Message from the CEO

Education is the foundation of every successful society, and books are the most reliable medium for spreading knowledge. Scholar Publications was founded with the vision to provide students and educators with high-quality, authentic, and curriculum-aligned academic content.

Books publication is not just our identity — it is our legacy. We are not merely associated with publishing; we are committed to strengthening the intellectual and academic foundation of our nation.

The development of each book begins with careful selection of authors. We publish only those books that are written by renowned, experienced, and field-expert professors, ensuring both academic strength and relevance to examination requirements.

Our mission goes beyond publishing — we aim to distribute knowledge effectively to every school and college across Punjab. Our trained marketing team regularly engages with teachers, collects their feedback, and provides them with content that is truly beneficial for both instructors and students.

We are grateful to Allah Almighty for choosing us for this important mission, and we pray that our efforts bring positive change to Pakistan's educational landscape.

Warm regards,
Muhammad Shahid Qureshi
CEO, Scholar Publications
Urdu Bazar, Lahore
0300 – 9441414



Published by:
Muhammad Shahid Qureshi
Scholar Publications
Qazafi Market, Urdu Bazar,
Lahore - Pakistan
042 - 37231595
37241133

Edition: 2026-27

Composed by:
Muhammad Adeel Akram

Designed by:
Atiq Ur Rehman

Printed at:
Nasir Baqir Printers
Rattigon Road, Lahore

All Rights Reserved. This book, in whole or in part, May not br reproduced, stored in a retrieval system, Or transmitted, in any form or by any means, electronic, mechanical, photocopy, recordings, in any Language or otherwise, without prior written Permission from publisher.

Table of Contents

13 Thermoregulation and Osmoregulation

Student Learning Outcomes (SLOs)	01
Chapter at a Glance	02
Theory	03
Check Understanding Solution	14
Exercise	15
Section 1: Multiple Choice Questions	15
Section 2: Short Answer Questions	16
Section 3: Long Answer Questions	17
Inquisitive Answer Questions	17
Self-Assessment	18

14 Human Urinary System

Student Learning Outcomes (SLOs)	19
Chapter at a Glance	20
Theory	21
Check Understanding Solution	34
Exercise	35
Section 1: Multiple Choice Questions	35
Section 2: Short Answer Questions	36
Section 3: Long Answer Questions	38
Inquisitive Answer Questions	38
Self-Assessment	39
Entrance Test (MCQs)	40

15 Human Nervous System

Student Learning Outcomes (SLOs)	41
Chapter at a Glance	42
Theory	43
Check Understanding Solution	80
Exercise	82
Section 1: Multiple Choice Questions	82
Section 2: Short Answer Questions	84
Section 3: Long Answer Questions	86
Inquisitive Answer Questions	88
Self-Assessment	89
Entrance Test (MCQs)	90

16 Human Endocrine System

Student Learning Outcomes (SLOs)	91
Chapter at a Glance	92
Theory	93
Check Understanding Solution	113
Exercise	113
Section 1: Multiple Choice Questions	113
Section 2: Short Answer Questions	115
Section 3: Long Answer Questions	117
Inquisitive Answer Questions	117
Self-Assessment	118
Entrance Test (MCQs)	119

17 Human Reproductive System

Student Learning Outcomes (SLOs)	121
Chapter at a Glance	122
Theory	123
Check Understanding Solution	132
Exercise	133
Section 1: Multiple Choice Questions	133
Section 2: Short Answer Questions	134
Section 3: Long Answer Questions	135
Inquisitive Answer Questions	135
Self-Assessment	136
Entrance Test (MCQs)	137

18 Inheritance

Student Learning Outcomes (SLOs)	139
Chapter at a Glance	140
Theory	141
Check Understanding Solution	181
Exercise	182
Section 1: Multiple Choice Questions	182
Section 2: Short Answer Questions	184
Section 3: Long Answer Questions	188
Inquisitive Answer Questions	189
Self-Assessment	191
Entrance Test (MCQs)	192

CamScanner

19 Chromosome And DNA

Student Learning Outcomes (SLOs)	195
Chapter at a Glance	196
Theory	197
Check Understanding Solution	235
Exercise	236
Section 1: Multiple Choice Questions	236
Section 2: Short Answer Questions	239
Section 3: Long Answer Questions	241
Inquisitive Answer Questions	242
Self-Assessment	244
Entrance Test (MCQs)	244

20 Biotechnology

Student Learning Outcomes (SLOs)	245
Chapter at a Glance	246
Theory	247
Check Understanding Solution	260
Exercise	261
Section 1: Multiple Choice Questions	261
Section 2: Short Answer Questions	262
Section 3: Long Answer Questions	263
Inquisitive Answer Questions	263
Self-Assessment	264
Entrance Test (MCQs)	265

21 Immunity

Student Learning Outcomes (SLOs)	267
Chapter at a Glance	268
Theory	269
Check Understanding Solution	285
Exercise	286
Section 1: Multiple Choice Questions	286
Section 2: Short Answer Questions	287
Section 3: Long Answer Questions	290
Inquisitive Answer Questions	290
Self-Assessment	291
Entrance Test (MCQs)	292

22 Biostatistics

Student Learning Outcomes (SLOs)	293
Chapter at a Glance	294
Theory	295
Check Understanding Solution	314
Exercise	314
Section 1: Multiple Choice Questions	314
Section 2: Short Answer Questions	315
Section 3: Long Answer Questions	316
Inquisitive Answer Questions	317
Self-Assessment	318

23 Pharmacology

Student Learning Outcomes (SLOs)	319
Chapter at a Glance	320
Theory	321
Check Understanding Solution	329
Exercise	330
Section 1: Multiple Choice Questions	330
Section 2: Short Answer Questions	331
Section 3: Long Answer Questions	331
Inquisitive Answer Questions	332
Self-Assessment	332

24 Evolution

Student Learning Outcomes (SLOs)	333
Chapter at a Glance	334
Theory	335
Check Understanding Solution	347
Exercise	348
Section 1: Multiple Choice Questions	348
Section 2: Short Answer Questions	349
Section 3: Long Answer Questions	350
Inquisitive Answer Questions	351
Self-Assessment	352
Entrance Test (MCQs)	353

25 Ecology

Student Learning Outcomes (SLOs)	355
Chapter at a Glance	356
Theory	357
Check Understanding Solution	377
Exercise	377
Section 1: Multiple Choice Questions	377
Section 2: Short Answer Questions	378
Section 3: Long Answer Questions	381
Inquisitive Answer Questions	381
Self-Assessment	383

CHAPTER 13

THERMOREGULATION AND OSMOREGULATION

Student Learning Outcomes (SLOs)

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

- Describe three elements i.e., receptors, control center and effectors which operate homeostatic mechanisms.
- Relate the homeostatic mechanisms with the negative and positive feedback systems.
- Define thermoregulation and explain its needs.
- Classify animals on the basis of the source of body heat i.e., ectotherms and endotherms.
- Classify the animals on the basis of the ability to thermoregulate i.e., poikilotherms and homeotherms
- Describe the regulatory strategies in man for thermoregulation.
- Differentiate between osmoconformers and osmoregulators.
- Define osmoregulation.
- Explain the problems faced by osmoregulators.
- Explain the different methods of osmoregulation found in freshwater, marine water and terrestrial animals.

CamScanner

Thermoregulation and Osmoregulation — Concept Map

1. HOMEOSTASIS (Stable internal environment)

- **(a) Basic Mechanism**
  - (i) **Receptors** (Detect changes & transmit signals).
  - (ii) **Control Centre** (Process info: Brain, spinal cord, glands).
  - (iii) **Effectors** (Muscles contract / Glands secrete to restore set point).
- **(b) Feedback Mechanisms**
  - (i) **Negative Feedback** (Reverses stimulus change, e.g., temperature regulation).
  - (ii) **Positive Feedback** (Amplifies stimulus change, e.g., childbirth, blood clotting).
  - (iii) **Unregulated Positive Feedback** (Can cause health problems, e.g., excessive inflammation).

2. OSMOREGULATION (Water and solute balance)

- **(a) Osmoconformers & Osmoregulators**
  - (i) **Osmoconformers** (Body fluids match stable environment / Isotonic).
  - (ii) **Osmoregulators** (Actively control internal concentration despite environment).
- **(b) Problems & Methods by Habitat**
  - (i) **Freshwater** (Hypertonic → Large dilute urine + active salt transport).
  - (ii) **Marine Water** (Hypotonic → Drink seawater + chloride/rectal glands + concentrated urine).
  - (iii) **Terrestrial Habitats** (Dry land → Impermeable skin/chitin/keratin + behavioral shelter + metabolic water).
- **(c) Nature of Excretory Products**
  - (I) **Ammonia** (Highly toxic → 500 mL water/g → Ammonotelic, e.g., aquatic animals).
  - (II) **Urea** (Less toxic → 50 mL water/g → Ureotelic, e.g., mammals).
  - (III) **Uric Acid** (Least toxic precipitates → 1 mL water/g → Uricotelic, e.g., birds/reptiles/insects).

3. THERMOREGULATION (Internal body temperature maintenance)

- **(a) Heat Source Classification**
  - (i) **Ectotherms** (Gain heat from external environment, low metabolism).
  - (ii) **Endotherms** (Generate heat internally via metabolism, have insulation).
- **(b) Temperature Stability Classification**
  - (I) **Poikilotherms** (Body temperature varies with surroundings).
  - (ii) **Homeotherms** (Maintain constant core temperature using brain hypothalamus).
- **(c) Human Thermoregulation** (Endothermic homeotherms via negative feedback)
  - (I) Responses to Overheating / Hyperthermia.
  - (II) Responses to Cooling / Hypothermia

INTRODUCTION

➢ **Chapter's Intro:**

- In this chapter, we will study **homeostasis.**
- We will explore the mechanisms of **thermoregulation** and **osmoregulation.**
- We will also examine the **importance of maintaining homeostasis** for the health and survival of human being.

HOMEOSTASIS

Q.1 Define the term homeostasis and give its three examples. LQ

Ans. Homeostasis:

- A vital process by which living organisms **maintain** a stable **internal environment,** despite changes in their external environment is called **homeostasis.**
- Homeostasis consists of a **wide range of mechanisms** that work together to regulate the body's internal environment.
- **Examples of Homeostasis:** Thermoregulation, Osmoregulation, Excretion.

Topic: Basic Mechanism of Homeostasis:

Q.2 How is homeostasis maintained? Also name its three elements. SQ

Ans. Homeostasis is maintained through the **collaboration of three essential elements.**

➢ **Elements of Homeostatic Mechanism:**
(i) Receptors. (ii) Control Centre. (iii) Effectors.

Q.3 Describe three elements which operate homeostatic mechanisms. Exercise UQ-1

OR Describe the three elements of homeostatic mechanism in detail? Explain the homeostasis mechanism by considering the example of human body temperature. LQ

Ans. Three Elements of Homeostatic Mechanism:

(i) Receptors (Sensors):

- **Definition:** The specialized structures **(organs, tissues, cells or subcellular components)** that can detect the changes in the **internal or external** environment are called **receptors** or **sensors.**
- They also transmit the **information** of changes to the control centre. (Brain)
- **Examples:**
  - **Receptors of Temperature (Thermoreceptors):** Receptors cells present in the skin can detect changes in temperature.
  - **Pressure Receptors (Mechanoreceptors):** Receptors cells in the blood vessels can detect changes in **blood pressure** and pass information of the **control centre.**

Check Understanding!

Q.1 A runner on a hot Lahore afternoon experiences a sharp rise in internal core temperature. Match each homeostatic element (1. Hypothalamus, 2. Sweat glands/vessels, 3. Thermoreceptors):

(A) 1=Receptor, 2=Control, 3=Effector
(B) 1=Control, 2=Effector, 3=Receptor
(C) 1=Effector, 2=Receptor, 3=Control
(D) 1=Control, 2=Receptor, 3=Effector

(ii) Control Centre:

- **Definition:** An element of homeostasis mechanism which receives information from the **receptors,** process this **information,** and sends appropriate message to the **effectors** is called **control center**
- These messages ensure that the **internal environment** remains within a narrow range of **set points.**
- These set points are optimal for the body's function.
- **Examples:** The **brain, spinal cord** and **endocrine glands** act as control centres in homeostasis.

(iii) Effectors:

- **Definition:** The parts of the body which **respond** when they receive message from the control centres are called **effectors.**

CamScanner

- **Examples:** Muscles and glands.
  - **Muscles:** They respond by contracting.
  - **Glands:** They show response by releasing their secretions.
- In this way, the responses of effectors restore the internal environment to its set points.

➢ **Homeostasis Mechanism of Human Body Temperature:**

- When the body temperature **drops** below the **set point (36.1 – 37.8°C)**, effectors in the **skin** and **muscles** cause **shivering** and **vasoconstriction**.
- This response increases heat production and raises the body temperature to the **set point**.

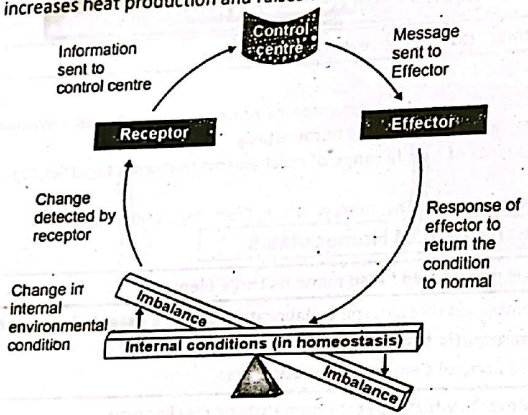


Figure: Elements of homeostasis

Topic: Feedback Mechanisms:

Q.4 Relate the homeostatic mechanisms with the negative and positive feedback systems. Exercise L/Q.2

OR Define feedback mechanisms, name & describe its two types with the help of examples. L/Q

Ans. Feedback Mechanisms:

- **Definition:** A regulatory process in which the output or product of a system is used to control the behavior of the system itself is called **feedback mechanisms.**
- **Feedback mechanisms** are the foundations of **homeostasis.**

➢ **Types of Feedback Mechanism:**

- There are two types of **feedback mechanisms:**
  (1) Negative Feedback. **(2) Positive Feedback.**

(1) Negative Feedback:

- **Definition:** A mechanism in which the **output or product** of a system **reduces or decreases** the activity of the system is called **negative feedback mechanism.**
- It is the most common form of **regulation.**
- **Examples: Regulation** of body **temperature, blood glucose** levels, and **hormone secretion.**

Explanation of Negative Feedback Mechanism: [An example of human body temperature]

- **Detection of Change:** If body temperature **exceeds** the **set point of 37°C**, the thermoreceptors in the hypothalamus of **brain** detect this change.
- Thermoreceptors send signals to the **control** centre (thermoregulator in hypothalamus).
- The control centre sends messages to **effectors** (e.g., sweat glands). The effectors respond by producing sweat which lowers the **temperature.**
- The output of this process (lowering of temperature to the set point) influences the thermoreceptors **negatively.**

- As a result, the thermoreceptors stop sending message to the **control centre.**

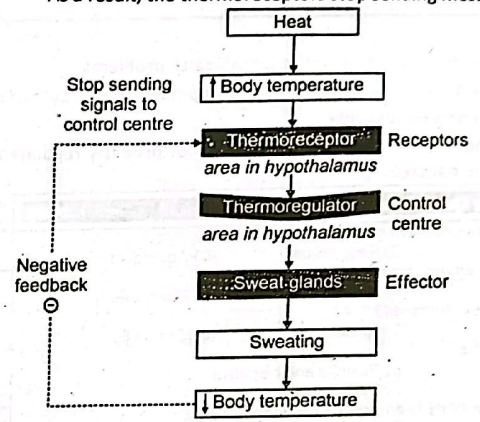


Figure: Negative feedback system to control body temperature

Check Understanding!

Q.2. If the body's alarm system mistakenly keeps raising the temperature even higher when it is already too hot, what type of feedback loop is happening, and why is this dangerous?

(2) Positive Feedback:

- **Definition:** A **regulatory** mechanism in which the **output** or **product** feed **increases the activity** of the system is called **positive feedback system.** In this way, the positive feedback enhances the **original** stimulus.
- **Less Common:** In homeostasis, positive feedback is **less common** than negative feedback. It often **happens** in the processes that require rapid and significant changes.
- **Examples:** Blood clotting, labour and childbirth.

Explanation of Positive Feedback Mechanism: (An example of childbirth Control)

- During childbirth, **contractions of the uterus** send nerve impulses to the control centre (part of hypothalamus).
- The control centre sends **signals** to pituitary gland to release oxytocin hormone. Oxytocin then stimulates **further contractions** of the uterus, which in turn sends more **nerve impulses** to hypothalamus, leading to the release of more oxytocin. This **positive feedback** loop continues until the baby is born.

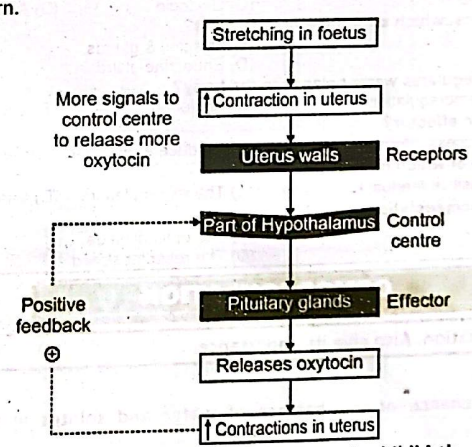


Figure: Positive feedback system to in childbirth

CamScanner

Q.5 How does un-regulated positive feedback system result in health problem? Justify with the help of example. S/Q

Ans. **Unregulated Positive Feedback:**

- Sometimes, the un-regulated positive feedback systems can result in **health problems.**
- **Example:** In severe **inflammation or infection**, the immune cells release proteins called **cytokines.**
- Cytokine proteins further stimulate the **immune response.**
- **Effects of uni-regulated Positive Feedback:** If this positive-feedback is not **properly regulated**, it can lead to excessive inflammation and tissue **damage.**

Multiple Choice Questions (MCQs)	Key
1. What is the maintenance of a stable internal environment called? (A) Excretion. (B) Homeostasis. (C) Respiration. (D) Adaptation.	1.(B)
2. Which part of the body detects changes in the environment? (A) Effectors. (B) Control centre. (C) Receptors. (D) Hormones.	2.(C)
3. Which of the following acts as a control centre in humans? (A) Muscles. (B) Sweat glands. (C) Spinal cord. (D) Skin cells.	3.(C)
4. What are the two types of feedback mechanisms? (A) Internal and External. (B) Positive and Negative. (C) Active and Passive. (D) Fast and Slow.	4.(B)
5. Why is negative feedback more common in the body than positive feedback? (A) It speeds up changes. (B) It maintains stability. (C) It creates new products. (D) It stops all functions.	5.(B)
6. What happens to the original stimulus in a positive feedback loop? (A) It is reduced. (B) It is reversed. (C) It is enhanced. (D) It is ignored.	6.(C)
7. Why can unregulated cytokine release be dangerous for health? (A) It stops blood flow. (B) It causes over-activity. (C) It lowers temperature. (D) It heals too quickly.	7.(B)
8. If the human body is a house, which part acts like the thermostat? (A) The window (Receptor). (B) The heater (Effector). (C) The control panel (Control Centre). (D) The door (Stimulus).	8.(C)
9. Imagine the receptors stop working; what is the immediate result? (A) Effectors will overheat. (B) No information reaches the brain. (C) Set points will increase. (D) Muscles will contract.	9.(B)
10. A system that "adds fuel to the fire" best describes which process? (A) Negative feedback. (B) Osmoregulation. (C) Positive feedback. (D) Thermoregulation.	10.(C)
11. During cold weather, why does the body cause shivering? (A) To lose heat. (B) To increase heat. (C) To lower set point. (D) To release sweat.	11.(B)
12. Which hormone is applied by the body to increase uterine contractions? (A) Cytokine. (B) Insulin. (C) Oxytocin. (D) Adrenaline.	12.(C)
13. When blood pressure changes, which structures first detect it? (A) Brain & spinal cord. (B) Muscles & glands. (C) Blood vessel receptors. (D) Endocrine glands.	13.(C)
14. Which process specifically regulates water balance in the body? (A) Thermoregulation. (B) Osmoregulation. (C) Shivering. (D) Childbirth.	14.(B)
15. What is the primary role of an effector? (A) Detect a change. (B) Process information. (C) Produce a response. (D) Set the optimal point.	15.(C)
16. Blood clotting is an example of which mechanism? (A) Negative feedback. (B) Positive feedback. (C) Thermoregulation. (D) Vasoconstriction.	16.(B)
17. What is the "set point" in a homeostatic system? (A) The maximum limit. (B) The optimal value. (C) The external temperature. (D) The receptor speed.	17.(B)

OSMOREGULATION

Q.6 Define the term osmoregulation. Also give its importance. S/Q

Ans. **Osmoregulation:**

- **Definition:** The maintenance of the balance of water and solutes in the body fluids is called **osmoregulation.**

➢ **Importance of Osmoregulation:**

(i) It ensures that the body **fluids** do not become too **dilute** or **too** concentrated.

