes

Sometimes, an organism develops a completely new set of adaptive features that create an entirely new species. This **evolutionary process** by which new biological species arise is called speciation. The **physical isolation or specialization of a species** can lead to speciation.

Figure 10.6 Squirrel living underground

Speciation may also be induced **artificially**, **through animal husbandry**, **agriculture**, or **laboratory experiments**.

B. Human Impacts on the Environment

Learning Objectives

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

- explain major human activities that has affected the environment.
- describe how transportation and mining affects our soil and water.
- identify some of our lifestyle that has degraded our environment.

Earth is home to millions of species. All species, including humans, has an impact on its environment. Accelerated **globalization** and earth's environmental change have deep roots in **humanity's relationship with nature** since time immemorial. The problems are accelerating as humans continue to strive for greater **economic development**.

Activity 10.2

Analyse National Environment Protection Act 2007

Instruction: Read the environment protection Act below and answer the questions that follow.

National Environment Protection Act 2007

4.1 The National Environment Protection Act was enacted in 2007. This is the over arching legislation for the environment sector and all other Acts and regulations governing the use of land, water, forests, minerals and other natural resources are drafted in consistent to this act. The Act outlays principles and legal framework that has implication on forest governance and management. It requires a person taking natural resources from the environment or deriving the economic benefits to ensure sustainable use and management of those resources and their ecology. Likewise a person polluting the environment or causing ecological harm is responsible for the course of contentment, avoidance, abatement, medical compensation, mitigation, remediation and restoration. A person using or extracting natural resources shall be liable to pay for ecosystem/environmental services.

4.2 The act calls for conservation of Natural resources to be based on a participatory approach aimed at achieving an equitable sharing of the cost and benefits of conservation among resource users. It also provides promoting the use of clean energy and alternative technologies in order to reduce use of fuel wood/timber from primary forest.

4.3 The NEPA 2007 calls for conservation and protection of wet lands, alpine regions, watersheds and other vulnerable ecosystems in addition to the existing protected areas. For inter-generational equity and sustainable utilization of natural resources, the Act provides for bio-prospecting and other commercial extraction and export from the country, of any in situ or ex situ plant and animal genetic resources.

Environmental Audit Guideline (RRA, 2013), pp 51

Questions

i. What is the importance of the Act?
ii. What is the purpose of bio-prospecting?
iii. What are the roles of consumers towards the sustainable use of the environment?
iv. Name some organizations that are safeguarding the environment in Bhutan?
v. How can you contribute towards enforcing this Act?

Humans are **part of an ecosystem** and have profound impact on the environment. Humans have always **exploited the natural environment** of the earth, often intensively for various reasons resulting to **degradation** of the environment that we live in. Some of the major factors that have led to decline of natural environments are due to **human activities**.

a. Economic development

Economic activities of human too often outweigh environmental consideration, resulting in devastation. **Expansion of towns** for human settlements, construction of roads and other mega projects, and expansion of agricultural land in the villages have always **resulted in deforestation**. These economic activities result to deforestation, which directly or indirectly affect the habitat of organisms and their populations. **Habitat of plants and animals**, both terrestrial and aquatic, often are being **fragmented** and **isolated**, resulting in massive **decline in flora and fauna** in the environment.

i. Extensive farming

Extensive farming is a **system of crop cultivation** using small amounts of labour and capital in relation to area of land being farmed. The **crop yield** depends primarily on the natural fertility of the soil, land topography, the climate, and the availability of water. Extensive farming produces a lower yield per unit of land, its use commercially requires large areas of land in order to be profitable.

Consequently, large areas of land are prone to erosion and flash floods. Extensive agriculture farming by use of **chemicals** for better crop yields to meet the demand for large human population leads to **air** and **water pollution**.

ii. Transportation and mining

Transportation, **mining** and **industries** are the main contributors to air pollution by producing gaseous wastes, burning fuels and toxic deposits. **Water pollution**, involving pesticides, sediments, excessive nutrients, toxic waste, and oil spills cause high mortality in aquatic life, and interfere with reproduction, besides **destroying habitat** of organisms. Water pollution has resulted in **eutrophication** and **biomagnification**. Biomagnification is accumulating larger amount of poisonous substances at each higher level of consumers.

Figure 10.7 Transportation and mining

iii. Lifestyle

Another threat posed by humans on environment is by increasing the level of **consumption**. The **life-style** and **consumption patterns** of many people are beyond what the earth can support. Consumption can be direct or indirect. We depend on the environment for food and shelter, which is direct consumption. Indirect consumption is use of natural resources like water, timber and minerals for the benefit of humans. The phenomenon that follows consumption is the waste generation.

The **industrial process** such as packaging, distribution, use of the product produce still more waste. Waste becomes pollution when the **level of contamination** impairs the **aesthetic quality** or **productive capacity** of the atmosphere, water, soil, or landscape; that is, when ecosystems are significantly damaged. It is inevitable, but can be reduced. Unscientific ways of disposal of waste pollutes land, water and air. For instance, when a chemical pollutant enters a body of water, it can **impact surrounding wildlife**, **watershed** and **residents**.

Human beings are **consumers** by nature—we have to consume to survive but informed consumers can learn to **consume responsibly**. What, then, can the individual do to reduce his or her personal '***load***' on nature? The fact is that making careful consumer choices can greatly reduce the negative impacts of one's personal lifestyle.

Figure 10.8 Consumption and waste production

Activity 10.3

Human's pressure on the environment

In groups, discuss on the following areas of humans' negative impacts on the environment.

Copy and complete the Table 10.2. Make a presentation to the class.

Table 10.2 Relation between human activities and environment

Sl.No.	Human activities	Pressure on the environment	Impacts on the environment	Suggested measures to decrease the impacts on the environment
1	Using land for agriculture			
2	Extracting natural resources for livelihood			
3	Clearing forest for roads and settlement			
4	Extracting minerals for industries			
5	Wastes disposed of into the environment			
6	Raring large livestock in a community			

Questions

i. What human activity has impacted the environment most in your locality?
ii. What do you conclude from the activity?
iii. Why do you think, some flora and fauna get extinct from the earth?
iv. As an individual, how can you minimize the exploitation of the environment?
v. What are some of the measures taken by our government to curb the rampant use of environment?

