SUPER ECONOMY EDITION

Test Edition
Model Textbook of

BIOLOGY

Based on National Curriculum of Pakistan 2022-23

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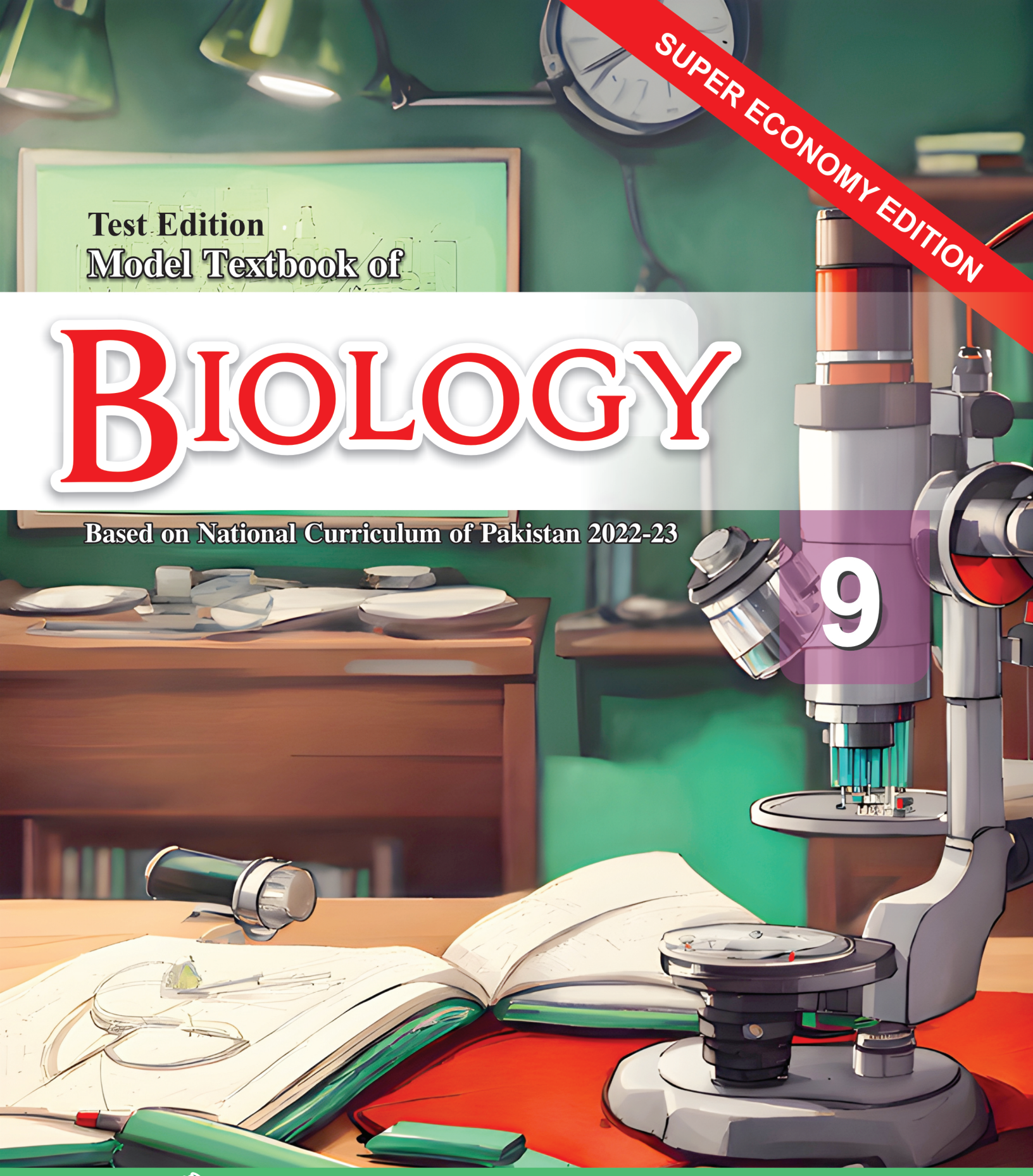

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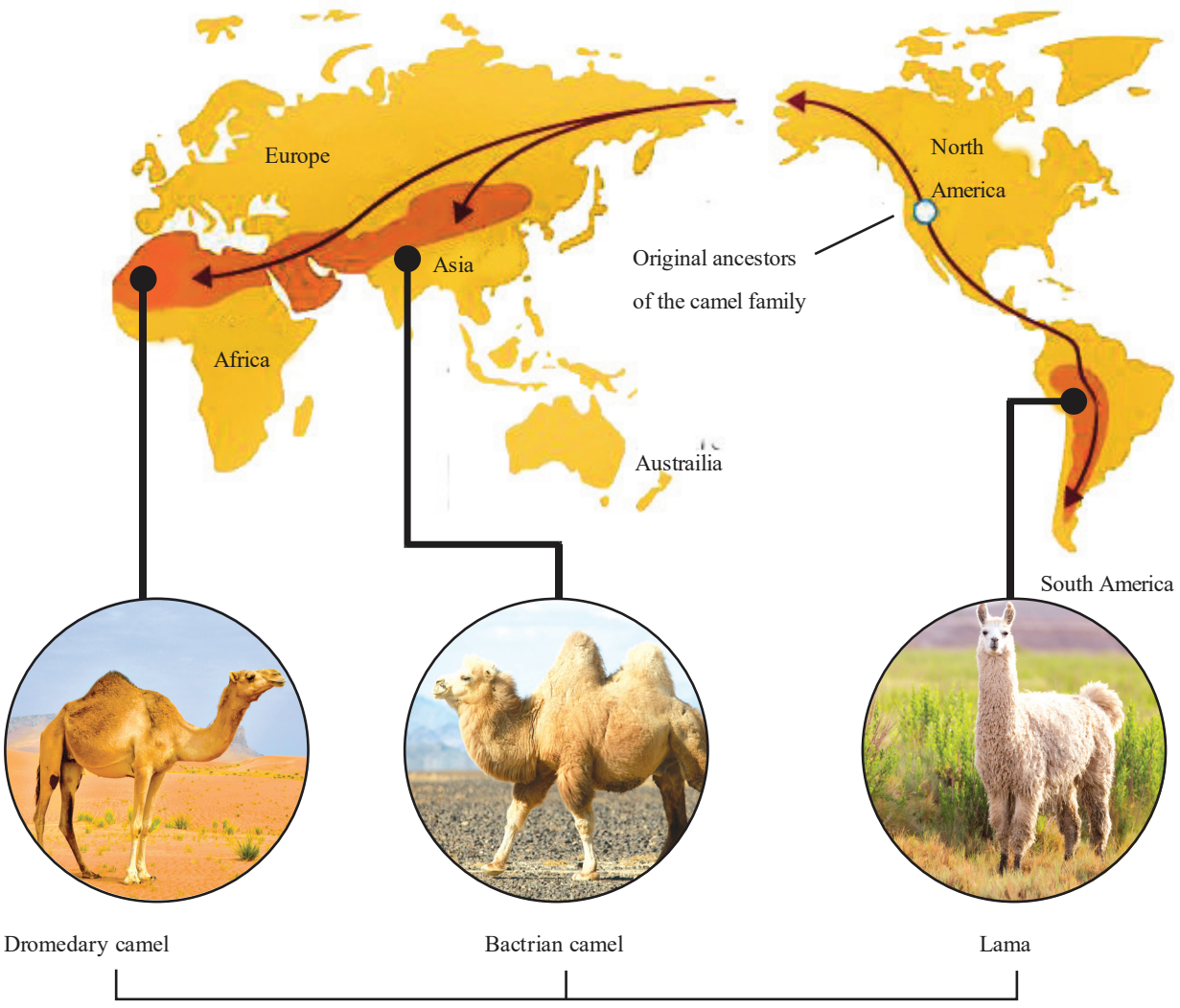
Biology

Grade 9th



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A Textbook of Biology
for Grade 9

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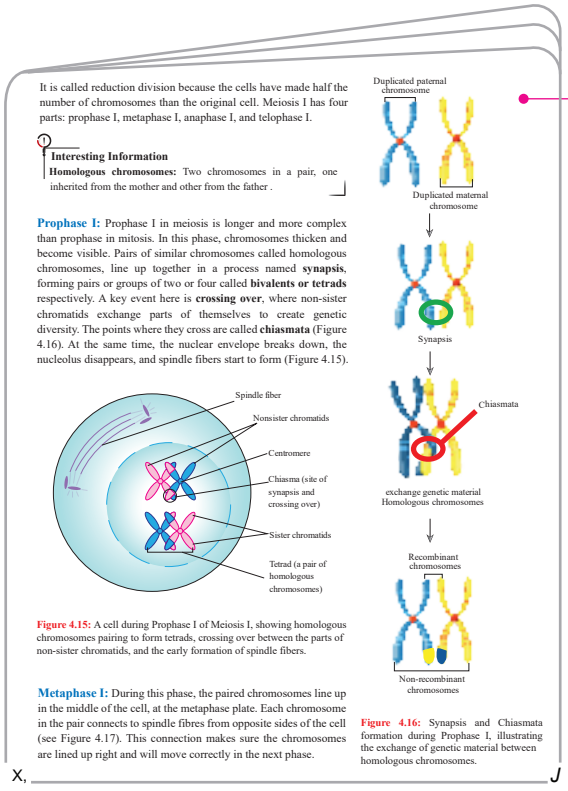
Preface

This Grade 9 Biology textbook, aligned with the 2023 curriculum, is designed to enhance students' learning experience. It features high-quality pictorial representations, real-life applications, and experimental skills. The book includes high-order thinking exercises, skill sheets for testing understanding, group activities, and recorded video lectures with animations and simulations. It is structured to aid teachers in creating assessment questions based on Bloom's Taxonomy. At the end of the book, a comprehensive glossary provides quick term references. This educational tool aims to enrich students' knowledge and appreciation of biology.

The QR codes in the biology textbook provide easy access to video lectures for gaining knowledge and skill sheets for practical application. They make learning more interactive, letting students watch lectures and practice skills right when they need them, making studying biology more engaging and effective.



It is called reduction division because the cells have made half the number of chromosomes than the original cell. Meiosis I has four parts: prophase I, metaphase I, anaphase I, and telophase I.

Interesting Information

Homologous chromosomes: Two chromosomes in a pair, one inherited from the mother and other from the father .

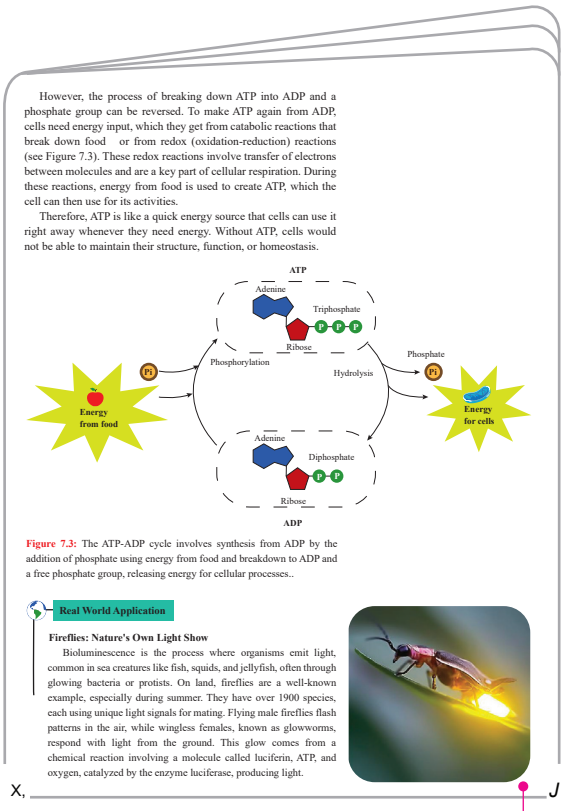
Prophase I: Prophase I in meiosis is longer and more complex than prophase in mitosis. In this phase, chromosomes thicken and become visible. Pairs of similar chromosomes called homologous chromosomes, line up together in a process named **synapsis**, forming pairs or groups of two or four called **bivalents or tetrads** respectively. A key event here is **crossing over**, where non-sister chromatids exchange parts of themselves to create genetic diversity. The points where they cross are called **chiasmata** (Figure 4.16). At the same time, the nuclear envelope breaks down, the nucleolus disappears, and spindle fibers start to form (Figure 4.15).

Figure 4.15: A cell during Prophase I of Meiosis I, showing homologous chromosomes pairing to form tetrads, crossing over between the parts of non-sister chromatids, and the early formation of spindle fibers.

Metaphase I: During this phase, the paired chromosomes line up in the middle of the cell, at the metaphase plate. Each chromosome in the pair connects to spindle fibres from opposite sides of the cell (see Figure 4.17). This connection makes sure the chromosomes are lined up right and will move correctly in the next phase.

Figure 4.16: Synapsis and Chiasmata formation during Prophase I, illustrating the exchange of genetic material between homologous chromosomes.

Diagrams in a biology textbook create strong mental images that stick with students, making it easier to remember and understand complex information quickly. These visuals serve as powerful memory aids, reinforcing concepts in a way that stays in students' mind for a long time.



However, the process of breaking down ATP into ADP and a phosphate group can be reversed. To make ATP again from ADP, cells need energy input, which they get from catabolic reactions that break down food or from redox (oxidation-reduction) reactions (see Figure 7.3). These redox reactions involve transfer of electrons between molecules and are a key part of cellular respiration. During these reactions, energy from food is used to create ATP, which the cell can then use for its activities.

Therefore, ATP is like a quick energy source that cells can use it right away whenever they need energy. Without ATP, cells would not be able to maintain their structure, function, or homeostasis.

Figure 7.3: The ATP-ADP cycle involves synthesis from ADP by the addition of phosphate using energy from food and breakdown to ADP and a free phosphate group, releasing energy for cellular processes..

Real World Application

Fireflies: Nature's Own Light Show

Bioluminescence is the process where organisms emit light, common in sea creatures like fish, squids, and jellyfish, often through glowing bacteria or protists. On land, fireflies are a well-known example, especially during summer. They have over 1900 species, each using unique light signals for mating. Flying male fireflies flash patterns in the air, while wingless females, known as glowworms, respond with light from the ground. This glow comes from a chemical reaction involving a molecule called luciferin, ATP, and oxygen, catalyzed by the enzyme luciferase, producing light.

Real life examples in a Grade 9 biology book help us see how biology applies to the world around us. They make learning more interesting and show us how important biology is in our daily lives.

SLO based Model Video lecture

Salient Features

Comprehensive Learning
Engage students with videos, simulations, and practical worksheets.

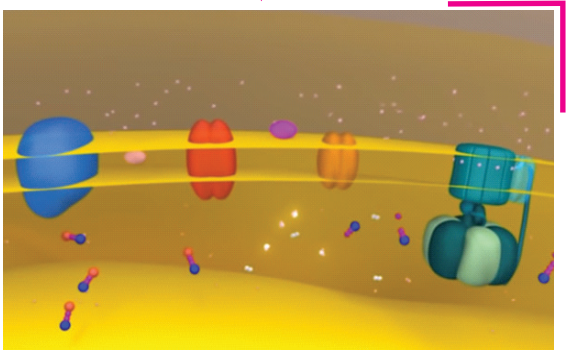
Structured Lesson Plan
Well-organized with clear objectives, PPTs, and a question bank.

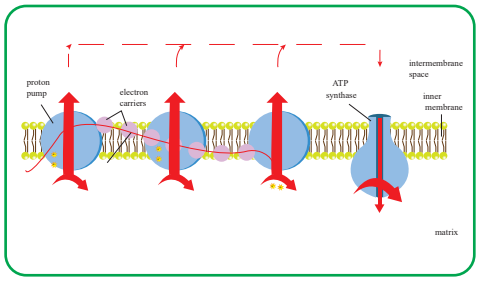
Engaging Multimedia
Visual appeal through PPTs and interactive simulations.

Assessment & Tracking
Diverse question bank and progress monitoring.

Adaptable & Accessible
Scalable and accessible, suitable for all learners.

Animation

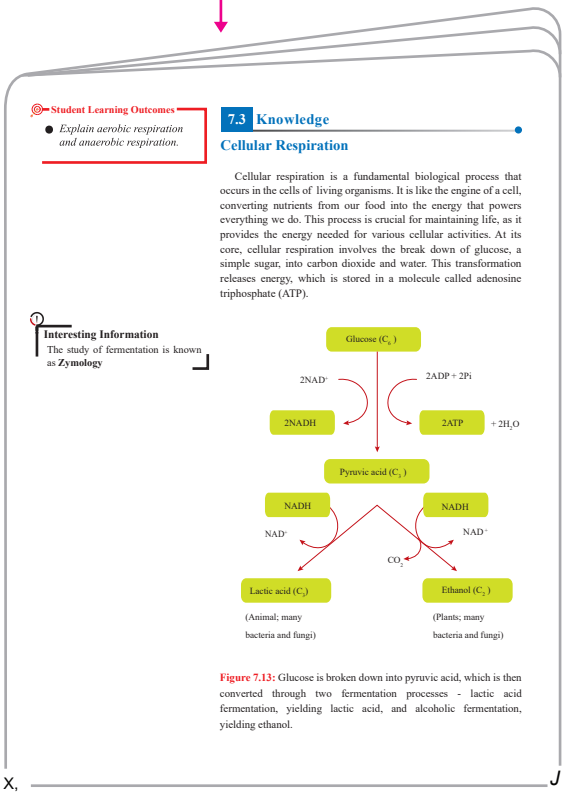




Skills Sheet

SLO No: B - 09 - F - 08
Explain aerobic respiration and anaerobic respiration

KNOWLEDGE



Student Learning Outcomes
- *Explain aerobic respiration and anaerobic respiration.*

7.3 Knowledge

Cellular Respiration

Cellular respiration is a fundamental biological process that occurs in the cells of living organisms. It is like the engine of a cell, converting nutrients from our food into the energy that powers everything we do. This process is crucial for maintaining life, as it provides the energy needed for various cellular activities. At its core, cellular respiration involves the break down of glucose, a simple sugar, into carbon dioxide and water. This transformation releases energy, which is stored in a molecule called adenosine triphosphate (ATP).

Interesting Information
The study of fermentation is known as **Zymology**

Figure 7.13: Glucose is broken down into pyruvic acid, which is then converted through two fermentation processes - lactic acid fermentation, yielding lactic acid, and alcoholic fermentation, yielding ethanol.

CONTENTS

CHAPTER 1

Introduction to Biology

Plastic surgery

Plastic surgery is a medical speciality that involves altering a person's physical appearance by moving and reshaping tissues such as fat, bone, and cartilage. One of the most common procedures is **Rhinoplasty**, also known as a "**nose job**," which involves reshaping the nose by adjusting the bone and cartilage. Another popular operation is **Reconstructive plastic surgery** focuses on restoring functionality to damaged body parts and not just improving physical appearance. This type of surgery is often performed on individuals who have suffered severe burns and involves the removal of damaged tissue and skin grafting to improve both function and cosmetic appearance

Student Learning Outcomes

- State Quran instructs to reveal the study of life.
- Define Biology .
- Define major fields of biology as Botany, Zoology and Microbiology.
- Define with examples that biology has many sub-fields. - Cytology - Embryology - Genetics Molecular Biology - Pathology - Ecology - Marine Biology - Immunology - Morphology Anatomy - Histology - Physiology - Taxonomy - Paleontology – Pharmacology
- Relate that biology connects with other natural sciences. Students should be able to distinguish in terms of the broad subject matter the below fields: - Biophysics - Biochemistry - Computational Biology -Biogeography - Biostatistics - Biotechnology - Bioeconomics
- Identify the careers in Biology and Explain with example which show that biology is a subset of the natural sciences and of the life sciences.
- Justify with examples that science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas.
- Describe the steps of the scientific method: that is Recognition, Observation, Hypothesis, Deduction, Experiments, and Results.
- Evaluate the terms 'hypothesis', 'theory' and 'law' in the context of research in the natural sciences.

All the above mentioned SLOs are classified into knowledge and skills for the better understanding of students.

After studying this Unit, the students will be able to:

Knowledge

1. Understand how the Quran encourages the study of life.
2. Definition and understanding of the subject of biology.
3. Understand the major fields of biology: Botany, Zoology, and Microbiology .
4. Definition and examples of sub-fields of biology such as Cytology, Embryology, Genetics, etc.
5. Understand how biology interacts with other natural sciences like Biophysics, Biochemistry, etc.
6. Recognize various career opportunities in the field of Biology .
7. Understand the collaborative nature of science and the importance of interdisciplinary research
8. Understand the steps of the scientific method: recognition, observation, hypothesis, deduction, experiments and results .
9. Understand the terms 'hypothesis', 'theory', and 'law' in the context of research in the natural sciences

Skills

1. Ability to interpret relevant verses from the Quran that highlight the importance of studying life and nature.
2. Comprehension and recall of the definition of biology.
3. Differentiation and identification of major biological branches and their primary focus areas.
4. Recognition of specific sub-fields within biology and associating them with relevant examples or key concepts.
5. Analytical thinking to draw connections between biology and other natural sciences. Ability to categorize and distinguish between overlapping scientific disciplines
6. Analytical thinking to identify the careers that are related to biology.
7. Evaluation of real-world examples where collaboration led to scientific advancements
8. Sequential thinking to understand and apply the steps of the scientific method in practical scenarios.
9. Critical thinking to differentiate between hypothesis, theory and law. Comprehension and application of skills to utilize these terms appropriately in a scientific context.