(ii) It is **essential** for many physiological processes, including **maintaining proper** blood **pressure**, enabling the **proper** function of organs, and regulating metabolism.

Recalling

Osmosis:

- Osmosis is the **diffusion of water** across a membrane, and it always occurs from a more dilute (hypotonic) solution to a less dilute (hypertonic) solution.
- The osmotic pressure of a solution is a measure of its tendency to take in water by osmosis.

Topic: Osmoregulators and Osmoconformers:

Q.7 Name two types of animals on the basics of ability to osmoregulate. S/Q

Ans. **Types of Animals on the Basics of Ability to Osmoregulate:**

- On the basis of the ability of osmoregulation, the animals are divided into two groups: **(1) Osmoconformers. (2) Osmoregulators.**

Q.8 Describe the terms osmoconformers and Osmoregulators and give their examples. L/Q

Ans. **Osmoconformers:**

- **Definition:** The animals which have the osmotic concentrations of their internal body fluids **matches** with their external environment, hence they **do not** need to **maintain** the **concentration** of **water and solutes** in their bodies are called **osmoconformers.**
- So, these concentrations change with the changes in **surrounding** medium and they remain isotonic to their environment.
- Such **animals** are usually found in **environments** with relatively stable **solute concentrations**, such as marine water.
- **Examples of Osmoconformers:** All **marine invertebrates**, some **freshwater invertebrates** and some marine vertebrates like **hag fishes, sharks** and **rays.**

Check Understanding!

Q.3. A marine hagfish stays isotonic with the ocean, but a freshwater fish actively manages its internal water balance. Identify their strategies:

(A) Both Conformers.
(B) Both Regulators.
(C) Hagfish: Conformer; Fish: Regulator.
(D) Hagfish: Regulator; Fish: Conformer

➢ **Osmoregulators:**

- **Definition:** The animals which **regulate the concentrations** of water and solute in body fluids are called **Osmoregulators.**
- Osmoregulators may be **hypotonic** or **hypertonic** so they have to maintain constant internal concentrations despite the changing concentration in the **external environment.**
- They use various mechanisms for **osmoregulation** e.g., active transport of salts, accumulation of salts, and water conservation etc.
- **Examples of Osmoregulators:** Most vertebrates in aquatic and terrestrial environments are osmoregulators.

Topic: Problems and Methods of Osmoregulation:

Q.9 How do freshwater animals maintain their internal "Hypertonic" environment? Exercise L/Q.3

Ans. **Mechanism of Osmoregulation in Freshwater:**

- The freshwater animals are **hypertonic** as compared to their **external environment.**

➢ **Problems Facing By Freshwater Animals:**

(i) **Hypertonic** means **that they have higher** solute concentration in **body fluids** than the surrounding water so water continuously **enters their** bodies through osmosis, **particularly** across **permeable surfaces** like gills.

(ii) The essential salts and ions (like Na^+ and Cl^-) diffuse **out of the body** into the surrounding water.

Check Understanding!

Q.4. Why does marine bony fish face a constant risk of dehydration, and how do their gills and kidneys adapt to survive this challenge?

CamScanner

Adaptations For Osmoregulation:

(i) **Produce Dilute Urine:** For osmoregulation, they prevent water from entering their bodies and eliminate the excess water that does enter. For this purpose, they produce large volumes of diluted urine.

(ii) **Active Intake of Salts:** To compensate the loss of salts, they actively transport salts back into their bodies. Unlike their marine water animals, freshwater animals rarely drink water.

Topic: Osmoregulation in Marine Water:

Q.10 Which major problems do "Marine Animals face" & how do they osmoregulate? Exercise L/Q.2

Ans. Mechanism of Osmoregulation in Marine Water:

- Most marine animals are **hypotonic** as compared to their environment. This means that external environment has a **much higher solute** (salt) concentration than their internal tissues.

Major Problems of Marine Animals:

- Water constantly leaves their bodies via osmosis through the **gills and skin.**
- Salts continuously **diffuse** from the environment into their bodies.
- In addition, they have **excess of salts** in the body **due to drinking of sea** water.

Adaptations for Osmoregulation:

(i) **Drink Sea Water Continuously:** To compensate for the water loss, marine animals drink seawater continuously.

(ii) **Produce Concentrated Urine:** They also conserve water by producing very **small amounts** of highly concentrated urine.

(iii) **Actively Remove Salts through Gills:** To remove the excess salts, specialized **chloride cells** in the gills use energy (ATP) to actively pump salts out of the blood and back into the **environment.**

(iv) **Remove Salts through Kidney:** They also remove excess salts through their kidneys.

(v) **Remove Salts through Rectal Glands:** Some marine fishes also have special salt excreting glands in rectum called **rectal glands.** These glands remove salts from blood into the digestive tract which are then eliminated along with faeces.

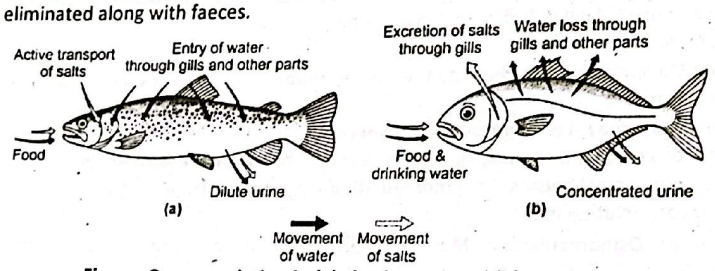


Figure: Osmoregulation in (a)- freshwater and (b)- marine water

Topic: Osmoregulation in Terrestrial Habitats:

Q.11 What are the major problems faced by animal of terrestrial habitat & what are their adaptions for osmoregulation? Exercise L/Q.3

Ans. Problems for Terrestrial Habitat:

- Terrestrial animals lose water to the environment through **evaporation** from **respiratory surfaces,** through the skin, and via the **excretion of waste.**

Adaptations for Osmoregulation in Terrestrial Habitats:

- They have to **ensure that** water intake (from drinking and food) and metabolic water production is equal to the water **lost** to the environment.
- These animals have anatomical, physiological, and behavioral adaptations to maintain osmotic balance.
- Have they have relatively impermeable outer layers to **prevent evaporative** water loss.

- **Have Waxy Exoskeleton:** Insects possess a **waxy** exoskeleton made of chitin.
- **Have Water Proof Keratin:** Reptiles have waterproof scales made of keratin.
- **Have Dead Keratin Skin + Oil Secreting Gland:** Mammals and birds have dead, **keratinized** skin cells and also have oil secreting glands in skin.
- **Have Kidneys to Conserve Water:** Their kidneys play a vital role to retain water inside the body. Moreover, they convert the primary waste product of protein metabolism i.e., ammonia into urea or uric acid which require less amount of water for excretion.
- **Staying Underground During Heat (Desert Animals):** Many desert animals stay underground during the heat of the day to avoid evaporation. They emerge only at night when the air is cooler and more humid.
- **Eat Carbohydrated Food:** These animals feed upon seeds of desert plants in which large amount of carbohydrate are stored.
- **Conserve Metabolic Water:** Some animals, like the Kangaroo Rat, survive entirely on **metabolic water** (produced as a by-product of cellular respiration).

Check Understanding!

Q.5 A desert kangaroo rat survives without drinking water by eating dry seeds. Which adaptation protects it from the severe dehydration risk of land habitats?

(A) Sweating constantly to cool down.
(B) Producing highly concentrated urine and dry feces.
(C) Absorbing moisture directly through the skin.
(D) Drinking stored body fat directly.

Q.12 What is anhydrobiosis? S/Q

Ans. Anhydrobiosis:

- The ability of some animals to tolerate the **extreme lost** of water is called **anhydrobiosis.**
- Certain invertebrates, like **tardigrades** (water bears), enter a dormant state when they lose almost all their body water.
- They come to active life years later when water returns.

Topic: Nature of Excretory Products in relation to Habitat:

- In many animals, osmoregulation is coupled with the **removal of metabolic** wastes from the body.
- The nitrogenous wastes (e.g., ammonia, urea, uric acid) are the main **metabolic** wastes.
- These wastes are excreted as **water solutes.**

Q.13 Explain the nature of nitrogenous wastes in relation to habitat. Exercise L/Q.4

OR Describe the nature of excretory products in relation to habitat. L/Q

Ans. Nature of Excretory Products In Relation To Habitat:

- The animals of different types of **habitats** excrete different forms of nitrogenous wastes.

(1) Ammonia – NH_3 [Excretion in Aquatic Habitat]:

- Ammonia is produced when **amino group** ($-NH_2$) is removed from amino acids and nucleic acids and is combined with H^+ to form ammonia (NH_3) in the liver.
- **Ammonia** is highly toxic and so it is **excreted rapidly.**
- One **gram of ammonia** requires **500 mL** of water to dissolve it to nontoxic level. Such plenty of water can only be afforded by **freshwater animals.**
- **Examples:** Most fishes, protozoans, sponges, coelenterates.
- The marine animals excrete ammonia directly into the water.
- **Ammonotelic Animals:** Animals which excrete ammonia as their major nitrogenous wastes are called **ammonotelic.**

Check Understanding!

Q.6 Why does a human body shiver and restrict blood flow to the skin when exposed to extreme cold, and what regulatory role do these responses play?

(2) Urea – $CO(NH_2)_2$ [Excretion in Moderate Habitat]:

- As the terrestrial animals face the challenge of **conserving water,** they cannot afford to excrete ammonia with a plenty of water.

CamScanner

- They convert ammonia to urea in their liver and then excrete urea through kidneys. Urea is less toxic than ammonia, so it requires less water for its excretion from the body.
- One gram of urea requires 50 mL water to dilute it to the nontoxic level.
- **Ureotelic Animals:** The animals which excrete urea as their major nitrogenous waste product are called **ureotelic.**

(3) Uric acid – $C_5H_4N_4O_3$ [Excretion in Dry Habitat]:

- The animals which face an extreme water conservation challenge due to the arid nature of their environment remove uric acid.
- They cannot afford to even excrete urea.
- They convert ammonia to uric acid by using lot of energy.
- Uric acid is even less toxic than urea, so it require lesser amount for water for its excretion than urea.
- Uric acid is less soluble in water and makes precipitates.
- One gram of uric acid requires just 1 mL of water for its excretion.
- **Uricotelics:** The animals which excrete uric acid are called **uricotelics.**
- **Examples:** Insects, desert animals, birds and most reptiles.

Uric Acid Metabolism in Human:

- Humans also excrete a small amount of uric acid in urine.
- Uric acid is a by-product of the breakdown of purines (found in many foods, particularly meat and some types of vegetables).
- Uric acid is produced in the liver. In healthy individuals, most of the uric acid produced is excreted in the urine, but when there is an excess of uric acid in the blood, it can lead to the formation of uric acid crystals in joints and tissues, causing painful conditions such as **gout.**

Multiple Choice Questions (MCQs)

		Key
1.	Which animals match their body fluid osmotic concentration to the environment? (A) Osmoregulators. (B) Ammonotelic. (C) Osmoconformers. (D) Ureotelic.	1.(C)
2.	Which marine vertebrates act as osmoconformers? (A) Bony fishes. (B) Marine whales. (C) Hag fish. (D) Freshwater fish.	2.(C)
3.	What classification applies to most aquatic and terrestrial vertebrates? (A) Osmoconformers. (B) Osmoregulators. (C) Ammonotelic. (D) Ureotelic.	3.(B)
4.	Why do freshwater animals rarely drink water? (A) Osmotic influx. (B) Mineral lack. (C) Gill absorption. (D) Toxic salts.	4.(A)
5.	What type of urine do freshwater animals produce? (A) Concentrated urine. (B) Diluted urine. (C) Solid paste. (D) Viscous urea.	5.(B)
6.	Why are freshwater animals hypertonic to their environment? (A) Lower solutes. (B) Higher solutes. (C) Equal solutes. (D) Constant drinking.	6.(B)
7.	Why do marine animals constantly drink seawater? (A) Temperature control. (B) Water compensation. (C) Waste removal. (D) Salt storage.	7.(B)
8.	What is the function of specialized chloride cells in marine fish gills? (A) Water absorption. (B) Ammonia production. (C) Salt pumping. (D) Urea conversion.	8.(C)
9.	What specific rectal structure do some marine fishes use to remove salts? (A) Chloride cells. (B) Rectal glands. (C) Kidneys. (D) Gills.	9.(B)
10.	What outer layer adaptation do reptiles use to prevent water loss? (A) Waxy exoskeleton. (B) Oil glands. (C) Mucus layer. (D) Waterproof scales.	10.(D)
11.	What material forms the waxy exoskeleton of insects? (A) Chitin. (B) Keratin. (C) Cellulose. (D) Collagen.	11.(A)
12.	What primary sources must terrestrial animals balance to match water loss? (A) Gills, skin. (B) Seawater, rain. (C) Drinking, food. (D) Urine, faeces.	12.(C)
13.	Which animal survives entirely on metabolic water? (A) Desert birds. (B) Freshwater fish. (C) Marine sharks. (D) Kangaroo Rat.	13.(D)
14.	Where do desert animals shelter during the heat of the day? (A) Open dunes. (B) Underground. (C) Deep water. (D) Tree tops.	14.(B)
15.	What chemical removal process forms ammonia from amino and nucleic acids? (A) Deamination. (B) Osmosis. (C) Excretion. (D) Diffusion.	15.(A)
16.	Where is ammonia formed in the body? (A) Kidneys. (B) Liver. (C) Gills. (D) Rectum.	16.(B)
17.	How much water is required to dissolve one gram of ammonia? (A) 50 mL (B) 1 mL (C) 500 mL (D) 5 mL	17.(C)
18.	What primary nitrogenous waste do terrestrial animals excrete? (A) Ammonia. (B) Urea. (C) Uric acid. (D) Purine.	18.(B)

					Key
19.	What term describes tardigrades entering a dormant state after losing water? (A) Hibernation.	(B) Estivation.	(C) Anhydrobiosis.	(D) Osmoconformation.	19.(C)
20.	What is the breakdown origin of uric acid in humans? (A) Amino acids.	(B) Nucleic acids.	(C) Purines.	(D) Proteins.	20.(C)
21.	What painful joint condition arises from excess blood uric acid? (A) Anemia.	(B) Gout.	(C) Scurvy.	(D) Edema.	21.(B)
22.	What waste product do arid-adapted animals convert ammonia into for maximum conservation? (A) Urea.	(B) Uric acid.	(C) Ammonia.	(D) Purine.	22.(B)
23.	How much water is required to dissolve one gram of uric acid? (A) 500 mL	(B) 50 mL	(C) 1 mL	(D) Zero mL	23.(C)
24.	Which marine vertebrates act as exceptions by being osmoconformers? (A) Bony fishes.	(B) Hag fishes.	(C) Aquatic mammals.	(D) Amphibians.	24.(B)

THERMOREGULATION

Q.14 Define the term thermoregulation. S/Q

Ans. Thermoregulation:

- The homeostatic process by which **organisms** maintain their **internal body temperature** within a tolerable range, regardless of the temperature of the external environment is called **thermoregulation.**

Q.15 How is thermoregulation important for living organisms? L/Q

Ans. Importance of Thermoregulation for Living Organisms:

- Thermoregulation is very important for animals.

(i) Effects on Enzymes Functions:

The enzymes have **an optimal** temperature at which they function most efficiently.

(a) If **temperature falls** below the **optimal,** enzyme-substrate collisions decrease, and **metabolic rates drop.**

(b) If **temperatures rises** well above the optimal, enzymes begin to denature and lose their function permanently.

(ii) Effect on Lipid Bilayer:

The **lipid bilayer** of cell membranes is temperature-sensitive.

(a) At **high temperatures,** cell membranes can lose their **selective permeability.**

(b) At **low temperatures** can make membranes **rigid and brittle.**

Check Understanding!

Q.7 If an animal transitions from an abundant aquatic habitat to a dry desert, which excretory product must it evolve to produce, and why?

(A) Ammonia (high toxicity).
(B) Urea (moderate water cost).
(C) Uric acid (maximum water conservation).
(D) Amino acids (direct storage).

Topic: Types of Animals on the basis of Heat Source:

Q.16 Name the two types of animals on the basis of heat source. Exercise L/Q.5

Ans. Types of Animals on the Basis of Heat Source:

(1) Ectotherms. (2) Endotherms.

Q.17 Define the term "ectotherm" & give examples. Exercise L/Q.5

Ans. Ectotherms:

- The animals that **gain most** of their body heat from **external sources** are called **ectotherm.** Their internal temperature generally changes with the temperature of their surroundings.
- **Examples:** Most invertebrates are ectotherms. Among the vertebrates, fishes, amphibians, and reptiles are also ectotherms.

Q.18 How do ectotherms adapt themselves according to changing external temperature? Exercise L/Q.5

Ans. Adaptations in Ectotherms For Thermoregulation:

(i) Rely on External Heat: In ectotherms, the metabolism rate is very low. They cannot produce enough heat to raise and maintain their body temperature. So, they rely on the heat from the environment.

(ii) Bask Sun in Cold: Ectotherms use behavioral thermoregulation. If they are too cold, they bask in the sun (radiation) or sit on a warm rock (conduction).

CamScanner

(iii) **Seek Shade/Burrow in Hot:** If they are too hot, they seek shade or burrow into the cool earth. In very cold climates, they become dormant during the coldest months.

Q.19 What are endotherms? Also give their adaptation for thermoregulation. Exercise L/Q.1

Ans. Endotherms:

- The animals which generate the majority of their body heat through internal metabolism are called endotherms.
- They maintain a relatively constant body temperature, often higher than the environment.
- **Examples:** Birds and mammals are endotherms.

➢ **Adaptation For Thermoregulation:**

- When it gets cold, they may shiver (muscle contractions) or burn brown adipose tissue for heat.
- Most endotherms have insulation to retain heat such as hair, feathers, or fat.

Topic: Types of Animals on the Basis Ability of Thermoregulation:

Q.20 Classify the animals on the basis of ability of thermoregulation. Exercise L/Q.1

Ans. Types of Animals on the Basis of Thermoregulation:

- On the basis of ability of thermoregulation animals have two main groups:
  (i) Poikilotherms. (ii) Homeotherms.

Q.21 Differentiate poikilotherms & homeotherms. Exercise L/Q.1

Ans.

Poikilotherms	Homeotherms
• The animals that are unable to maintain their body temperature within narrow limits are called poikilotherms. • Their body temperature changes, usually matching the temperature of environment. • **Examples:** All invertebrates are poikilotherms. The vertebrates: fishes, amphibian and reptiles are also poikilotherms.	• The animals which maintain relatively constant internal body temperatures, regardless of environmental fluctuations or changes are called homeotherms. • They use **"thermostats"** (hypothalamus in the brain) to trigger cooling or heating responses. • **Examples:** Mammals, birds, and Humans maintain their internal temperature at roughly 37°C whether they are in very cold or very hot environments.

Topic: Thermoregulation in Humans:

Q.22 How do human regulate their internal temperature? SC

Ans. Thermoregulation in Human:

- Humans are endothermic homeotherms.
- Human regulate body temperature through negative feedback mechanism.
- The thermoreceptors present in skin detect an increase or decrease in body temperature.
- Thermoreceptors send signals to the control centre i.e., hypothalamus which also contains thermoreceptors.
- Hypothalamus sends signals to muscles and glands which produce corrective responses to regulate internal temperature.
- **Examples:** Responses to overheating, responses to cooling.

- Poikilotherms do not need to consume massive amounts of food to "fuel" a constant temperature.
- It allows them to survive in nutrient-poor environments where a homeotherm would starve.