Summary

- Adaptation is any behavioural, morphological, or physical change that enhances an organism's ability to survive and reproduce in a given environment.
- The uptake of carbon and the loss of water under different environmental conditions like seasonal and annual variations is a homeostasis process in plants.
- There are many different kinds of interactions between organisms in an ecosystem.
- Competition is an interaction, in which two or more organisms compete or fight for the same limited resources, such as food, shelter and sunlight.
- Decomposition is the breakdown of chemical bonds of plant and animal tissues, thereby, converting the organic matter to inorganic nutrients.
- Human impacts the environment due to economic activity such as extensive farming, transportation and mining and cosumerist lifestyle.
- Waste production and disposal pollutes land, air and water.

http://5e.plantphys.net/contents.php

http://www.brainbeau.com/index.php/en/ap-biology-online-quizzes-a-tests

http://www.getbodysmart.com/

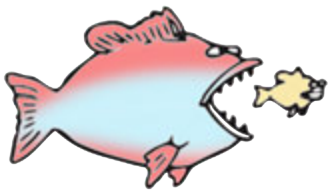
http://www.101science.com/sdall.htm

http://ecsd-fl.schoolloop.com/L.17.20

Review Questions

A. Each question in this part is followed by four possible choices of answers. Choose the correct answer.

1. Which is true about the organisms shown in the diagram on the right?



   A. Predation and autotroph
   B. Herbivore and prey
   C. Producer and consumer
   D. Heterotroph and predation

2. The major reason humans have negatively affected the environment is
   A. did not pass laws to protect environment.
   B. use of chemicals.
   C. converting forest into agricultural land.
   D. industrial revolution.

3. Which term refers to the ecological niche of many bacteria and fungi in an ecosystem?
   A. Producer
   B. Herbivore
   C. Scavenger
   D. Decomposers

4. Annually, earthworms make migration deeper into the soil to escape the cold winter and move back to the upper soil, when soil is warmer in summer, as shown in the diagram on the right. This response is

   A. genetic change.
   B. occasional change.
   C. behavioural change.
   D. morphological change.

5. Humans are consumer by nature. However, informed consumer can reduce ones personal 'load' to nature by
   A. consuming responsibly.
   B. raising livestocks.
   C. growing crops.
   D. replanting plants.

6. Genetically Modified Organisms are result of
   A. adaptation.
   B. variation.
   C. speciation.
   D. mutation.

7. The modification of beak in the diagram on the right exhibits

   A. genetic change.
   C. behavioural change.
   B. occasional change.
   D. morphological change.

8. Students collect lots of trashes and dump them in landfills. Which one of the natural resource will be most threatened?

   A. Air
   C. Mineral deposit
   B. Nutrients and pH balance of soil
   D. Sunlight

9. Which of the following is not the negative impact of extensive farming on environment?
   A. Requires large area
   C. Use of chemicals
   B. Requires less labours
   D. Pollutes air and water

10. Human activities, whether accidental or intentional, are threatening the stability of the planet's ecosystems. Which one of the human activity is least related to Bhutan?
   A. Agricultural practices have exposed soil to the weather, resulting in great loss of topsoil
   B. Untreated sewage wastes and runoff from farms and municipals have led to increased water pollution
   C. Disposal of radioactive nuclear wastes
   D. Burn fossil fuels and deplete ozone layer by addition of greenhouse gases

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

1. White-bellied Heron (*Ardea insignis*) is in the brink of losing its …….. due to *Puna Tsangchu* hydro projects.
2. The dominant and intelligent species on the earth is……
3. Extensive farming harms the environment mainly due to the use of ..... to improve crop yields.
4. The accumulation of poisonous chemicals at different level of food chain results in.....……..
5. Respiring through gills are adaptive features of some …… animals.

C. Differentiate between the following pairs.

1. Inter-specific and intra-specific competition.
2. Adaptation and evolution.
3. Habitat and niche.
4. Predator and prey.

D. Match the items of Column I with the most appropriate items of Column II. Rewrite the correct matching pairs.

Column I	Column II
1. Camouflage	a. This is the environment (place) where animal lives.
2. Predator	b. These are animals that are eaten by other animals.
3. Prey	c. This means that animal can blend into its surroundings.
4. Adaptation	d. Tiger preys on deer.
5. Habitat	e. Yaks in Bhutan can survive and breed on high altitudes.

E. Answer the following questions.

1. Define adaptation. Write a few examples of adaptation that you have noticed in your community.
2. The way animal behaves is as important to its survival as its colour patterns and its anatomy. Name few organisms that exhibit behavioural adaptations.
3. Give a few examples as to how political or cultural views influence environmental quality.
4. Human activities have polluted land and water. How does this pollution affect the population of plants and animals of the environment?
5. Habitat destruction is a major cause in the massive decline of fauna and flora. Write some of the human activities that have destroyed habitat in our country.
6. What would have happened, if there were no decomposers?
7. The slash and burning is a time old farming practice in Bhutan. The contemporary law bans such practice. Explain.
8. What are some ways humans have positively impacted the environment?
9. How does 'camouflage' help animals in our environment? If preys do not have this property, how will this affect the ecosystem?
10. Study the excerpts of the Pesticides Act of Bhutan 2000 and answer the questions

that follow.

The Pesticides Act of Bhutan 2000 has been enacted with the objective to:

i. ensure integrated pest management (IPM) is pursued, limiting the use of pesticides as the last resort.

ii. ensure that only appropriate types and quality of pesticides are introduced in the country.

iii. ensure that pesticides are effective when used as recommended.

iv. minimize deleterious effects on human beings and the environment consequent to the application of pesticides.