1.1 Knowledge

Quran and the Study of Life (Biology)

The relationship between science and religion is interesting, especially between Islam and biology. The Quran, which is the holy book of Islam, talks a lot about nature and living things. Here are a few Quranic verses related to it:

وَجَعَلْنَا مِنَ الْمَآءِ كُلَّ شَيْءٍ حَيٍّ ط (سورۃ الانبیاء:۳۰)

"And We made from water every living thing."

The Quran talked about how important water is for life, and science says the same thing. Every living thing, from tiny bacteria to humans, needs water. Our bodies have a lot of water, even in key parts like our brain and heart (see Fig. 1.1). This tells us water is really important for life.

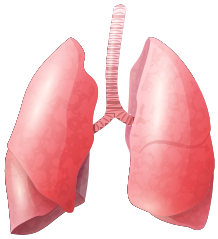
Student Learning Outcomes

- *State Quran instructs to reveal the study of life.*

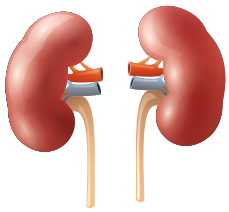
Knowledge Booster

According to H.H. Mitchell, Journal of Biological Chemistry: "the brain and heart are composed of 73% water, and the lungs are about 83% water. The skin contains 64% water, muscles and kidneys are 79%, and even the bones are 31% watery" Figure 1.1.

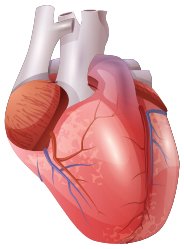
Brain-73%



Lung-83%



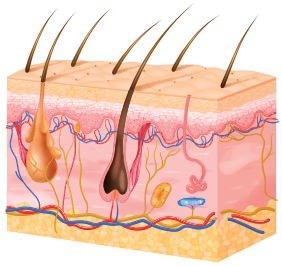
Kidney-79%



Heart-73%

Muscles-79%

Bones-31%



Skin-64%

Figure 1.1 : Water content in different body organs emphasises importance of water in the body.

Knowledge Booster

The study published in the journal PLoS Biology, revealed that humans share the planet with as many as 8.7 million different forms of life.

وَاللّٰهُ خَلَقَ كُلَّ دَآبَّةٍ مِّنْ مَّآءٍ ۚ فَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى بَطْنِهٖ ۚ وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰى رِجْلَيْنِ ۚ وَمِنْهُمْ مَّنْ يَّمْشِيْ عَلٰٓى اَرْبَعٍ ۭ يَخْلُقُ اللّٰهُ مَا يَشَاۗءُ ۭ اِنَّ اللّٰهَ عَلٰي كُلِّ شَيْءٍ قَدِيْرٌ ۝ (سورۃ النور:۴۵)

"And Allah has created every moving creature from water. So, some of them move on their bellies, and some of them move on two legs, and some of them move on four. Allah creates what He wills. Surely, Allah is powerful over everything."

The verse tells us that Allah made lots of different animals, like those that crawl and those that walk (see Figure 1.2). This mix of animals and where they live is called biodiversity. It is good for our Earth because each animal, big or small, like snails or humans, has an important job in nature. This variety shows Allah's creativity and is very important for keeping our planet healthy.

Learning about this variety of life helps us understand how living things are classified, which is something students will study in the chapter on Biodiversity and Classification.

Crawling Snail

Ostrich with two legs

Camel with four legs

Figure 1.2: Diversity Among Animals

وَبَدَاَ خَلْقَ الْاِنْسَانِ مِنْ طِيْنٍ ۚ (سورۃ سجدہ:۰۷)

"And started the creation of man from clay(soil)."

The Quran explains that humans are made of elements similar to those in clay (Table 1). This shows we have a close connection to the Earth. Plants absorb these elements from the soil, and we get them when we eat plants. After we die, these elements return to the soil. This creates a cycle that connects all life on Earth. The Quran teaches us about the link between humans, nature, and the environment. In the following verse, Allah reveals more secrets about.The process of human development over fourteen `centuries ago

Table 1: Elements Common in Human and Soil:

Oxygen	Phosphorus	Iron
Carbon	Potassium	Silicon
Hydrogen	Sulfur	
Nitrogen	Sodium	
Calcium	Magnesium	

ثُمَّ خَلَقْنَا النُّطْفَةَ عَلَقَةً فَخَلَقْنَا الْعَلَقَةَ مُضْغَةً فَخَلَقْنَا الْمُضْغَةَ عِظٰمًا فَكَسَوْنَا الْعِظٰمَ لَحْمًا ثُمَّ اَنْشَاْنٰهُ خَلْقًا اٰخَرَ ؕ فَتَبٰرَكَ اللّٰهُ اَحْسَنُ الْخٰلِقِيْنَ ؕ ﴿۱۴﴾ (سورۃ المومنون:۱۴)

"Then We developed the drop into a clinging clot (of blood), then developed the clot into a lump (of flesh), then developed the lump into bones, then clothed the bones with flesh, then We brought it into being as a new creation. So Blessed is Allah, the Best of Creators."

This verse describes how a human grows before birth. It starts with a tiny drop, which turns into a clot of blood and then into a small piece of flesh. Next, bones form and are covered with flesh. Finally, a new human is fully formed. This shows how Allah is seen as the greatest creator in the process of life's creation.

Figure 1.3: A honey bee drinks nectar from flowers, producing honey that can heal people. This emphasises the wonders of nature.

وَ اَوْحٰى رَبُّكَ اِلَى النَّحْلِ اَنِ اتَّخِذِيْ مِنَ الْجِبَالِ بُيُوْتًا وَّ مِنَ الشَّجَرِ وَ مِمَّا يَعْرِشُوْنَ ﴿۶۸﴾ ثُمَّ كُلِيْ مِنْ كُلِّ الثَّمَرٰتِ فَاسْلُكِيْ سُبُلَ رَبِّكِ ذُلُلًا ؕ يَخْرُجُ مِنْۢ بُطُوْنِهَا شَرَابٌ مُّخْتَلِفٌ اَلْوَانُهٗ فِيْهِ شِفَآءٌ لِّلنَّاسِ ؕ اِنَّ فِيْ ذٰلِكَ لَاٰيَةً لِّقَوْمٍ يَّتَفَكَّرُوْنَ ﴿۶۹﴾ (سورۃ النحل:۶۸۔۶۹)

"And your Lord inspired to the bee, 'Take for yourself among the mountains, houses, and among the trees and [in] that which they construct. Then eat from all the fruits and follow the ways of your Lord laid down [for you].' There emerges from their bellies a drink, varying in colors, in which there is healing for people. Indeed, in that is a sign for a people who give thought."

This verse from Surah An-Nahl tells us about bees. It says that Allah guides bees to make homes in mountains, trees, and other places. The bees eat different fruits (Figure 1.3) and follow a path set by Allah. They produce honey in various colours (Figure.1.4), which can heal people. This verse shows us that bees have a special role in nature and that their honey is important for us. It encourages us to think about the wonders of life and nature.

Knowledge Booster

In Surah An-Nahl (68-69), it is clearly indicated that the words used to instruct the honey bees to collect honey from nectar are for the female gender. Interestingly, the study on honey bees revealed to the world that Worker bees are female bees who collect nectar from the flower and convert it into honey.

Figure 1.4: Honey bees produce different colours of honey.

وَهُوَ الَّذِیۡۤ اَنۡزَلَ مِنَ السَّمَآءِ مَآءً ۚ فَاَخۡرَجۡنَا بِهٖ نَبَاتَ كُلِّ شَیۡءٍ فَاَخۡرَجۡنَا
مِنۡهُ خَضِرًا نُّخۡرِجُ مِنۡهُ حَبًّا مُّتَرَاكِبًا ۚ وَمِنَ النَّخۡلِ مِنۡ طَلۡعِهَا قِنۡوَانٌ دَانِیَةٌ
وَّجَنّٰتٍ مِّنۡ اَعۡنَابٍ وَّالزَّیۡتُوۡنَ وَالرُّمَّانَ مُشۡتَبِهًا وَّغَیۡرَ مُتَشَابِهٍ ؕ
اُنۡظُرُوۡۤا اِلٰی ثَمَرِهٖۤ اِذَاۤ اَثۡمَرَ وَیَنۡعِهٖ ؕ اِنَّ فِیۡ ذٰلِكُمۡ لَاٰیٰتٍ لِّقَوۡمٍ یُّؤۡمِنُوۡنَ ﴿۹۹﴾

(سورۃ الانعام:۹۹)

"And it is He Who sends down water (rain) from the sky, and with it, We bring forth vegetation of all kinds, and out of it We bring forth green stalks, from which We bring forth thick clustered grain. And out of the date palm and its spathe come forth clusters of dates hanging low and near, and gardens of grapes, olives and pomegranates, each similar (in kind) yet different (in variety and taste). Look at their fruits when they begin to bear, and the ripeness thereof. Verily! In these things, there are signs for people who believe."

Knowledge Booster

The Quran highlights various plants that have notable health benefits: figs are great for digestion; olive trees produce olives that support heart health; grapes are also beneficial for the heart; date palms provide dates that help in digestion; and pomegranates are known to reduce the risk of chronic diseases.

This verse says that Allah sends rain to make many kinds of plants grow. It talks about green plants that give us grains, date palms with dates, and gardens with grapes, olives, and pomegranates. Each plant is similar but has different types and tastes. The verse tells us to look at how fruits grow and become ripe. It suggests that in the growth and variety of fruits, there are signs and lessons for people who believe in teaching about the wonders of nature and life.

Skill:1.1

Objective: Ability to interpret relevant verses from the Quran that highlight the importance of studying life and nature.

Test Yourself

Short answer-based questions:

1. Quran signifies the importance of water for life. Tell the percentage of water in brain, skin and kidneys?
2. The Quran informs that humans are made of elements similar to those in clay. Name any four elements that are common between human and clay?

1.2 Knowledge

Introduction to Biology

Biology comes from two Greek words: **"bios"** meaning life and **"logos"** meaning study. It is about studying all living things, from tiny bacteria to big whales (Figure 1.5). Lamarck was the first to use the word "biology." This subject helps us understand how living things like plants and animals interact with the world around them. It shows us our place in nature. When we study biology, we learn about how living things are made, how they grow, where they come from, where they live, and how they adopte to environmental changes.

Student Learning Outcomes

- *Define Biology*

Do you Know?

Aristotle was the first to investigate living organisms scientifically. As a result, he is referred to as the "Father of Biology".

Bacteria

Fungi

Dragon's Blood Tree

Altas Moth

Australian Cuscus

Blue Whale

Figure 1.5: A collection of living organisms from left to right: Bacteria, Fungi, Dragon's Blood tree, Altas Moth, Australian Cuscus and Blue Whale.

Biology is always exciting because there is always something new to discover. We will explore its different branches next, and each one helps us understand a different part of life and the world around us.

Skill:1.2

Objective: Comprehension and recall of the definition of biology.

1.3 Knowledge

Major fields of Biology

Student Learning Outcomes

- *Define major fields of biology as Botany, Zoology and Microbiology.*

Biology is a vast and diverse discipline that seeks to understand the many aspects of life. At a broad level, the major fields include Botany, Zoology, and Microbiology:

Figure 1.6: Illustration of different types of plants

Botany

Botany is the study of plants (Figure 1.6). It looks at how plants grow, make new plants, and how they live.

Zoology

Zoology is the study of animals (see Figure 1.7). It explores how animals live, grow, and behave.

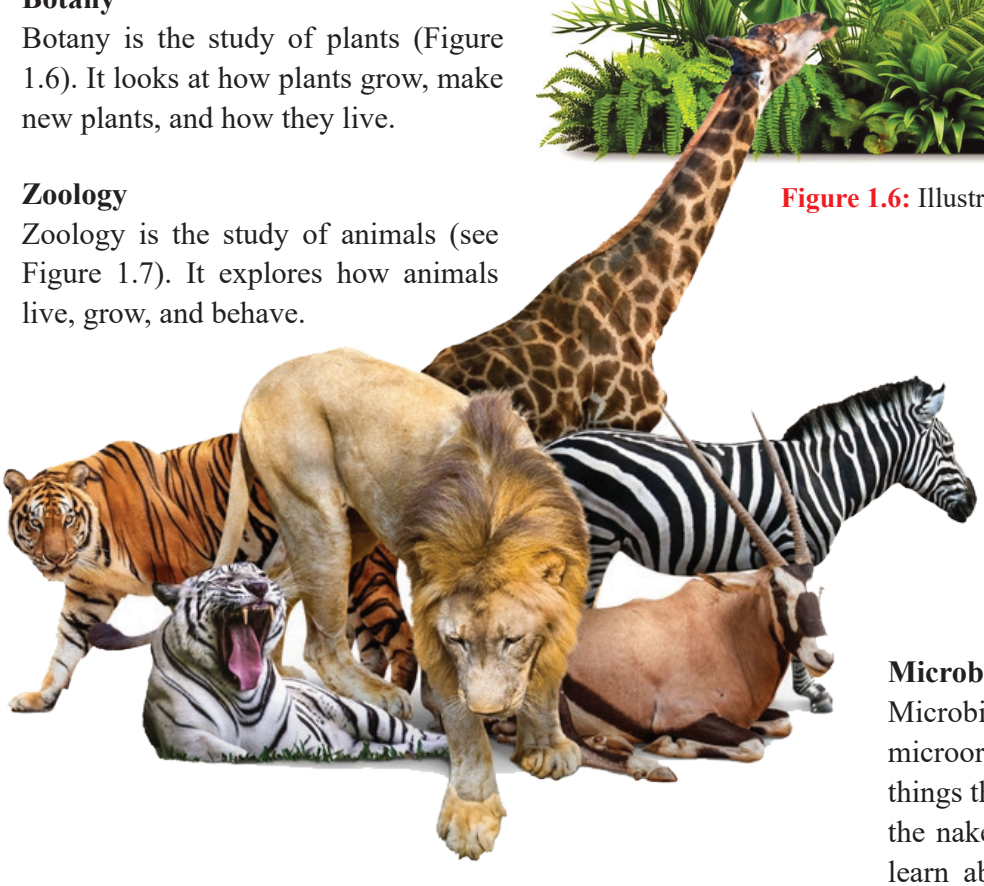


Figure 1.7: A display of biodiversity in the animal kingdom.

Microbiology

Microbiology is the study of microorganisms, which are living things that are too small to be seen with the naked eye (Figure 1.8). It helps us learn about these small creatures and how they impact our health and the world around us.

Skill: 1.3

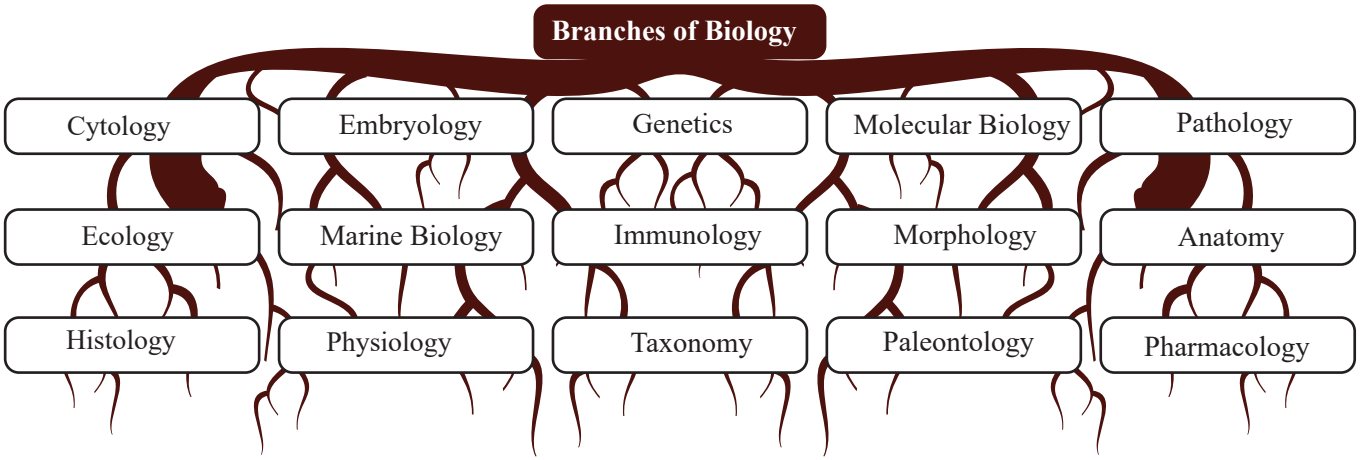
Objective: Differentiation and identification of major biological branches and their primary focus areas.

Figure 1.8: Growth of microorganisms on a petri dish.

1.4 Knowledge

Sub-fields of Biology

Going beyond the main areas of Botany, Zoology, and Microbiology, it is interesting to see that biology has many smaller areas, each looking at specific things.



Cytology

Cytology is the study of cells. Cytologists examine the structure, function, and development of cells. For instance, a cytologist studies the structure of the cell membrane, such as how it allows certain molecules to pass through while keeping others out.

Embryology

Embryology is the study of the development of an organism from an embryo to a complete individual. Embryologists focus on the various stages of this development. For example, an embryologist looks into how the human heart develops.

Genetics

The study of genes and heredity is known as genetics. The study of genetics focuses on the inheritance of qualities from parents to offspring. For example, a geneticist researches how parents pass on the genes that determine a child's eye colour.

Molecular Biology

The study of the molecules that comprise living organisms is known as molecular biology. Molecular biologists investigate the structure and function of biomolecules. For example, a molecular biologist studies the structure of DNA, such as how the base pairs are arranged and how the DNA molecule is coiled.

Student Learning Outcomes

- *Define with examples that biology has many sub-fields. - Cytology - Embryology - Genetics - -Molecular Biology- Pathology - Ecology - Marine Biology - Immunology - Morphology Anatomy - Histology - Physiology - Taxonomy - Paleontology - Pharmacology*

Knowledge Booster

Study of Fungi:
Mycology is the study of fungi Mycologists learn about how fungi grow, their shapes, and their roles in nature. They also look at how fungi can be used in food, medicine, and industry.

Pathology

Pathology is the study of disease. Pathologists study the causes, symptoms and treatment of diseases. A pathologist, for instance, investigates the causes of cancer.

Ecology

Ecology is the study of how living things interact with each other and their environment. Living things are called **biotic factors**, and non-living things are called **abiotic factors**. For example, the red panda in the eastern Himalayas depends on bamboo plants for food (biotic factor) and is affected by temperature and rainfall (abiotic factors). These factors affect their population in their habitat.

Marine Biology

The study of life in the oceans is called marine biology. Marine biologists research the variety of marine life and how it interacts with the water. A marine biologist, for instance, studies the behaviour of whales, such as how they communicate with each other.

Do you Know?

Edward Jenner is known as the "Father of Immunology" because he created the first successful vaccine, which was for **smallpox**. His work laid the foundation for modern vaccines and the study of how to protect people from infectious diseases.

Immunology

Immunology is the study of the immune system. Immunologists study how the immune system protects the body from disease. For example, an immunologist examines how antibodies are produced to fight off viruses.

Morphology

Morphology is the study of the form and structure of organisms. Morphologists study the external and internal features of organisms For example , a morphologist investigates the evolution of the shape of a bird's beak. Different birds have different beak shapes that are adapted to their diet.

Web Question?

What are the beak shapes of hawks and ducks, and why do they have these shapes?

Anatomy

Anatomy is the study of the internal structure of organisms. Anatomists study the organs, tissues, and cells of organisms. For example, an anatomist examines the structure of the human heart, such as how the chambers of the heart are arranged.

Histology

Histology is the study of tissues. Histologists study the structure and function of tissues. For example, studying the different types of connective tissue is an example of histology.

Physiology

The study of the functions of various parts of living things is called physiology. For example, studying how the heart pumps blood is an example of physiology.

Taxonomy

Taxonomy is the study of the classification of organisms. Taxonomists classify organisms based on their shared characteristics. For example, a taxonomist classifies new species of plants or animals, such as how they are related to other species.