Q.23 Describe the regulatory strategies in man for thermoregulation in overheating & cooling. Exercise L/Q.7

Ans. Regulatory Strategies In Man For Thermoregulation:

(1) Regulatory Strategies And Responses to Overheating (Hyperthermia):

- **Hyperthermia:** The condition in which body temperature rises above 37°C (is called hyperthermia) at this condition vasodilation occurs.
  - **(i) Vasodilation:** It is the expansion of blood capillaries which lie just beneath the epidermis of the skin. So, there is more flow of blood in these capillaries to remove more heat from blood.
  - **(ii) Activation of Sweating:** Responses also include sweating. Evaporation of sweat carries heat from the body and produces cooling effect.
  - **(iii) Decrease of Thyroxine:** The thyroid gland may decrease the secretion of thyroxine, which lowers the basal metabolic rate. So, the internal heat production is reduced.

- Hypothermia and hyperthermia are dangerous conditions that happen when the body cannot keep its normal temperature (37°C or 98.6°F).
- **Hypothermia:** It means the body temperature is too low.
- **Hyperthermia:** It means it is too high. Hyperthermia caused by an infection is called a fever.

(2) Regulatory Strategies And Responses to Cooling (Hypothermia):

- **Hypothermia:** The condition when body temperature falls below 37°C is called hypothermia.
- The responses may include vasoconstriction, shivering and increase in metabolic rate.
  - **(i) Vasoconstriction** reduces blood flow to the skin and so there is less loss of heat from blood.
  - **(ii) Shivering:** Spasmodic contraction of skeletal muscles which produces heat which helps to raise the body temperature.
  - **(iii) Goosebumps:** Tiny muscles at the base of hair follicles contract (goosebumps). Air is trapped in the erected hair and act as insulator for the heat.
  - **(iv) Increase Metabolism:** Increased metabolic rate also produces heat to raise the body temperature.

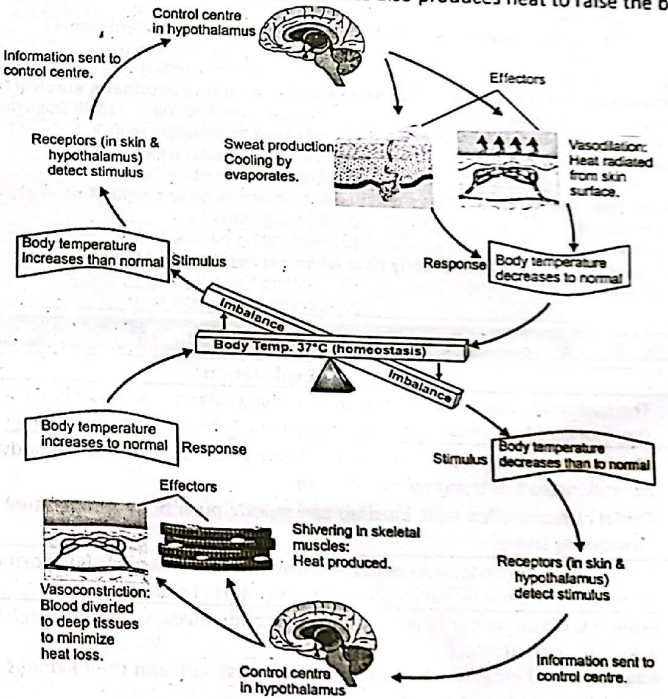


Figure: Thermoregulation in humans

Multiple Choice Questions (MCQs)

1. What is the homeostatic process by which organisms maintain their internal body temperature within a tolerable range?
(A) Osmoregulation. (B) Thermoregulation. (C) Excretion. (D) Respiration
2. At which level do enzymes function most efficiently to maintain metabolic rates?
(A) Minimum range. (B) Optimal temperature. (C) Denaturation point. (D) Freezing level.
3. Which category of animals gains most of their body heat from external sources?
(A) Endotherms. (B) Homeotherms. (C) Ectotherms. (D) Mammals.
4. What happens to the lipid bilayer of cell membranes when temperatures rise too high?
(A) Lose selective permeability. (B) Become rigid and brittle.
(C) Increase enzyme production. (D) Stop all chemical reactions.
5. Which of the following vertebrates are classified as ectotherms?
(A) Birds and mammals. (B) Fishes, amphibians, reptiles.
(C) Mammals and birds. (D) Only warm-blooded species.
6. How do ectotherms regulate their body temperature when they are too cold?
(A) Sweating heavily. (B) Bask in sun. (C) Shivering muscles. (D) Burning brown fat.
7. What physiological action do endotherms take when their environment gets cold?
(A) Vasodilation. (B) Sweating. (C) Shivering. (D) Panting.
8. What is a primary physiological response when human body temperature rises above thirty-seven degrees Celsius?
(A) Vasoconstriction. (B) Vasodilation. (C) Hair erection. (D) Increased shivering.
9. Why do low temperatures negatively affect cell membrane function?
(A) Making membranes rigid. (B) Causing fast denaturation.
(C) Increasing sweat output. (D) Accelerating blood flow.
10. Why are poikilotherms able to survive in nutrient-poor environments where homeotherms might starve?
(A) They consume massive food. (B) Low food needs.
(C) Constant high metabolism. (D) Internal heat generation.
11. Why does the thyroid gland decrease the secretion of thyroxine during hyperthermia?
(A) Lower basal metabolism. (B) Stimulate heavy shivering.
(C) Increase blood pressure. (D) Stop sweat production.
12. How can the reliance on external heat sources be evaluated regarding ectotherm survival?
(A) It wastes energy. (B) It saves food. (C) It causes overheating. (D) It stops movement.
13. How effective is the hypothalamus in homeotherms compared to poikilotherms?
(A) Maintains constant temperature. (B) Matches external weather.
(C) Relies entirely on rocks. (D) Prevents all metabolism.
14. Design a behavioral response for an ectotherm that needs to lower its body temperature in extreme heat.
(A) Burrowing underground. (B) Basking actively.
(C) Shivering muscles. (D) Generating metabolic heat.
15. Create a strategy used by humans to trap body heat when exposed to cold temperatures.
(A) Expanding capillaries. (B) Erecting hair follicles.
(C) Increasing sweat flow. (D) Decreasing muscle tone.

Key
1.(B)
2.(B)
3.(C)
4.(A)
5.(B)
6.(B)
7.(C)
8.(B)
9.(A)
10.(B)
11.(A)
12.(B)
13.(A)
14.(A)
15.(B)

Check Understanding (Solutions)

Q.	Option	Explanation
1.	(B)	• The hypothalamus is the control center, sweat glands and vessels act as effectors, and skin thermoreceptors serve as receptors detecting the temperature change.
2.	S/Q	• **Mechanism:** This is a positive feedback loop because it pushes the body further away from normal instead of trying to cool it down. • **Threat:** Uncontrolled heat build-up can quickly push body temperature to dangerous, life-threatening levels.
3.	(C)	• Osmoconformers passively match environmental salt levels, while osmoregulators actively maintain internal balance despite external changes.
4.	S/Q	• **Problem:** Ocean water is saltier than their body fluids, causing them to continuously lose water through osmosis. • **Adaptation:** Their gills actively pump out excess salt, and their kidneys produce very little urine to save precious water.

5.	(B)	• Terrestrial animals face constant dehydration risks. Desert species adapt by minimizing water loss through highly concentrated waste and utilizing metabolic water.
6.	S/Q	• **Problem:** Extreme cold causes dangerous heat loss from the body to the environment. • **Adaptation:** Shivering uses muscle contraction to generate metabolic heat, while skin vasoconstriction traps heat in the core to protect vital organs.
7.	(C)	• Dry habitats require uric acid because it is insoluble in water, allowing excretion as a dry paste to prevent severe dehydration.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. Which term covers the rest of the three?
(a) Osmoregulation. (b) Excretion. (c) Thermoregulation. (d) Homeostasis.
2. Marine fishes compensate for water loss by:
(a) Producing dilute urine. (b) Drinking seawater. (c) Absorbing salt. (d) Reducing thirst.
3. How do freshwater fish primarily gain water?
(a) Drinking. (b) Active transport. (c) Osmosis. (d) Diffusion.
4. What is the primary heat source for endotherms?
(a) Sunlight. (b) Internal metabolism. (c) Warm rocks. (d) Convection.
5. What is the control center for human thermoregulation?
(a) Pituitary gland. (b) Hypothalamus. (c) Adrenal gland. (d) Medulla oblongata.
6. Which waste product requires the most water for excretion?
(a) Ammonia. (b) Urea. (c) Uric acid. (d) Creatinine.
7. Which nitrogenous waste is the least toxic and water-insoluble?
(a) Urea. (b) Ammonia. (c) Uric acid. (d) Nitrate.
8. In which part of the body, the conversion of ammonia to urea takes place?
(a) Liver. (b) Muscles. (c) Brain. (d) Small intestine.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(d)	Homeostasis.	• Homeostasis is the broad umbrella term that encompasses osmoregulation, thermoregulation, and excretion.
2.	(b)	Drinking seawater.	• Living in a hypertonic environment causes marine fish to continuously lose water, which they combat by drinking seawater.
3.	(c)	Osmosis.	• Freshwater fish live in a hypotonic environment, causing water to continuously enter their bodies passively via osmosis across the gills and skin.
4.	(b)	Internal metabolism.	• Endotherms generate their primary body heat through high rates of internal metabolic activity rather than relying on external sources.
5.	(b)	Hypothalamus.	• The hypothalamus functions as the body's master thermostat to monitor and regulate core body temperature.
6.	(a)	Ammonia.	• Ammonia is highly toxic and must be diluted with large amounts of water to prevent cellular damage during excretion.
7.	(c)	Uric acid.	• Uric acid is minimally toxic and precipitates into a solid paste or crystal, requiring almost no water for elimination.
8.	(a)	Liver.	• The liver contains the metabolic enzymes necessary to convert toxic ammonia into less toxic urea via the urea cycle.

CamScanner

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Define osmoregulators and osmoconformers.

Ans.

Osmoregulators	Osmoconformers
• Organisms that actively regulate and maintain a constant internal osmotic pressure and salt balance regardless of environmental fluctuations. • **Examples:** Freshwater fish maintaining salt balance against a hypotonic environment.	• Organisms that allow their internal osmotic concentration to conform or match to that of their surrounding environment. • **Examples:** Marine invertebrates like sea anemones and jellyfish.

Q.2 Define thermoregulation and explain its needs.

Ans. Thermoregulation: The physiological process by which animals control and maintain their body temperature within a tolerable, optimal range.

Needs: It is vital because it sustains stable internal temperatures necessary to ensure optimal enzymatic activity, metabolic efficiency, and cellular function.

Q.3 What are the two types of animals on the basis of the ability to thermoregulate?

Ans. Types of Animals on the Basis of Thermoregulation:

- On the basis of ability of thermoregulation animals have two main groups:
  (i) Poikilotherms. (ii) Homeotherms.

Q.4 Differentiate between:

- **Osmoregulators and osmoconformers**
- **Vasodilatation and vasoconstriction**
- **Ammoniotelic and ureotelic**
- **Ectotherms and endotherms**
- **Homeotherms and poikilotherms**
- **Ureotelic and uricotelic**

Ans. Osmoregulators and Osmoconformers:

Osmoregulators	Osmoconformers
• Osmoregulators actively expend energy to control and maintain their internal fluids constant despite external changes. **Examples:** Freshwater fish actively pumping in salts.	• Osmoconformers passively allow their internal salt concentration to fluctuate and match the surrounding seawater. • **Examples:** Marine jellyfish letting their body fluids match the ocean.

Ectotherms and Endotherms:

Ectotherms	Endotherms
• Ectotherms get their **body heat** from outside sources because they have a low metabolic **heat production.** • **Examples:** Snakes basking on rocks to warm up versus birds.	• Endotherms produce their own body heat through a high internal metabolic rate. • **Examples:** Mammals generating internal body warmth.

Vasodilatation and Vasoconstriction:

Vasodilatation	Vasoconstriction
• Vasodilatation is the **widening** of surface blood vessels to increase blood flow and release body heat into the air.	• Vasoconstriction is the **narrowing** of vessels to reduce blood flow and trap heat inside the core.

Homeotherms and Poikilotherms:

Homeotherms	Poikilotherms
• Homeotherms use physiological mechanisms to keep their internal temperature **completely stable.** • **Examples:** Humans maintaining a steady core temperature.	• Poikilotherms have variable internal temperatures that shift up and **down depending** on the surrounding temperature. • **Examples:** Frogs changing their body temperature as the pond water warms or cools.

Ammoniotelic and Ureotelic:

Ammoniotelic	Ureotelic
• Ammoniotelic organisms excrete nitrogen waste **immediately** as highly toxic ammonia which requires a **large volume** of water to dilute. • **Examples:** Aquatic bony fish excreting ammonia directly into the water.	• Ureotelic organisms convert the toxic ammonia into **safer,** less toxic urea that can be excreted with moderate fluid loss. • **Examples:** Land mammals producing urea in the liver to excrete in urine.

Ureotelic and Uricotelic:

Ureotelic	Uricotelic
• Ureotelic animals excrete **their nitrogen** waste as **water-soluble** urea requiring moderate water loss. • **Examples:** Adult amphibians excreting liquid urea versus birds.	• Uricotelic animals convert waste into a concentrated, **insoluble** solid paste of uric acid to save nearly all bodily water. • **Examples:** Lizards excreting dry white uric acid droppings.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Describe three elements which operate homeostatic mechanisms.

Ans. See Page No. 03 (Q.3)

Q.2 Relate the homeostatic mechanisms with the negative and positive feedback systems.

Ans. See Page No. 04 (Q.4)

Q.3 Explain the different methods of osmoregulation found in freshwater, marine water and terrestrial habitats.

Ans. See Page No. 07-08 (Q.9, Q.10, Q.11)

Q.4 Explain the nature of nitrogenous wastes in relation to habitat.

Ans. See Page No. 9 (Q.13)

Q.5 Classify animals on the basis of the source of body's heat.

Ans. See Page No. 11 (Q.16, Q.17, Q.18, Q.19)

Q.6 Classify the animals on the bases of the ability to thermoregulate.

Ans. See Page No. 12 (Q.20,Q.21)

Q.7 Describe the regulatory strategies in man for thermoregulation.

Ans. See Page No. 13 (Q.23)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Why positive feedback mechanisms in humans are sometimes associated with severe health problems?

Ans. Positive Feedback Mechanisms in Humans Associated with Severe Health Problems:

- **Pushes Away From Balance:** Unlike normal body controls that try to fix a **problem,** positive feedback keeps pushing the body further away from its **normal state.**
- **Uncontrolled Spiral:** It creates a runaway chain reaction or vicious cycle.
- **Leads to Harm:** For example, a high fever can trigger chemical reactions that make body temperature rise even higher, which can damage organs or cause death if not stopped.

Q.2 List some of the behavioural responses of the animals to maintain homeostasis.

Ans. Behavioural Responses of the Animals to Maintain Homeostasis:

(i) Moving for Temperature: Animals move into the shade or underground burrows to cool down, or sit in the sun to warm up.

(ii) Changing Activity Time: Desert animals become active only at night to avoid losing water in the daytime heat.

(iii) Bathing: Animals like elephants roll in mud or water to cool their bodies down through evaporation.

CamScanner

Q.3 Draw a flow chart to show negative feedback of homeostatic mechanisms by taking an example of hormone.

Ans. Flow Chart to Show Negative Feedback of Homeostatic Mechanisms: (Example of Hormone)

- **Stimulus:** Drop in Core Body Temperature.
  ↓
- **Receptor:** Thermoreceptors in skin and core detect cold.
  ↓ Sensory Neuron
- **Control Center:** Hypothalamus (Brain) processes information.
  ↓ Motor Neuron
- **Effector:** Skeletal muscles and blood vessels respond.
  ↓
- **Response:** Shivering generates heat and vasoconstriction conserves it.
  ↓
- **Feedback:** Body temperature returns to normal, inhibiting the hypothalamus (Negative Feedback).

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. (1 x 6 = 06)

(i) What is the maintenance of a stable internal environment called?
(A) Excretion. (B) Homeostasis. (C) Respiration. (D) Adaptation.

(ii) During cold weather, why does the body cause shivering?
(A) To lose heat. (B) To increase heat.
(C) To lower set point. (D) To release sweat.

(iii) Why do marine animals constantly drink seawater?
(A) Temperature control. (B) Water compensation. (C) Waste removal. (D) Salt storage.

(iv) What chemical removal process forms ammonia from amino and nucleic acids?
(A) Deamination. (B) Osmosis. (C) Excretion. (D) Diffusion.

(v) At which level do enzymes function most efficiently to maintain metabolic rates?
(A) Minimum range. (B) Optimal temperature. (C) Denaturation point. (D) Freezing level.

(vi) Why are poikilotherms able to survive in nutrient-poor environments where homeotherms might starve?
(A) They consume massive food. (B) Low food needs.
(C) Constant high metabolism. (D) Internal heat generation.

Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) How is homeostasis maintained? Also name its three elements.
(ii) How does un-regulated positive feedback system result in health problem? Justify with the help of example.
(iii) Differentiate poikilotherms & homeotherms.
(iv) Define thermoregulation and explain its needs.
(v) What is anhydrobiosis?
(vi) Differentiate between Vasodilatation and vasoconstriction.
(vii) How do ectotherms adapt themselves according to changing external temperature?
(viii) Differentiate between Ureotelic and uricotelic.

Q.3 Extensive Questions. (4 x 2 = 8)

(a) Describe the three elements of homeostatic mechanism in detail? Explain the homeostasis mechanism by considering the example of human body temperature.
(b) Describe the nature of excretory products in relation to habitat.

CHAPTER 14

HUMAN URINARY SYSTEM

Student Learning Outcomes (SLOs)

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

- Outline different organs of the (human) urinary system.
- Describe the structure of the kidney.
- Relate the structure of the kidney with its function.
- Explain the detailed structure of a nephron.
- Explain the processes of glomerular filtration, selective re-absorption and tubular secretion as the events in kidney functioning.
- Explain regulatory mechanism involved in concentration of urine
- Justify the functioning of kidneys as both excretion and osmoregulation.
- Compare the function of two major capillary beds in kidneys i.e., glomerular capillaries and peritubular capillaries.
- List urinary tract infections and the bacteria responsible.
- Explain the causes and treatments of kidney stones.
- Outline the causes of kidney failure.
- Explain in detail the mechanism and problems related to dialysis.
- Describe the principles and the problems associated with kidney transplant.

CamScanner

Human Urinary System — Concept Map

1. HUMAN URINARY SYSTEM
(Excretion, osmoregulation, & pH regulation)

(a) Structure of Kidney & Nephron
- **Gross Anatomy** (2 Kidneys, 2 Ureters, Urinary Bladder, Urethra).
- **Internal Zones** (Renal Capsule, Cortex outer 1/3, Medulla inner 2/3 with pyramids, Renal Pelvis).
- **Nephron** (Functional unit ~1 million/kidney).
  - **Renal Corpuscle** (Glomerulus capillary network + Bowman's capsule).
  - **Renal Tubule** (PCT → Loop of Henle descending/ascending → DCT → Collecting Duct).
- **Types of Nephrons** (Cortical 85% with short loops & Juxtamedullary with long loops).

(b) Blood Supply
- Renal Artery → Afferent Arterioles → Glomerulus → Efferent Arterioles → Peritubular Capillaries & Vasa Recta → Venules → Renal Vein

(c) Urine Formation
(i) **Glomerular Filtration** (High pressure ultrafiltration forces water/solutes into Bowman's capsule).
(ii) **Selective Reabsorption** (PCT, loop of Henle, and collecting duct reabsorb water, glucose, and salts).
(iii) **Tubular Secretion** (DCT secretes H+, K+, ammonia, and drug toxins to regulate blood pH).

2. REGULATION OF URINE CONCENTRATION

(a) Counter-current Mechanism
- Maintains high NaCl gradient in renal medulla via counter-current flow in loop of Henle and vasa recta.

(b) Hormonal Control
(i) **Antidiuretic Hormone** (ADH) (Hypothalamus/Posterior pituitary → increases collecting duct water permeability / deficiency causes Diabetes Insipidus).
(ii) **Aldosterone** (Adrenal cortex → increases Na+ reabsorption and K+ excretion in DCT/collecting duct).