Environmental Audit Guideline (RRA, 2013), pp 52.

a. Why should Bhutan enact the Pesticide Act?

b. How does this Act contribute to the better health of people and environment?

Model Question Paper

Biology **Writing Time**: 2 Hours

Class IX **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

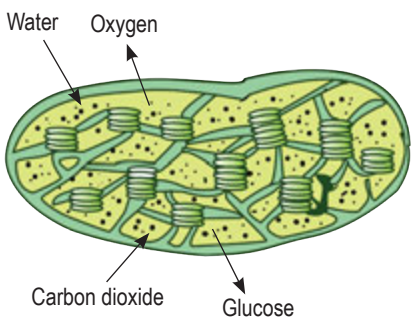
a. Each question in this section is provided with four possible options. Choose the most appropriate option. **[1×25=25]**

i. A cell has a membrane that allows water, oxygen, carbon dioxide, and glucose to pass through. But other substances are blocked from entering, this membrane is called

A. freely permeable. C. perforated.

B. selectively permeable. D. non-conductive.

ii. The diagram on the right side illustrates the movement of materials involved in a process that is vital for the energy needs of organisms. The process illustrated occurs within



A. vacuoles. C. chloroplasts.

B. ribosomes. D.mitochondria.

iii. In Jigme Dorji Wangchuck National Park containing varieties of flowering trees, shrubs and herbs, there is sign board that says "Take nothing but pictures, leave nothing but footprints." This message is necessary because

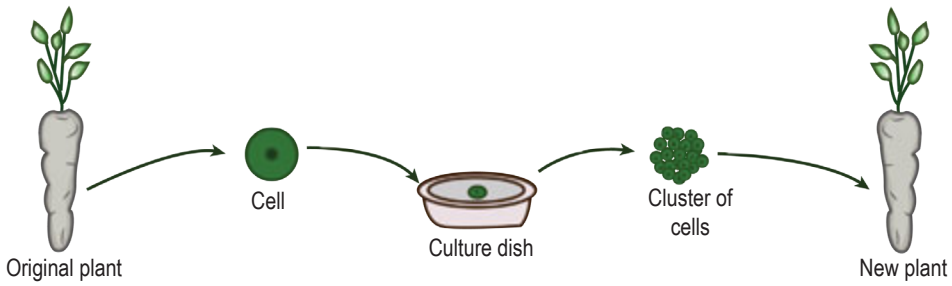
A. humans can destroy habitats by removing flowering trees and shrubs.

B. all animals feed directly on flowering shrubs that may be removed by people.

C. removal of flowering trees and shrubs will decrease biodiversity.

D. flowering shrubs grow best in state forests and parks.

iv. The diagram below represents the cloning of a carrot plant. Compared to each cell of the original carrot plant, each cell of the new plant will have



A. half the number of chromosomes and the same types of genes

B. half the number of chromosomes, but different types of genes

C. the same number of chromosomes and the same types of genes

D. the same number of chromosomes, but different types of genes

v. To produce large tomatoes that are resistant to diseases, some seed companies use the pollen from one variety of tomato plant to fertilize a different variety of tomato plant. This process is an example of

A. selective breeding.

B. genetic engineering.

C. DNA sequencing.

D. cloning.

vi. A population of termites initially consists of darkly coloured and brightly coloured members. After several generations, termite population consists about 99% of darkly coloured members, because the brightly coloured termites are easier for a predatory to locate. This situation is an example of the evolution of a new species.

A. natural selection.

B. artificial selection.

C. structural adaptation.

D. competition.

vii. In order for the body to maintain homeostasis, chemical decomposition of food to produce energy must be followed by

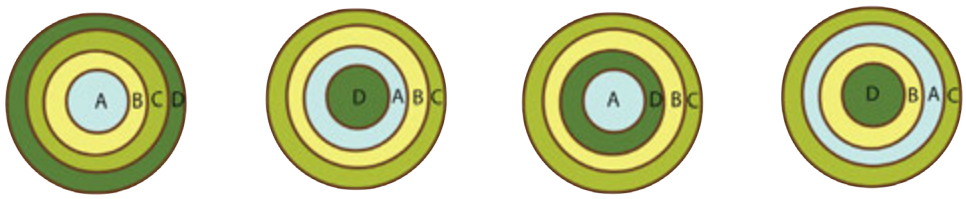
A. water intake.

B. muscle contractions.

C. waste removal.

D. nervous impulses.

viii. Which diagram best represents the relative locations of the structures in the list below?



A–chromosome

B–nucleus

C–cell

D–gene

A. (1) C. (3)

B. (2) D. (4)

ix. The fight-or-flight response includes greater cardiac output and a rise in blood pressure. This response is due to

A. insulin secreted by the pancreas.

B. thyroxine secreted by the thyroid gland.

C. oxytocin secreted by the pituitary gland.

D. adrenaline secreted by the adrenal glands.

x. Which of the following best explains how stems transport water to other parts of the plant?

A. Through a chemical called chlorophyll C. Through a system of tubes

B. By using photosynthesis D. By converting water to food

xi. Which list gives the correct order of food traveling through the digestive system after it is swallowed?