Palaeontology

The study of fossils is called palaeontology. Palaeontologists study the fossils of extinct organisms. They use fossils to learn about the evolution of life on Earth. For example, palaeontologists study the fossils of dinosaurs to know how they lived and died.

Pharmacology

Pharmacology is the study of drugs. Pharmacologists study the effects of drugs on living things and the development of new drugs. For example, a pharmacologist examines the effects of new drugs on cancer cells, such as how the drugs kill cancer cells without harming healthy cells.

Test Yourself

Short answer-based questions:

1. What do marine biologists study?
2. Explain the primary focus of cytology.
3. What does a taxonomist do?
4. What is the primary focus of embryology?
5. Describe the main difference between zoology and botany.
6. Define pathology.

1.5 Knowledge

Biology and Natural Sciences

The relationship between science and religion is interesting, especially between Islam and biology. The Quran, which is the holy book of Islam, talks a lot about nature and living things. Here are a few Quranic verses related to it:

Biology does not work alone. It works with other sciences to understand nature. These sciences utilize each other's methods

Interesting Information

All plants are classified in the kingdom Plantae. Within the kingdom Plantae, there are two main phyla: angiosperms and gymnosperms. Within the phylum Angiosperms, there are over 300,000 species of plants. These species are further classified into classes, orders, families, genera, and species.

Web Question?

Find out who is the father of Modern Botany, Modern Genetics and Modern Embryology?

Skill:1.4

Objective: Recognition of specific sub-fields within biology and associating them with relevant examples or key concepts.

Student Learning Outcomes

- *Relate that biology connects with other natural sciences. Students should be able to distinguish in terms of the broad subject matter the below fields: - Biophysics - Biochemistry - Computational Biology - Biogeography - Biostatistics - Biotechnology - Bioeconomics.*

Figure 1.9: A biophysics lab in National Institute of Standards and Technology.

and techinques that helps scientists learn more about life and how living things relate to their surroundings. Here are some examples of how biology connects with other natural sciences:

Biophysics

Biophysics is the application of physical principles to biological problems. It looks at how physical forces like intermolecular forces or electricity work in the world of living organisms (Figure 1.9). For example, biophysicists might study how nerves in our body send electrical signals.

Biochemistry

Biochemistry is the study of the chemical processes and interactions that occur in living systems. Biochemists study the structure and function of biomolecules such as carbohydrates, lipids, proteins and nucleic acids (Fig. 1.10). For example, biochemistry can help understand how enzymes catalyze reactions.

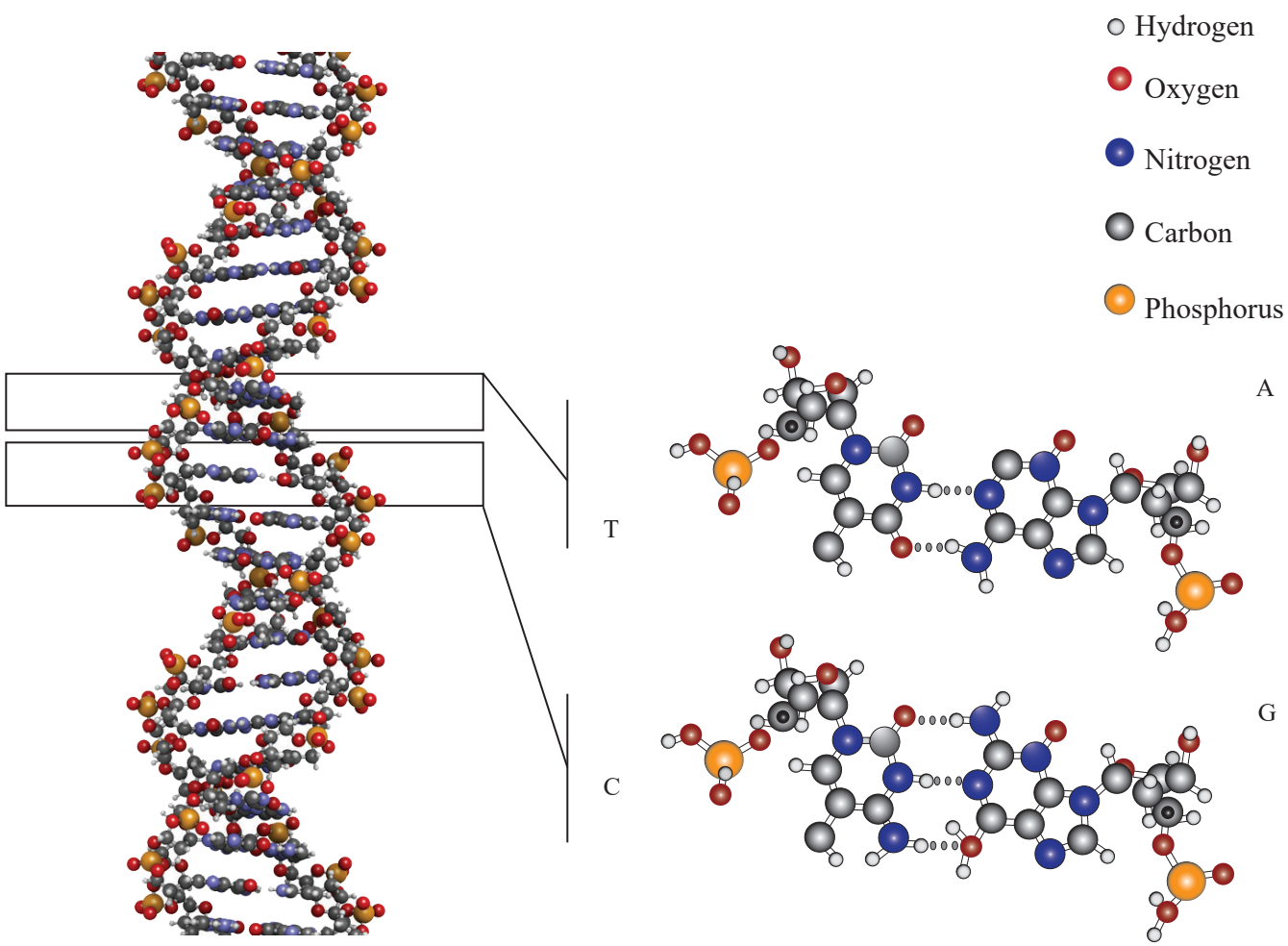


Figure 1.10: The biochemical structure of the DNA double helix

Computational Biology

Computational biology is the use of computers and mathematics to learn about living things (students will learn more about computational biology in grade 12). Scientists in this field use computer programs and databases (like a digital library) to answer difficult biological questions. For instance, they can help read genes and guess how proteins look.

Do you Know?

Computational biology used computers to organize and analyze vast amounts of genetic information, making it possible to fully understand human **chromosome 22**, the first chromosome to be fully sequenced. This important step in 1999 helped scientists learn more about human DNA.

Biogeography

Biogeography is the study of the geographic distribution of living organisms on Earth. It also examines the abiotic factors, such as temperature and rainfall, that affect their distribution (see Figure 1.11).

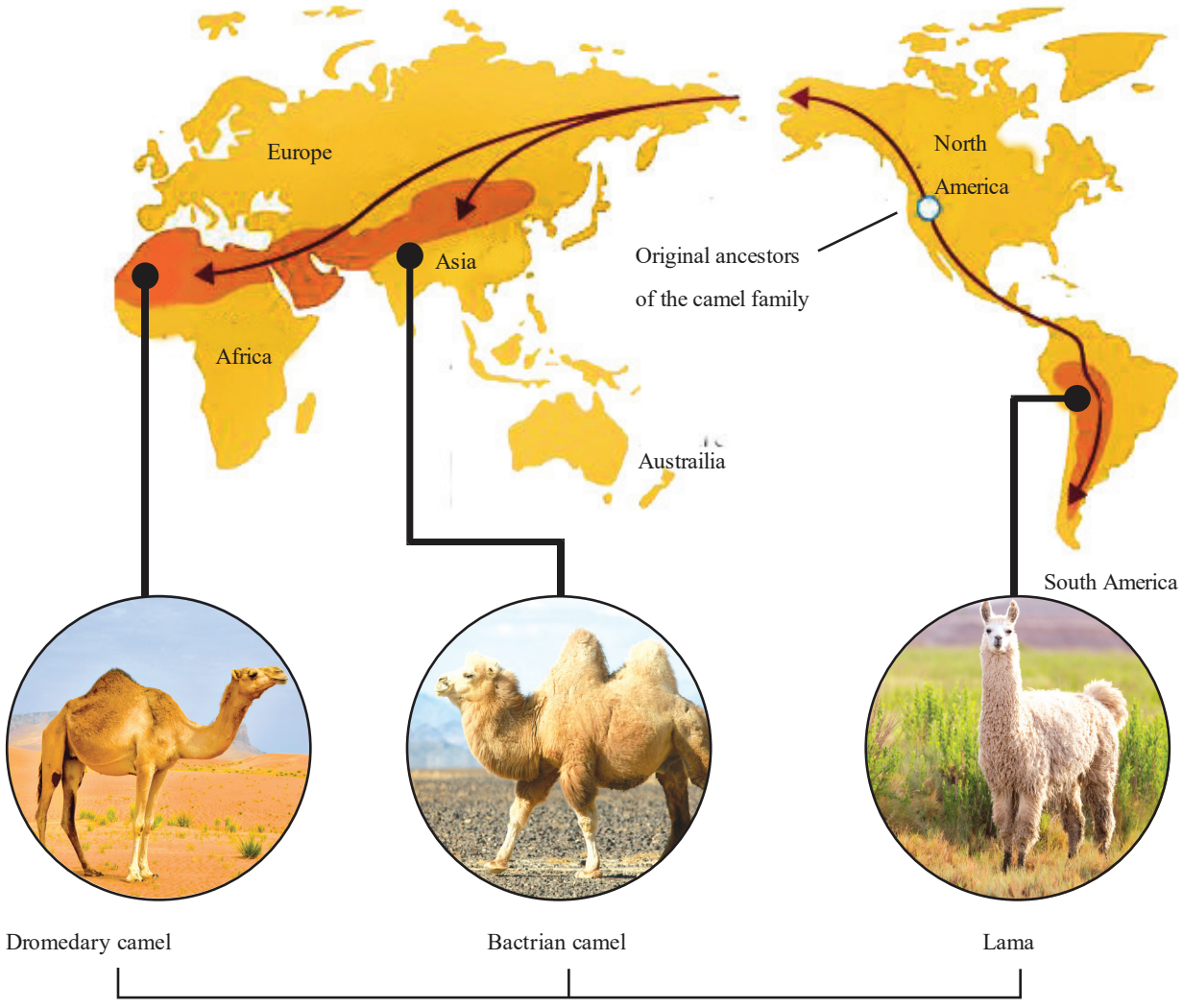


Figure 1.11 : The geographic distribution of members of the camel family across different regions of the Earth.

Biostatistics

Biostatistics is the application of math and statistics to study living things. It helps scientists understand data from biology, like how often a disease occurs or how a new medicine works.

Biotechnology

Biotechnology is the application of science and technology to work with living things to make valuable products. It includes making medicine and growing better crops. Figure 1.12 illustrates the production of human insulin through biotechnology.

Bioeconomics

Bioeconomics is about studying how biology and economics work together. It explores how we use living things and the environment to make products and services, and how this affects the economy and ecosystem (nature). This includes things like farming, fishing, and managing natural resources.

Knowledge Booster

Plasmid DNA is a small, circular piece of DNA that exists separately from the main DNA in bacteria. Scientists use plasmids as tools to add new genes into bacteria for research, like making medicines.

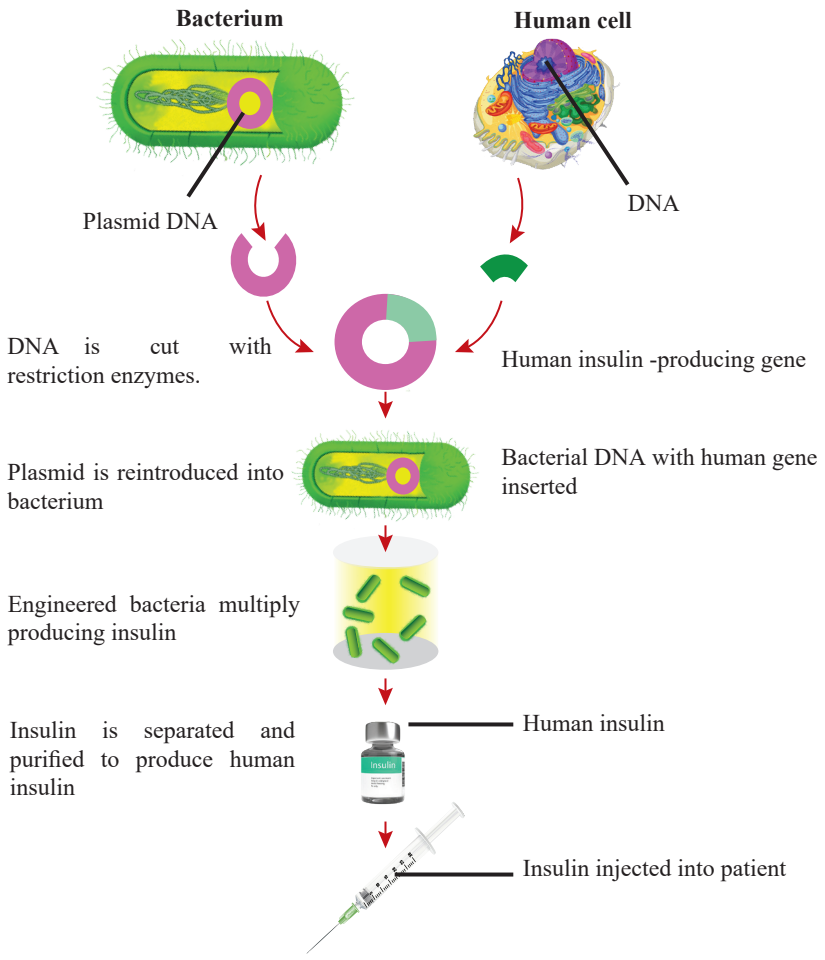


Figure 1.12 : Diagrammatic representation of human insulin production through biotechnology.

Skill: 1.5

Objective: Analytical thinking to draw connections between biology and other natural sciences. Ability to categorize and distinguish between overlapping scientific disciplines

Test Yourself

Short answer-based questions:

1. What does biophysics study about living things?
2. How does biochemistry help us understand our body's reactions?
3. What is the goal of computational biology in studying genes?
4. How is biotechnology used to make medicines like insulin?

1.6 Knowledge

Careers in Biology

Biology offers a wide range of job opportunities. As a main part of natural and life sciences, it helps us understand life and its many connections. Let us look at some careers in biology.

Student Learning Outcomes

- *Identify the careers in Biology and Explain with example which show that biology is a subset of the natural sciences and of the life sciences.*

Medicine / Surgery

Medicine is career deals with diagnosing and treating sickness when a person is not feeling well. Physician focus on treatment using non surgical methods. Surgeons are doctors who perfome surgery to fix problems inside patients body. MBBS is a special program where doctors learn both medicine and surgery to help people when they are sick in different ways (see Figure 1.13). These professionals work in places like hospitals and clinics to treat patients and make them feel better.

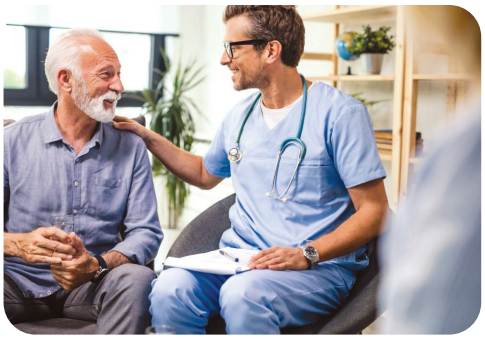


Figure 1.13: A doctor treating a patient.

Agriculture

Agriculture involves growing plants and raising animals for food, fiber, and other resources. Professionals in this field work on farms, in agricultural research, and in food production industries. They focus on crop growth, livestock management, and sustainable farming practices.

Horticulture

Horticulturists specialize in growing flowers, fruits, vegetables and ornamental plants. They work in greenhouses, gardens and nurseries. Their expertise includes plant breeding, garden management, and cultivation of various plant species (Fig. 1.14).

Figure 1.14 : A horticulturist watering the plants in the garden.

Biotechnology

Biotechnology uses biological processes to develop new technologies and products. Biotechnologists work with small things like bacteria to create useful products. They can make fuel from plants or develop bacteria that clean up pollution from environment They apply their knowledge to areas like medicine, agriculture, and environmental conservation.

Forensic Science

Forensic scientists help the police by examining evidence from crime scenes. They study things like hair or fingerprints to identify who was there (Fig. 1.15). They use science to solve crimes and keep people safe. In Pakistan, their skills are contributing in making sure investigations are accurate and decisions in court are fair.

Figure 1.15: A forensic scientist collecting data at a crime scene.

Figure 1.16 : Scientists in the forest are surveying the ongoing research on forest plants.

Fisheries and Wildlife

This field focuses on the conservation and management of fish and wildlife species and their habitats. Specialists work in natural reserves, parks, and aquatic environments. They study animal behaviours, ecosystem dynamics, and conservation techniques.

Forestry

Forestry is about managing and conserving forests and forest resources. Foresters work in forest management, conservation, and research. They focus on tree health, forest ecology, and resource management (Figure 1.16).

Biology: A Subset of Natural and Life Sciences

Biology is a part of both natural sciences and life sciences. **Natural sciences,** like physics and chemistry, study the natural world. Biology focuses on life, adding more to our understanding of nature. For example, while physics may explain light's properties, biology shows us how plants use light for photosynthesis, which is important for life.

On the other hand, **life sciences** focus more on different parts and activities of living things. While all life sciences study life, biology covers a wide range, from tiny processes in cells (like in molecular biology) to big systems in nature (like in ecology). For example, in studying DNA, molecular biology looks at how DNA is built and copies itself, while evolutionary biology studies how changes in DNA over time can lead to evolution.

Just like the heart is a part of the human body and also important on its own, biology is a part of bigger science areas but also a big and important subject by itself, studying all about life.

Knowledge Booster

In Pakistan, scientists have used biotechnology to create a special kind of cotton plant called **Bt cotton**. This new type of cotton can protect itself from certain pests without needing many chemical pesticides, which is better for the environment and could help farmers in the future.

Skill: 1.6

Objective: Analytical thinking to identify the careers that are related to biology.

Test Yourself

Short answer-based questions:

1. What is forestry and what do foresters work on?
2. What do forensic scientists do and how do they assist in criminal investigation?
3. What is the difference between agriculture and horticulture?

1.7 Knowledge

Science: A Collaborative Field

Science is about exploring and discovering new things. In science, researchers from various subjects work together to explore complex problems. This is called interdisciplinary research. For example, to study animal behaviour in biology, we need to know about their environment (ecology) and how their bodies work (chemistry). This shows how different science subjects are connected.

Science is a collaborative field where people with different skills work together, share knowledge, and sometimes have different ideas to find new things. By using knowledge from different science areas, we can learn more about our world. Now, let us look at some examples of how these different science areas help each other.

Student Learning Outcomes

- *Justify with examples that science is a collaborative field that requires interdisci- plinary researchers working together to share knowledge and critique ideas.*

Climate Change Research

Understanding global climate change is about more than just temperatures. It involves learning from oceanographers who study the oceans, meteorologists wtho study the weather, biologists who look at living things, and sociologists who understand how people's actions affect the environment. All these experts work together to give us a full picture of how our planet's climate is changing.

The World of Renewable Energy

Producing clean energy is more than just putting solar panels on roofs. It includes physicists working on the best ways to use sunlight, engineers making systems to store energy, environmental scientists checking how these technologies affect nature, and economists looking at the costs and benefits for people. When these experts work together, they help build a future that is good for the environment and sustainable for everyone.

Human Genome Project

This project was a big effort to identify every gene in human DNA. Biologists looked at the DNA structure, while computer scientists handled a lot of data. Chemists studied how molecules interact, and physicists provided special tools for detailed observations. By combining different areas of study, the project gave a full understanding of human genetics.

Medical Imaging Technology

The MRI machine, which is really important for medical check

Interesting Information

The development of the **Mars Rover** by NASA is a fascinating project that resulted from the collaboration between astronomers, engineers and computer scientists. This teamwork led to the creation of a robot that could explore the surface of Mars, sending back valuable data about the planet's environment and potential for life, demonstrating the power of combining expertise from different scientific fields to explore the unknown.

Figure 1.17 : A medical professional studying the MRI scan conducted by medical imaging technologists.

Skill:1.7

Objective: Evaluation of real-world examples where collaboration led to scientific advancements.

ups, was not made only by doctors. Physicists who know about magnetism, engineers who built the machine, biologists and medical experts who understand the human body, and computer scientists who work with the images all helped make it (Figure 1.17).