3. DISORDERS OF URINARY TRACT

(a) Urinary Tract Infections (UTIs)
- **Bacterial infection** (mostly E. coli) treated with antibiotics and fluids.

(b) Kidney Stones
- Crystalline mineral deposits (70% calcium oxalate) →

Treatment of Kidney Stones:
- Treated via ECSWL shockwaves or PNL surgery.

(c) Kidney Failure
- **Acute** (sudden) vs. **Chronic** (irreversible) loss of kidney function.

Treatment of Kidney Failure:
- **Renal Dialysis** →
(i) Haemodialysis (external dialyzer machine) &
(ii) Peritoneal Dialysis (abdominal peritoneum).

(d) Kidney Transplant
- Replacing non-functioning kidney with donor kidney (Related, Unrelated, or Deceased donors) requiring immunosuppressant.

INTRODUCTION

Chapter's Intro:
- In this chapter, we will **explore** the remarkable **architecture** and **functioning of the kidneys.**
- We will also study the **life-saving technologies** used when this vital system weakens.

HUMAN URINARY SYSTEM

Q.1 Define urinary or excretory system. S/Q

Ans. Urinary or Excretory System:
- The system which is responsible for excretion and urine production is called **urinary or excretory system.**

Critical Thinking
- Given the definition of excretion, why the large intestine is not classified as a major excretory organ?

Q.2 What are the three essential roles of urinary system? S/Q

Ans. Three Essential Roles of Urinary System:
- The urinary system performs three essential roles simultaneously given below:

i. **Nitrogenous Waste:** Urinary system helps in filtering out **urea**, a nitrogenous waste of protein breakdown in the liver.
ii. **Osmoregulation:** This system maintains the "water-to-salt" balance of the blood by adjusting how much water is reabsorbed or excreted.
iii. **pH and Ion Regulation:** It also helps in balancing levels of sodium, potassium, and hydrogen ions to keep blood slightly basic (around pH 7.4).

Check Understanding!
Q.1 Why is the elimination of undigested food via the large intestine excluded from the biological definition of excretion?
(A) It is controlled by somatic nerves.
(B) It never crosses a cell membrane.
(C) It consists only of water.
(D) It uses active transport.

Q.3 Define excretion & give examples of excretory wastes. S/Q

Ans. Excretion:
- In biological terms, excretion is the process by which an organism eliminates the **metabolic wastes.**
- **Example of the Metabolic Wastes:** Nitrogenous wastes, extra water, and extra salts.

Q.4 Write the names of the components of urinary system, also give brief description of each component & draw labelled diagram of urinary system. L/Q

Ans. Components of Urinary System:
- The human urinary system consists:
  (i) A Pair Kidneys. **(ii)** Two Ureters. **(iii)** One Urinary Bladder. **(iv)** One Urethra.

(i) A Pair Kidneys:
- **Location of Kidney:** Kidneys are located high in the **abdominal** cavity, one on each side of the vertebral column, between the **12th thoracic and 3rd lumbar vertebrae.**
- **Position of Right & Left Kidney:** Due to the **position of liver**, the right kidney is **slightly lower** and smaller than the left one.
- The upper parts of both kidneys are partially protected by the **11th and 12th ribs.**

(ii) Two Ureters:
- The ureters are **about 25 cm** long tubes.
- A ureter begins at the **funnel-shaped** renal pelvis in kidney.
- Ureters from both kidneys extend **downward** and open in a single urinary bladder.
- Ureters transport urine from the kidney to the urinary bladder.

(iii) One Urinary Bladder:
- The urinary bladder is a hollow and distensible **muscular organ.**

CamScanner

- It is located within the pelvic cavity.
- It serves as urine reservoir or storage bag.

(iv) One Urethra:

- The urethra is a tube that carries urine from urinary bladder to the outside of the body.

➢ **Labelled Diagram of Urinary System:**

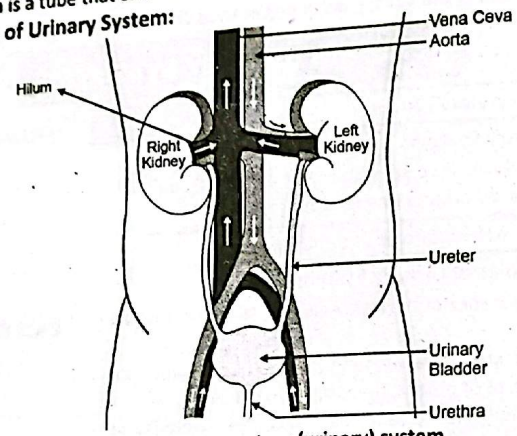


Figure: Human excretory (urinary) system

Topic: Structure of Kidney:

Q.5 Describe the external & internal structure of kidney.

Q.6 Why right kidney is slightly lower & smaller than left kidney?

Ans. Structure of Kidney:

(A) External Structure of Kidney:

- A kidney is a **reddish brown**, bean shaped organ.
- Each kidney, has an **adrenal gland** on its top.
- The kidney and its adrenal gland are surrounded by a **fibrous renal capsule.**
- Each kidney has a **convex** and a **concave side.**
- **Renal Hilum:** A depressed area on the **concave side** is the **renal hilum** (also called hilus). At this point, the renal artery enters the kidney and the **renal vein** and **ureter leave.**

Check Understanding!

Q.2 Formulate an anatomical reaso why the right kidney is positione lower than the left kidney.

(B) Internal Structure of Kidney:

- Internally, a kidney consists of **two portions:**
  - **(a) Renal Cortex:** The outer portion is called **renal cortex.** It forms roughly **70%** of its total mass of kidney.
  - **(b) Renal Medulla:** The inner portion is called **renal medulla.** It forms roughly **30%** of its total mass of kidney.
- **Renal Pelvis:** The **renal pelvis** is a funnel-shaped structure in the centre of kidney.
- Blood enters the kidney through a renal artery and leaves through a renal vein.
- The **renal medulla** consists of a number of **cone-shaped renal pyramids.** Urine is collected in renal pelvis and exit the kidney through ureter.

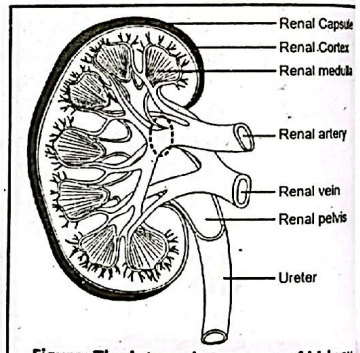


Figure: The internal structure of kidney

Topic: Structure of Nephron:

Q.7 Describe the structure of kidney and relate it with its function. Exercise L/Q.1

Q.8 Explain the detailed structure of nephron. Exercise L/Q.2

Ans. Structure of Kidney in Relation to its Functions (Structure of Nephron):

- Each kidney contains about **one million microscopic** tubular structures called nephrons.
- Nephrons are the functional units of kidney.

➢ **Structure of Nephron:**

- **Parts of Nephron:** A nephron consists of two **main portions: (1)** Renal Corpuscle. **(2)** Renal Tubule.
- Renal corpuscle consists of **two associated structures:**
  - **(i) Glomerulus:** It is a capillary network derived from an afferent renal arteriole.
  - **(ii) Bowman's capsule:** It is a cup-shaped, double-walled sac that surrounds the glomerulus.

➢ **Structure of Renal Tubule:**

- Renal tubule is a long **tubule** that leads away from the Bowman's capsule.
- It consists of **three connected** portions:
  - **(a) The proximal convoluted tubule:** It is the beginning portion and is highly coiled. It dips into the medulla.
  - **(b) The Loop of Henle:** It is a U-shaped hairpin turn. It consists of **two limbs:**
    - **(i)** The descending limb continues toward the medulla.
    - **(ii)** The ascending limb returns toward the cortex and reaches parallel to renal corpuscle.
  - **(c) The Distal Convoluted Tubule:** Which is highly coiled again in which loop of Henle opens.

Check Understanding!

Q.3 Which immediate defect would occur if a nephron completely lacked a proximal convoluted tubule?

(A) Loss of bulk reabsorption.
(B) Uncontrolled blood cell creation.
(C) Failure to filter plasma.
(D) Collapse of Bowman's capsule.

- The distal convoluted tubules of multiple nephrons drain into a single **collecting duct.** As these ducts descend through the medulla, they merge to form larger papillary ducts, which ultimately discharge into the renal pelvis.

➢ **Types of Nephrons:**

- Nephrons are categorized into **two types** based on their **location** within the kidney:
  - **(i) Cortical Nephrons:**
    - These nephrons make the majority (about 85%) of **nephrons.**
    - These are located **primarily** within the **renal cortex.**
    - **Have Short-U Shape Tube:** They possess relatively **short loops of Henle.**
  - **(ii) Juxtamedullary nephrons:**
    - These nephrons originate **deep in the cortex,** near the medulla.
    - **Have Longer-U Shape Tube:** They have **long loops of Henle** that extend deep into the renal medulla.

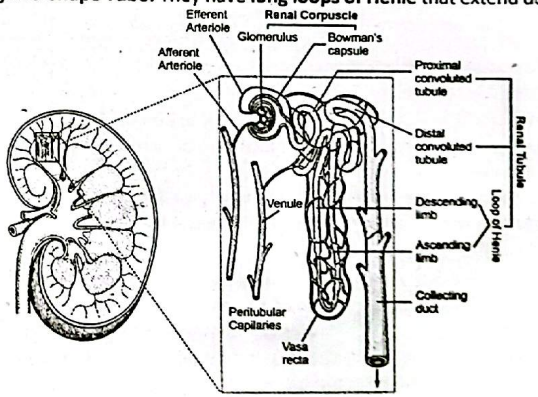


Figure: Structure of nephron

CamScanner

Topic: Blood Supply of the Kidney:

Q.9 Write a note on blood supply of kidney. L/Q

Ans. Blood Supply of Kidney:

- The kidneys are highly vascularized organs, receiving approximately 20 – 25% of the total cardiac output.

Check Understanding!
Q.4 Analyze why the kidneys receive 20–25% of total cardiac output despite their small mass.

(a) Renal Artery:

- The pathway of **blood** inside kidney begins with the **renal artery**, which enters the **kidney at the hilum.**
- It divides into branches which give rise to afferent arterioles.
- Arteriole leads into the **capillary bed** i.e., glomerulus. Unlike most capillary beds in the body that drain into venules, the glomerular capillaries drain into an **efferent arteriole.**

(i) Efferent Arteriole: The efferent arteriole branches into **peritubular capillaries.**

(ii) Peritubular capillaries: The capillaries which form a **dense network** around the proximal and distal convoluted tubules in the renal cortex.

(iii) Vasa Recta: In **juxtamedullary nephrons**, the **efferent arterioles** also give rise to vasa recta. These are long and straight capillary networks in medulla that run parallel to the **loops of Henle.**

(b) Renal Vein:

- After the exchange of materials, the **capillaries converge to form** venules.
- The venules merge into **larger veins**, eventually opening into the **renal vein.**
- The renal **vein exits** the kidney at the hilum and drains into the **inferior vena cava.**
- Vena cava inferior returns the filtered, "clean" blood to the heart.

Topic: Functioning of Kidney:

Q.10 Explain the main processes in kidney functioning. Exercise L/Q.3, L/Q.1

OR What is the primary function of kidney, also discuss three steps of urine formation by kidneys? L/Q

Ans. Primary Function of Kidney:

- Kidneys **filter metabolic wastes** and **extra water** from blood and excrete them in the form of urine, so filtration of wastes from blood is primary function of kidney.

➢ **Formation of Urine:**

- The process of urine formation **comprises** three major steps that take place in the nephron:
  (i) Glomerular Filtration. (ii) Selective Reabsorption. (iii) Tubular Secretion.

(i) Glomerular Filtration:

- The first step in the formation of urine is a physical process known as **glomerular filtration** (or **ultrafiltration**).

Mechanism of Glomerular Filtration:

- The efferent arteriole is narrower than the **afferent arteriole.** Due to this difference, the blood within the **glomerular capillaries** remains under relatively **high pressure.**
- The high-pressure in **glomerulus** forces **water, urea, glucose, amino acids, vitamins,** and **various salts** (Na^+, K^+, Cl^-) from blood into the Bowman's capsule.

- While doing the excretory function, kidneys also work as osmoregulatory organs.
- Kidneys control the salt **concentrations** of body fluids by forming dilute urine (when body fluids are hypotonic) and concentrated urine (when body fluids are **hypertonic** and there is dehydration).

Glomerular Filtrate:

- About **one-fifth** (20%) of the fluid portion of the blood **filters** into the Bowman's capsule and is called **Glomerular filtrate.**
- **Plasma proteins** (e.g., albumin and globulins) **and blood** cells are **too large** to pass through the capillary walls. So, these structures **remain in the blood.**

(ii) Selective Reabsorption:

- The glomerular filtrate **contains not only** wastes but also **vital nutrients** that the body cannot afford to lose.
- Selective reabsorption is the **process** by which **useful materials** are transported from renal tubule back into the blood through **peritubular capillaries.**
- Most reabsorption occurs in the **proximal convoluted tubule.** In this region, **about 75%** of the water returns from the filtrate to the capillaries by **osmosis.**
- **Glucose, amino acids,** and **salts** (sodium, potassium, and calcium) are returned from proximal tubule to the blood by active transport.
- **Absorption of Water in Descending Limb:** As the filtrate moves further, more water is reabsorbed in the descending limb of the loop of Henle.
- **Ascending limb** is impermeable to water but **actively transports** salts out of the tubule.
- **Note:** Some water and salts are also absorbed from distal **convoluted tubule.**
- **Collecting duct** is the final site for water reabsorption.

Check Understanding!
Q.5 What happens to the glomerular filtration rate if systemic blood pressure drops drastically?
(A) Filtration rate doubles.
(B) Urea pumps backward.
(C) Filtration stops entirely.
(D) Red cells enter tubules.

(iii) Tubular Secretion:

- Tubular secretion is **opposite** to **reabsorption.**
- In this process, the **epithelial cells** of the **distal convoluted tubule** take some materials from **surrounding blood** and secrete them **into the filtrate.**
- **Secreted Substances:** Include **hydrogen ions, ammonium, potassium ions,** and **various metabolic toxins** or drug residues (like penicillin).
- **Importance:** Through tubular secretion of **hydrogen ions,** the kidneys play role in maintaining the **acid-base balance (pH) of the blood.**

Q.11 How is urine eliminated from kidney? (or) Trace the pathway of urine from kidney to out of body. S/Q

Ans. Elimination of Urine:

- The urine is collected from the **collecting ducts,** and flows through the **renal pelvis** into a ureter.
- Ureter **leads** to the urinary bladder, the muscular contractions of the **bladder** force urine out of the body through urethra.

➢ **Pathway of Urine from Kidney to out of Body:**

Collecting Ducts ⟶ Renal Pelvis ⟶ Ureter ⟶ Urinary Bladder ⟶ Urethra.

Q.12 How much amount of urine is eliminated per day in adult human & which factors effect urine amount? S/Q

Ans. • A normal adult eliminates from **1 to 2 L of urine a day.**

Tidbit
- In hot weather, the body loses more water through **sweat,** leading the kidneys to conserve water and produce a **smaller** volume of concentrated urine.

➢ **Factors which Effect Amount of Urine:**

- The amount of urine is highly variable and depends on **several factors.**

(i) The **more water** or **hydrating fluids** we consume, the higher is the urine output.

(ii) Diets with high **salt trigger** water retention and decrease urine production.

(iii) Physical **exercise** leads to water loss through respiration and perspiration, which generally decreases **urine volume.**

CamScanner

Multiple Choice Questions (MCQs)

		Key
1.	What is the primary process by which an organism eliminates metabolic wastes? (A) Digestion. (B) Excretion. (C) Respiration. (D) Circulation.	1.(B)
2.	Between which spinal vertebrae are the human kidneys located within the abdominal cavity? (A) 10th thoracic and 1st lumbar. (B) 12th thoracic and 3rd lumbar. (C) 5th lumbar and 1st sacral. (D) 9th thoracic and 2nd lumbar.	2.(B)
3.	What is the approximate length of the human ureters connecting the kidneys to the urinary bladder? (A) 10 cm (B) 15 cm (C) 25 cm (D) 40 cm	3.(C)
4.	What percentage of total nephrons do cortical nephrons constitute within the human kidney? (A) 15% (B) 50% (C) 75% (D) 85%	4.(D)
5.	Which essential role of the urinary system maintains the "water-to-salt" balance of the blood? (A) Filtration. (B) Osmoregulation. (C) Secretion. (D) Digestion.	5.(B)
6.	Which inner portion of the kidney contains a number of cone-shaped renal pyramids? (A) Renal medulla. (B) Renal cortex. (C) Renal pelvis. (D) Renal capsule.	6.(A)
7.	Which specialized capillary network runs parallel to the loops of Henle in the renal medulla? (A) Glomerulus. (B) Afferent arterioles. (C) Peritubular capillaries. (D) Vasa recta.	7.(D)
8.	What is the specific water permeability characteristic of the ascending limb of the loop of Henle? (A) Permeable. (B) Impermeable. (C) Absorptive. (D) Secretory.	8.(B)
9.	Approximately what percentage of total cardiac output is received by the highly vascularized kidneys? (A) 5–10% (B) 10–15% (C) 20–25% (D) 40–50%	9.(C)
10.	When body fluids are hypertonic and dehydration occurs, how do the kidneys adjust urine formation? (A) Dilute urine. (B) Concentrated urine. (C) Excessive volume. (D) Stopped production.	10.(B)
11.	During glomerular filtration, which components of the blood are normally too large to pass through the capillary walls into the Bowman's capsule? (A) Mineral salts. (B) Plasma proteins. (C) Amino acids. (D) Glucose molecules.	11.(B)
12.	Based on renal responses to dietary habits, what impact does a diet high in salt have on urine production? (A) Increased output. (B) Water retention. (C) Complete cessation. (D) Accelerated flow.	12.(B)
13.	Through which specific nephron process are drug residues like penicillin eliminated from the surrounding blood directly into the filtrate? (A) Ultrafiltration. (B) Reabsorption. (C) Tubular secretion. (D) Osmosis	13.(C)
14.	If a normal adult consumes a high volume of hydrating fluids daily, how will their overall urine output respond? (A) Decrease. (B) Increase. (C) Stop. (D) Stabilize.	14.(B)
15.	Why is the right human kidney positioned slightly lower and smaller than the left kidney? (A) Aortic arch. (B) Pelvic tilt. (C) Stomach size. (D) Liver position.	15.(D)
16.	Why does the blood within the glomerular capillaries remain under relatively high pressure? (A) Wider venules. (B) Narrower efferent arteriole. (C) Shorter renal artery. (D) Direct pumping.	16.(B)
17.	What structural feature distinguishes juxtamedullary nephrons from cortical nephrons? (A) Shorter glomerulus. (B) Absent collecting ducts. (C) Long loops of Henle. (D) Larger Bowman's capsule.	17.(C)
18.	How does the structure of the proximal convoluted tubule assist in its primary function? (A) Smooth walls. (B) Highly coiled. (C) Wide lumen. (D) Thin lining.	18.(B)
19.	A student claims that the human urinary system is solely responsible for liquid waste elimination. How accurate is this evaluation based on its three essential roles? (A) Incomplete. (B) Fully accurate. (C) Completely false. (D) Overstated.	19.(A)
20.	An instructor evaluates the branching of efferent arterioles into peritubular capillaries rather than venules. What is the functional justification for this design? (A) Enhancing pressure. (B) Preventing rupture. (C) Accelerating flow. (D) Enabling reabsorption.	20.(D)
21.	A medical report states that tubular secretion only handles drug residues. How accurate is this assessment given normal physiology? (A) Fully valid. (B) Proven fact. (C) Misleading. (D) Irrelevant.	21.(C)
22.	To engineer a synthetic tubule segment that maximizes passive water return without active transport, which natural structure must be modeled? (A) Ascending limb. (B) Descending limb. (C) Distal tubule. (D) Collecting duct.	22.(B)
23.	To design a therapeutic model targeting blood pH regulation within the nephron, which cellular mechanism must be simulated? (A) Hydrogen ion secretion. (B) Glucose uptake. (C) Sodium reabsorption. (D) Urea filtration.	23.(A)

REGULATION OF THE URINE CONCENTRATION

Topic: Counter-current Mechanism:

Q.13 Explain that concentration of urine is regulated by counter-current and hormonal mechanisms. Exercise LO 4.4

OR Define the counter-current mechanism & how does counter-current mechanism make the urine concentrated. LO

Ans. (A) Counter-Current Mechanism:

- **Definition:** Counter-current mechanism is a process **in the loop of Henle** where **filtrate flows** in opposite direction in **descending** and **ascending loop of Henle**, this creates a high salt concentration in the medulla of kidney, which draws water out of the filtrate, back into blood via vasa recta helping the kidneys to reabsorb water & produce concentrated urine.
- For the **reabsorption of water from** the loop of Henle and **collecting duct, nephrons** create and maintain higher concentration of salts (NaCℓ) in the **surrounding fluid**.
- It is done by **counter-current mechanism.**
- The **descending** limb is **permeable** to water but **not to salts.**
- The **ascending** limb is **impermeable** to water but actively transports salts out of tubule.
- When filtrate flows through the descending limb, water is **reabsorbed** into the surrounding fluid because the surrounding fluid has **more salts.**
- When fluid flows through the ascending limb, it **actively transports** sodium ions from the filtrate to the surrounding fluid.
- The **chloride ions** follow **sodium ions.** So, the salt concentration of the fluid **remains high.**
- As **urine passes** down the collecting duct through this **salty fluid,** water moves out **by osmosis (Due to Higher Salts Outside)** and enters blood via the **vasa recta.**

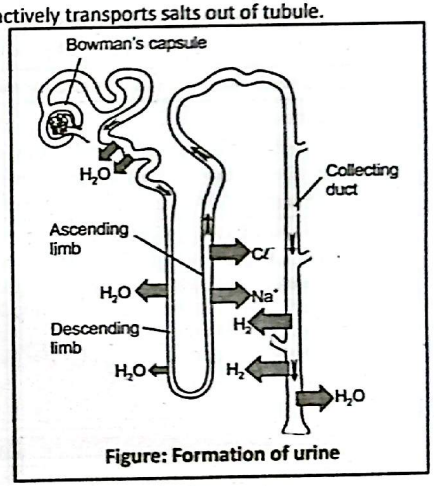


Figure: Formation of urine

(B) Urine Conc. Through Hormones:

- When body needs to **conserve water,** kidneys excrete a **hypertonic urine,** i.e. conc. urine.
- When there is much water in body, kidneys excrete a **hypotonic urine,** i.e. dilute urine.
- These functions of kidneys are coordinated by the following hormones:

(1) Role of Antidiuretic Hormone (ADH) in Making Urine Conc.