A. Stomach, oesophagus, large intestine, small intestine

B. Small intestine, large intestine, oesophagus, stomach

C. oesophagus, stomach, large intestine, small intestine

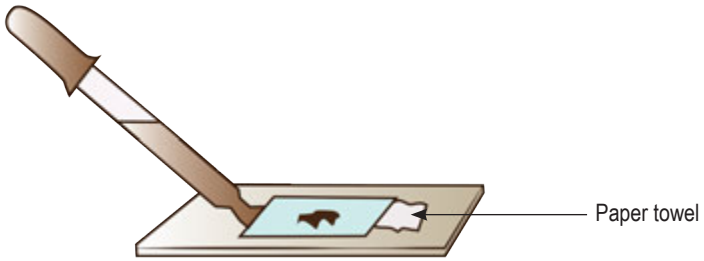
D. oesophagus, stomach, small intestine, large intestine

xii. Chemicals present in correcting fluid, marker pen and wood polish that cause changes in body if inhaled in large amount is an example of

A. alcohol. C. hydrogen cyanide.

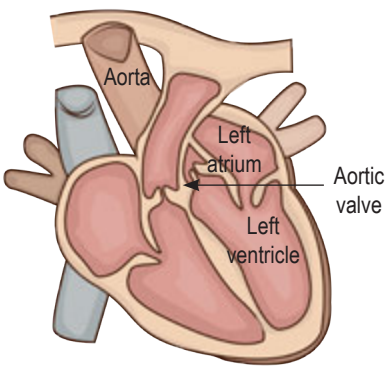
B. solvents. D. nicotine.

xiii. Which laboratory procedure is represented in the diagram below?



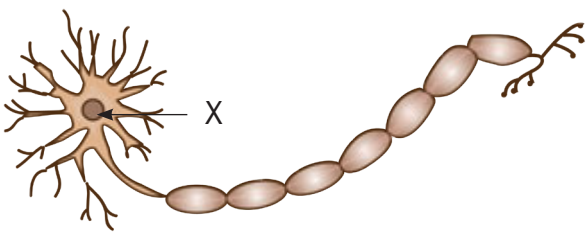
A. Placing a coverslip over a specimen
B. Removing a coverslip from a slide
C. Adding stain to a slide without removing the coverslip
D. Reducing the size of air bubbles under a coverslip

xiv. The diagram of a human heart is given on the right. When contracted, the left ventricle pumps oxygenated blood to the body. What is the purpose of the aortic valve that separates the left ventricle from the aorta?



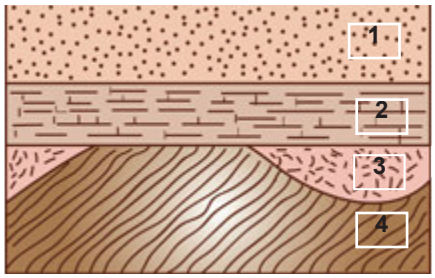
A. To prevent blood from flowing back into the left ventricle
B. To prevent blood from flowing into the aorta
C. To push blood into the left ventricle
D. To push blood into the aorta

xv. Which statement best describes a function of the entire structure shown on the right?



A. It unites with an egg cell during fertilization
B. It synthesizes a hormone involved in the control of blood sugar level
C. It releases chemicals involved in nerve to nerve communication
D. It controls the replication of genetic material

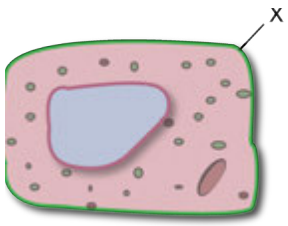
xvi. The diagram below shows a geologic cross section.Which rock layer most likely contains fossils of the most recently evolved organisms?



A. 1 C. 3

B. 2 D. 4

xvii. The part of the diagram labelled 'X' is made up of



A. protein.

B. cellulose.

C. chitin.

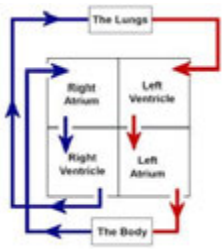
D. lipid.

xviii. Which of the following conditions is least likely to increase the rate of transpiration in a plant?

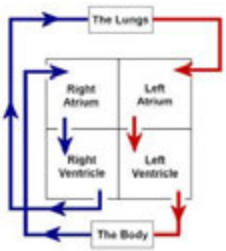
A. Increased sunlight C. An increase in humidity

B. A rise in temperature D. Increased air movement

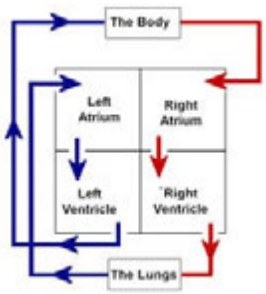
xix. Which diagram below shows the correct flow of blood in human body?



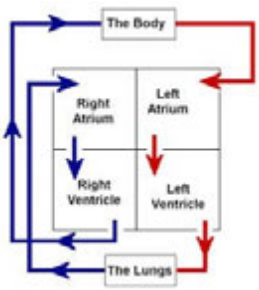
I



II



III



IV

A. I C. III

B. II D. IV

xx. Which of the following disease is unlikely to be caused by smoking?

A. Haemophilia
B. Emphysema
C. Bronchitis
D. Lung cancer

xxi. Which of the following is correct, when we inhale

A. the intercostal muscles contract and the ribs move down.
B. the diaphragm muscles contract and the ribs move up.
C. the diaphragm muscles contract and the ribs move down.
D. the intercostal muscles contract and the diaphragm muscles relax.

xxii. After a vigorous activity, a runner's blood would leave a muscle to have

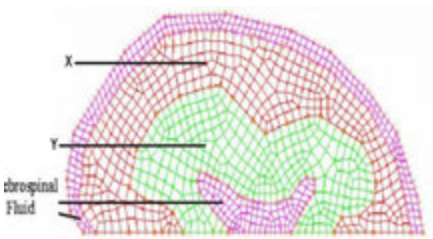
A. less carbon dioxide, less oxygen and less glucose.
B. more carbon dioxide, less oxygen and less glucose.
C. more carbon dioxide, more oxygen and less glucose.
D. more carbon dioxide, more oxygen and more glucose.

xxiii. A student investigated the range of heights of a plant species. She measured the height of 5 plants in a population as 120, 125, 127,149 and 150 in millimetres, respectively. This ranges of heights is an example of

A. genetics.
B. variation.
C. evolution
D. interaction.

xxiv. A transverse section through the spinal cord is examined under the high power of the microscope. Part labeled 'X' and part labeled 'Y' are

A. gray matter and white matter respectively.
B. white matter and gray matter respectively.
C. cerebellum and corpus callosum respectively.
D. corpus callosum and cerebrum respectively.



xxv. According to the Dietary Guidelines for Americans, moderate drinking is up to 1 drink per day for women and up to 2 drinks per day for men. If a woman is pregnant, she should take 'no'

A. more than three standard alcoholic drinks per day.
B. more than one standard alcoholic drink per day.
C. more than five standard alcoholic drinks per week.
D. alcoholic drinks at all.