Test Yourself

Short answer-based questions:

1. What different scientific fields contributed to the development of the MRI machine?
2. How do various experts collaborate to understand global climate change?
3. What roles do different scientists play in advancing renewable energy technologies?
4. Why is interdisciplinary collaboration essential in projects like the Human Genome Project?

Student Learning Outcomes

- *Describe the steps of the scientific method: that is Recognition, Observation, Hypothesis, Deduction, Experiments, and Results.*

1.8 Knowledge

The Scientific Method in Biology

Biology is a branch of natural sciences that studies life, from cellular processes to ecosystem dynamics. To navigate its complexity, biologists use a method called the **scientific method.** The scientific method is a systematic approach used by scientists to investigate and understand the natural world. This method provides a framework for biologists to ask questions, make observations, develop hypotheses, conduct experiments, and analyze results. It allows biologists to make discoveries, like that of DNA and development of vaccines, and to collaborate and share knowledge. It is essential for advancing our understanding of biology and the living world.

Let us understand the scientific method through the example of investigating dengue fever, a disease spread by mosquitoes:

Figure 1.18 : A mosquito (*Aedes aegypti*) transmits the dengue virus to humans, spreading dengue fever.

Recognition

The first step in the scientific method is **recognition**, which means identifying a problem or a question that needs to be solved or answered. This often starts with noticing something intriguing. For example, a biologist might notice that some people get sick with dengue fever after mosquito bites and think about why this happens and how it can be prevented. Recognition is important because it sets the focus for the research and makes researchers curious about the topic. It can come from various sources, such as personal experience, literature review, previous research, or social needs.

Observation

The second step in the scientific method is **observation**, which means gathering data or information about the problem or question. Observation can be done using different senses, such as sight, hearing, touch, smell, or taste (see the Figure 1.19 & 1.20). For instance, a biologist studying dengue fever might observe patients' symptoms, like fever, headache, rash, joint pain or bleeding.

Observations can be classified into two types: qualitative and quantitative. **Qualitative observation** is related to the qualities or characteristics of something, such as colour, shape, texture, or behaviour. For example, if you notice a red rash on the skin of a dengue fever patient, it is a qualitative observation. **Quantitative observation**, on the other hand, measures the quantity or amount of something, such as size, weight, or temperature. For instance, measuring how much a patient's body temperature increases during dengue fever is a quantitative observation. Quantitative observations are often considered more reliable as they involve the use of numbers. However, qualitative observations are also important because they can provide valuable details and context that numbers alone may not convey. Therefore, both types of observation are essential in scientific investigations.

Figure 1.19: A dengue control worker examines vessels for dengue larvae using his senses.

Do you Know?

Biologists often check the results of an experiment by using their senses, like seeing or listening. To see microscopic objects or hear very soft sounds, they use tools like microscopes for seeing and microphones for listening, which helps them collect more information.

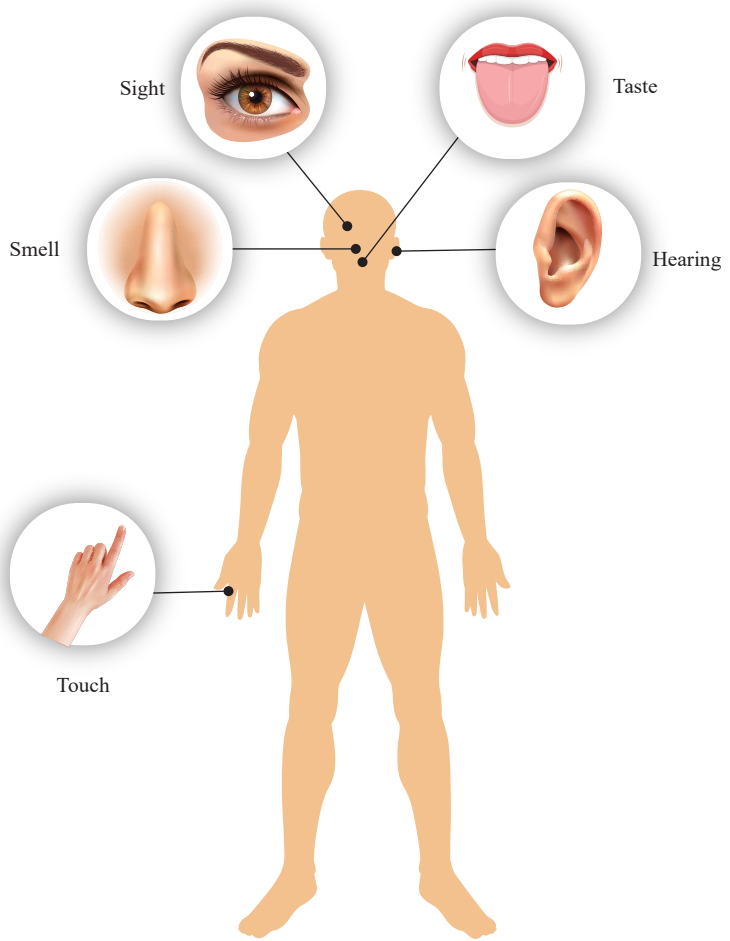


Figure 1.20: Illustration of five senses used for observations, each related to a particular sense organ, i.e. nose for smell.

Interesting Information

Scientific methods are based on two key principles. Firstly, everything that happens in nature is caused by natural reasons. Secondly, the fundamental laws of nature are consistent everywhere and at every moment, which is known as the principle of uniformity.

Hypothesis

The third step in the scientific method is creating a **hypothesis**, which is a logical and testable statement about the cause of a problem based on observations and previous knowledge. For example, a biologist can hypothesize that dengue fever is caused by a virus that is transmitted by mosquitoes. A good hypothesis should be simple, clear, testable, and able to be proven wrong.

There are two ways to form a hypothesis: inductive and deductive reasoning. **Inductive reasoning** involves drawing a general conclusion from specific observations. For example, if every person bitten by a mosquito gets sick with dengue fever, a biologist might conclude that all mosquitoes in the area carry the virus that causes dengue fever. The deductive reasoning is discussed below:

Deduction

The fourth step in the scientific method is deduction. It involves making logical predictions based on the given hypothesis. Deduction relies on a process called **deductive reasoning**, where specific conclusions are drawn from general principles. Deductions employ "if-then" logic to form predictions. For instance, if biologists hypothesize that dengue fever is transmitted by mosquitoes, then they might conclude that killing or repelling mosquitoes would reduce the number of dengue fever cases. Deduction is critical as it verifies if the hypothesis is valid and consistent. Moreover, it helps scientists plan experiments to prove or disprove the hypothesis.

Figure 1.21: A person being sprayed by an insect repellent.

Experiments

The fifth step in the scientific method is doing experiments. This means testing the predictions from the hypothesis. Experiments are careful tests where scientists change some things and see how these changes affect other things. For example, a biologist might test if applying insect repellent on the skin can stop mosquito bites and dengue fever.

Good experiments should have a clear and specific objective, have a detailed procedure, and change one variable (independent) at a time to see its effect. To ensure the accuracy of their experiment, scientists contrast the **control group** (this group did not get any treatment and is constant) with the **experimental group** (this group received treatments and the effects of treatment can be seen) and interpret results accordingly. In the experimental group, the **independent variable** is the one that is changed, and its effects are observed on the **dependent variable**.

For instance, in an experiment on insect repellent, the control group is not sprayed, while the experimental group receives insect repellent (Figure 1.21). Applying insect repellent is the independent variable, while mosquito bites and cases of dengue fever are the dependent variable.

Teacher's Guideline

Elaborate the following terminologies to the students:

(i) independent variable (ii) dependent variable (iii) control variable

Results

The sixth step in the scientific method is analyzing the results. This means interpreting at the data from experiments to see if it proves or disproves the hypothesis. Biologists share their findings in scientific publications or meetings and conferences within the scientific community. They often use tables, graphs , or charts to show the data clearly.

For example, the hypothetical results of an experiment are shown in the table below. It shows how many mosquito bites and dengue cases each group (control and experimental) has before and after using insect repellent.

Table 2

Group	Time	Mosquito Bites	Dengue Cases
Control	Before	13	3
Control	After	13	3
Experimental	Before	13	3
Experimental	After	5	1

After analyzing the table, we see that the experimental group using insect repellent had fewer mosquito bites and dengue cases, while the control group not using it stayed the same. This suggests that insect repellent can lower the risk of getting mosquito bites and dengue fever.

Then, the scientist makes a conclusion. This is where they summarize the study's findings, answering the main question with the data they collected. They talk about what the results mean, any possible errors, and how this can help in real life. For example, a biologist may conclude that insect repellent really does reduce mosquito bites and dengue fever. They might also talk about how this can help in places where dengue fever is common and mention any limitations in their study.

A good conclusion is clear and based on the results. It admits any uncertainties and might suggest ideas for more research.

The scientific method is flexible and can change based on what is being studied. It is like a cycle, sometimes going back to earlier steps when new information is found. It is a very useful way to learn and solve problems in science.

Real World Application

Scientific Inquiry Has Limitations

Understanding the health effects of certain foods, like the artificial sweetener saccharin, can be challenging due to complex scientific studies. In the 1970s, studies suggested saccharin might cause bladder cancer in rats, leading the FDA to propose a ban and require warning labels. However, these studies had limitations, such as using very high doses of saccharin, which is not realistic for humans. Also, other factors like genetic predisposition or lifestyle choices make it hard to pinpoint a single cause of cancer in humans. By 2000, laws requiring warning labels on saccharin were removed, reflecting uncertainties in the research. This case shows that one study, especially a small or limited one, does not provide a complete answer, and health-related headlines should be viewed with this in mind.

Skill:1.8

Objective: Sequential thinking to understand and apply the steps of the scientific method in practical scenarios.

1.9 Knowledge

Hypothesis, Theory and Law in Natural Sciences

Student Learning Outcomes

- *Evaluate the terms 'hypothesis', 'theory' and 'law' in the context of research in the natural sciences.*

In natural sciences, three important words are often used: hypothesis, theory, and law. They are key parts of the scientific method, which is how scientists learn about the world. Knowing what each word means and how they are used is very important for anyone doing scientific inquiry.

Hypothesis: A Beginning Point of Scientific Inquiry

A hypothesis is a tentative explanation or idea that scientists can test. It starts from initial observation or asking a question. The hypothesis makes a statement that can be checked with experiments. It is the first step in doing scientific research. Scientists make a hypothesis, then do tests to see if it is right. They keep testing and making new hypotheses based on what they find.

A hypothesis guides their research and helps focus on certain questions. If a hypothesis is consistently supported by evidence, it can lead to bigger ideas called theories.

Theory: A Well-Substantiated Explanation

A theory is a detailed explanation of some aspect of nature that is supported by multiple evidence. It is different from a hypothesis because it has been tested many times and scientists generally agree on it. Theories serve as guiding principles in science, facilitating research and experimentation, explaining various phenomena, and leading to new hypotheses.

A scientific theory is based on known facts and accurate predictions and can explain a wide range of phenomena. However, it can be proven wrong. Theories represent scientists' collective understanding and agreement in a particular field of study. They can lead to new inventions and discoveries. Examples of theories include Einstein's Theory of General Relativity in physics and Lamarck's Theory of Inheritance of acquired characteristics in biology.

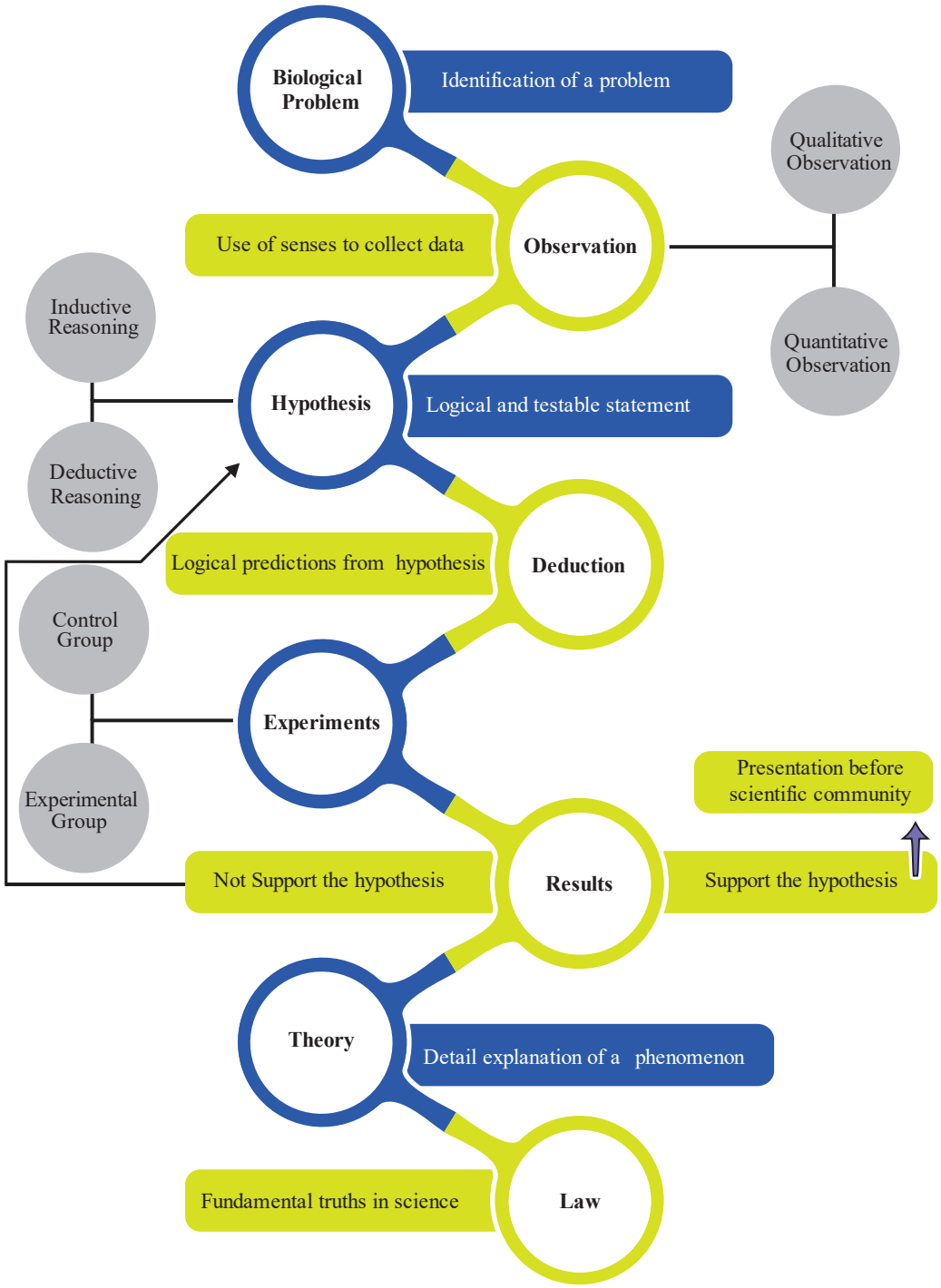
Do you Know?

People sometimes use the word "theory" to mean a guess or an idea that has not been proven. However, scientists use "theory" to describe a principle that has been tested multiple times and is supported by extensive evidence, explaining many different observations and experimental data.

Law: A Universal Truth

A scientific law is a universal statement that tells us how things always happen in nature, often written with mathematical expressions. Laws do not explain why things happen; they simply describe what happens. Laws act as foundational truths in science upon which theories and hypotheses are built. Examples are Newton's laws of motion in physics and Mendel's laws of inheritance in biology. Scientific laws are the same everywhere and always, giving scientists a solid base to do their work.

In summary, scientific understanding grows from a hypothesis to a theory and then to a law. A hypothesis, tested and proven, can become a theory, which is a wider explanation of things. If parts of a theory are always true, they might become a law. Hypotheses, theories, and laws together form a system for understanding the world, showing that science is always improving and involves working together.



Flow chart of Scientific Method

Test Yourself

Short answer-based questions:

1. What is the difference between a theory and a law in science?
2. What does a qualitative observation focus on?
3. Describe the role of an independent variable in an experiment.
4. How is inductive reasoning different from deductive reasoning?
5. In what ways are scientific results communicated?
6. What kind of information does a scientific law provide?

Long answer-based questions:

1. Elaborate on the steps of the scientific method and explain how they contribute to the development of scientific knowledge.
2. Discuss the role and importance of theories and laws in the field of science.

Skill:1.9

Objective: Critical thinking to differentiate between hypothesis, theory and law. Comprehension and application of skills to utilize these terms appropriately in a scientific context.

Key Points

- The Quran instructs us to study life.
- Biology is the study of life and living organisms.
- Major fields of biology include Botany (study of plants), Zoology (study of animals), and Microbiology (study of microorganisms).
- Biology encompasses diverse sub-fields, ranging from Cytology (cells) to Pharmacology (drugs and their effects).
- Biology intersects with other sciences, leading to specialized fields like Biophysics (biology + physics) and Biochemistry (biology + chemistry).
- Biology offers various career opportunities and is a core component of both the natural sciences and life sciences.
- Science is a collective endeavor; interdisciplinary teams share and critique ideas to enhance knowledge.
- The scientific method involves steps like observation, hypothesis formation, experimentation, and results interpretation.
- In scientific research, a hypothesis is testable, a theory is a well-supported explanation, and a law describes consistent natural phenomenon.

Extensive Exercise

01 Encircle the most suitable answer

1. What does MBBS stand for?

a) Bachelor of Medicine and Bachelor of Surgery
b) Master of Biology and Biological Studies
c) Bachelor of Medical Biological Sciences
d) Master of Biochemical Biological Studies

2. What is the role of horticulturists?

a) Disease diagnosis
b) Plant breeding and cultivation
c) Performing surgeries
d) Developing medicines

3. The study of how living things interact with each other and their environment is known as:

a) Physiology
b) Anatomy
c) Ecology
d) Genetics

4. What does the field of forensic science involve?

a) Garden management **b)** Examination of evidence from crime scenes
c) Livestock management **d)** Drug development

5. What is the study of diseases and their causes called?

a) Pharmacology **b)** Pathology
c) Physiology **d)** Anatomy

6. Which of the following best describes the field of biotechnology?

a) Study of diseases **b)** Study of marine life
c) Use of biological processes to develop technologies
d) Management of forest resources

7. Which field applies computer technology to biological research?

a) Biogeography **b)** Biostatistics
c) Computational biology **d)** Bioeconomics

8. The scientific method in biology starts with:

a) Hypothesis **b)** Recognition of a problem
c) Analysis of results **d)** Deduction

9. A good hypothesis must be:

a) Proven right **b)** Complex
c) Testable and potentially falsifiable **d)** Based on a single observation

10. A Well-Substantiated explanation of hypothesis is called:

a) Observation **b)** Deduction
c) Experimentation **d)** Theory

02 Mismatched Pair Questions

Profession	Description
Biophysics	Studies economic impact on organisms
Human Genome Project	Starts with the creation of scientific hypothesis
Bio economics	Studies electrical signals in nerves
Hypothesis	Genetic Mapping
Scientific Method	Tentative Explanation

03 More-Than-One-Correct-Option Type Multiple Choice Questions

1. What topics does the field of agriculture cover?

a) Crop growth **b)** Livestock management
c) Sustainable farming **d)** Forest conservation

2. The study of horticulture includes which of the following?

a) Garden management **b)** Plant breeding
c) Cultivation of plant specie **d)** Disease treatment

3. What does the study of marine biology encompass?

a) Behavior of marine animals **b)** Conservation of marine ecosystems
c) Interaction of marine life with water **d)** Cellular structure of marine plants

4. What areas does the scientific method in biology cover?

a) Recognition **b)** Observation
c) Hypothesis **d)** Law formation

5. Which of these are true about the roles in biology?

a) Surgeons perform surgeries
b) Horticulturists specialize in plant breeding
c) Forensic scientists examine crime scene evidence
d) Fisheries specialists manage agricultural farms

6. The Human Genome Project involved which of the following fields?

a) Biology **b)** Computer science
c) Bioeconomics **d)** Biogeography

7. Which aspects are considered in the study of biogeography?

a) Intermolecular forces **b)** Geographic distribution
c) Temperature **d)** Rainfall

8. What are the applications of biostatistics in biology?

a) Understanding disease occurrence **b)** Developing new medicines
c) Analyzing genetic information d) Economic analysis

9. In the scientific method, what steps follow the recognition of a problem?

a) Observation **b)** Hypothesis
c) Experiment **d)** Analysis of results

10. A scientific law:

a) Is always expressed with mathematical equations. **b)** Describes how things happen in nature.
c) Is a tentative explanation of phenomena. **d)** Acts as a foundational truth in science

04 Assertion-Reason Type Questions

In each of the following questions, two statements are given, one labelled as Assertion (A) and the other as Reason (R). Examine the statements carefully and mark the correct answer according to the instructions given below:

(a) If both A and R are correct and R is the correct reason for A
(b) If both A and R are correct but R is not the reason for A
(c) If A is correct and R is wrong
(d) If A is wrong and R is correct

1. Assertion (A): Biology is integral to the natural and life sciences.
Reason (R): It provides insights into the complex interactions of living organisms. ☐

2. Assertion (A): Forestry is about managing forest ecosystems.
Reason (R): Foresters focus on tree health and sustainable resource management. ☐

3. Assertion (A): Anatomy studies the internal structures of organisms.
Reason (R): Anatomists may specialize in plant anatomy. ☐

4. Assertion (A): Marine biology studies life in the oceans.
Reason (R): Marine biologists also focus on aquatic plants and their environment. ☐

5. Assertion (A): Biotechnologists work in the field of environmental conservation.
Reason (R): They can develop bacteria that clean pollution. ☐

6. Assertion (A): The Human Genome Project was an interdisciplinary effort that involved biologists, chemists, and computer scientists.
Reason (R): Interdisciplinary research is a collaborative approach where different scientific disciplines work together to solve complex questions.