- ADH is the body's **primary tool** for water conservation.
- It is **produced** by the **hypothalamus** and secreted by the posterior pituitary gland.
- When the body is **dehydrated** or has taken salty food, the higher **concentration of salts in blood** is detected by **osmoreceptors** present in the hypothalamus.
- The hypothalamus sends signals to the **posterior pituitary** to create a sensation of thirst and to release ADH.

Check Understanding!

Q.6 Design a short feedback loop showing how eating salty food triggers water conservation.

Tidbit

- ADH increases the blood volume. It results in an increase in blood pressure.
- ADH also causes the blood vessels to constrict or narrow. This constriction further increases blood pressure.

CamScanner

- **ADH acts on the walls of the collecting ducts and make them more permeable to water.** So, more water moves from the filtrate into the **hypertonic fluid** and then into blood.
- In this way, **concentrated urine** is produced and water is conserved.
- When the **concentration of salts** falls in blood, the hypothalamus stops ADH secretion.
- The walls of the collecting duct become **less permeable to water.** So, **less water is reabsorbed,** resulting in the excretion of **dilute urine.** As a result, the **blood volume** and blood pressure decrease.

Tidbit

- Aldosterone also promotes the excretion of potassium ions in the urine.
- It helps to prevent hyperkalemia, a condition in which the blood potassium levels become too high and can lead to dangerous cardiac arrhythmias.

(2) Role of Aldosterone in Urine Concentration:

- Aldosterone is the **hormone** responsible for regulating **sodium and potassium** levels of urine.
- It is produced by the **adrenal cortex** (the outer layer of adrenal gland present on the top of kidney).
- **Aldosterone** is secreted when blood **pressure drops or sodium levels** in the blood are too low.
- Aldosterone acts on the walls of the **distal convoluted** tubule and the collecting duct.
- It increases **sodium ions reabsorption** from the filtrate into the blood. Due to higher concentration of sodium ions in blood, water also moves from **filtrate into the blood.**

Check Understanding!

Q.7 A patient presents with severe hyperkalemia and cardiac arrhythmias. Dysfunction in which hormone is the likely cause?
(A) Excess ADH secretion.
(B) Insulin overproduction.
(C) Cortisol shutdown.
(D) Aldosterone deficiency.

Q.14 How is diabetes insipidus resulted abnormality of ADH? S/Q

Ans. Diabetes Insipidus:

- A person who cannot produce **enough ADH** due to pituitary **damage** constantly excretes a large volume of dilute urine. This disorder is known as **diabetes insipidus.**
- **Effects:** Such a person is in danger of becoming severely **dehydrated** with very low blood pressure.

Two capillaries Beds in Kidneys:

In kidney, two distinct capillary beds work in sequence to process blood.

i. **Glomerular capillaries** are located within the Bowman's capsule. These capillaries are designed for filtration. They operate under high blood pressure which forces water and small solutes out of the blood and into the nephron.

ii. **Peritubular capillaries** surround the renal tubules. Their primary role is reabsorption and secretion. They operate under low hydrostatic pressure and pull essential nutrients (glucose, ions) and water back into the bloodstream from the tubules. They also secrete specific toxins into the tubule.

Multiple Choice Questions (MCQs)	Key
1. What is the permeability property of the descending limb of the loop of Henle? (A) Permeable water. (B) Impermeable water. (C) Permeable salts. (D) Impermeable both.	1.(A)
2. How do salts move out of the ascending limb of the loop of Henle? (A) Passive osmosis. (B) Active transport. (C) Simple diffusion. (D) Filtration pressure.	2.(B)
3. What type of urine do kidneys excrete when the body needs to conserve water? (A) Hypotonic urine. (B) Isotonic urine. (C) Hypertonic urine. (D) Dilute urine.	3.(C)
4. Where in the body is Antidiuretic Hormone (ADH) produced? (A) Posterior pituitary. (B) Adrenal cortex. (C) Hypothalamus. (D) Bowman's capsule.	4.(C)
5. Which gland secretes ADH into the bloodstream? (A) Adrenal gland. (B) Posterior pituitary. (C) Hypothalamus. (D) Renal cortex.	5.(B)
6. In hot weather, why do kidneys produce a smaller volume of concentrated urine? (A) Sweating loss. (B) Increased salt. (C) Low pressure. (D) Excess ADH.	6.(A)
7. How does ADH cause water to move from the filtrate into the blood? (A) Constricting vessels. (B) Making walls permeable. (C) Pumping sodium. (D) Raising pressure.	7.(B)
8. Why is a person suffering from diabetes insipidus in severe danger? (A) High pressure. (B) Extreme dehydration. (C) Hyperkalemia risk. (D) Excess glucose.	8.(B)

9. Which layer of the adrenal gland produces aldosterone? (A) Adrenal medulla. (B) Posterior pituitary. (C) Adrenal cortex. (D) Hypothalamus	9.(C)
10. Under what bodily condition is aldosterone secreted? (A) Blood pressure drops. (B) Blood pressure rises. (C) Water level high. (D) Potassium levels drop.	10.(A)
11. Which parts of the renal tubule are acted upon by aldosterone? (A) Bowman's capsule. (B) Descending limb. (C) Distal convoluted tubule. (D) Glomerular capillaries.	11.(C)
12. Where are glomerular capillaries located? (A) Collecting duct. (B) Bowman's capsule. (C) Renal tubules. (D) Adrenal cortex.	12.(B)
13. Why do peritubular capillaries operate under low hydrostatic pressure? (A) Pull nutrients back. (B) Force filtration. (C) Restrict water. (D) Constrict vessels.	13.(A)
14. If peritubular capillaries accidentally operated under high hydrostatic pressure, what main process would fail? (A) Blood filtration. (B) Hormone secretion. (C) Salt transport. (D) Nutrient reabsorption.	14.(D)

DISORDERS OF URINARY TRACT

Q.15 What are disorders of urinary tract also give its some common examples. S/Q

Ans. Disorders of Urinary Tract:

- A **variety of disorders** which affect the **structure and function** of kidneys and urinary tract are called **disorders of urinary tract.**
- **Common Examples:**
  (i) Urinary tract infections. (ii) Kidney stones. (iii) Kidney failure. (iv) Polycystic kidney disease.

Topic: Urinary Tract Infections (UTIs):

Q.16 What are urinary tract infections (UTIs)? Write its causes, symptoms & treatment. L/Q

Ans. Urinary Tract Infections (UTIs):

- **Definition:** The infections of **urethra, urinary bladder, ureters & kidneys** are called **urinary tract infections or UTIs.**

➢ **Causes of UTIs:**

- Urinary tract infections (UTIs) are usually caused by **bacteria,** most commonly ***Escherichia coli.*** These bacteria enter the urinary system through urethra and infect the bladder, ureters, or kidneys.

➢ **Symptoms of UTIs:**

- The **symptoms** of a UTI include a frequent and urgent need to urinate.
- Pain or burning during urination.
- Cloudy or strong-smelling urine.
- Lower abdominal pain.
- Sometimes fever or chills.

➢ **Treatment of UTIs:**

- Treatment involves a course of **antibiotics** to kill the causative bacteria.
- Drinking **plenty** of water and **urinating** frequently can also help to flush out the bacteria and alleviate symptoms.

Topic: Kidney Stones:

Q.17 What are kidney stones? Discuss its major types with causes. Exercise Q.5

Ans. Kidney Stones:

- The hard, crystalline mineral materials that stick together to form small **"pebbles"** within the kidney or urinary tract are called **kidney stones.**
- They may **stay in kidneys** or travel out of the body through the **urinary tract.**

Check Understanding!

Q.8 Contrast the urine pH indicators used to identify calcium oxalate versus uric acid kidney stones.

CamScanner

➢ **Types of Kidney Stones:**

(i) Calcium Oxalate Stones: 70% of kidney stone patients have stones of **calcium oxalate.**

- **Causes:** These stones are formed due to **hypercalciuria** (High calcium in urine) and **hyperoxaluria** (increased level of oxalate level in urine).
- 10% of patients may have stones of **uric acid.**

(ii) Uric Acid Stones: Hyperuricemia (increased amount of uric acid in blood) is the cause of **uric acid stones.**

(iii) Cystine + Phosphate Stones: High concentration of **cystine** and **phosphates** in urine also cause kidney stones.

- Continuous dehydration in the body increases the chances of kidney stone formation.

Tidbit

- Doctors diagnose the nature of kidney stone by studying the urine test of patient.
- When urine is acidic, the stone is of calcium oxalate.
- When the urine is alkaline, the stone is of calcium phosphate.
- When urine is acidic, the stone is of uric acid (or cystine).
- Calcium-oxalate stones form across a range of pH (pH-Independent).

Q.18 Discuss the kidney stone treatment with the help of lithotripsy and elaborate its two types. Exercise L/Q.5

Ans. Treatment of Kidney Stones:

- Treatment of kidney stones usually involves lithotripsy i.e., breaking of stones.

➢ **Types of Lithotripsy:**

- There are two methods of lithotripsy:

(1) Extracorporeal Shockwave Lithotripsy (ECSWL):

- In Extracorporeal Shockwave Lithotripsy (ECSWL), an instrument called **lithotripter generates** shockwaves from outside the **patient's body.**
- These shockwaves break the stone into small pieces.
- Most of pieces then pass out through urine.

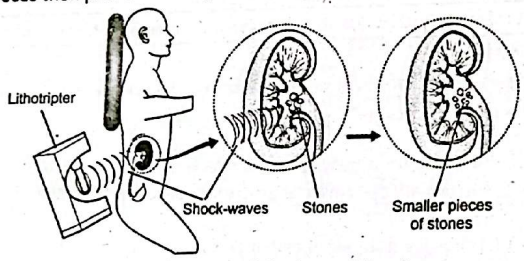


Figure: Extracorporeal shockwave lithotripsy

(2) Percutaneous Nephro-lithotripsy (PNL):

- In case of **larger stones,** Percutaneous Nephro-lithotripsy (PNL) is used.
- In PNL technique, a tube is inserted from the **patient's back** into the kidney. A small **camera** called nephroscope is inserted through the tube to visualize the stone.
- Ultrasound **equipment** is then inserted to break the stone.
- The stone pieces can be **grasped** with special equipment and pulled out **from the kidney.**

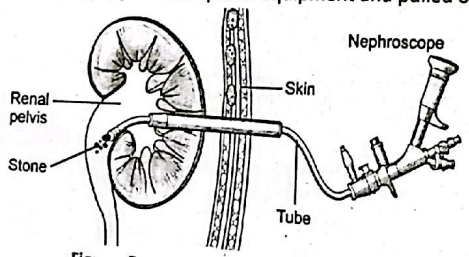


Figure: Percutaneous Nephrolithotripsy

Topic: Kidney Failure:

Q.19 What is kidney/renal failure? Describe the types of kidney failure with their major causes.

Ans. Kidney/Renal Failure:

- A condition in which the kidneys lose their ability to filter **wastes from** the blood and **regulate fluid** and salt balance in the body is called **kidney/renal failure.**

➢ **Types of Kidney Failure:**

1. **Chronic Kidney Failure:**
   - A type of kidney failure which develops **over a longer** period of time and is **irreversible.**

   Causes of Chronic Kidney Failure:
   - It is often caused by underlying conditions like **diabetes, high blood pressure, or kidney disease** (chronic infection, inflammation of glomeruli etc.).
2. **Acute Kidney Failure (also called kidney injury):**
   - A type of kidney failure which occurs suddenly and often resolves with treatment.

   Cause of Acute Kidney Failure:
   - It may be due to kidney infection, or blockage in urinary tract (due to kidney stones, bladder cancer, enlarged prostate).
   - Certain medications such as **NSAIDs,** and blood clots in renal arteries or arterioles can also cause this type.

Topic: Dialysis:

Q.20 What is renal dialysis? Discuss two common methods of renal dialysis, elaborate your answer with the help of labelled diagram. Exercise L/Q.6

Ans. Renal Dialysis:

- **Renal dialysis** is the treatment of **renal failure** in which the metabolic wastes are filtered from blood by artificial methods.

➢ **Types of Renal Dialysis:**

- There are two **general types** of renal dialysis:
  (1) Haemodialysis. (2) Peritoneal dialysis.

(1) Haemodialysis:

- A type of **renal dialysis** in which the **wastes** are removed by circulating the blood **outside the body** through an equipment named **dialyzer** or **artificial kidney** is called **Haemodialysis.**
- The dialyzer is an equipment & a type of filter which contains a semipermeable membrane (made of cellulose).

Mechanism of Haemodialysis:

- In this method of **treatment,** a catheter is inserted into **an artery,** usually in the arm.
- The blood is **then circulated** through dialyzer which also **contains** a special fluid called **dialysate.**
- As the blood passes through the **dialyzer,** the **dialysate** (Fluid) attracts the **wastes, water,** and **salts** to move out from blood, the filtrates passes through semipermeable membrane and dissolves in dialysate.
- The clean blood then returns to the body through a second catheter **inserted in a vein.**

Check Understanding!

Q.9 What physical principle drives urea removal from blood during Haemodialysis?

(A) High-pressure ultrafiltration.
(B) Passive diffusion down a gradient.
(C) Active cellular transport.
(D) Osmotic protein attraction.

CamScanner

(2) Peritoneal Dialysis:

- **Definition:** Peritoneal dialysis involves the use of peritoneal membrane that lines the abdominal cavity.

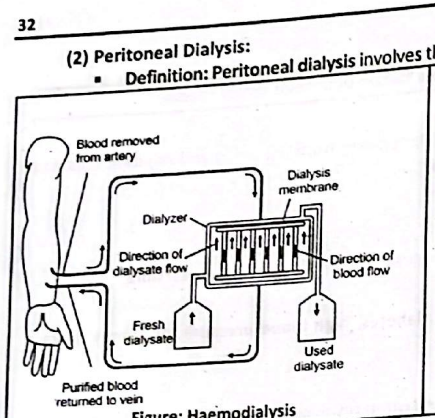


Figure: Haemodialysis

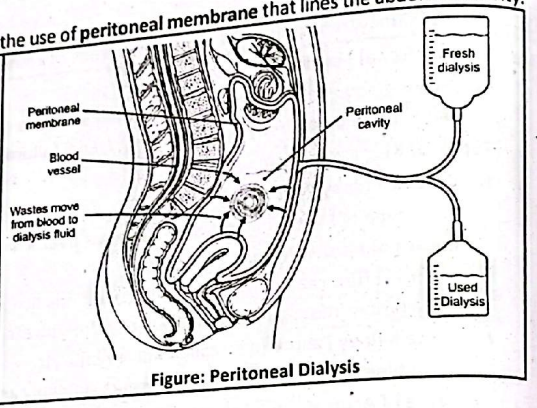


Figure: Peritoneal Dialysis

Mechanism of Peritoneal Dialysis:

- In this process, **1.5 to 2 liter of dialysate** is infused into the **patient's abdomen** through a catheter.
- The dialysate is left in abdomen for **4 to 6 hours**.
- Waste **products** and **excess** fluid from the blood capillaries of peritoneum pass into the dialysate.
- The used dialysate is **drained out** of the abdomen and discarded.
- This process is **repeated** several times a day, to achieve adequate clearance of waste products and excess fluid.

Topic: Problems Associated with Dialysis:

Q.21 Discuss the problems associated with dialysis. Exercise L/Q.6

Ans. Problems Associated with Dialysis:

- While dialysis can be **life-saving** for people with **kidney failure**.
- There are several problems associated with this treatment.

(i) Increases Infection Risk: Dialysis requires access to the bloodstream, which increases the risk of infections.

(ii) Cause of Hypotension: Hypotension, or low blood pressure, is a common complication of haemodialysis.

(iii) Causes Muscle Cramp: Muscle cramps can occur during dialysis due to changes in salt levels.

(iv) May Cause Pneumonia: Dialysis can cause anaemia, which can lead to fatigue and weakness.

(v) May Cause Dehydration: If too much fluid is removed too quickly, it can lead to dehydration or low blood pressure.

(vi) May Cause Depression: Dialysis treatments can be emotionally challenging. Patients may feel anxious, **depressed**, or overwhelmed by the demands of the treatment.

Check Understanding!

Q.10 Explain why regular haemodialysis patients frequently develop secondary anaemia.

Topic: Kidney Transplant:

Q.22 What is kidney transplant? Why is it needed, also give the precautions for kidney transplant? S/Q

Ans. Kidney Transplant:

- **Surgical Procedure:** Kidney transplant is a **surgical procedure** in which a person's non-functioning kidney is replaced with a healthy kidney from a donor.
- **Need of Kidney Transplant:** This treatment is offered to **individuals** with **end-stage** kidney failure.
- **Precautions for Kidney Transplant:** Kidney transplant process requires **careful evaluation**, matching, and monitoring to ensure the best results for both the recipient and the donor.

Q.23 Discuss the potential donour for kidney transplant, including related, unrelated & deceased donours. L/Q

Ans. Potential Donors for Kidney Transplant:

(i) Best Related Donor:

- A person who is **genetically** related to the recipient, such as a parent, sibling, or child can be the best **donor of kidney**.

(ii) Unrelated Donor:

- The donor **cannot be genetically** related to the recipient, such as a spouse, friend, or co-worker.
- This type of donation is **less common** but can still be successful if the donor's and recipient's blood group and **tissue** type match.

(iii) Deceased Donor:

- Many people register with hospitals for donation of their organs after their death. Their organs, including the kidneys, can be donated to individuals in need of a transplant.
- Deceased donor's kidneys are carefully matched to recipients based on blood group, tissue type, and immune system compatibility.

Check Understanding!

Q.11 Why is a genetically related family member preferred over an unrelated donor for a kidney transplant?