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. **[5]**

Column A	Column B
1. Alpha cell	(a) Cortisone
2. Beta cell	(b) Glucocorticoids
3. Adrenal cortex	(c) Oxytoxin
4. Posterior pituitary	(d) Insulin
5. Anterior pituitary	(e) Glucagon

c. Fill in the blanks by writing suitable word(s). **[1×5=5]**

i. The genetic material of an apple cell is composed of …….

ii. A sudden change in the DNA of a chromosome can usually be passed on to future generations, if the change occurs in a……cell.

iii. A variation causes the production of an improved variety of apple. The best method to use to obtain additional apple trees of this variety in the shortest period of time is ……..

iv. For a beneficial variation to have a selective advantage in the course of evolution, it must be ..... by the offspring.

v. The pancreas releases insulin, helping humans to keep blood sugar levels stable is an example of a feedback mechanism that maintains.....

d. State whether the following statements are 'True' or 'False' and correct the false statements: **[1x5=5]**

i. The homeostatic mechanism in humans that regulates blood pH depends on the feedback of information from hormone receptors.

ii. Carbon monoxide gas is used in photosynthesis.

iii. Lysosome release energy from sugars.

iv. Spleen secretes a hormone that regulates the rate of metabolism of the body.

v. The tissue in which nutrients move in plants is the phloem.

e. *Answer the following questions:*

a. Write down the difference between the following pairs as per the direction.

i. Guttation and transpiration (**occurence in plants**). **[1]**

ii. Positive and negative feedback mechanism (**Example**). **[1]**

ii. Copy and complete the table below. **[4×0.5 = 2]**

System	Structure	Function
E.g. Digestive system	Large intestine	Reabsorption of water from the undigested food.
	Oesophagus	Acts as a passage for the food from mouth to stomach.
Circulatory system		
Respiratory system		

f. Give reasons **[2×2=4]**

a. Cloning does not result in genetic variation.

b. Skin is the first line of non-specific defence.

g. Name the following **[4×0.5=2]**

a. The substance which was needed to join the insulin gene to the bacterial DNA.

b. The wave of electrical disturbance that passes over the nerve cell.

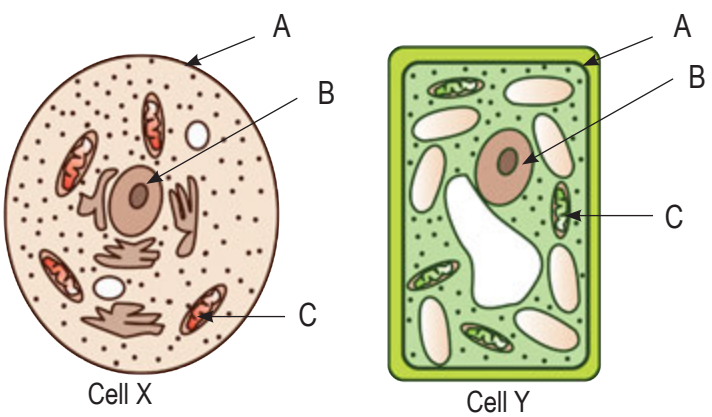
c. The cell organelle responsible for intracellular digestion.

d. A substance, other than food, which has a physiological effect when ingested, or otherwise introduced into the body.

Section B (50 marks)
Attempt only FIVE Questions

Question 2

a. The diagram below shows two cells, X and Y. Observe and answer the questions i through v.



i. Identify any one organelle common to both the cells from the labelled parts. **[1]**

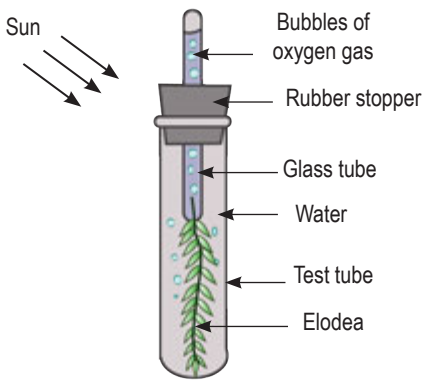
ii. State one function of the organelle that you identified in question i. **[1]**

iii. Identify one process that is carried out in cell Y that is not carried out in cell X. **[1]**

iv. Identify one organelle in cell X, which performs similar function to the human heart. **[1]**

v. If cell X and Y require the use of energy for excretion of waste from them, which substance would be the source of this energy for them? **[1]**

b. A student set up an experiment as shown below. A small water plant (*Elodea*) was placed in bright sunlight for five hours as indicated below. Bubbles of oxygen gas were observed being released from the plant.



i. Write chemical equation for the process illustrated above. **[1]**

ii. Write two importance of the above process. **[1]**

iii. What substance did the plant most likely absorb from the water for the process that produces the oxygen gas? **[1]**

c. Identify the following traits as entirely genetic, or environmental and genetic.

{*eye colour, tallness, masculinity, blood group, agility, maleness, natural hair colour, obesity, ability to sing*} **[2]**

Entirely genetic:.....

Environmental and genetic:.....

Question 3

a. Study the following text, and answer the questions i through iii.

A student conducted an investigation to determine the effect of various environmental factors on the rate of transpiration in plants. The student prepared 4 groups of plants. Each group contained 10 plants of the same species and leaf area. Each group was exposed to different environmental factors. The apparatus shown in the diagram was constructed to measure water loss by the plants over time in 10-minute intervals for 30 minutes. The results are shown in the data table.