7. Assertion (A): Scientific laws describe what happens in nature without explaining why those phenomena occur.
Reason (R): Laws are foundational truths in science built upon tested and proven hypotheses.

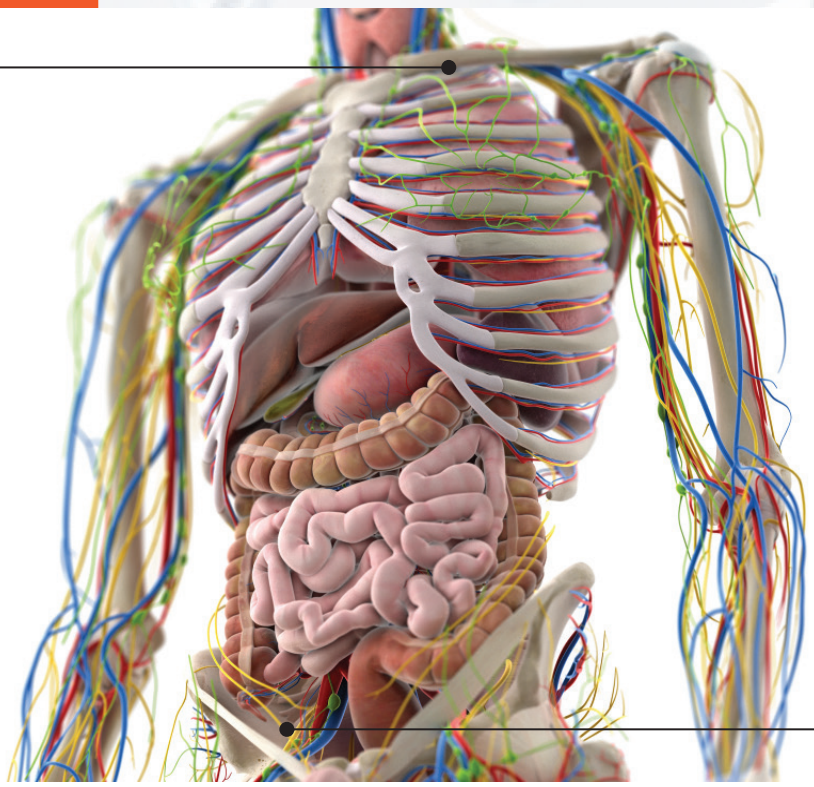
8. Assertion (A): Hypotheses, once proven, become laws.
Reason (R): Laws are universal truths that tell us how things always happen in nature.

9. Assertion (A): An experiment's control group is exposed to the experimental treatment.
Reason (R): The control group in an experiment is used as a benchmark to measure the effects of the independent variable.

10. Assertion (A): The scientific method is a sequential process that starts with the formulation of a hypothesis.
Reason (R): A hypothesis is a tentative explanation for an observation or a problem that can be tested through scientific research.

CHAPTER 2

Cellular Organization



Truth Behind the 'Fruit or Vegetable' The rumour that tomatoes are fruits is actually a botanical fact. In botany, a fruit is defined as any structure that contains seeds and develops from the flowering part of a plant. Apples, cherries, oranges, peaches, and raspberries are all fruits. So, in a botanical sense, tomatoes are classified as fruits because they develop from the flower of the plant and contain seeds. So, things that we consider veggies, including green beans, bell peppers, and pumpkins, are actually fruits. Vegetables can come from any part of the plant that does not necessarily develop from the flower or contain seeds, such as the leaves of spinach, the roots of carrots, and stem of potatoes.

Student Learning Outcomes

- Distinguish between tissues, organs and systems with examples from animals and plants.
- Describe the concept of emergent properties as gain in functionalities and how it applies to the following:
  going from sub-cellular organelles to cells
  going from cells to tissues
  going from tissues to organs
  going from organs to systems
  going from systems to living organisms
- Enlist the different types of tissue come together to form the stomach organ in the human body.
- Discuss the different types of tissue come together to form the leaf.
- Discuss the organ systems come together to form the human body.
- Discuss the various organs and systems of the human body work to maintain homeostasis
- Describe the advantages of homeostasis
- Explain plant physiology in terms of structures and roles of various plant organs.

All the above mentioned SLOs are classified into knowledge and skills for the better understanding of students.

After studying this Unit, the students will be able to:

Knowledge

1. Understand the differences between tissues, organs, and systems in animals and plants, such as muscle tissue, the heart and the circulatory system in animals, or vascular tissue and leaves in plants.
2. Know the different types of tissue that form a leaf, such as the epidermal tissue, palisade and spongy mesophyll, and vascular tissue.
3. Understand plant physiology in terms of structures and roles of various plant organs like roots, stems, leaves, and flowers.
4. Comprehend the concept of emergent properties as new functionalities that arise when going from simpler to more complex biological levels, such as from organelles to cells, cells to tissues, tissues to organs, organs to systems, and systems to organisms.
5. List and understand the different types of tissue that come together to form the human stomach, including muscular, epithelial, connective, and nervous tissues.
6. Understand the composition of major organ systems of the human body.
7. Describe the roles of key organs and systems in the human body in maintaining homeostasis and its advantages in maintaining a stable internal environment for optimal functioning of the body

Skills

1. Ability to identify and describe examples of tissues, organs, and systems in animals and plants.
2. Ability to discuss how these tissues contribute to the functions of the leaf, including photosynthesis, gas exchange, and transpiration.
3. Ability to explain the functions of these plant organs in processes such as photosynthesis, transport of nutrients, growth, and reproduction.
4. Skill in explaining how each step in biological complexity contributes to new functions and abilities in living organisms.
5. Ability to describe the roles of these tissues in the overall function of the stomach.
6. Evaluate how organ systems interact and work together to form the human body.
7. Analyze how different organs and systems collaborate to regulate internal conditions and maintain homeostasis.
   Ability to explain the importance of homeostasis in response to external and internal changes.

2.1 Knowledge

Understanding Tissues, Organs, and Systems in Animals and Plants

Student Learning Outcomes

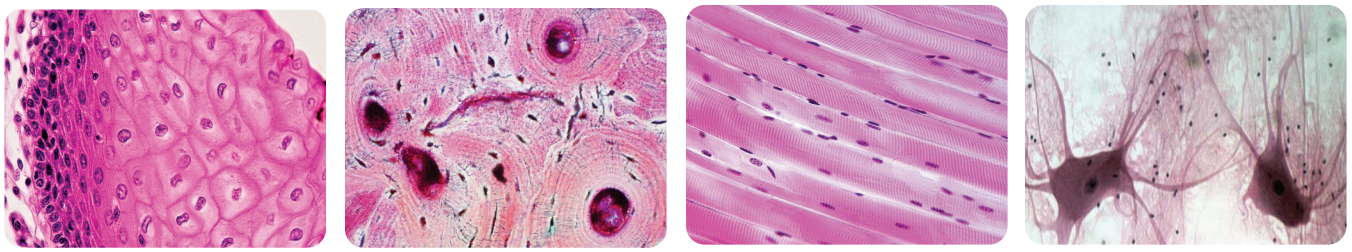
- *Distinguish between tissues, organs and systems with examples from animals and plants.*

Knowledge Booster

Epithelial tissues can be categorized into various types, each containing cells with a distinct shape. For example, cells in squamous epithelial tissue are flat, cuboidal epithelial tissue is cube-shaped, and those in columnar epithelial tissue are tall and elongated. Each type of epithelial tissue is adapted to its specific function in the body.

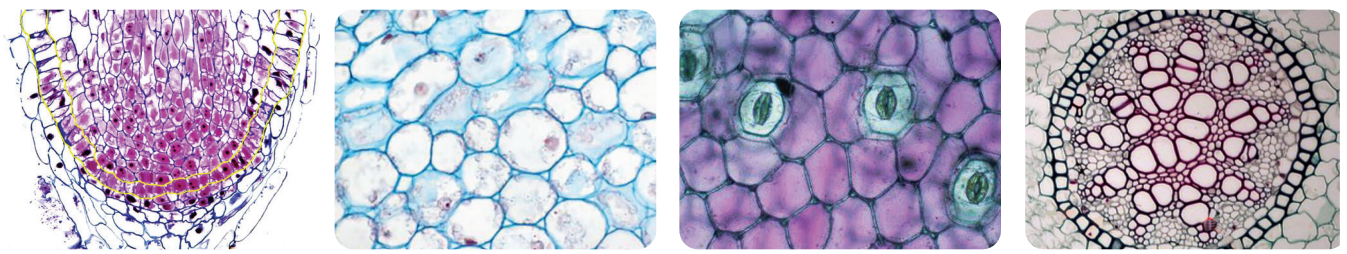
Cells are the fundamental units of life, providing the structural and functional foundation for all living things. Within each cell, various subcellular structures, called **organelles**, such as mitochondria and ribosomes, carry out specialized functions essential for the cell's survival and operation (see chapter 3 for details). These cells are organized into groups that live and work together. Groups of cells that work collectively to perform common or related functions are called **tissues**.

In animals, tissues are classified into four primary types: **epithelial tissue,** which forms protective barriers; **connective tissue**, which supports, connects, and binds other tissues; **muscle tissue**, which facilitates movement; and **nervous tissue**, which transmits signals throughout the body as shown in Figure 2.1 (see details in human stomach). In plants, tissues are categorized into **meristematic tissue**, responsible for growth; **ground tissue**, involved in photosynthesis; **epidermal tissue**, offering protection from the external environment; and **vascular tissue**, ensuring the transport of water and nutrients (see Figure 2.2).



(a) Epithelial tissue **(b)** Connective tissue **(c)** Muscle tissue **(d)** Nervous tissue

Figure 2.1: Types of animal tissues



(a) Meristematic tissue **(b)** Ground tissue **(c)** Epidermal tissue **(d)** Vascular tissue

Figure 2.2: Types of plant tissues

Tissues are organized into groups to perform specific or related functions in an organism, forming an **organ**. In animals, examples of organs include the lungs, heart, stomach, kidneys, ovaries, and testes, while in plants, the primary organs are the roots, leaves, stems, and flowers.

If different organs perform related functions, they form an **organ system.** The digestive system is an example of an organ system in humans. In contrast, plants do not have organ systems in the same way animals do. Plants possess organs which work together to support the plant's life.

Test Yourself

Short answer-based questions:

1. What function does vascular tissue serve in plants?

2. Name some examples of organs found in animals?

2.2 Knowledge

The Leaf Structure: Tissues and Function

A leaf is commonly known as a green, flat part of a plant, but it is actually a complex structure composed of various tissues. It serves several essential functions, such as photosynthesis, gaseous exchange, and transpiration. The main types of tissues that make up a leaf are:

Epidermal Tissue: The epidermal tissue forms the outer layer of the leaf and acts as a protective barrier between the plant and its environment. It is usually thin and transparent, allowing light to pass through to the photosynthetic cells present beneath. This layer is covered by a waxy substance called the **cuticle**, which helps prevent water loss through evaporation. Within the epidermis are bean-shaped cells known as **guard cells**, which surround and regulate tiny openings called **stomata** (see Figure 2.3). These stomata play a key role in the gaseous exchange, allowing carbon dioxide to enter the leaf for photosynthesis and oxygen and water vapour to exit. Moreover, the process of transpiration (loss of water vapours from plant surface) is also regulated by these stomata.

Mesophyll Tissue: The tissue that lies below the epidermis is known as mesophyll tissue. It is a specialized type of **ground tissue** found within the leaves of plants. This tissue is organized into two regions:

Palisade mesophyll is composed of tightly packed columnar cells organized in one or more layers and is abundantly rich in

Knowledge Booster

Meristematic cells are small and cuboidal in shape. They have thin cell walls and large nuclei, reflecting their high metabolic activity and capacity for cell division.

Skill:2.1

Objective: Ability to identify and describe examples of tissues, organs, and systems in animals and plants.

Student Learning Outcomes

- *Discuss the different types of tissue come together to form the leaf.*

Interesting Information

Certain plant species have evolved their leaves to maximize their ability to catch as much sunlight as possible. On the same tree, leaves that grow in bright sunlight are thicker, smaller in size, and packed with more chloroplasts per unit area. In contrast, leaves that grow in the shade have chloroplasts spread out to avoid blocking each other's light, unlike the leaves that grow in the sun.

Knowledge Booster

Bundle sheath cells are specialized cells that surround the vascular bundles in the leaves and stems of certain plant species arranged in a tightly packed layer, forming a sheath-like structure. These cells provide structural support to the leaf by surrounding and protecting the vascular bundles.

Do you Know?

The cells of ground tissue are called parenchyma cells. In a leaf, mesophyll cells are a special version of **parenchyma cells** that have adapted over time for their specific role within the leaf's structure.

Interesting Information

Leaf hairs, also known as **trichomes**, are small outgrowths or projections found on the surface of leaves and other plant parts. They protect plants from excess transpiration, high temperature, ultraviolet (UV) light, and herbivore attacks.

chloroplasts. These cells carry out most of the leaf's photosynthesis, the conversion of sunlight into chemical energy in the form of glucose.

Spongy mesophyll is situated beneath the palisade mesophyll. It contains loosely arranged, irregular-shaped cells with air spaces between them . These air spaces allow carbon dioxide to diffuse more efficiently into the mesophyll cells and enable the quick removal of oxygen from these cells, thereby facilitating gaseous exchange. Although spongy mesophyll cells also contain chloroplasts and contribute to photosynthesis, their primary function is to support the exchange of gases necessary for photosynthesis and respiration within the leaf.

Vascular Tissues: Vascular tissues, which include the xylem and phloem, are located within the midribs and veins of the leaf. The **xylem** in leaves plays a crucial role in supplying water and minerals absorbed by the roots to the leaf tissues for photosynthesis and other metabolic processes. On the other hand, the **phloem** carries the sugars produced during photosynthesis from the leaves (source) to different parts (sink, see Chapter 8) of the plant.

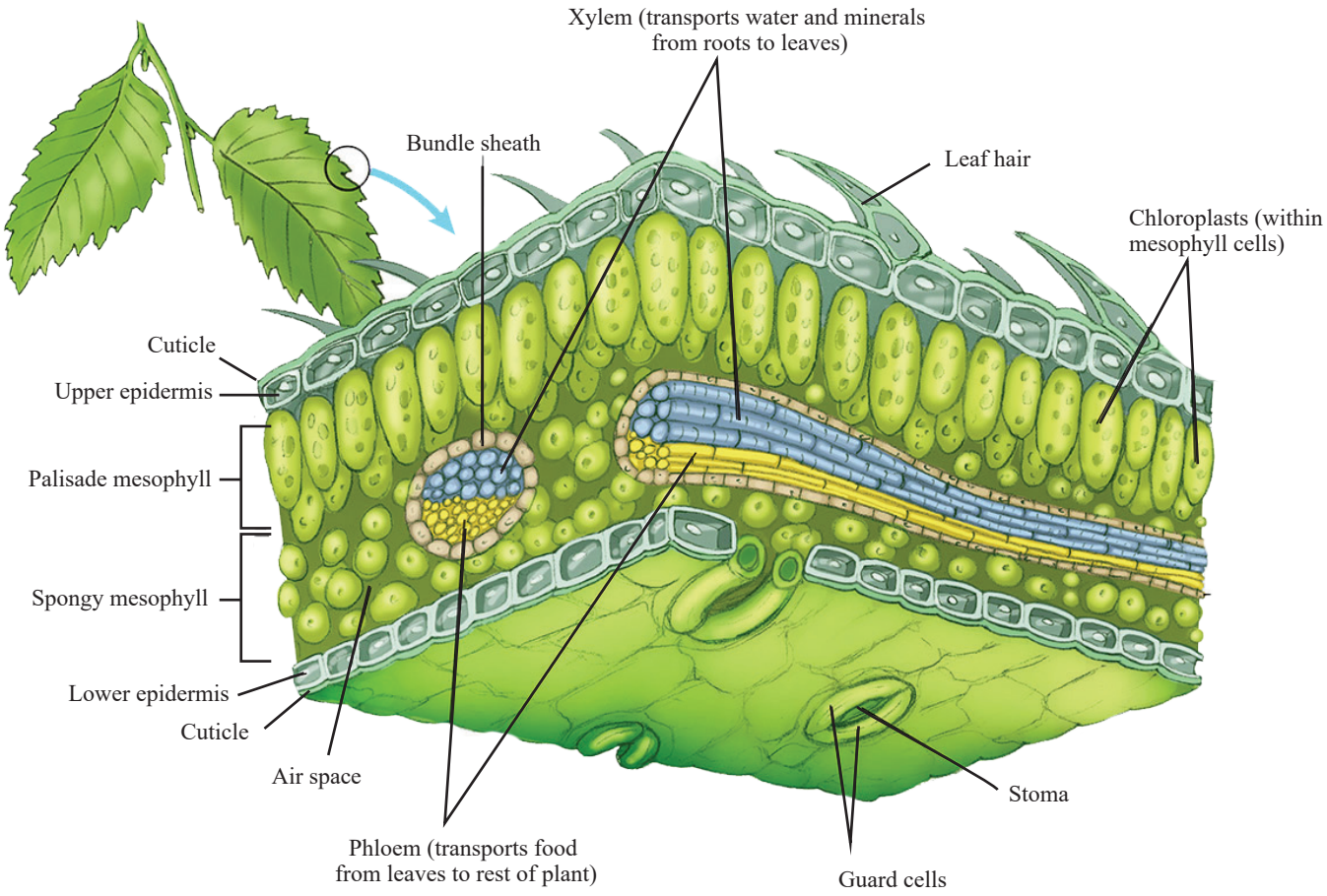


Figure 2.3: A cross-sectional view of the leaf highlights the types of tissues present; epidermal, mesophyll, and vascular tissue. Note the arrangement of these tissues in the leaf.

Together, these tissues enable the leaf to function as an efficient organ, not only for photosynthesis but also for gas exchange and transport of vital nutrients, playing an essential role in the plant's overall health and growth.

Test Yourself

Short answer-based questions:

1. What is the role of epidermal tissue in a leaf?
2. Where does photosynthesis primarily occur in a leaf?
3. What is the function of the spongy mesophyll in a leaf?
4. How do the xylem and phloem contribute to the leaf's function?

Skill:2.2

Objective: Ability to discuss how epidermal, mesophyll and vascular tissues contribute to the functions of the leaf, including photosynthesis, gas exchange, and transpiration.

2.3 Knowledge

Plant Physiology: Structures and Roles of Various Plant Organs

Student Learning Outcomes

- *Explain plant physiology in terms of structures and roles of various plant organs.*

Plant physiology involves understanding the structures of different parts of a plant and their specific roles. The primary plant organs include roots, stems, leaves, and flowers (see Figure 2.4). Each of these organs has a distinct structure and plays a specific role in the plant's growth, stability and reproduction.

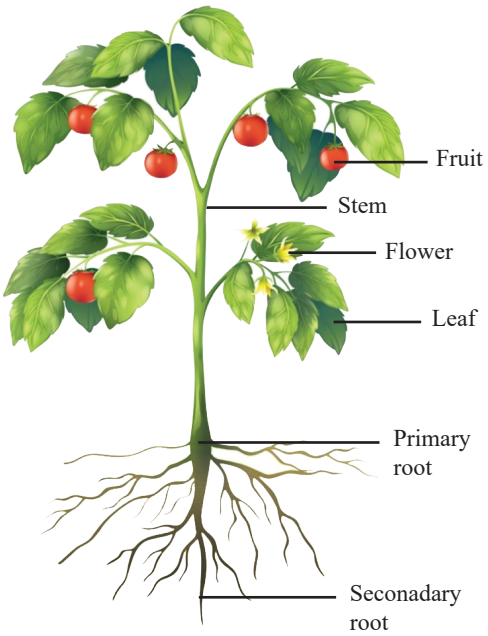


Figure 2.4: Parts of a Flowering plant

Roots

Often hidden underground, roots are important for a plant's stability and nourishment. They come in two main forms: **taproots**, which have a single dominant root with smaller lateral roots, and **fibrous roots**, which are a network of roots all about the same size (see Figure 2.5). Roots anchor the plant firmly in the soil and absorb water and dissolved minerals from the soil, which are essential for the plant's growth. In addition, they sometimes store food.