(A) Zero risk of infection.
(B) Doubled urine capacity.
(C) Higher HLA match probability.
(D) Immunity to surgical shock.

Tidbit

Kidney Donation:

- Kidney donation can be a life-saving gift for someone with **end-stage kidney** disease.
- Donating a kidney does not have significant long-term health risks for the donor.
- Studies have shown that kidney donors generally **experience** no negative impact on their overall health or lifespan.

For Information

(i) Pakistan's First Kidney Transplant Center:

- Pakistan's first kidney transplant centre was established in 1985 at the **Sindh Institute of Urology** and Transplantation (SIUT) in Karachi.
- It is one of the world's largest transplant centres.

(ii) PKLI & RC:

- The Pakistan Kidney and Liver Institute & Research Center (PKLI&RC) was established in 2017 in Lahore.
- It was established to address Pakistan's growing burden of kidney and live diseases.



Q.24 Discuss the potential complications & risk associated with kidney transplant? Exercise L/Q.7

Ans. Problems Associated with Kidney Transplant:

There are some potential complications and **risks associated** with kidney transplant. For example;

(i) Risk of Organ Rejection:

- The **recipient's immune** system may recognize the **transplanted** kidney as a foreign object and attack it, leading to organ rejection.
- Organ rejection can occur even if the patient is taking **immunosuppressant medications** to prevent rejection.

(ii) Risk of Infections:

- Patients with a suppressed **immune system** are at a higher risk of developing infections after a transplant.

(iii) Risk of Blood Pressure, Weight Gain & Cancer:

- Recipients are given **immunosuppressant medications** to prevent organ rejection.
- Such medicines can have side effects such as high blood pressure, weight gain, and increased risk of infections and cancers.

Multiple Choice Questions (MCQs)	Key
1. Which bacteria most commonly cause urinary tract infections? (A) Staphylococcus. (B) E. coli. (C) Streptococcus. (D) Salmonella.	1.(B)
2. What percentage of kidney stone patients have stones of calcium oxalate? (A) Fifty percent. (B) Ten percent. (C) Seventy percent. (D) Thirty percent.	2.(C)
3. What equipment is used to circulate blood outside the body in haemodialysis? (A) Dialyzer. (B) Nephroscope. (C) Lithotripter. (D) Catheter.	3.(A)

CamScanner

4. In which year was Pakistan's first kidney transplant center established at SIUT in Karachi?
(A) Nineteen ninety-five. (B) Two thousand seventeen. (C) Two thousand five. (D) Nineteen eighty-five.
5. In which city is the Pakistan Kidney and Liver Institute & Research Center (PKLI&RC) located?
(A) Karachi. (B) Lahore. (C) Islamabad. (D) Rawalpindi.
6. What is the treatment for a bacterial urinary tract infection?
(A) Lithotripsy session. (B) Haemodialysis filter. (C) Antibiotics course. (D) Organ transplant.
7. What is the general medical definition of lithotripsy given in the text?
(A) Filtering blood. (B) Flushing bacteria. (C) Breaking stones. (D) Removing kidney.
8. What instrument generates external shockwaves in Extracorporeal Shockwave Lithotripsy?
(A) Lithotripter. (B) Nephroscope. (C) Dialyzer. (D) Catheter.
9. What small camera is inserted through a tube during Percutaneous Nephrolithotripsy?
(A) Dialyzer. (B) Nephroscope. (C) Lithotripter. (D) Catheter.
10. How does chronic kidney failure develop and progress according to the text?
(A) Sudden recovery. (B) Rapid healing. (C) Temporary infection. (D) Over longer period.
11. Which membrane lines the abdominal cavity and is used in peritoneal dialysis?
(A) Semi-permeable cellulose. (B) Peritoneal membrane. (C) Renal capsule. (D) Bladder wall.
12. Besides antibiotics, what action can help flush out bacteria and alleviate UTI symptoms?
(A) Drinking water. (B) Eating salt. (C) Restrict fluids. (D) Taking NSAIDs.
13. High calcium in urine (hypercalciuria) directly causes the formation of which stones?
(A) Uric acid. (B) Calcium phosphate. (C) Calcium oxalate. (D) Cystine stones.
14. Which medication class is specifically listed as a potential cause of acute kidney failure?
(A) Antibiotics. (B) NSAIDs. (C) Dialysate. (D) Insulins.
15. Why does haemodialysis increase the risk of infections according to the text?
(A) Low pressure. (B) Muscle cramps. (C) Bloodstream access. (D) Fluid loss.
16. What medicines are given to transplant patients to prevent organ rejection?
(A) Antibiotics. (B) Immunosuppressant medications. (C) Dialysate fluids. (D) Pain relievers.
17. Based on urine test diagnostics, what type of kidney stone is indicated if the urine is persistently acidic?
(A) Calcium phosphate. (B) Calcium oxalate. (C) Uric acid. (D) Cystine stones.
18. What problem can occur if too much fluid is removed too quickly during dialysis?
(A) High pressure. (B) Dehydration. (C) Hyperkalemia spike. (D) Infection rise.
19. Who are cited as the best choice of kidney donor?
(A) Genetically related. (B) Unrelated friend. (C) Deceased donor. (D) Co-worker donor.
20. Which kidney stone treatment method is used specifically in the case of larger stones?
(A) ECSWL only. (B) PNL. (C) Dialysis. (D) Antibiotic therapy.
21. What do studies show regarding long-term health risks for living kidney donors?
(A) High organ failure. (B) Severe weakness. (C) No significant risks. (D) Shortened lifespan.
22. If a dialyzer's semipermeable membrane (made of cellulose) allows blood cells and large proteins to pass through into the dialysate, what structural layout failed?
(A) Filter separation. (B) Dialysate flow. (C) Catheter route. (D) Blood pumping.
23. If immunosuppressant medications suppress a transplant recipient's immune system, what specific secondary condition are they placed at a higher risk of developing?
(A) Stone formation. (B) Muscle cramps. (C) Infections. (D) High sugar.

4.	(D)
5.	(B)
6.	(C)
7.	(C)
8.	(A)
9.	(B)
10.	(D)
11.	(B)
12.	(A)
13.	(C)
14.	(B)
15.	(C)
16.	(B)
17.	(C)
18.	(B)
19.	(A)
20.	(B)
21.	(C)
22.	(A)
23.	(C)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(B)	• Excretion strictly removes metabolic waste generated inside cells. Undigested food residues were never processed metabolically by body tissues.
2.	S/Q	• The large physical mass of the liver in the upper right abdominal quadrant displaces the right kidney inferiorly.
3.	(A)	• The proximal convoluted tubule is responsible for reabsorbing roughly 75 percent of filtered water, glucose, and essential amino acids.

4.	S/Q	• This massive blood supply is required to continuously filter systemic metabolic wastes and maintain precise body fluid osmoregulation.
5.	(C)	• Glomerular filtration depends entirely on high capillary hydrostatic pressure. If blood pressure falls below the threshold needed to overcome resistance, filtration ceases.
6.	S/Q	• High blood salt increases plasma osmolarity, activating hypothalamic osmoreceptors to release ADH and stimulate thirst for water retention.
7.	(D)	• Aldosterone promotes sodium reabsorption while driving potassium excretion into the urine. A deficiency prevents potassium clearance, causing dangerous hyperkalemia.
8.	S/Q	• Calcium oxalate stones form in acidic urine with high calcium/oxalate, whereas uric acid stones form specifically in persistently acidic urine alongside hyperuricemia.
9.	(B)	• Haemodialysis uses a concentration gradient across a semipermeable membrane, allowing urea to passively diffuse out of the blood into the dialysate.
10.	S/Q	• Mechanical destruction of red blood cells in dialysis tubing and reduced erythropoietin production from failing kidneys cause chronic anaemia.
11.	(C)	• Successful long-term graft survival depends on matching Human Leukocyte Antigens (HLA) to minimize immune rejection, which is more likely among blood relatives.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQS

1. Which one of these is not a part of single nephron?
(a) Distal convoluted tubule. (b) Collecting duct. (c) Bowman's capsule. (d) Loop of Henle.
2. In a healthy person, glucose is present in blood but not in urine. This is because glucose molecules are;
(a) Reabsorbed from the proximal convoluted tubule to blood. (b) Oxidised in kidneys. (c) Stored in kidneys. (d) Too large to enter Bowman's capsule.
3. The sizes of molecules present in Bowman's capsule are smaller than the sizes of molecules present in;
(a) Afferent renal arteriole. (b) Collecting duct. (c) Loop of Henle. (d) Proximal tubule.
4. If a drug reduces mitochondrial activity in nephrons, which chemical will be present in increased amounts in the urine?
(a) Ammonia. (b) Glucose. (c) Uric acid. (d) Urea.
5. The water content of blood is regulated by ADH. In which part of the nephron this regulation occurs?
(a) Bowman's capsule. (b) Proximal convoluted tubule. (c) Loop of Henle. (d) Collecting duct.
6. In kidneys, glucose is reabsorbed into blood. Where does this reabsorption occur?
(a) Bowman's capsule. (b) Glomerulus. (c) Proximal convoluted tubule. (d) Collecting duct.
7. In normal conditions, which one is completely reabsorbed from renal tubule into blood?
(a) Urea. (b) Water. (c) Salts. (d) Glucose.
8. If the loops of Henle are absent in all nephrons, what would happen?
(a) No urine formation. (b) Formation of urine with normal concentration. (c) Formation of concentrated urine. (d) Formation of dilute urine.
9. In peritoneal dialysis, the lining of which part of the body acts as a filter?
(a) Stomach. (b) Intestine. (c) Lungs. (d) Abdomen.
10. During which of these treatments, the patients are prescribed immunosuppressant drugs?
(a) Lithotripsy. (b) Haemodialysis. (c) Kidney transplant. (d) Peritoneal dialysis.

CamScanner

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(b)	Collecting duct.	• The collecting duct receives urine from multiple nephrons, making it a drainage tube rather than a structural part of an individual nephron.
2.	(a)	Reabsorbed from the proximal convoluted tubule to blood.	• Filtered glucose is completely reclaimed by active transport back into the peritubular capillaries specifically at the proximal convoluted tubule.
3.	(a)	Afferent renal arteriole.	• Ultrafiltration at the glomerulus blocks large plasma proteins and cells from entering Bowman's capsule, meaning molecules in the arteriole are larger overall.
4.	(b)	Glucose.	• Active transport of glucose requires ATP from mitochondria; reducing mitochondrial activity halts reabsorption, leaving glucose in the urine.
5.	(d)	Collecting duct.	• ADH increases the water permeability of the walls of the distal convoluted tubule and collecting duct to concentrate urine.
6.	(c)	Proximal convoluted tubule.	• The microvilli and active transport mechanisms of the proximal convoluted tubule facilitate the nearly 100% reabsorption of filtered glucose.
7.	(d)	Glucose.	• Under non-diabetic conditions, all filtered glucose is completely reabsorbed so none is lost in normal urine.
8.	(d)	Formation of dilute urine.	• The loop of Henle establishes the necessary medullary concentration gradient required to reabsorb water and concentrate urine.
9.	(d)	Abdomen.	• Peritoneal dialysis uses the peritoneal membrane lining the abdominal cavity and surrounding the intestines as a natural semi-permeable filter.
10.	(c)	Kidney transplant.	• Immunosuppressants are strictly required after organ transplants to suppress the recipient's immune system and prevent graft rejection.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Justify the functioning of kidneys as both excretion and osmoregulation.

Ans. Functioning of Kidneys as Both Excretion and Osmoregulation:

(a) Excretory Function of Kidney: The kidneys filter metabolic wastes, such as urea and excess salts, from the blood stream to be removed from the body as urine.

- **Examples:** Filtering excess nitrogenous waste produced from protein breakdown.

(b) Osmoregulatory Function of Kidney: The kidneys carefully control water and solute concentrations in the body fluids to maintain a stable internal environment despite **external changes.**

- **Examples:** Reabsorbing more water during dehydration to concentrate urine.

Q.2 List the organs of the urinary system.

Ans. Organs of the Urinary System:

(i) **Kidneys:** Pair of bean-shaped organs responsible for filtering blood, producing urine, and maintaining osmoregulation.
(ii) **Ureters:** Muscular tubes that transport urine downward from the kidneys to the urinary bladder.
(iii) **Urinary Bladder:** A hollow, muscular, elastic sac that temporarily stores urine until it is released.
(iv) **Urethra:** A single tube that carries urine from the urinary bladder to the outside of the body during urination.

Q.3 Define glomerular filtration.

Ans. Glomerular Filtration:

- The initial, non-selective process where high blood pressure **forces water, ions,** and small molecules out of the glomerular capillaries and into the Bowman's capsule.

Q.4 Compare the function of glomerular capillaries and peritubular capillaries.

Ans.

Function of Glomerular Capillaries	Peritubular Capillaries
• A specialized bed of **high-pressure** capillaries dedicated to filtering water and small solutes out of the blood and into the nephron tubule present inside Bowman's capsule.	• A network of low-pressure capillaries surrounding the **renal tubules** responsible for the reabsorption of useful substances and secretion of wastes.

Q.5 What are the three main processes involved with urine formation?

Ans. Three Main Processes Involved with Urine Formation:

(i) Glomerular Filtration:
- The bulk transfer of water and small **dissolved** solutes from the blood into the Bowman's capsule.
- This process forces plasma fluid across the filtration membrane.

(ii) Tubular Reabsorption:
- The selective movement of essential nutrients, water, glucose and ions from the renal tubules back into the **peritubular blood capillaries.**
- It involve the reabsorbing all glucose and most water back into the bloodstream.

(iii) Tubular Secretion:
- The active **transport** of unwanted ions, drugs, and excess hydrogen ions from the blood directly into the **nephron tubule.**
- It involves the secretion of excess potassium and hydrogen ions to maintain blood pH.

Q.6 What are the causes of kidney failure?

Ans. Causes of Kidney Failure:

(i) Chronic Hypertension: Long-term high blood pressure damages and weakens the delicate blood vessels inside the kidneys, reducing their ability to filter blood effectively.
(ii) Diabetes Mellitus: Chronically high blood sugar levels force the kidneys to overwork, eventually damaging the filtration membranes and leading to protein leakage and kidney failure.

Q.7 Why do blood and dialysate flow in opposite direction?

Ans. Blood and Dialysate Flow in Opposite Direction:

- **Countercurrent Flow:** Flowing blood and **dialysate** in opposite directions maintains a constant concentration gradient along the entire length of the **dialysis membrane.**
- It helps in maximizing the removal of **waste toxins** and preventing complete equilibrium to ensure continuous diffusion of materials.

Q.8 Differentiate between:

- **Afferent and efferent arterioles.**
- **Chronic and acute renal failure.**
- **Haemodialysis and peritoneal dialysis.**
- **Renal cortex and renal medulla.**

Ans. Afferent and Efferent Arterioles:

Afferent	Efferent Arterioles
• The afferent arteriole brings unfiltered blood into the **glomerulus** at a wider diameter.	• The efferent arteriole carries filtered blood away from the glomerulus at a narrower diameter to build high filtration pressure.

Chronic and Acute Renal Failure:

Chronic Renal Failure	Acute Renal Failure
• Chronic renal failure is a long-term, progressive, and irreversible loss of kidney function over months or years. • It is the gradual kidney destruction from long-term diabetes.	• Acute renal failure is a sudden, often reversible loss of kidney function caused by trauma, toxins, or infection. • It is the sudden kidney shutdown from severe blood loss or poisoning.

CamScanner

Haemodialysis and Peritoneal Dialysis:

Haemodialysis	Peritoneal Dialysis
• Haemodialysis filters waste prom blood externally using an artificial machine and a dialyzer outside the body. • In this method blood pumped through a hospital dialysis machine.	• Peritoneal dialysis uses the patient's own abdominal peritoneal membrane as a natural filter inside the body. • It helps in versus cleansing fluid cycling directly into the patient's abdominal cavity.

Renal Cortex and Renal Medulla:

Renal Cortex	Renal Medulla
• The renal cortex is the outer, lighter-grained region of the kidney that contains glomeruli and convoluted tubules. • **Examples:** Outer layer holding Bowman's capsules.	• The renal medulla is the inner, darker region arranged into pyramids containing the loops of Henle and collecting ducts. • **Examples:** Inner pyramid structures holding collecting ducts.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Describe the structure of kidney and relate it with its function.

Ans. See Page NO. 23, 24 (Q.7, Q.10)

Q.2 Explain the detailed structure of nephron.

Ans. See Page NO. 23 (Q.8)

Q.3 Explain the main processes in kidney functioning.

Ans. See Page NO. 24 (Q.10)

Q.4 Explain that concentration of urine is regulated by counter-current and hormonal mechanisms.

Ans. See Page NO. 27 (Q.13)

Q.5 Explain the causes and treatments of kidney stones.

Ans. See Page NO. 29-30 (Q.17, Q.18)

Q.6 Explain in detail the mechanism and problems related to dialysis.

Ans. See Page NO. 31-32 (Q.20, Q.21)

Q.7 Describe the principles and the problems associated with kidney transplant.

Ans. See Page NO. 33 (Q.24)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Hypothesize kidney stone by studying the urine test of relevant patients.

Ans.
- **Presence of Blood:** Urine tests often reveal microscopic red blood cells (hematuria) because stones scrape the lining of the urinary tract.
- **Crystal Formation:** Finding high levels of mineral crystals, such as calcium oxalate or uric acid, suggests stone formation is occurring.
- **Abnormal pH:** Unusually acidic or basic urine pH levels can point to specific types of chemical imbalances that trigger stones.

Q.2 Describe the importance of kidney donation for the benefit of kidney failure patients.

Ans. Importance of Kidney Donation for the Benefit of Kidney Failure Patients:

(i) **Life-Saving Treatment:** It provides a definitive, life-saving solution for patients suffering from end-stage renal (kidney) failure.

(ii) **Better Quality of Life:** A successful transplant restores normal body filtration, offering a much better and more active life than dialysis.

(iii) **Freedom from Dialysis:** It frees patients from the physical pain, high costs, and time-consuming routine of regular dialysis sessions.

Q.3 Name the important kidney transplant centres in your city.

Ans. Important Kidney Transplant Centres in Your City: (Example: Lahore)

(i) **Pakistan Kidney and Liver Institute (PKLI):** A state-of-the-art, premier institution dedicated to advanced kidney and liver transplants.

(ii) **Sheikh Zayed Hospital:** Features a well-established and trusted renal transplant and urology department.

(iii) **Mayo Hospital:** A major public hospital in Lahore providing specialized kidney surgery and transplant services.

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. **(1 x 6 = 06)**

(i) When body fluids are hypertonic and dehydration occurs, how do the kidneys adjust urine formation?
(A) Dilute urine. (B) Concentrated urine. (C) Excessive volume. (D) Stopped production.

(ii) What is the permeability property of the descending limb of the loop of Henle?
(A) Permeable water. (B) Impermeable water. (C) Permeable salts. (D) Impermeable both.

(iii) If peritubular capillaries accidentally operated under high hydrostatic pressure, what main process would fail?
(A) Blood filtration. (B) Hormone secretion. (C) Salt transport. (D) Nutrient reabsorption.

(iv) How does chronic kidney failure develop and progress according to the text?
(A) Sudden recovery. (B) Rapid healing. (C) Temporary infection. (D) Over longer period.

(v) Which kidney stone treatment method is used specifically in the case of larger stones?
(A) ECSWL only. (B) PNL. (C) Dialysis. (D) Antibiotic therapy.

(vi) If the loops of Henle are absent in all nephrons, what would happen?
(A) No urine formation. (B) Formation of urine with normal concentration.
(C) Formation of concentrated urine. (D) Formation of dilute urine.

Q.2 Write short answers of the following questions. **(2 x 8 = 16)**

(i) Define excretion & give examples of excretory wastes.
(ii) How much amount of urine is eliminated per day in adult human & which factors effect urine amount?
(iii) Define glomerular filtration.
(iv) Differentiate between Haemodialysis and Peritoneal Dialysis.
(v) Discuss two capillaries beds in kidneys.
(vi) Differentiate between cortical nephron and juxtamedullary nephron.
(vii) What are disorders of urinary tract also give its some common examples.
(viii) Describe the importance of kidney donation for the benefit of kidney failure patients.

Q.3 Extensive Questions. **(4 x 2 = 8)**

(a) Write the names of the components of urinary system, also give brief description of each component & draw labelled diagram of urinary system.
(b) Explain the causes and treatments of kidney stones.