Environmental factors	Average total water in mL over time			
	0 min	10 min	20 min	30 min
Normal classroom conditions	0.0	2.2	4.6	6.6
Classroom conditions + tube light	0.0	4.2	7.6	11.7
Classroom conditions + fan	0.0	4.5	7.6	11.0
Classroom conditions + mist	0.0	1.3	2.4	3.7

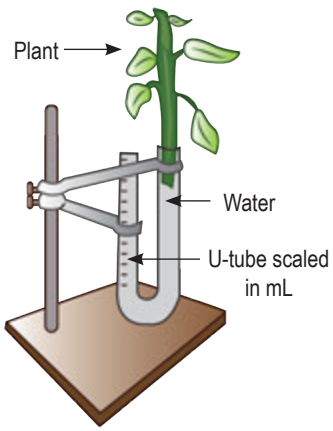
i. Write the hypothesis for the experiment. **[1]**

ii. Identify the environmental factor that resulted in the lowest rate of transpiration. **[1]**

iii. Identify the control experiment in the investigation. **[1]**

iv. What is your conclusion from the data? **[1]**

v. How would experimental result change, if it was conducted outside the classroom? **[1]**



b. Answer the questions i and ii based on the information below.

Two adaptations of the monarch butterfly that aid in its survival are the production of a certain chemical, and a distinctive colouration that other animals can easily recognize. When a monarch butterfly is eaten, the chemical present results in a bad taste to the predator. Although the viceroy butterfly does not contain the chemical that tastes bad to a predator, it does resemble the monarch in size, shape and colouration.

i. Explain how the combination of this chemical and the distinctive colouration aid in the survival of the monarch butterfly. **[1]**

ii. How do the characteristics of the viceroy butterfly aid in its survival? **[1]**

c. Explain how drug addiction leads to family and personal problem. **[2]**

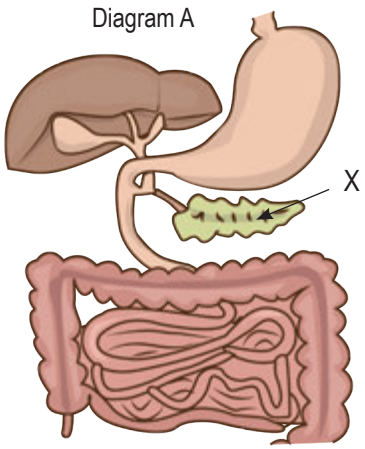
d. Pancreas is both a duct gland as well as a ductless gland. Explain. **[1]**

Question 4

a. List two human activities that have negative impact on the quality of environment. **[2]**

b. How can you support that evolution is true? **[2]**

c. Study the diagram below and answer the questions that follow. Diagram A represents a portion of the human body.

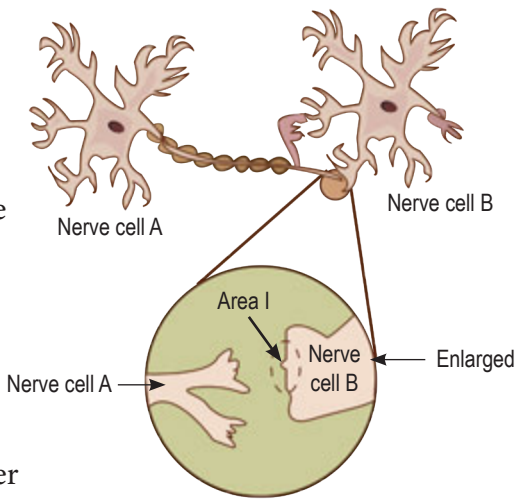


i. Identify the structure labelled X in the diagram. [1]

ii. Name one secretion of structure labelled X in diagram A. [1]

iii. State one problem for the organism that would result from a malfunction of the structure you identified. [1]

d. Base your answers to questions i through iii on the diagram of nerve cells.



iv. What does the magnified structure represent? [1]

v. Name a chemical molecule that might be released from nerve cell A and be recognized and bind to Area I of nerve cell B. [1]

vi. Write the function of the magnified structure. [1]

Question 5

a. Study the information given below, answer the questions i through iv.

A number of bean seeds planted at the same time produced plants that were later divided into two groups, A and B. Each plant in group A was treated with the same concentration of gibberellic acid (a plant hormone). The plants in group B were not treated with gibberellic acid. All other growth conditions were kept constant. The height of each plant was measured on 5 consecutive days, and the average height of each group was recorded in the data table below.

Data Table

	Average Plant Height (cm)				
	Day 1	Day 2	Day 3	Day 4	Day 5
Group A	5	7	10	13	15
Group B	5	6	6.5	7	7.5

i. Using the information in the data table, construct a line graph. [1]

ii. State a valid conclusion that can be drawn concerning the effect of gibberellic acid on bean plant growth. [1]

iii. Describe the control of the experiment above. [1]

iv. Name any other plant hormone that would most likely have the same effect on the growth of a plant. [1]

b. Name the hormone responsible for the following functions: [1x3 =3]

i. Maintains glucose level in the blood.

ii. Prepares the body during an emergency.

iii. Responsible for normal growth of the whole body.

c. What are the two main causes of heritable variation? [1]

d. In a cereal variety, a breeder might select for high yield; disease, frost or drought resistance; early maturation; short straw (easier to harvest); reduced need for fertilisers; good quality of product (e.g. high in protein); processing qualities (e.g. good for making bread).

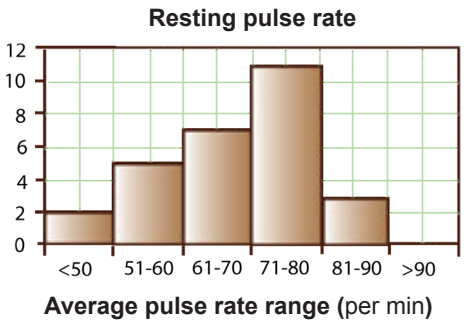
i. In an animal farm, what might a breeder select? [1]

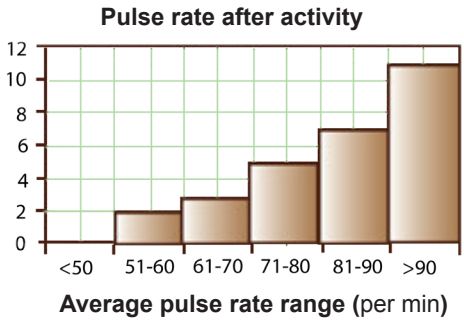
ii. What are two advantages and disadvantages of breeding plants of these qualities? [1]

Question 6

a. Base your answers to questions i through iii on the histograms below.