(a) Tap root. (b) Fibrous root.

Figure 2.5: Types of roots (a) Taproot for deep anchorage (b) Fibrous Root for enhanced nutrient absorption.

Knowledge Booster

In certain plants like mangroves, roots even participate in photosynthesis.

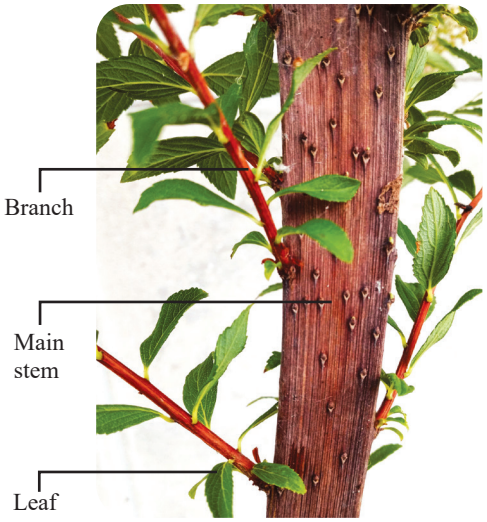


Figure 2.6: Diagram of a stem structure of a woody plant illustrating multiple branches, each supporting leaves.

Stems

Stems, whether woody as in trees or softer in non-woody plants, act as the plant's backbone. They support leaves, flowers, and fruits and play a key role in transporting water, nutrients, and food throughout the plant (see Figure 2.6). Internally, the stem consists of two primary vascular tissues, namely xylem and phloem for transport. Some stems, such as tubers (potatoes) and bulbs (onions), act as storage organs for nutrients and water, supporting the plant's survival during adverse conditions (see Chapter 9).

Leaves

Above ground, leaves are typically flat and green, consisting of a broad blade and a petiole connecting the leaf to the stem (see Figure 2.7). Their primary role is in photosynthesis. Leaves are also vital for gaseous exchange, taking in carbon dioxide and releasing oxygen through stomata and for transpiration, which involves releasing water vapour into the air (as discussed previously in detail).

Knowledge Booster

The arrangement of vascular tissues in the stem contributes significantly to the plant's mechanical support. Xylem, with its thick-walled cells, provides rigidity and strength to the stem, enabling it to bear the weight of the plant's parts and withstand environmental stresses such as wind.

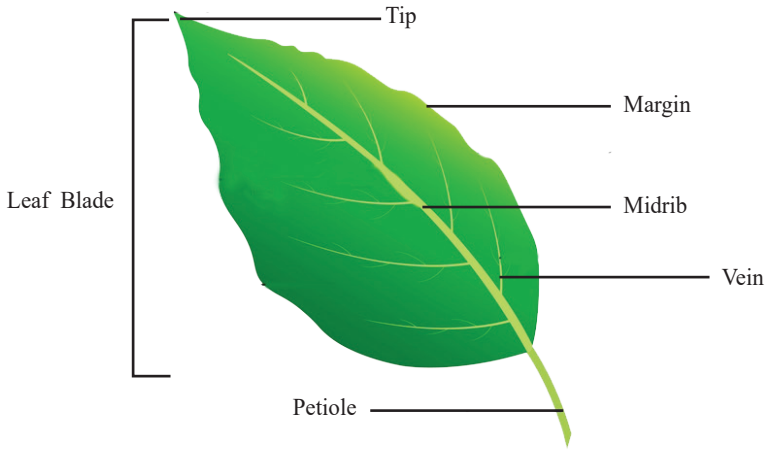


Figure 2.7: A labelled diagram of a leaf

Interesting Information

The density of stomata on a leaf's surface differs among plant species. For instance, the leaves of **corn** can have as many as 10,000 stomata per square centimeter on both sides. The scarlet **oak** surpasses this, with more than 100,000 stomata per square centimeter on the underside of the leaf and none on the top side. Despite the specific patterns of distribution, stomata are important in managing the exchange of gases.

Flowers

Flowers are the reproductive organs of plants. The typical structure of a flower consists of four main parts: sepals, petals, stamens, and carpel. **Sepals** form the outermost layer usually green in colour and protect the flower buds. While **petals** are usually brightly coloured and fragrant, attracting pollinators to the flower. **Stamens** are the male reproductive structures of the flower. Each stamen consists of a filament and an anther, and is responsible for producing pollen grains (male gametophyte). The **carpel** is the female reproductive structure consisting of the stigma, style and

ovary (see Figure 2.8) and is responsible for the production of embryo sacs (female gametophyte, see Chapter 9). Flowers are significant as they attract pollinators to assist pollen transfer and are essential in producing seeds and fruits. Fruits develop from flowers and contain seeds. They protect and help disperse seeds, which carry the potential to grow into new plants.

Do you Know?

Most flowers pollinated by animals have brightly coloured petals, while those pollinated by wind have small or no petals and sepals.

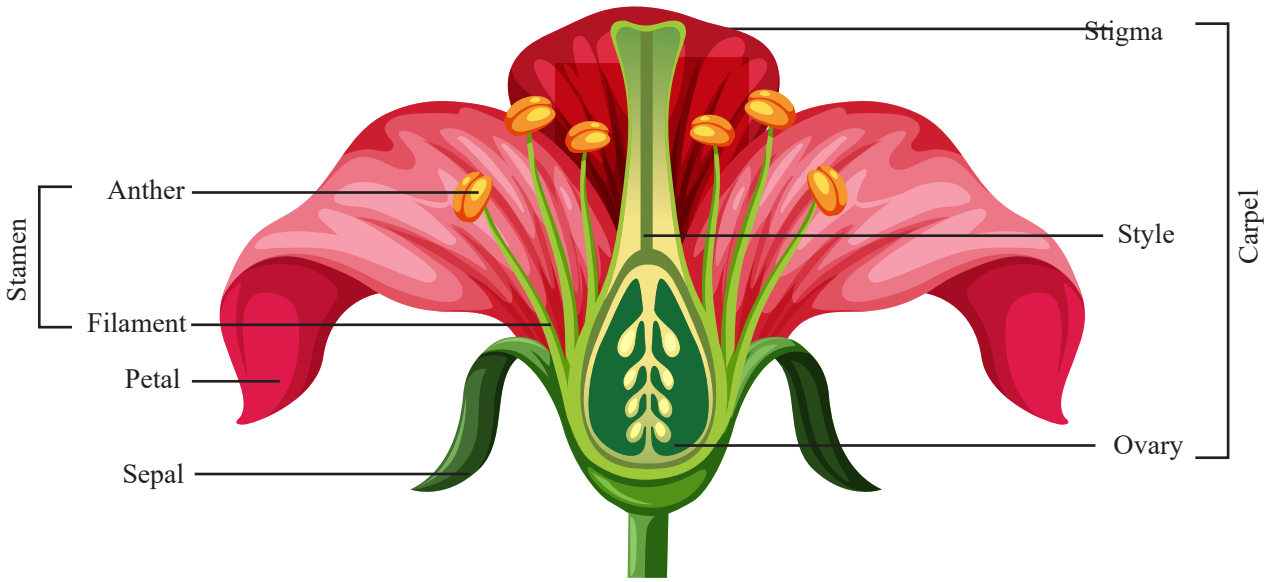


Figure 2.8: The parts of a flower include the stamen (male reproductive organ), carpel (female reproductive organ), petals, and sepals.

Knowledge Booster

One or more carpels merge to form the structure called a **pistil**.

In essence, each plant organ, including roots, stems, leaves, and flowers has its own unique structure and function, all of which contribute to the plant's overall health, growth, and survival.

Interesting Information

Generally, a stigma is either sticky or covered in hairs, which helps it catch pollen grains.

Test Yourself

Short answer-based questions:

1. What are the two main types of roots in plants, and what are their functions?
2. What is the primary role of leaves in plants?
3. What are the functions of stems in plants?
4. How flowers are important for plants?

Long answer-based questions:

1. Describe the role of roots in plant physiology and how they contribute to a plant's overall health and growth.
2. Explain the interconnected roles of leaves, stems, and flowers in a plant's survival and reproduction.

Skill:2.3

Objective: Ability to explain the functions of these plant organs in processes such as photosynthesis, transport of nutrients, growth, and reproduction.

Student Learning Outcomes

- *Describe the concept of emergent properties as gain in functionalities and how it applies to the following:*
- *going from sub-cellular organelles to cells*
- *going from cells to tissues*
- *going from tissues to organs*
- *going from organs to systems*
- *going from systems to living organisms*

2.4 Knowledge

Emergent Properties in Biology

Emergent properties in biology refer to new abilities or functions that arise when moving from simpler to more complex levels of biological organization These properties are not predictable or explainable in the simpler levels but become apparent as these levels combine and interact to form complex levels. Emergent properties can be seen as a gain in functionalities at different levels of biological organization, such as:

Sub-cellular organelles like the mitochondria and ribosomes perform specific functions within a cell, as detailed in Chapter 3. Each organelle has its own properties and functions, but it cannot survive or function independently, an emergent property present in a cell but not in its individual organelle.

Take **muscle cells,** for example, where the collaborative actions of different organelles enable the cell to contract. Mitochondria, essential for energy production, provide the necessary power for this process. Ribosomes are tasked with creating specific proteins that are crucial for contraction. Moreover, the endoplasmic reticulum plays a primary role in managing calcium storage and release, a critical element required to contract muscle fibers. Through the combined functions of these organelles, muscle cells are equipped to perform the complex task of contraction, illustrating how the cell operates as the basic unit of life with emergent properties that arise from the collective operation of its sub-cellular structures.

Knowledge Booster

The properties of life only emerge when biomolecules are organized into cells. Thus, life is considered an emergent property resulting from the organization of matter into cells.

This idea of working together goes beyond just cells. It includes how groups of cells come together to make tissues that have a common role. While each cell has its own function, it cannot do the tissue's job by itself. For example, while muscle cells can contract on their own, when they are part of **muscle tissue**, like in the esophagus, they work in a coordinated way to create wave-like contractions called **peristalsis**. This movement is crucial for pushing food from the esophagus to the stomach.

This shows emergent properties at work again, where the collective action of cells in tissue achieves something that individual cells cannot, further illustrating the incredible complexity and collaboration in biological systems.

Furthermore, different tissues combine to form organs, demonstrating a higher level of biological organization, where each

tissue contributes to the organ's overall function. For instance, the **stomach** is made up of **epithelial tissue**, which is responsible for secreting digestive enzymes that break down proteins and **muscular tissue**, which helps mix the food through contraction and relaxation movements (see Knowledge 2.5 for detail).

This collaboration of various tissues enables the stomach to perform its main role in digestion. The ability of the stomach to digest food represents an emergent property, a capability that is not present in the individual tissues when isolated.

Do you Know?

Emergent characteristics are not specific to living organisms. For example, a collection of bicycle components cannot facilitate transportation; however, when assembled correctly, they enable you to cycle to a desired location. However, biological systems are significantly more complicated than such non-living models, which makes studying the emergent features of life particularly difficult.

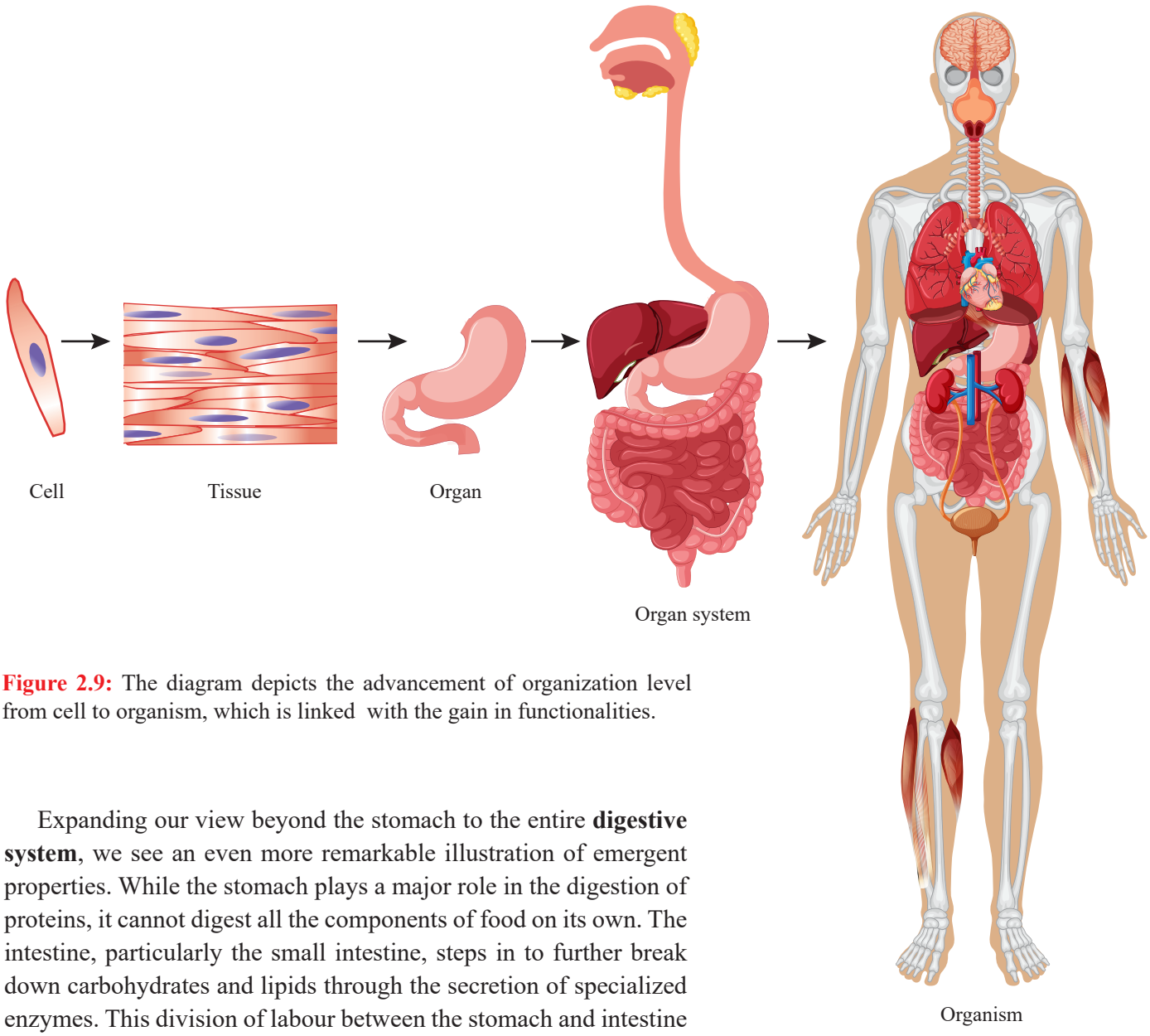


Figure 2.9: The diagram depicts the advancement of organization level from cell to organism, which is linked with the gain in functionalities.

Expanding our view beyond the stomach to the entire **digestive system**, we see an even more remarkable illustration of emergent properties. While the stomach plays a major role in the digestion of proteins, it cannot digest all the components of food on its own. The intestine, particularly the small intestine, steps in to further break down carbohydrates and lipids through the secretion of specialized enzymes. This division of labour between the stomach and intestine highlights the concept of cooperation among organs within a system to achieve efficient digestion.

Here, the digestive system as a whole demonstrates an emergent property, functioning in a more complex and united way than any of its parts could manage independently. This complexity and unity are key signs of emergent properties, highlighting the sophistication and collaborative nature of biological systems.

Moving to the whole **organism level**, emergent properties become even more evident, showing the simple yet crucial cooperation between different organ systems in the human body. The digestive system not only processes food but also works with the **circulatory system** to send nutrients to all cells. This partnership is vital for providing energy. Similarly, the **nervous system** helps by signalling when we are hungry and managing digestion, making sure our bodies work well. Moreover, the **immune system** works hand in hand with the digestive system to fight off germs from the food we eat, keeping us healthy.

These connections highlight how different systems, each with its unique role, come together to keep the organism healthy and functioning. This complex working together results in a living being that can thrive, adapt, and reproduce, showing the concept of emergent properties at the organism level where the whole is more complex and capable than just its parts. This view helps students understand the beauty and complexity of life, seeing how biological systems seamlessly work together for survival.

Knowledge Booster

Metabolism is recognized as an emergent property of life, originating from the cellular interactions among molecules, which are facilitated by the structured environment within the cell. Similarly, **consciousness** is identified as an emergent property of the brain that results from the interactions among numerous neurons across various brain regions.

Skill:2.4

Objective: Skill in explaining how each step in biological complexity contributes to new functions and abilities in living organisms.

Test Yourself

Short answer-based questions:

1. What are emergent properties in biology?
2. How do emergent properties manifest when going from organelles to cells?
3. What happens when cells form tissues in terms of emergent properties?
4. Can you give an example of an emergent property at the organism level?

2.5 Knowledge

The Human Stomach: Tissues and Function

The stomach is a vital organ in the digestive system, responsible for breaking down and processing the protein component of food. The stomach wall is composed of four primary layers, each with specific functions that enable efficient food storage (temporarily), mixing, and gradual release into the small intestine. These layers are the mucosa, submucosa (a supportive layer that houses blood vessels, connective tissues, and nerves), the muscular layer, and the outermost protective layer (see Figure 2.10). Each of these layers contains distinct types of tissues that work together to support the stomach's functions. The types of tissues in these layers of the stomach wall are:

Epithelial Tissue: This tissue lines the stomach, as it is present in the innermost layer (mucosa) of the stomach wall. The epithelial cells are special because they secrete **gastric juice**, which is essential for protein breakdown. Gastric juice includes hydrochloric acid (HCl), digestive enzymes (such as pepsin), and mucus. The primary function of **HCl** is to create an acidic environment in the stomach lumen, which is crucial for the activation of **pepsin**. Once activated, pepsin catalyzes the breakdown of proteins, converting them into smaller components (amino acids). The **mucus** in the gastric juice plays a protective role by coating the inner lining of the stomach, creating a barrier that protects the stomach lining from the corrosive effects of hydrochloric acid.

Connective Tissue: Connective tissue is primarily found within the submucosa layer, situated just beneath the mucosa layer (see Figure 2.10). It provides structural support to the stomach and maintains its shape. This tissue connects the various layers of the stomach wall with each other and houses blood vessels and nerves. Moreover, the connective tissue is also present in the outermost layer of the stomach wall, where it serves as a protective barrier for the stomach against friction and mechanical damage.

Muscular Tissue: The muscular tissue of the stomach is present in the third layer of the stomach wall. The muscles in this layer are arranged in different directions, including outer **longitudinal muscles** and inner **circular muscles**. The continuous contraction and relaxation of this tissue allows the stomach to mix food with gastric juice and break it down into a semi-liquid form.

Student Learning Outcomes

- *Enlist the different types of tissue come together to form the stomach organ in the human body.*

Interesting Information

The stomach communicates hunger signals to the brain by releasing hormones when it is empty, stimulating the sensation of hunger.

Knowledge Booster

An ulcer in the stomach, known to doctors as a **peptic ulcer**, is a sore that develops when the stomach's protective lining is eroded, often damaging the stomach's mucous membrane and the underlying tissue layers.

Nervous Tissue: Nervous tissue is primarily concentrated in the muscular and submucosa layers of the stomach wall. This tissue controls the digestive processes of the stomach. It sends signals to the stomach muscles, prompting them to contract for digestion, and regulates the secretion of gastric juices.