CamScanner

ENTRANCE TEST MDCAT

1. Those nephrons which are present along the border of the cortex and medulla are called: (UHS 2015)
A. Juxtamedullary nephrons. B. Internal nephrons. C. Cortical nephrons. D. Outer nephrons.

2. When water is in short supply, increased water retention occurs through the: (UHS 2015)
A. Cortical nephrons. B. Juxtamedullary nephrons. C. Proximal convoluted tubule. D. The tissue of cortex.

3. In nephrons, counter-current multiplier occurs at: (UHS 2015)
A. Loop of Henle. B. Bowman's Capsule. C. Collecting duct. D. Glomerulus.

4. Ascending loop of Henle does not allow outflow of: (UHS 2015)
A. Na^+ ions. B. Cl^- ions. C. K^+ ions. D. water.

5. A larger quantity of dilute urine is produced in diabetes insipidus this disease is due to the deficiency of: (UHS 2015)
A. Antidiuretic Hormone. B. Thyroxin. C. Aldosterone. D. Cortisol.

6. Water and sodium ions are reabsorbed in: (UHS 2015)
A. urinary bladder and urethra. B. Ureter. C. Adrenal cortex. D. Loop of Henle.

7. Bowman's capsule continues as extensively convoluted portion known as: (UHS 2016)
A. Peritubular capillaries. B. Efferent arterioles. C. Proximal convoluted tubules. D. Afferent arterioles.

8. A hormone released from posterior pituitary lobe acts to actively transport water from filtrate in collecting tubules back to kidney is known as: (UHS 2016)
A. Renin. B. Angiotensin. C. Anti-diuretic hormone. D. Growth factor.

9. The removal metabolic waste from the blood is called: (UHS 2016)
A. Thermoregulation. B. Kidney failure. C. Osmoregulation. D. Excretion.

10. Highly toxic nitrogenous excretory product is: (UHS 2016)
A. CO_2 B. Urea. C. Uric acid. D. Ammonia.

11. Urea cycle is the detoxification of: (UHS 2018)
A. Creatinine. B. Carbon dioxide. C. Amino acids. D. Ammonia.

12. _____ hormone is released from posterior lobe of pituitary gland: (UHS 2018)
A. Adrenaline. B. FSH. C. Thyroid stimulating hormone. D. Antidiuretic hormone.

13. The hormone which controls the uptake of the sodium ions in kidney and its maintenance in blood plasma is: (UHS 2018)
A. Somatotrophic hormone. B. Gonadotrophic hormone. C. Aldosterone hormone. D. Thyroxin hormone.

14. Keeping correct balance of ions and water in our body is called as: (UHS 2018)
A. Thermoregulation. B. Excretion. C. Osmoregulation. D. Selective reabsorption.

15. When filtration is completed the waste products through distal tube of nephron empties in: (UHS 2018)
A. Efferent arteriole. B. Peritubular capillaries. C. Collecting tubules. D. Proximal tubules.

16. Substances responsible for increasing the set point of the hypothalamus are called: (UHS 2019)
A. Pepsins. B. Prions. C. Pyrogens. D. Androgens.

17. The route of urine excretion from kidney to outside of body is: (UHS 2019)
A. Kidney→ureter→urinary bladder→urethra B. Kidney→ureter→urethra→urinary bladder C. Urinary bladder→kidney→ureter→urethra D. Kidney→urethra→urinary bladder→ureter

18. Substances responsible for increasing the set point of the hypothalamus are called: (UHS 2019)
A. Pepsins. B. Prions. C. Pyrogens. D. Androgens.

19. The main nitrogenous excretory product of humans is: (UHS 2019)
A. Uric acid. B. Urea. C. Ammonia. D. Ammonium.

ANSWERS KEY

1. A	2. B	3. A	4. D	5. A	6. D	7. C	8. C	9. D	10. D
11. D	12. D	13. C	14. C	15. C	16. C	17. A	18. C	19. B	



HUMAN NERVOUS SYSTEM

Student Learning Outcomes (SLOs)

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

- Recognize receptors as transducers sensitive to various stimuli.
- Trace the path of a message transmitted to the central nervous system for processing.
- Identify the three neurons (sensory, inter-, motor) involved in nervous transmission.
- Identify muscles and glands as the effectors.
- Annotate the detailed structure of a sensory neuron, associative and a motor neuron
- Relate the structure of neurons with functions.
- Differentiate between myelinated and non- myelinated neurons.
- Explain the function of the three types of neurons with the help of a reflex arc.
- Define nerve impulse.
- Describe the generation and transmission of nerve impulse.
- Name the factors responsible for the resting membrane potential of neuron.
- Evaluate from a graph the phenomena of polarization, depolarization, and hyperpolarization of membrane.
- Compare the velocities of nerve impulse in the axon membrane and in the synaptic cleft.
- Describe the role of local circuits in saltatory conduction of nerve impulse.
- Outline the structure of synapse.
- Explain synaptic transmission of nerve impulse.
- Classify neurotransmitters as inhibitory and excitatory and list some common examples.
- Identify the main components of the nervous system.
- Explain briefly the major divisions of the brain and their functions.
- Describe the architecture of human brain.
- Describe cranial and spinal nerves in man.
- Explain the structure, types and functions of the autonomic nervous system.
- Explain the structure and functioning of the receptors for smell, taste and touch / pain.
- Define narcotic drugs as agents that interact with the normal nervous activity.
- Compare the use and abuse of drugs with respect to heroin, Cannabis, nicotine, alcohol and inhalants like nail polish remover and glue.
- Explain the terms; drug addiction and drug tolerance with reference to caffeine and nicotine and their adverse effects.
- Associate the effects of drug addiction and tolerance with the functioning of the nervous system.
- Describe the way how pain medicines can reduce or numb pain in the human body.
- Discuss that certain pain medications are addictive.
- Classify nervous disorders into vascular, infectious, structural, functional and degenerative disorders.
- Describe the causes, symptoms and treatment of one type of each category of disorders outlined above.
- Explain the principles of the important diagnostic tests for nervous disorders i.e., EEG, CT scan and MRI.

CamScanner

Human Nervous System — Concept Map

1. NERVOUS COORDINATION
Basic Elements:
a) Receptors.
b) Central Nervous System (CNS)
c) Effectors.

2. NEURONS
- **Structure & Glial** (Cell body with Nissl's, Dendrites, Axon, Myelin via Schwann cells / Oligodendrocytes, Nodes of Ranvier).
- **Types**
a) Sensory/Unipolar.
b) Motor/Multipolar
c) Inter-neurons.
- **Reflex Arc** (Knee-jerk pathway).

3. NERVE IMPULSE
(a) Generation & Transmission:
- Resting Potential (-70 mV) → Depolarization (Na^+ in) → Repolarization (K^+ out) → Hyperpolarization → Return to RMP via Na^+/K^+ pump

(b) Velocities:
- Saltatory conduction in myelinated axons (up to 120 m/s)

4. SYNAPSE
(a) Transmission:
- Action potential → Ca^{2+} influx → Vesicle exocytosis → Neurotransmitter release → Postsynaptic receptor binding

(b) Neurotransmitters:
- Excitatory (Acetylcholine, Glutamate, Norepinephrine, Epinephrine, Dopamine, Serotonin).
- Inhibitory (GABA, Glycine, Endorphins)

5. BASIC ORGANIZATION OF HUMAN NERVOUS SYSTEM
(a) CNS
- **Protection** (Meninges: Dura mater, Arachnoid, Pia mater + Cerebrospinal fluid).
- **Brain** (Cerebrum lobes, Brainstem, Diencephalon/Limbic system, Cerebellum).
- **Spinal Cord** (H-shaped grey matter, outer white matter).

(b) PNS
- 12 pairs of Cranial Nerves.
- 31 pairs of Spinal Nerves (mixed).

(c) Motor Divisions
- Somatic (Voluntary skeletal muscles).
- Autonomic (Involuntary: Sympathetic vs. Parasympathetic).

6. RECEPTORS IN HUMAN BODY
- **Taste:** Taste buds in papillae (Cranial nerves VII, IX, X).
- **Smell:** Olfactory chemoreceptors in nasal epithelium (Cranial nerve I).
- **Touch & Pain:** Nociceptors + Mechanoreceptors (Meissner's, Hair follicle, Merkel, Pacinian, Ruffini).

7. EFFECTS OF DRUGS
(a) Dynamics: Addiction, Tolerance, Withdrawal, Dopamine receptor downregulation (Caffeine, Nicotine).

(b) Abuse: Heroin, Cannabis, Nicotine, Alcohol, Inhalants

8. DISORDERS
- Vascular (Stroke).
- Infectious (Meningitis).
- Structural (Brain tumors, spinal injuries).
- Functional (Headaches, migraines).
- Degenerative (Parkinson's, Huntington's, MS, Alzheimer's).

9. DIAGNOSTIC TESTS
- **Diagnostic Tests:** EEG, CT scan, MRI

INTRODUCTION

Chapter's Intro:
- You have studied the basic elements of homeostasis.
- Here, in this chapter you will study them with reference to the nervous system.

Q.1 Why is coordination needed? S/Q

Ans. Need of Coordination:
- To survive, every animal must **stay connected** to the world around it.
- They need to **sense** and respond to **changes** in environment.
- The activities of their organs and systems are also **coordinated.**
- **Example:** The heart rate, breathing rate, digestion, and many other functions are coordinated.
- Due to such coordination, every function is regulated according to the needs of the body.

Tidbit
- Think of your body as a large, complex city. For the city to run smoothly, the traffic lights, emergency services, and power plants must all talk to each other. This **"talking"** is what we call **coordination.**

Q.2 Name two types of coordination in human & complex animals. S/Q

Ans. Two Types of Coordination in Human & Complex Animals:
- In humans and other complex animals, there are two types of coordination i.e.,
  i. **Nervous Coordination:** Which is controlled by the nervous system.
  ii. **Chemical Coordination:** Which is controlled by the endocrine system.
- This chapters deals with details of the human nervous system.

NERVOUS COORDINATION

Q.3 Define nervous coordination & how is it done? S/Q

Ans. Nervous Coordination:
- A type of coordination in which **nervous system** controls coordination with external environment and among the different parts of the body is called **nervous coordination.**
- Nervous coordination is done by **means of electrical signals.**

Topic: Basic Elements of Nervous Coordination:

Q.4 Why is nervous system most important for homeostasis? S/Q

Ans. Most Important for Homeostasis:
- For homeostasis, the nervous system is the **most important** because it **regulates other systems** and also maintains homeostasis by itself.

Tidbit
- Receptors act as transducers because they convert one form of energy into another form e.g., rod and cone cells in the retina of eye convert the light energy into nerve impulse **(electrochemical energy).**

Q.5 Name the basic components of nervous Coordination. S/Q

Ans. Basic Components of Nervous Coordination:
(1) Receptors. (2) Central Nervous System. (3) Effectors.

Q.6 Discuss the three components of nervous coordination. L/Q

Ans. Three Components of Nervous Coordination:

(1) Receptors:
- These are organs, **tissues or cells** - such as eyes, ears, or skin that detect stimuli (the changes in the external and internal environment). They act as **transducers.**
- When they receive stimuli, they generate nerve impulses in sensory neurons.
- For processing the **information,** the sensory neurons carry nerve impulse to central nervous system.

Check Understanding!
Q.1 What are organs, tissues, or cells like eyes and ears that detect stimuli called?
(A) Effectors. (B) Receptors.
(C) Neurons. (D) Synapses.

CamScanner

(2) Central Nervous System:
- It is the control centre of **nervous coordination**. It consists of **brain** and **spinal cord**.
- These parts are made of associative neurons (also called **inter-neurons**).
- They receive the nerve impulses from sensory neurons and process them.
- After processing, they **send nerve impulses** to effectors via motor neurons.

(3) Effectors:
- These are the parts which produce responses on **receiving nerve** impulse sent by the central nervous system via motor neurons.
- **Muscles and glands** act as effectors.
- **Muscles** produce response by contracting while **glands** produce secretion.

Path of Message in Nervous Coordination:
- So, in nervous coordination, the **path of a message** (nerve impulse) consists of receptors, sensory neurons, central nervous system (inter-neurons), motor neurons, and effectors. In this pathway, the neurons act as the functional units.

Receptors ⟶ Sensory Neurons ⟶ CNS ⟶ Motor Neurons ⟶ Effectors

Multiple Choice Questions (MCQs)	Key
1. What are the two types of coordination found in humans and complex animals? (A) Nervous, chemical. (B) Internal, external. (C) Sensory, motor. (D) Electrical, physical.	1.(A)
2. By what means is nervous coordination carried out? (A) Chemical messengers. (B) Electrical signals. (C) Hormonal secretions. (D) Mechanical waves.	2.(B)
3. Why do receptors act as transducers? (A) They process data. (B) They convert energy. (C) They contract muscles. (D) They secrete hormones.	3.(B)
4. What is the direct role of sensory neurons in the nervous coordination pathway? (A) Carry to CNS. (B) Contract muscles. (C) Produce secretions. (D) Process impulses.	4.(A)
5. Why is the nervous system considered the most important system for maintaining homeostasis? (A) It regulates others. (B) It pumps blood. (C) It digests food. (D) It stores energy.	5.(A)
6. How do the two types of effectors differ in their responses? (A) Contracting vs secreting. (B) Electrical vs chemical. (C) Internal vs external. (D) Sensory vs motor.	6.(A)

NEURONS

Q.7 What are neurons? S/Q

Ans. Neurons:
- A **structural** and **functional** unit of nervous system is called **neuron.**
- The function of the nervous system (responding to the environment and coordinating body activities) is actually carried out by specialized cells celled **neurons** (also called **nerve cells**).

Topic: Structure of Neuron:

Q.8 Explain the structure of a neuron. Exercise L/Q.1

Ans. Structure of a Neuron:
- As we know **neuron** is structural &functional unit of nervous system.
- There are **many variations in the structure** of neurons.
- But all neurons have the **three basic** components:
  (i) Cell body. (ii) Dendrites. (iii) Axon.

(i) Cell Body:
- The cell body is an **enlarged** region of the neuron cell.

Check Understanding!
Q.2 Outline the structure and specific functions of dendrites within a neuron.

- The nucleus of neuron and most of its organelles are located in **cell body.**
- The cytoplasm in cell body is characterised by the presence of Nissl's granules.
- **Nissl's Granules:** The group of ribosomes and rough endoplasmic reticulum are called **Nissl's granules.**

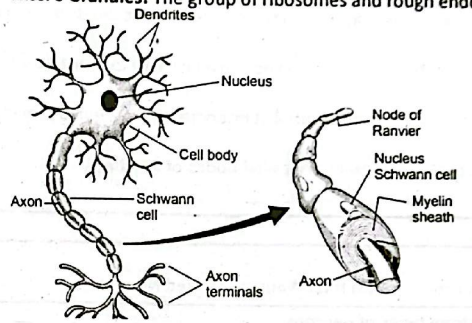


Figure: Structure of a model neuron

Tidbit
- **An axon can be quite long:** the axons controlling the muscles in your feet are more than a meter long, and the axons that extend from the skull to the pelvis in a **giraffe** are about **three meters long!**

(ii) Dendrites:
- Dendrites are **membrane-bounded** extensions of cell body.
- Dendrites **receive information** from other neurons or other cells.
- Dendrites convert the **information** into **nerve impulses** and carry it **toward cell body.**
- From cell body, the impulses are **conducted** away along an axon.
- **Motor** and **inter-neurons** receive impulses from **many different** sources simultaneously. That is why, they possess **highly branched** dendrites.

(iii) Axon:
- Axon is a **long and membrane bounded** extension of cell body.
- It transmits **impulses** away from **cell body.**
- A neuron may have a **single axon** or branching axons.
- The end of an axon is called the **axon terminal.**
- It may contact and communicate with a **muscle cell, a gland cell, or another neuron.**

Topic: Supporting Cells - The Neuroglia:

Q.9 What are neuroglia & how are neuroglia important for neurons? S/Q

Ans. Neuroglia:
- In the nervous system, there are **special cells** which support neurons.
- The supporting cells of neuron are called **neuroglia or glial cells.**

➢ **Importance of Neuroglia For Neurons:**
- They supply **nutrients** to neurons, **remove wastes,** and provide immunity.
- **Examples:** Schwann cells and oligodendrocytes.

Q.10 What are Schwann cells & oligodendrocytes, how they play different role in neurons? S/Q

Ans. Schwann Cells & Oligodendrocytes:
- They are **wrapped** around the **axons** of many neurons, and make **myelin sheaths** (sheaths of multiple membrane layers) around the axons.
- **Schwann Cells:** They produce myelin sheaths around the axons in the **peripheral nervous system.**
- **Oligodendrocytes:** They produce myelin sheath in **central nervous system.**

Q.11 What is myelin sheath? How is it important for nerve impulse? Also discuss the role of myelin sheath in naming of axons. L/Q

Ans. Myelin Sheath:
- An **insulating covering** around axon is called **myelin Sheath.**
- **Importance:** It helps in the fast transmission of nerve impulse along the axons.

CamScanner

➢ **Role of Myelin Sheath in Naming of Axons:**

(i) Myelinated Axons: The neurons which have myelin sheaths around axons are called **myelinated axons.**

(ii) Non-myelinated Axons: The neurons which do not have such covering are called **nonmyelinated axons.**

- In the CNS, myelinated axons make white matter, and the nonmyelinated dendrites and cell bodies make grey matter.
- In the peripheral nervous system, both myelinated and non-myelinated axons are bundled together to form **nerves.**
- In myelinated neurons, the myelin sheath is interrupted at **intervals** of 1 to 2 mm by small gaps (non-myelinated parts).

(iii) Nodes of Ranvier: The non-myelinated interruptions are called **nodes of Ranvier.**

Topic: Types of Neurons:

Q.12 Name the three types of neurons? S/Q

Ans. Three Types of Neurons:

(1) Sensory Neuron. (2) Motor Neuron. (3) Inter-Neurons (Mixed Neurons).

Q.13 Describe the structure & functions of three types of neurons. L/Q

Ans. Structure & Functions of Three Types of Neurons:

(1) Sensory Neurons:

- **Function:** The neuron which **conduct impulses** from **receptors** to central nervous system.

Structure of Sensory Neurons:

- Their cell bodies are located outside of the CNS in the form of **clusters called ganglia.**
- Their cell body gives rise to a **dendrite** on one side and an axon at the other.
- **Most sensory neurons are pseudo-unipolar:** A single process leaves the cell body and splits into a peripheral branch (to the receptor) and a central branch (an axon into the CNS).
- The terminal end of dendrite has many smaller branches, which are connected to the receptors.

Check Understanding!

Q.3 Which glial cells produce myelin sheaths around axons in the central nervous system?

(A) Schwann cells.
(B) Sensory cells.
(C) Oligodendrocytes.
(D) Astrocytes.

(2) Motor Neurons:

- **Function:** The neurons which conduct **impulses away** from **central nervous system** to effectors.

Structure of Motor Neurons:

- They have a **cell body** on one end, a long axon and many dendrites.
- Their cell bodies are **located in the CNS.**
- They are multipolar. It means that they have many dendrites that branch out into many smaller dendrites.
- Their dendrites make contact with other neurons in brain and **spinal cord.**

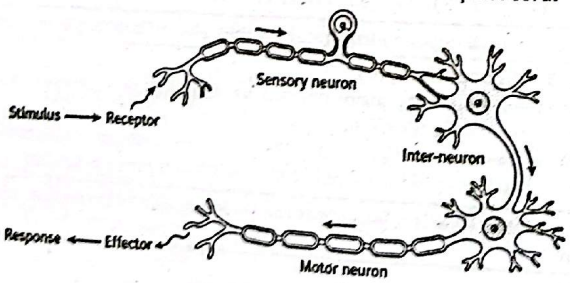


Figure: Types of neurons

(3) Inter-Neurons (Associative Neurons):

- **Function:** The neurons which occur entirely within the **CNS.** They receive **impulses** from sensory neurons or other inter-neurons and transmit impulses to motor neurons or other inter-neurons.

Structure of Inter-Neurons:

- Some inter-neurons have short axons and form circuits with nearby neurons to analyse small information.
- Other inter-neurons have long axons and connect with **other inter-neurons** in different regions of the brain and spinal cord.