Students in a class recorded their resting pulse rates and their pulse rates immediately after strenuous activity. The data obtained are shown in the histograms.





i. What would be an appropriate label for the y-axis in each histogram? [1]

ii. What can you conclude from the data, about the average resting pulse rate compared to the average after activity pulse rate? [1]

iii. State one biological explanation for the fact that not all students had the same resting pulse rate. **[1]**

b. Select any one of the environmental problems in Bhutan.

i. Mining

ii. Use of pesticides in agriculture fields

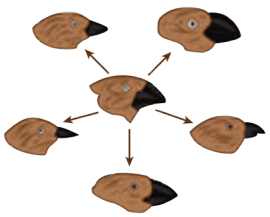
iii. Destruction of biodiversity with construction of roads

A. From the environmental problem that you selected, briefly describe about the problem in Bhutan. **[1]**

B. Explain how humans have caused the problem you selected. **[1]**

C. Suggest one specific action humans could take to reduce the problem you selected. **[1]**

c. The diagram below shows many finch species that originated from a single ancestral finch species in the Galápagos Islands.



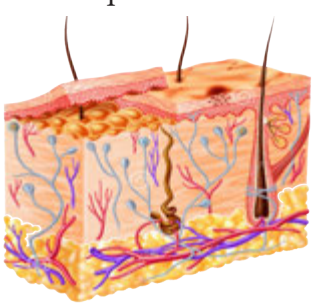
i. Explain why many different finch species originated from the single ancestral species? **[1]**

ii. No one has ever directly observed evolution happening, so why do you think it is true? **[1]**

d. Explain homeostasis. **[2]**

Question 7

a. The following two organs of the body are involved in homeostasis. Study and answer the questions i and ii.



X

Y

i. Identify the organ X and Y. **[1]**

ii. Briefly explain what each structure does in maintaining homeostasis of the human body. **[1]**

b. Write one function of the following. [2]

   i. Neutrophil

   ii. Macrophage

c. State the theory that best explain the ascent of sap. [1]

d. State any two factors responsible for ascent of sap? [1]

e. 'Substance abuse is one of the major problems for the Bhutanese society'. Justify. [2]

f. Explain two methods by which plants reduce transpiration. [2]

Glossary

Abscission: It is the shedding of various parts of an organism, such as a plant dropping a leaf, fruit, flower, or seed. In zoology, abscission is the intentional shedding of a body part, such as the shedding of a claw, husk, or the autotomy of a tail to evade a predator.

Acetylcholine: A neurotransmitter substance that carries information across the neuromuscular junction or synapses.

Active transport: The transport of a substance (salt or ions) across a cell membrane with the expenditure of energy, often against the concentration gradient.

Adaptation: In evolutionary biology, a particular structure, physiological process, or behaviour that makes an organism more fit to survive and reproduce.

Adsorption: It is the adhesion of molecules of gas, liquid, or dissolved solids to a surface. This process creates a film of the adsorbate (the molecules or atoms being accumulated) on the surface of the adsorbent. It differs from absorption, in which a fluid is dissolved by a liquid or solid.

Alveoli: The endings of the terminal bronchioles inside the lungs. These are the sites of gas exchange between air in lungs and the blood.

Biotechnology: It is any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.

Capillary action: It is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to external forces like gravity.

Cellular differentiation: It is the process by which a less specialized cell becomes a more specialized cell type. Differentiation occurs many times during the development of a multicellular organism as the organism changes from a single zygote to a complex system of tissues and cell types.

Centromere: The point on a chromosome to which spindle fibres attach during nuclear division.

Cellulose: A complex polysaccharide which is the main constituent of the cell wall in most plants.

Clone: Genetically identical cells or organisms produced from a common ancestor by asexual reproduction.

Competition: Resources of every sort are mostly in limited supply, and so organisms

must compete for them. For example, plants may compete for space, light and mineral ions. Animals may compete for food, shelter and mates.

Control: The set-up in **(in experiment)** which the factor under study is eliminated for comparing with the experiment in which the factor is provided.

Cytoplasmic streaming: The movement of the fluid substances (cytoplasm) within a plant or an animal cell. This fluid movement transports nutrients, proteins, and other substances within cells.

Dermatis: It is a dietary supplement for those who are suffering from skin disease either due to direct contact with an irritating substance, chemicals, certain food that contains wheat, dairy products, or to an allergic reaction. Symptoms include redness, itching, burning and in some cases blistering.

Diploid: An organism whose cells have two strands (homologous chromosomes) in each chromosome, forming a pair.

Dormancy: It is a period in an organism's life cycle when growth, development, and (in animals) physical activity are temporarily stopped. This minimizes metabolic activity and therefore helps an organism to conserve energy

Ectoderm: The outermost of the three germ layers, which appears early in the development of an animal embryo. In vertebrates, ectoderm subsequently gives rise to hair, skin, nails or hooves, and the lens of the eye; the epithelia of sense organs, etc.

Emulsification: Break-up of oil and fat into tiny droplets which remain suspended in water as an emulsion.

Eutrophication: It is the process by which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen. This can be a problem in marine habitats such as lakes as it can cause algal blooms.

Exudation: The escape of fluid, cells, and cellular debris from blood vessels and their deposition in or on the tissues, usually asthe result of inflammation.

Foetus: The later stage of an embryo, still contained in an egg or uterus; in humans, the unborn young from the eighth week of pregnancy to the moment of birth.