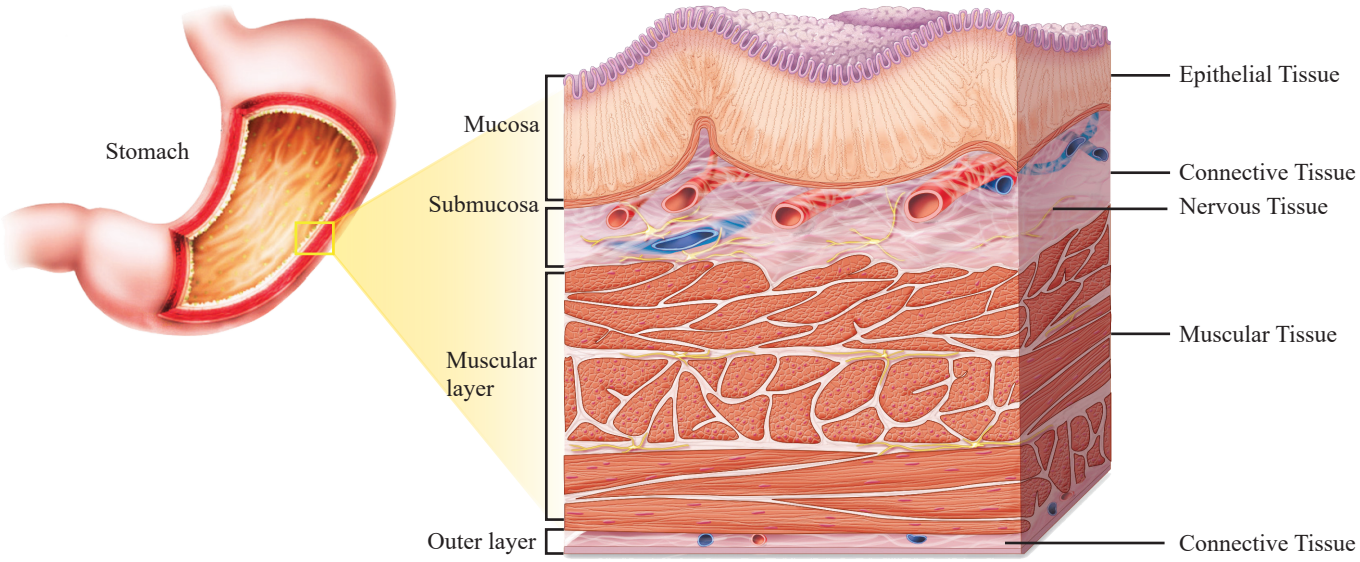


Figure 2.10: A cross-sectional view of stomach highlighting epithelial, connective, nervous, and muscular tissue.

In summary, the stomach's complex structure, comprised of epithelial, connective, muscular, and nervous tissues within its four-layered wall, is well organized to efficiently process food. This setup ensures both the mechanical breakdown of food and the chemical digestion of proteins, underscoring the significance of various stomach tissues in the digestive system.

Skill:2.5

Objective: Ability to describe the roles of epithelial, connective, muscular and nervous tissues in the overall function of the stomach.

Test Yourself

Short answer-based questions:

1. What is the role of muscular tissue in the stomach?
2. What function does epithelial tissue serve in the stomach?
3. How does connective tissue contribute to the stomach's structure?
4. What is the function of nervous tissue in the stomach?

2.6 Knowledge

Major Organ Systems in the Human Body

The human body is a complex and highly organized structure made up of various organ systems that work together to maintain life and health. Each organ system has a specific function, but they all interact closely to ensure the body operates efficiently. Here is a detailed discussion of how these organ systems come together to form the human body:

Student Learning Outcomes

- Discuss the organ systems come together to form the human body.

Integumentary System

The integumentary system includes the skin, hair, nails, sweat glands and sebaceous glands. The skin is the largest organ of the body and consists of two main layers: the **epidermis** and the **dermis**. The epidermis is the outermost layer which protects us. The dermis contains blood vessels, nerves, hair follicles, sweat glands and sebaceous glands (see Figure 2.11). Sweat glands help regulate body temperature by producing sweat and sebaceous glands produce oil to keep the skin and hair moisturized. Hair and nails are made of a protein called **keratin**. Hair helps with insulation and sensation, while nails protect our fingertips. Overall, this system forms a protective covering for our body and is essential for temperature regulation.

Knowledge Booster

Acne is a skin problem where hair follicles get blocked with oil and dead skin cells, leading to pimples, blackheads or whiteheads, often on the face, chest and upper back. It is very common in teens because of hormone changes that make the skin's oil glands to produce more oil, but it can happen at any age. Although it is not harmful, it can leave scars and can be stressful for people who have it.

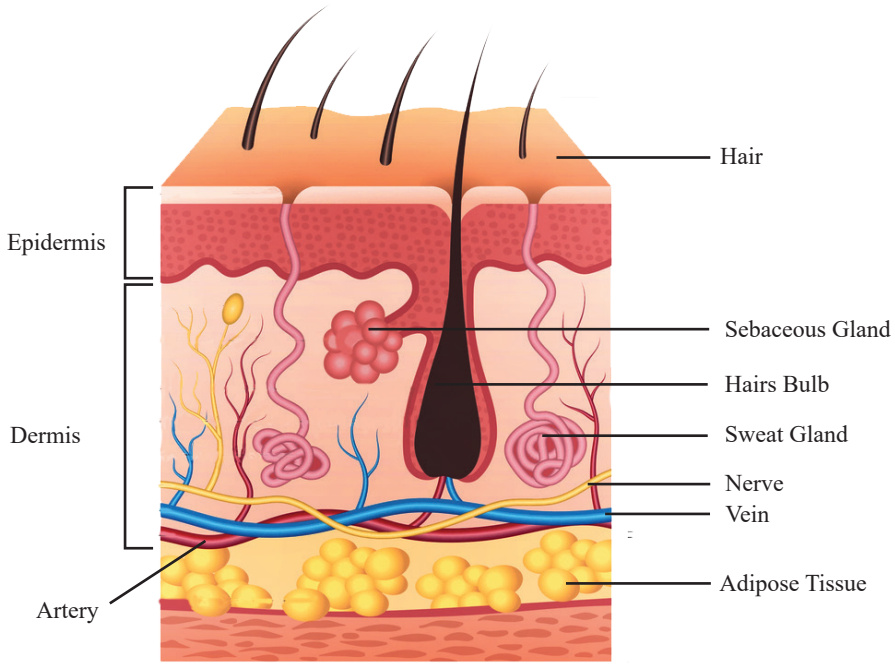


Figure 2.11: The integumentary system forms the layer of the body most exposed to the environment. It includes the sweat glands, sebaceous glands, hair and skin.

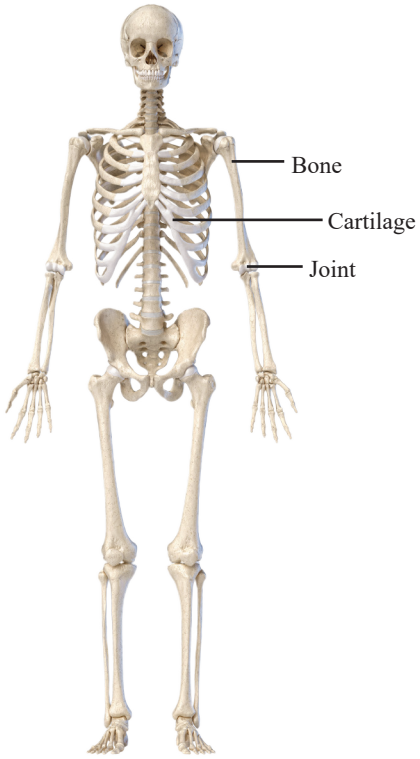


Figure 2.12: Skeletal system with bones, cartilage and joints.

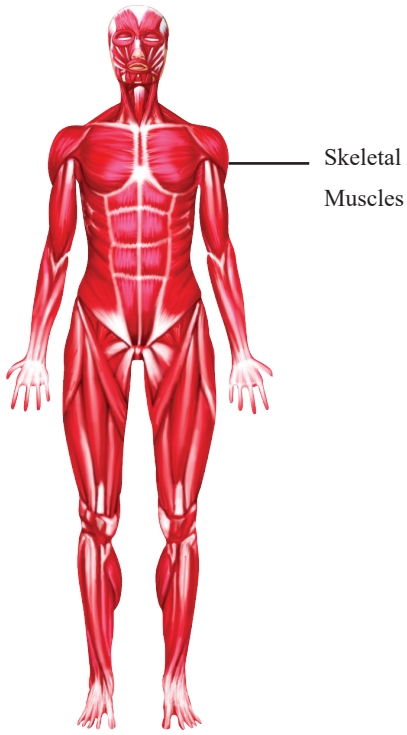


Figure 2.13: Muscular system

Skeletal System

The skeletal system consists of bones, cartilage, joints and ligaments (see Figure 2.12). It provides a framework that helps the body maintain its shape, protects vital organs and enables us to move. **Bones** are hard connective tissues that vary in shape and size. **Joints** are points where two or more bones meet, allowing movement. **Ligaments** are strong bands that hold bones together at joints. **Cartilage** is a flexible connective tissue that covers the ends of bones at joints, reducing friction during articulation of bones. All these components collaborate to enable the movement of the body. Additionally, this system also produces blood cells and stores minerals like calcium. It is vital for maintaining the overall health and structure of the body.

Muscular System

The muscular system consists of three types of muscles: skeletal, smooth, and cardiac muscles, along with tendons. **Skeletal** muscles are connected to bones and are responsible for the movement of our body parts (Figure 2.13). **Tendons** are strong connective tissue bands that attach skeletal muscles to bones. **Smooth** muscles are present in organs like the stomach and assist in automatic movements such as the movement of food through the digestive tract. **Cardiac** muscle is only found in the heart and helps pump blood. Together, these muscles and tendons enable us to move, maintain body posture, and regulate body temperature.

Nervous System

The nervous system includes the brain, spinal cord and nerves (see Figure 2.14). The **brain** is the control centre of the body, handling thoughts and decisions. The **spinal cord** is an elongated structure extending from the brain to the spinal column. It acts as a communication pathway between the brain and the body. **Nerves** are made up of bundles of nerve fibers that carry messages from the brain to different body parts and back to the brain. The two most abundant cells of the nervous system are neurons and neuroglia. **Neurons** are special cells that send these messages using electrical and chemical signals. **Neuroglia** are helper cells that protect and support neurons. These parts of the nervous system help control everything our body does, from moving and feeling to thinking and breathing.

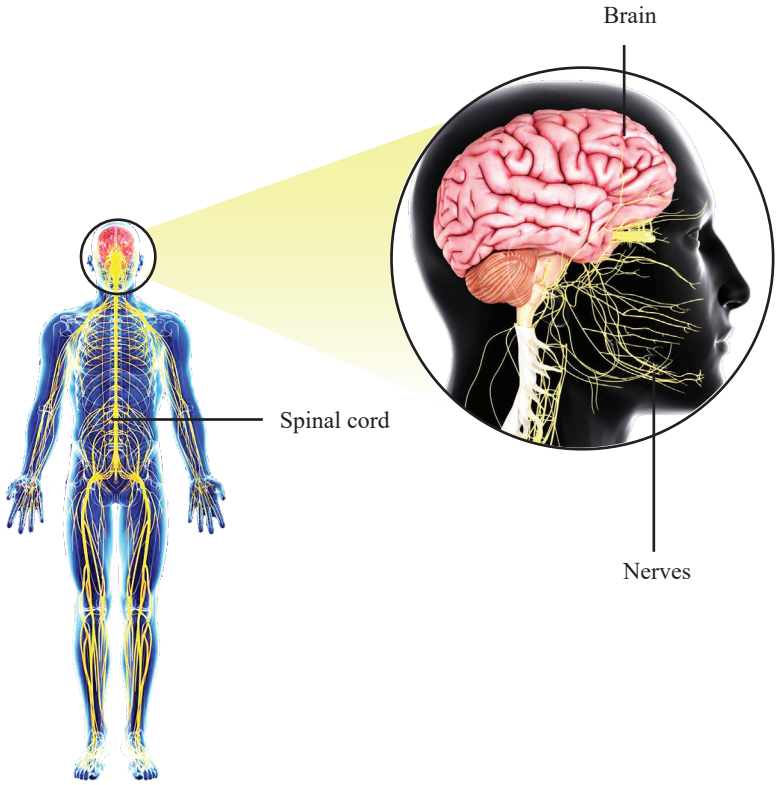


Figure 2.14: Nervous system comprising brain, spinal cord and nerves.

Endocrine System

The endocrine system includes glands like the pituitary, thyroid, adrenal glands, pancreas, etc (see Figure 2.15). These glands make **hormones**, which are special chemicals that regulate growth, metabolism, stress, blood sugar, reproduction and sleep. Hormones travel in the blood to reach target cells and perform their roles in different body parts, thus keeping everything balanced and working well. This system works with the nervous system to make sure the body functions efficiently.

Knowledge Booster

Gigantism is a rare disorder caused by the overproduction of growth hormone by the pituitary gland during childhood and adolescence. This leads to excessive growth of bones and tissues, resulting in abnormally tall stature and enlarged body parts. Without treatment, gigantism can lead to serious health complications, but with proper management, individuals can achieve a normal lifespan and quality of life.

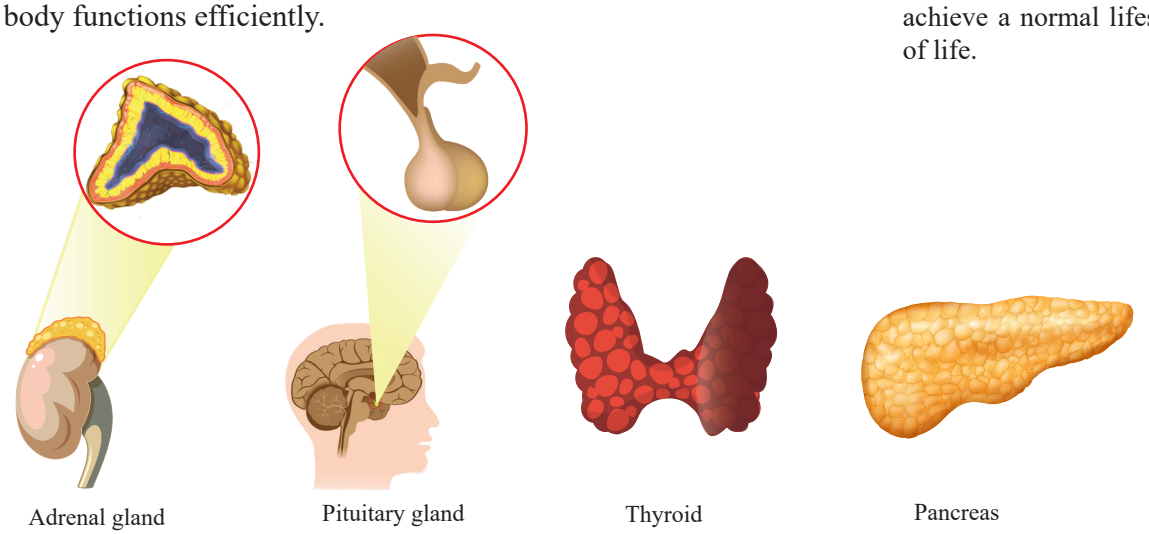


Figure 2.15: Important glands of endocrine system

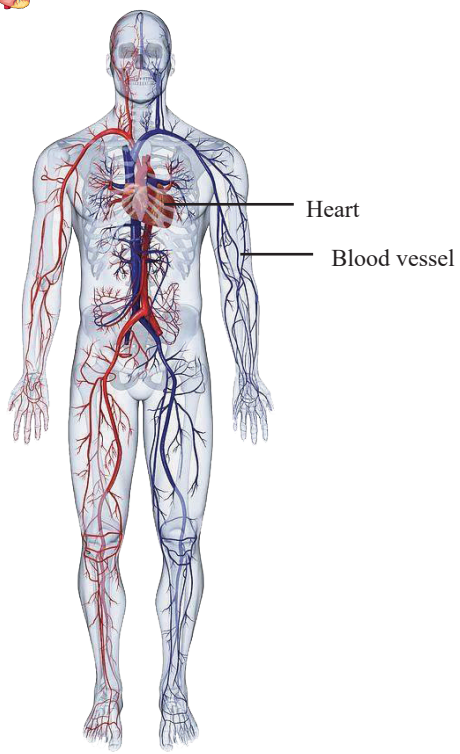


Figure 2.16: The human circulatory system comprises the heart, blood vessels and blood.

Circulatory System

The primary components of the circulatory system are the heart, blood vessels and blood (see Figure 2.16). The **heart**, a four-chambered organ, pumps blood, which travels through **arteries** to reach all parts of the body and then returns to the heart through **veins**. Microscopic blood vessels called **capillaries** connect arteries and veins, allowing the exchange of oxygen, nutrients, and waste products between blood and tissues. **Blood**, composed of red and white blood cells, platelets and plasma, carries these substances throughout the body. This system is vital for maintaining the body's homeostasis and overall health.

Urinary System

The urinary system consists of a pair of kidneys, a pair of ureters, a urinary bladder, and a urethra (see Figure 2.17). Its primary function is to eliminate waste products and excess water from the blood. The **kidneys** filter the blood to produce urine, which then passes through the **ureters** and gets stored in the **bladder**. The bladder holds the urine until it is time for urination, and then the urine exits the body through the **urethra**. This system also regulates the water balance of the body (discussed in detail in the following knowledge).

Knowledge Booster

Kidney stones are hard mineral deposits that form in the kidneys due to various factors like dehydration or high mineral levels in urine. Symptoms include severe pain, nausea and blood in urine. Treatment includes increased fluid intake and medical procedures like lithotripsy. Prevention focuses on hydration and dietary changes. Complications may arise if left untreated, but with proper management, most people can pass kidney stones without long-term issues.

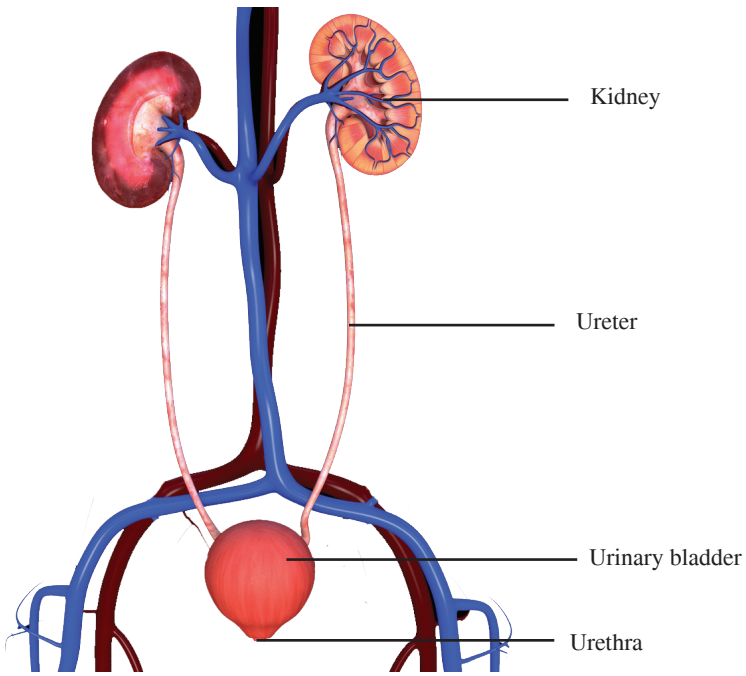


Figure 2.17: The organs of the urinary system include kidneys, ureters, urinary bladder and urethra.

In conclusion, the human body is a complex network of organ systems that work together to sustain life. Each system plays a unique role, but they all rely on one another to keep the body functioning properly. This interdependence is an important aspect of the remarkable organization of the human body.

Test Yourself

Short answer-based questions:

1. What is the primary function of the circulatory system?
2. What organs are involved in the urinary system?
3. What is the role of the endocrine system?
4. What does the nervous system comprise?

Long Question

1. Explain the composition of skeletal and muscular systems in the human body.

Skill:2.6

Objective: Evaluate how organ systems interact and work together to form the human body.

2.7 Knowledge

Homeostasis

Student Learning Outcomes

- *Discuss the various organs and systems of the human body work to maintain homeostasis*
- *Describe the advantages of homeostasis*

Homeostasis, derived from Greek words meaning "similar" and "steady," is the process by which living organisms maintain a stable internal environment despite changes in the external surroundings. The necessity for homeostasis arises because while the external environment can vary widely, the internal conditions of an organism must remain relatively constant to support life processes.

It regulates blood and tissue fluid composition, maintaining factors like temperature, water content, and the levels of oxygen, carbon dioxide, and glucose within narrow limits. This regulation is essential for optimal cellular function and overall organism health. For instance, the human body maintains a temperature near 37°C for efficient enzyme activity (see Chapter 6 for details). It tightly controls blood glucose levels to provide cells with a consistent energy supply, highlighting the critical role of homeostasis in sustaining life.

Do you Know?

The set point is the ideal value of a variable that the body aims to maintain, like the desired body temperature or glucose concentration.

Maintaining Homeostasis: The Role of Organs and Systems

Homeostasis relies on **negative feedback mechanisms**, which correct deviations from set point or normal values. This process involves three components: a **receptor** (sensor) detecting environmental changes, a **control center** receiving this information and deciding the response and an **effector** reversing the change to restore the system to its set point. Figure 2.18 summarizes the negative feedback loop.

Knowledge Booster

A **feedback mechanism** is a process used by the body to maintain a stable internal environment, known as homeostasis. It works by the body constantly monitoring and adjusting important levels and conditions, like temperature and blood sugar, to keep them within a safe range. This ensures that the body operates smoothly and remains healthy, adapting to changes both inside and outside the body. There are two types of feedback mechanisms; negative and positive feedback mechanisms.

Interesting Information

Positive feedback mechanism is a process that amplifies a change, pushing it further in the same direction. An example of positive feedback is **blood clotting**. When a wound occurs, platelets rush to the site and stick together to form a temporary plug. Besides, they release chemicals that attract more platelets to form a stable clot. This cascade of events increases rapidly until the bleeding is stopped, demonstrating how positive feedback helps the body respond quickly to injury and prevent excessive blood loss.

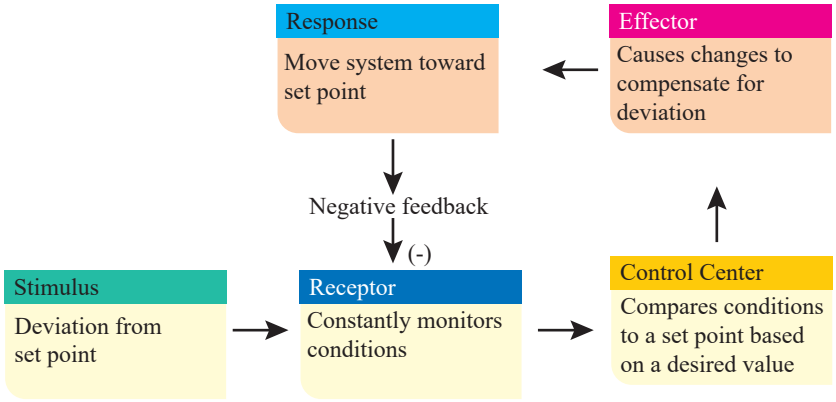


Figure 2.18: Generalized diagram of a negative feedback loop.

The role of various organs and systems of the human body in regulating water concentration, blood glucose levels and body temperature by using negative feedback mechanisms are discussed below:

Ask your Teacher?

Name the receptor, control center and effectors involved in the regulation of water concentration.

Regulation of Water Concentration

The body maintains water balance through a coordinated system involving osmoreceptors, the hypothalamus (a part of the brain) and kidneys. **Osmoreceptors** are the sensitive cells within the hypothalamus of the nervous system that detect changes in blood water concentration. Upon detecting dehydration (low water levels in the blood), these receptors trigger the **hypothalamus** to release antidiuretic hormone (ADH) from the pituitary gland. ADH acts on the kidneys, causing them to reabsorb more water in the bloodstream. This reduces the amount of water lost in the urine. As a result, the blood's water concentration increases. This process is a prime example of a negative feedback mechanism for homeostasis. This coordinated interaction between the nervous, endocrine and urinary systems ensures water levels remain within a narrow, healthy range, demonstrating the efficiency of the body's regulatory systems.

Knowledge Booster

There are two types of cells in the pancreas linked with glucose regulation; **beta** and **alpha cells**. Beta cells release insulin to lower high glucose levels while alpha cells release glucagon to raise low glucose levels.

Homeostasis of Blood Glucose Levels

The pancreas regulates blood glucose levels as both the receptor and control center in the endocrine system. It releases **insulin** to lower high glucose levels and **glucagon** to raise low levels, maintaining a blood glucose level within the range of 90 to 100 mg/dL.

When food is consumed, blood glucose levels rise, triggering the pancreas to release insulin. This signals liver and muscle cells (effectors) to absorb and store glucose as glycogen, lowering blood glucose levels. Conversely, during fasting, blood glucose levels decrease, prompting the pancreas to release glucagon. This directs the liver to convert stored glycogen into glucose and release it into the bloodstream, raising blood glucose levels. This dynamic balance ensures a steady energy supply to cells, illustrating the collaboration between the pancreas (endocrine system), muscle cells (muscular system) and liver (digestive system) to maintain glucose levels for optimal energy management in the body (see Figure 2.19).

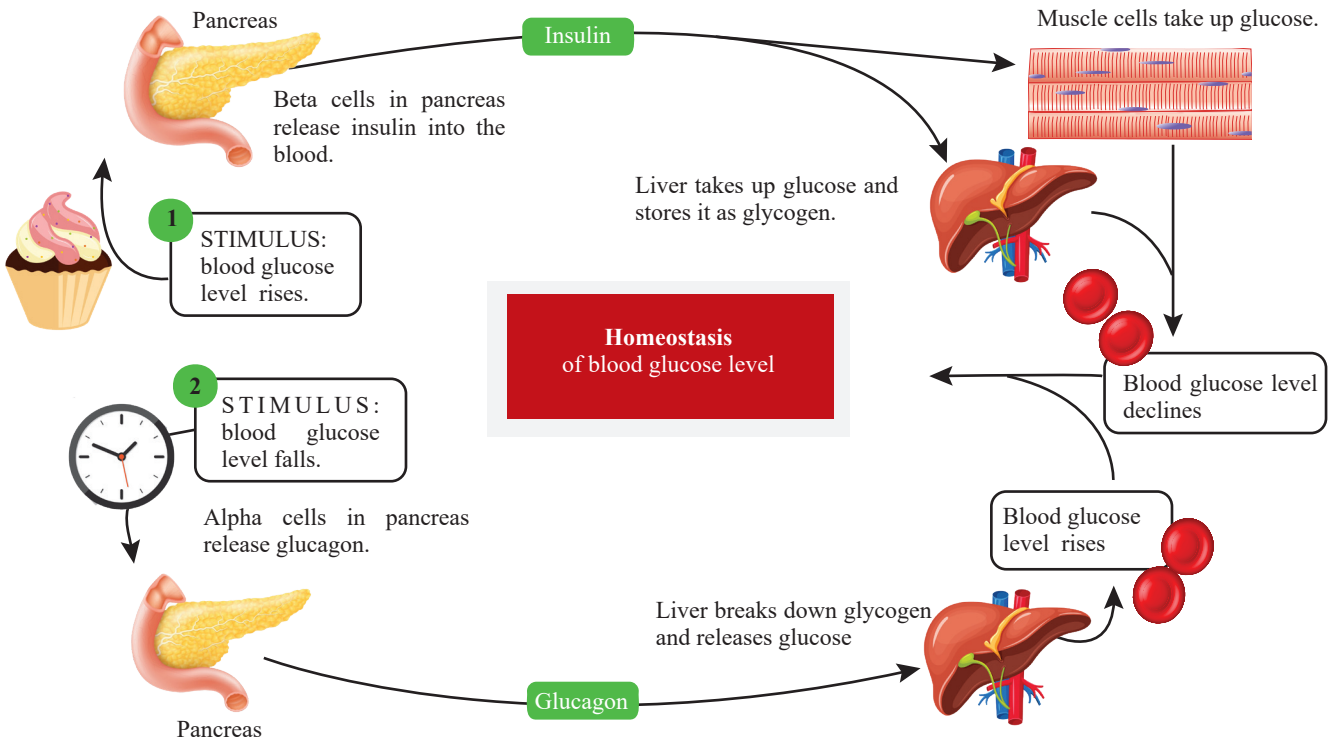


Figure 2.19: Blood glucose regulation in humans; Insulin lowers blood glucose by enhancing its uptake in body cells and converting it into glycogen to store it in the liver; Glucagon raises blood glucose by stimulating glycogen breakdown in the liver.

Maintenance of Body Temperature (Thermoregulation)

Body temperature regulation involves a coordinated interaction between the integumentary, nervous, muscular and circulatory systems to keep the internal environment stable. Temperature receptors in the skin and hypothalamus detect changes in temperature. When the body's temperature rises above the set point, the hypothalamus triggers cooling mechanisms: sweat glands

Interesting Information

Hypothalamus compares the current temperature to the body's set point, which is typically around 37°C (98.6°F) and determines whether the body needs to warm up or cool down.

produce sweat for evaporative cooling, while blood vessels in the skin dilate (vasodilation) to release heat. Conversely, when the temperature falls below the set point, the hypothalamus activates warming mechanisms: muscles may shiver to generate heat and blood vessels in the skin constrict (vasoconstriction) to conserve heat, as depicted in Figure 2.20. This coordinated response ensures body temperature remains within an optimal range for metabolic processes, illustrating the complex but efficient regulation of thermal homeostasis by multiple organ systems.

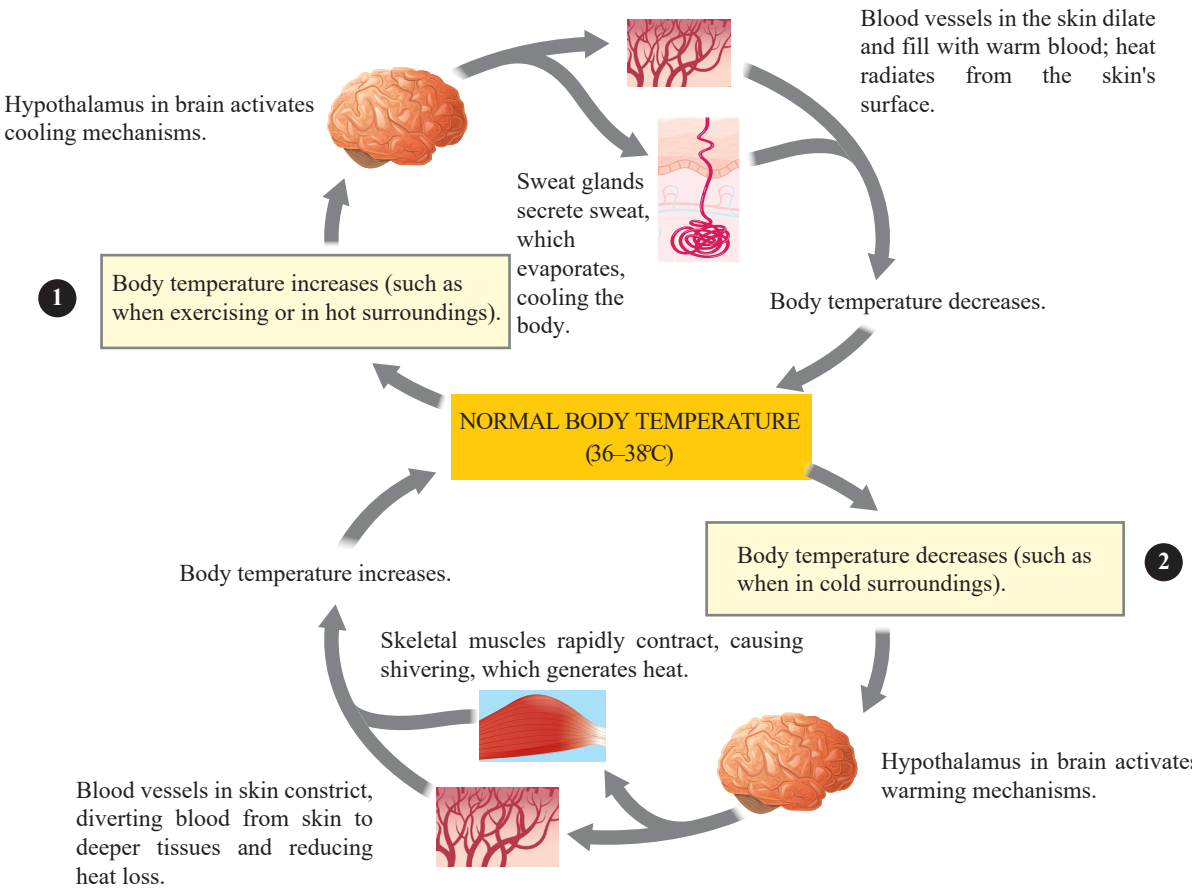


Figure 2.20: Homeostatic Regulation of Temperature in Human. If the body temperature rises above (right-hand side) or drops below (left-hand side) the setpoint, internal biological responses are initiated to return the temperature back to the setpoint range.

Overall, homeostasis involves the complex coordination of systems and organs to maintain internal stability and support organism health and functionality. This balance is crucial for the organism's ability to adapt and survive in various environmental conditions.

Similarly, plants also maintain their internal conditions despite changes in the external surroundings. Students will learn about homeostasis in plants in Chapter 8.

The Advantages of Homeostasis

This ability to regulate and balance various physiological parameters is crucial for the survival and well-being of an organism. Here are some advantages of homeostasis:

Homeostasis is crucial for maintaining a stable internal environment in the body, which is essential for the optimal functioning of cells and tissues. It ensures that conditions like temperature and pH are kept within a narrow range, allowing enzymes and other cellular processes to work efficiently. This regulation also protects the body from harmful conditions, such as extreme heat or cold, by triggering responses that maintain a safe internal temperature. Additionally, homeostasis allows the body to adapt to changes in the external environment, ensuring that energy levels are consistent by regulating blood glucose levels and maintaining the balance of fluids and electrolytes, which are vital for nerve transmission, muscle contraction and blood pressure.

Homeostasis also plays a key role in eliminating metabolic wastes and toxins, preventing their accumulation and potential harmful effects. It supports stable conditions for growth and development, ensuring that the body's systems develop correctly and function harmoniously. In summary, homeostasis is fundamental to the health and survival of an organism, enabling it to thrive in a constantly changing environment and maintain optimal functioning.

Test Yourself

Short answer-based questions:

1. Define homeostasis.
2. What hormone is released by the pituitary gland to regulate water balance?
3. What is the main role of glucagon in blood glucose regulation?
4. Describe the role of sweat glands in thermoregulation.

Long answer-based questions:

1. Explain the regulation of water concentration in the body, including the roles of osmoreceptors, the hypothalamus, and the kidneys.
2. Describe the process of thermoregulation in the human body.

Definition

Homeostasis helps maintain three main components of the body: water and salt concentration, temperature, and nitrogenous waste.

The process of regulating water and electrolytes in the body is known as **osmoregulation**. The maintenance of a steady internal body temperature is known as **thermoregulation**.

Excretion is the process by which animals eliminate waste products and nitrogenous waste from their bodies.

Skill:2.7

Objective: Analyze how different organs and systems collaborate to regulate internal conditions and maintain homeostasis.

Ability to explain the importance of homeostasis in response to external and internal changes.

Key Points

- Tissues are groups of similar cells performing a specific function; organs are made of different tissues for more complex functions; systems consist of organs working together. Examples in animals: muscle tissue, heart organ, and circulatory system. In plants: vascular tissue and leaf organ.
- Emergent properties describe new functionalities appearing at each level of biological complexity, such as enhanced capabilities in a cell compared to its individual organelles, and the advanced functions of organisms compared to their individual systems.
- The stomach comprises muscular, epithelial, connective, and nervous tissues, each contributing to its overall function of digestion and regulation.
- Leaves consist of epidermal, palisade mesophyll, spongy mesophyll, and vascular tissues, combining for functions like photosynthesis, gas exchange, and nutrient transport.
- Human body systems include circulatory, digestive, nervous, and skeletal systems, each with distinct roles, working in harmony for overall bodily function.
- Various organs and systems, like the endocrine and nervous systems, kidneys, and lungs, collaborate to maintain homeostasis, regulating aspects like temperature, pH, and fluid balance.
- Homeostasis maintains a stable internal environment crucial for optimal cellular and organ function, enabling adaptation and survival in varying external conditions.
- Plant physiology involves understanding the structure and function of roots (absorption and stability), stems (support and transport), leaves (photosynthesis), and flowers (reproduction).

Extensive Exercise

01 Encircle the most suitable answer

1. **What is the primary function of the root system in plants?**
   a) Photosynthesis b) Gas exchange
   c) Absorbing water and minerals d) Reproduction
2. **Which organ system is responsible for circulating blood in the human body?**
   a) Digestive b) Respiratory
   c) Circulatory d) Nervous
3. **What type of tissue lines the inner surface of the stomach?**
   a) Muscular b) Epithelial
   c) Connective d) Nervous
4. **Which part of the plant is primarily involved in photosynthesis?**
   a) Root b) Stem
   c) Leaf d) Flower
5. **Which systems are involved in regulating blood glucose levels?**
   a) Endocrine System b) Nervous System
   c) Circulatory System d) Urinary System
6. **Which tissue transports water in plants?**
   a) Xylem b) Phloem
   c) Epidermal d) Mesophyll

7. **What is the main function of the nervous system?**
   - **a)** Digesting food
   - **b)** Circulating blood
   - **c)** Controlling and coordinating body activities
   - **d)** Producing hormones
8. **Which organ in the human body filters blood and removes waste?**
   - **a)** Heart
   - **b)** Liver
   - **c)** Kidneys
   - **d)** Lungs
9. **What role do flowers play in plants?**
   - **a)** Absorbing nutrients
   - **b)** Supporting leaves
   - **c)** Facilitating reproduction
   - **d)** Storing food
10. **What is homeostasis?**
    - **a)** A type of hormone
    - **b)** Digestive process
    - **c)** The body's way of maintaining a stable internal environment
    - **d)** A respiratory function

02 Mismatched Pair Questions

Epidermal Tissue	Integumentary System
Sebaceous Gland	Filtering blood
Muscles	Protection
Kidneys	Controlling body activities
Nervous System	Movement

03 More-Than-One-Correct-Option Type Multiple Choice Questions

1. **Which tissues are found in the human stomach?**
   - **a)** Muscular
   - **b)** Epithelial
   - **c)** Connective
   - **d)** Nervous
2. **Which organs are part of the circulatory system?**
   - **a)** Lungs
   - **b)** Heart
   - **c)** Blood
   - **d)** Diaphragm
3. **Which processes occur in leaves?**
   - **a)** Photosynthesis
   - **b)** Gas exchange
   - **c)** Transpiration
   - **d)** Nutrient absorption
4. **What functions do roots perform?**
   - **a)** Anchor plant
   - **b)** Absorb water
   - **c)** Store food
   - **d)** Photosynthesis in some plants
5. **What are the roles of the circulatory system?**
   - **a)** Transport oxygen
   - **b)** Remove waste
   - **c)** Digest food
   - **d)** Regulate temperature
6. **What types of muscles are present in human body?**
   - **a)** Skeletal
   - **b)** Smooth
   - **c)** Cardiac
   - **d)** Tendons

7. **Which systems maintain homeostasis?**
   - **a)** Nervous
   - **b)** Endocrine
   - **c)** Digestive
   - **d)** Excretory
8. **Which tissues make up a leaf?**
   - **a)** Epidermal
   - **b)** Palisade mesophyll
   - **c)** Spongy mesophyll
   - **d)** Vascular
9. **Which organ is part of the skeletal system?**
   - **a)** Bones
   - **b)** Cartilage
   - **c)** Kidneys
   - **d)** Intestines
10. **What roles do stems play in plants?**
   - **a)** Support leaves
   - **b)** Conduct photosynthesis
   - **c)** Transport nutrients
   - **d)** Store food

04 Assertion-Reason Type Questions

In each of the following questions, two statements are given, one labelled as Assertion (A) and the other as Reason (R). Examine the statements carefully and mark the correct answer according to the instructions given below:

(a) If both A and R are correct and R is the correct reason for A
(b) If both A and R are correct but R is not the reason for A
(c) If A is correct and R is wrong
(d) If A is wrong and R is correct

1.Assertion (A): The circulatory system includes the heart, blood vessels, and blood.
Reason (R): The primary function of the circulatory system is to facilitate gas exchange in the lungs. ☐

2.Assertion (A): In plants the xylem is responsible for transporting water
Reason (R): Xylem vessels are part of the plant's vascular system, which moves nutrients and water from roots to leaves. ☐

3.Assertion (A): The pancreas is part of the endocrine system.
Reason (R): The pancreas produces digestive enzymes that break down food in the intestines. ☐

4.Assertion (A): The epidermal tissue in leaves secretes a waxy substance called cuticle.
Reason (R): The cuticle's primary function is to aid in the process of photosynthesis. ☐

5.Assertion (A): Muscle tissue in the human stomach helps in digestion.
Reason (R): Muscle tissue contracts and relaxes to churn food, mixing it with digestive enzymes. ☐

6.Assertion (A): The nervous system includes the brain, spinal cord, and nerves.
Reason (R): The main function of the nervous system is to transport nutrients throughout the body. ☐

7.Assertion (A): Sweating does not contribute to cooling the body down.
Reason (R): Because the evaporation of sweat from the skin surface actually reduces body temperature.

Assertion (A): Homeostasis refers to the body maintaining a stable internal environment.
Reason (R): Homeostasis is controlled exclusively by the endocrine system.

Assertion (A): Flowers are the reproductive organs of a plant.
Reason (R): The primary role of flowers is to facilitate photosynthesis.

Assertion (A): Leaves are responsible for releasing oxygen into the atmosphere.
Reason (R): This oxygen is a byproduct of the photosynthesis process occurring in leaves.