Follicle: In female mammals, an immature egg surrounded by uterine cells.

Feedback mechanism: Control mechanism whereby an increase or decrease in the concentration of some molecules respectively decreases or increases in its synthesis.

Fibrin: A type of protein that forms long strands during blood clotting process to trap red blood cells.

Gastrointestinal tract (digestive tract, GI tract, gut, or alimentary canal): It is an organ system within humans and other animals which takes in food, digests it to extract and absorb energy and nutrients, and expels the remaining waste as feaces and urine.

Genotype: The genetic constitution or gene make up of an organism.

Genetic engineering: Altering the genetic constitution of an organism by introducing new DNA into its chromosome.

Germ cell: It is any biological cell that gives rise to the gametes of an organism that reproduces sexually.

Glands: Collections of cells and tissues that produce substances for release such as endocrine glands that makes hormones.

Glycogen: A polysaccharide carbohydrate stored in the liver and muscles, also called animal starch.

Gonad: An organ that produces sex cells in animals either an ovary (female gonad) or testis (male gonad).

Gray matter: Regions of brain (outer region) and spinal cord (inner region) that appears gray, consisting chiefly of the cell bodies of neurons.

Habitat: Natural home of a plant or an animal.

Homeostasis: The maintenance of a steady state, such as a constant temperature or a stable social structure, by means of physiological or behaviour feedback responses.

Homologous chromosomes: They are chromosome pairs (one from each parent) that are similar in length, gene position, and centromere location.

Hybrid: The offspring of genetically unlike parents.

Imbibition: It is a special type of diffusion when water is absorbed by solids-colloids causing an enormous increase in volume. Examples include the absorption of water by seeds and dry wood.

Inflammation: A localized physical condition in which part of the body becomes reddened, swollen, hot, and often painful, especially as a reaction to injury or infection.

Lactation: It is the secretion and yielding of milk by females after giving birth. The milk is produced by the mammary glands, which are contained within the breasts

Melanin: The skin's natural pigment or colouring. It is produced by special cells called melanocytes, which lie in the bottom of epidermis.

Mesoderm: It is one of the three primary germ layers in the very early embryo. The other two layers are the ectoderm (outside layer) and endoderm (inside layer), with the mesoderm as the middle layer between them.

Mesophyll cells: They are a type of tissue found in the plant's leaves. There are two types of mesophyll cells: Palisade mesophyll cells and spongy mesophyll cells. The most important role of the mesophyll cells is in photosynthesis.

Metabolism: It is a term that is used to describe all chemical reactions involved in maintaining the living state of the cells and the organism.

Monosaccharide: It consists of one sugar unit that cannot be further broken down into simpler sugars.

Narcosis: It is state of stupor, drowsiness, or unconsciousness produced by drugs.

Nerve impulse: A wave of electrical disturbance that passes over the nerve cell.

Neuro-transmitter: A substance, produced in and released by one neuron, that diffuses across a synapse and excites or inhibits the post-synaptic neuron.

Nucleotide: A single unit of nucleic acid composed of phosphate, five carbon sugar, and purine or pyrimidine base.

Organic compound: It is any member of a large class of gaseous, liquid, or solid chemical compounds whose molecules contain carbon. Inorganic compound is any compound that lacks a carbon atom.

Pathogens: A bacterium, virus, or other microorganism that can cause disease.

Phenotype: The observable characteristics which is controlled genetically.

Psychosis: It is a severe mental disorder in which thought and emotions are so impaired that contact is lost with external reality.

Puberty: The period of growth during which humans become sexually mature.

Random assortment: It refers to the way chromosomes get organized into daughter cells during gamete (sperm and egg) formation. It means that each sperm and each egg will have different combinations of chromosomes, some of which will have come from the person's mother and others from the father.

Recombinant DNA technology: The application of genetic tools (restriction endonucleases, plasmids and transformation) to the production of specific proteins by biological 'factories' such as bacteria.

Sedative: It is a substance that induces sedation by reducing irritability or excitement.

At higher doses it may result in slurred speech, staggering gait, poor judgment, and slow, uncertain reflexes.

Senescence: It is the process by which cells irreversibly stop dividing and enter a state of permanent growth arrest without undergoing cell death.

Serum: Part of the blood plasma that is left behind after blood clotting has occurred.

Sex chromosome: A chromosome usually designated X or Y particularly concerned with sex detormination; e.g., in Drosophila and mammals including man, the female is XX and the male is XY.

Sodium pump: A system, usually requiring ATP, which transports sodium against its concentration gradient from the inside of cells to the outside.

Somatic cell: It is any cell that makes up an organism, except for a reproductive cell. For example, the cells that make up your skin are all somatic cells.

Stimulant: Any drug that excites any bodily function, but more specifically those that stimulate the brain and central nervous system. Stimulants induce alertness, elevated mood, wakefulness, increased speech and motor activity and decrease appetite.

Synapse: The space over which a nerve impulse passes from the terminal branches of the axon of one neuron to the dendrites of another neuron.

Transmutation: It is the action of changing of one element into another by radioactive decay, nuclear bombardment, or similar processes.

Stain: It is a reagent or dye that is used for staining microscopic specimens.

Spirometry: It is a common office test used to assess how well your lungs work by measuring how much air you inhale, how much you exhale and how quickly you exhale.

Vertebrate: It is an animal with a spinal cord surrounded by cartilage or bone. Animals that are not vertebrates are called invertebrates. Vertebrates include birds, fish, amphibians, reptiles, and mammals.

Vestigial organs: The organs or parts of the body considered not in use. They included the muscles of the ear, wisdom teeth, the appendix, the tail bone, body hair, and the semilunar fold in the corner of the eye.

Xerophyte: Any plant adapted to life in a dry or physiologically dry habitat (salt marsh, saline soil, or acid bog) by means of mechanisms to prevent water loss or to store available water.

Zygote: A cell formed by fusion of male and female gametes.