Topic: Reflex Arc:

Q.14 What are neural pathways & reflex arc? S/Q

Ans. Neural Pathways:

- The specific pathways in **nervous system** to receive, transmit and process impulses are called **neural pathways (arcs).**
- Neural pathways may compose of only a **few neurons,** or may be **more complex networks.**

Check Understanding!

Q.4 Describe the pathway and muscular response involved in the knee-jerk reflex arc.

➢ **Reflex Arc:**

- The simplest neural pathway which controls reflex action is called **reflex arc.**

Q.15 Define reflex action. S/Q

Ans. Reflex Action:

- An immediate, automatic and involuntary responses to external and internal stimuli is called reflex action.

Topic: The Knee-Jerk Reflex:

Q.16 Explain the function of the three types of neurons with the help of a reflex arc. Exercise L/Q.2

OR How is the reflex action of knee generated and discuss the role of neurons in reflex action of knee. L/Q

Ans. The Knee-Jerk Reflex:

➢ **Generation of Knee Reflex Action:**

- Knee-jerk is a reflex that occurs when **someone** hits the **tendon** below the knee (the patellar tendon) with a hammer.
- Tapping on that **tendon** acts as a stimulus.

➢ **Role of Neurons in Reflex Action of Knee:**

- The **stimulus** of tapping is sensed by a receptor present in the **quadriceps muscle** of the thigh.
- The receptor generates a nerve impulse in a **sensory** neuron. The sensory neuron carries this impulse to the **spinal cord.** Here, the sensory neuron **transfers** the impulse to a motor neuron without involving an **inter-neuron.**
- The motor neuron carries the impulse to the **effector** (quadriceps muscle) which contracts.
- It leads to the extension of the **lower leg at the knee** (i.e., the lower leg kicks forward).
- In the meantime, **sensory neuron** also activates an **inter-neuron** in spinal cord. The inter-neuron releases chemicals which inhibit the motor neurons that connect to the **hamstrings muscle.**
- It results in the relaxation of hamstrings during the **extension of the lower leg.**

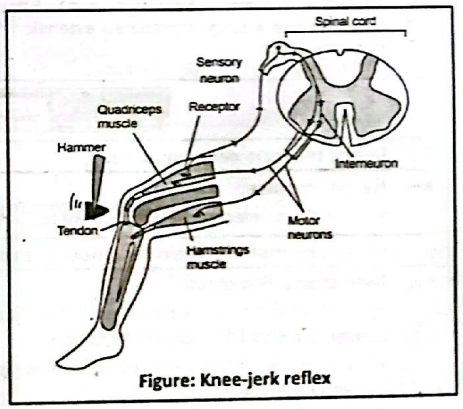


Figure: Knee-jerk reflex

CamScanner

Multiple Choice Questions (MCQs)

	Key
1. Nervous coordination operates rapidly through: (A) Hormones. (B) Blood circulation. (C) Electrical impulses. (D) Enzymes.	1.(C)
2. Neurons are the _____ units of the nervous system. (A) Secretory and excretory. (B) Structural and functional. (C) Muscular and connective. (D) Digestive and absorptive.	2.(B)
3. Which part of a neuron contains the nucleus, cytoplasm and organelles? (A) Axon. (B) Dendrite. (C) Cell body. (D) Axon terminal.	3.(C)
4. Dendrites mainly function to: (A) Carry impulses away from the cell body. (B) Carry impulses toward the cell body. (C) Produce myelin sheath. (D) Secrete neurotransmitters.	4.(B)
5. Which part of a neuron carries impulses away from the cell body? (A) Dendrite. (B) Axon. (C) Cell body. (D) Nissl granules.	5.(B)
6. The myelin sheath in the peripheral nervous system (PNS) is produced by: (A) Oligodendrocytes. (B) Inter-neurons (C) Astrocytes. (D) Schwann cells.	6.(D)
7. Nodes of Ranvier are: (A) Cell bodies of neurons. (B) Gaps in myelin segments. (C) Branches of dendrites. (D) Synaptic vesicles.	7.(B)
8. Which type of neuron carries impulses from receptors to the central nervous system? (A) Sensory neuron. (B) Inter-neuron. (C) Motor neuron. (D) Multipolar neuron.	8.(A)
9. Inter-neurons are mainly responsible for: (A) Activating muscles. (B) Processing information. (C) Receiving stimuli. (D) Producing myelin.	9.(B)
10. A reflex arc normally includes all of the following EXCEPT: (A) Receptor. (B) Sensory neuron. (C) Motor neuron. (D) Hormone.	10.(D)
11. Why are reflex actions faster than voluntary actions? (A) They bypass receptors. (B) Processing occurs in the spinal cord. (C) They do not involve neurons. (D) They occur only in muscles.	11.(B)
12. During the knee-jerk reflex, the sensory neuron directly excites the motor neuron supplying the: (A) Quadriceps. (B) Hamstrings. (C) Gastrocnemius. (D) Biceps femoris.	12.(A)
13. In the knee-jerk reflex, relaxation of the hamstrings occurs because the sensory neuron activates: (A) A motor neuron. (B) A Schwann cell. (C) An inhibitory inter-neuron. (D) An oligodendrocyte.	13.(C)
14. Which sequence correctly represents the pathway of a nerve impulse during nervous coordination? (A) Motor neuron → Receptor → CNS → Effector. (B) Receptor → Sensory neuron → CNS → Motor neuron → Effector. (C) Receptor → Motor neuron → Sensory neuron → Effector. (D) CNS → Receptor → Sensory neuron → Effector.	14.(B)
15. A neuron has a long, myelinated extension that conducts impulses away from the cell body. This structure is the: (A) Dendrite. (B) Cell body. (C) Nissl granule. (D) Axon.	15.(D)

NERVE IMPULSE

Q.17 Define the term nerve impulse. S/Q

Ans. Nerve Impulse:

- A wave of **electrochemical changes** that travels along the length of neuron is called **nerve impulse.**

Q.18 What is membrane potential & how is membrane potential generated & changed? S/Q

Ans. Membrane Potential:

- The difference in the electrical charges across cell membrane is called **membrane potential.**

➢ **Generation of Membrane Potential:**

- All cells, including neurons, have **electrical charges** on their inner and outer sides.
- The **inner side** of membrane (towards cytoplasm) is electrically negative while the outer side (towards extracellular fluid) is positive. This difference in **electrical charges** on both sides of membrane generates membrane potential.

Check Understanding!

Q.5 What is the resting membrane potential of a polarized resting neuron?
(A) +50 mV (B) 0 mV
(C) -30 mV (D) -70 mV

- These membrane potentials are due to different concentrations of positive and negative ions and due to the movement of ions **across cell membrane.**
- In most cells, the inward and outward movement of ions through the membrane is constant. So, the net negative charge on the inner side **remains constant.**

➢ **Change in Membrane Potential:**

- The cell membranes of muscle and neurons **can change the rates of ions movements.** So, their membrane potentials also change.

Topic: Generation and Transmission of Nerve Impulse:

Topic: (1) Before Nerve Impulse - Resting Membrane Potential:

Q.19 What is resting membrane potential (RMP)? Discuss the factors which establish resting membrane potential. Elaborate your answer with the help of diagram. L/Q

Ans. Resting Membrane Potential:

- The membrane potential when **inner side of neuron** is more **negative** & **outer side** is more positive is called **resting membrane potential.**
- A resting neuron (not conducting a signal) is said to be **polarized.** At this condition Membrane Potential is about **– 70 millivolts (–70mV).** The negative sign indicates that the **inside of the cell** is negative with respect to the outside.

Check Understanding!

Q.6 Explain the ionic events that occur during the depolarization phase of an active membrane potential.

➢ **Factors which Establish RMP:**

- In resting neurons, RMP is established by the following factors:

(1) More Anions At Inner Side:

- Large **negatively** charged molecules e.g., **proteins** and nucleic acids are more abundant inside the cell and cannot diffuse out. These molecules are called **fixed anions.**

(2) Concentration of K^+ & Na^+ ions & Working of Na-K Pumps:

- The concentration of K^+ is **30 times greater** inside the neuron than outside. While, the concentration of Na^+ **is 10 times** greater outside than inside the cell.
- Sodium-potassium pumps present in neuron membranes constantly move these ions against their concentration gradient by the expenditure of ATP.
- For every two K^+ that are actively transported inward, three Na^+ are pumped out as a result inside becomes more negative than outside & outside becomes more positive than inside.

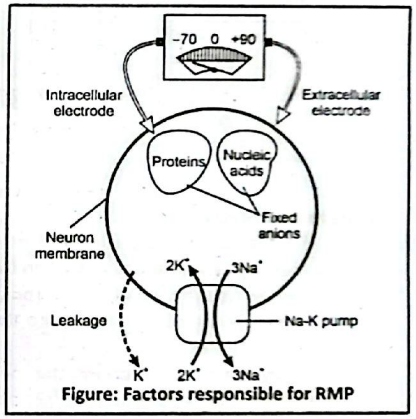


Figure: Factors responsible for RMP

(3) Some K^+ ions also leak out of the cell through K^+ gates of membrane.

Topic: (2) Generation of Nerve Impulse - Active Membrane Potential (AMP):

Q.20 Describe polarization, depolarization and hyperpolarisation of neuron membrane. Exercise L/Q.3, L/Q.4
OR What is active membrane potential & how is active membrane generated? L/Q

Ans. Active Membrane Potential:

- When a **neuron becomes active** (generates nerve impulse), the membrane potential at a region of neuron is reversed.
- When inside of membrane becomes more positive than the outside is called **Active Membrane Potential (or action potential).**

➢ **Generation of Nerve Impulse: (Generation of Action Potential)**

- The following events happen for **producing action potential (Generation of Nerve Impulse).**

CamScanner

(i) Depolarization:

- **Na-Gates Open:** The **Na^+ gates** of membrane **open** and Na^+ ions rush into the cell. This sudden inward movement of Na^+ ions reduces the negative charge inside of the membrane.
- **Change in Electrical Potential:** The electrical potential of the membrane changes from **–70 mV** towards zero and then reaches to 50 mV.
- The reversal of polarity from **–70mV to +50 mV** across two sides of membrane is called **depolarization**. This depolarization produces action potential on a **short region** of neuron for about **one millisecond.**

Tidbit

- The propagation of action potentials is similar to the action when people in a stadium perform the "wave". Individuals stay in place as they stand up (depolarize), raise their hands (action potential), and sit down again (repolarize).

(ii) Repolarization:

- After a **short period** of depolarization, Na^+ gates close and the K^+ gates open.
- So, **more K^+ ions** diffuse out. It makes the inside of cell negative again which is called **repolarization of membrane (negative inside and positive outside).**

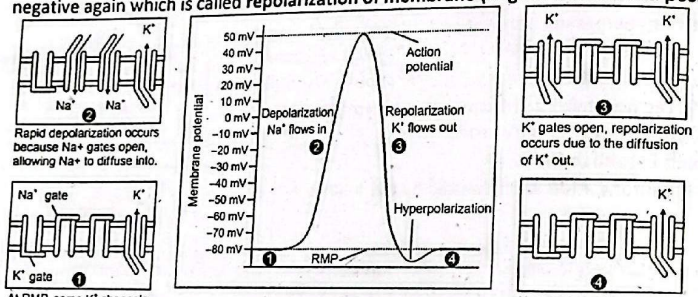


Figure: Generation of action potential

(iv) Hyperpolarization:

- The repolarization **carries the membrane** potential to a value slightly more negative than the resting potential for a brief period. This is called **hyperpolarization.**
- Hyperpolarization results due to the slight delay in closing all the **K^+ gates.**
- During **hyperpolarization**, the neuron cannot generate another **action potential** and period is called the **refractory period (Very short time).**

(iv) Return to Original RMP:

- After a short **refractory period**, original ionic distribution is restored by sodium-potassium pump and the membrane returns to its RMP i.e., **–70 mV.**
- In this way, the region of neuron prepares itself for the next action potential.

Topic: (3) Propagation of Action Potentials:

Q.21 How does action potential propagate? S/Q

Ans. Propagation of Action Potentials:

- In reality, action potentials (impulses) do not really **travel** along the axon.
- Rather, they are reproduced at **adjacent** regions along the axon.

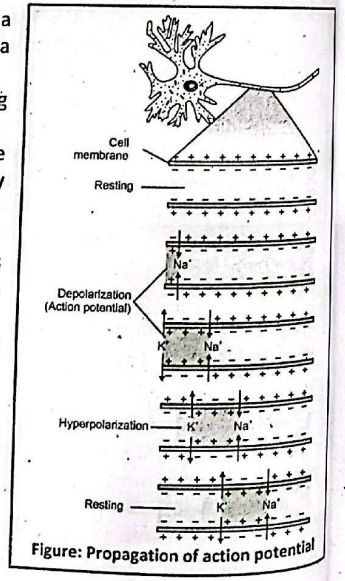


Figure: Propagation of action potential

- An action potential in a **region of axon** serves as a depolarization stimulus for the next region.
- So, the next region produces its own action potential.
- Meanwhile, the previous region repolarizes back to the RMP.

Topic: Velocities of Nerve Impulse:

- The strength (amplitude) of **action potentials** remains constant along the whole length of axon.
- The action potential at the **end of axon** is as **strong** as the first **action** potential.
- However, the velocity of nerve impulse i.e., speed of conduction of action potential may **vary.**

Check Understanding!

Q.7 What term describes the jumping of action potentials from one node of Ranvier to another in myelinated axons?
(A) Synaptic transmission.
(B) Saltatory conduction.
(C) Active transport.
(D) Hyperpolarization.

Q.22 Which factors can effect the velocity of the nerve impulse? S/Q

Ans. Factors Effect Velocity of Nerve Impulse:

- The velocity of nerve impulse is dependent on **two factors:**
  (i) Diameter of Axon. **(ii) Myelin Sheath on Axon.**
- The velocity is greater if the diameter of the **axon** is large or if the axon is myelinated.

Q.23 Describe the saltatory conduction of nerve impulse. Exercise Q.5
OR What is salutatory nerve impulse & how salutatory nerve impulse is conducted? Q

Ans. Saltatory Nerve Impulse:

- The action potential jump from one node of Ranvier to another, skipping the myelinated regions of membrane is called as saltatory conduction of nerve impulse.
- In myelinated axons, action potentials are only produced at the nodes of Ranvier.
- Saltatory nerve impulse up to **50 times** faster than the nerve impulse through the fastest **nonmyelinated axons.**
- In human, the **non-myelinated** neurons conduct impulses at speed of 1 to 3 metres per second.
- The myelinated neurons conduct at speeds of up to **120 meters per second.**

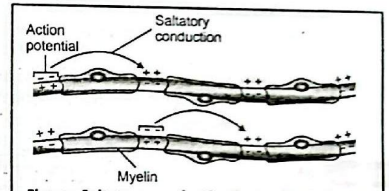


Figure: Saltatory conduction in myelinated axon

Multiple Choice Questions (MCQs)

		Key
1.	**The potential difference across the cell membrane is called the:** (A) Action potential. (B) Membrane potential. (C) Resting threshold. (D) Saltatory potential.	1.(B)
2.	**The resting membrane potential of a neuron is approximately:** (A) +70 mV. (B) 0 mV. (C) –70 mV. (D) –120 mV.	2.(C)
3.	**In a resting neuron, the inside of the cell is _____ relative to the outside.** (A) Negative. (B) Neutral. (C) Positive. (D) Equally charged.	3.(A)
4.	**The sodium-potassium pump moves _____ Na^+ ions out for every _____ K^+ ions moved in.** (A) 2, 3. (B) 3, 2. (C) 1, 2. (D) 2, 1.	4.(B)
5.	**The resting membrane is more permeable to:** (A) Sodium ions. (B) Calcium ions. (C) Chloride ions. (D) Potassium ions.	5.(D)
6.	**During depolarization, voltage-gated _____ channels open.** (A) Potassium. (B) Calcium. (C) Sodium. (D) Chloride.	6.(C)
7.	**Repolarization occurs mainly because:** (A) Na^+ enters the neuron rapidly. (B) K^+ leaves via voltage-gated channels. (C) Proteins leave the neuron. (D) Ca^{2+} enters the neuron.	7.(B)
8.	**During hyperpolarization, the neuron becomes:** (A) More positive than normal. (B) Permanently depolarized. (C) Equal to zero membrane potential. (D) More negative than the resting level.	8.(D)
9.	**Which phase ensures one-way propagation of a nerve impulse and limits firing frequency?** (A) Refractory period. (B) Hyperpolarization. (C) Depolarization. (D) Resting membrane potential.	9.(A)
10.	**In myelinated axons, action potentials occur mainly at the:** (A) Schwann cells. (B) Axon terminals. (C) Nodes of Ranvier. (D) Cell body	10.(C)
11.	**Why does a nerve impulse normally travel in only one direction along an axon?** (A) Sodium ions move only toward the axon terminal.	11.(B)

CamScanner

(B) Refractory period behind action potential prevents propagation.
(C) Potassium channels open only at the axon terminal
(D) Myelin blocks backward conduction.

12. Why do large-diameter axons conduct impulses faster than small-diameter axons because they?
(A) Contain more sodium ions. (B) Produce larger action potentials.
(C) Have more dendrites. (D) Offer less internal resistance.

13. Saltatory conduction is much faster because the impulse:
(A) Travels continuously along the membrane. (B) Jumps from one node of Ranvier to next.
(C) Bypasses the axon terminals. (D) Eliminates the need for action potentials.

14. Which type of axon is expected to conduct nerve impulses at the highest speed?
(A) Small non-myelinated axon. (B) Large non-myelinated axon.
(C) Thick myelinated axon. (D) Thin unmyelinated sensory axon.

12.(D) 13.(B) 14.(C)

SYNAPSE

Q.24 What is synapse? Briefly describe its structure. Exercise L/Q.6

Ans. Synapse:

- The **junction between** axon terminal of **one neuron** and the dendrites of other neurons, or effector cells (of muscle or gland) is called a **synapse.**

For Information

Q. What is neuromuscular Junction?
Ans. The synapse between a motor neuron and a muscle fibre is also called **neuromuscular junction.**

➢ **Structural Parts of Synapse:**

- At a synapse, the two neurons or a neuron and a cell are not in direct contact.
- **Synaptic Cleft:** A fluid-filled gap between two neurons called a **synaptic cleft.**
- **Pre-Synaptic Neuron:** The neuron whose **axon transmits** action potentials towards synapse is the presynaptic neuron.
- **Postsynaptic Neuron:** The neuron or cell on the other side of the synapse is the postsynaptic cell.

Check Understanding!

Q.8 Outline the initial steps of synaptic transmission from the arrival of an action potential to the exocytosis of neurotransmitters.

Topic: Mechanism of Synaptic Transmission:

Q.25 Explain synaptic transmission of nerve impulse. Exercise L/Q.7
OR What is synaptic transmission, discus its mechanism? L/Q

Ans. Synaptic Transmission:

- The movement of **action potential** across synapse is called **synaptic transmission.**

➢ **Mechanism of Synaptic Transmission:**

- The axon terminal of **presynaptic neuron** has several synaptic knobs.
- These knobs contain numerous **synaptic vesicles** which are packed with chemicals called **neurotransmitters.**
- When an action potential on a **presynaptic neuron** reaches a synapse, its information is transmitted to postsynaptic neuron or effector cell.

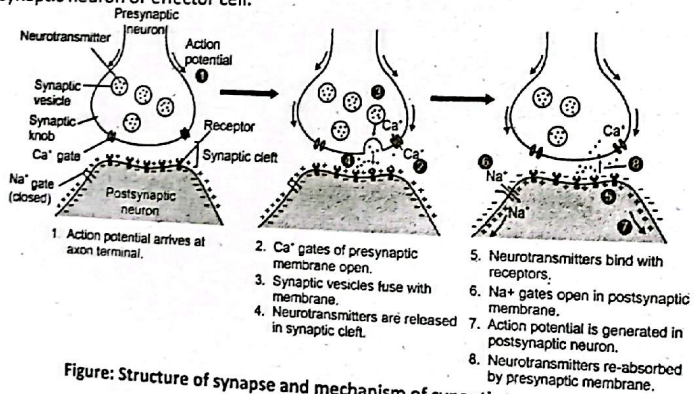


Figure: Structure of synapse and mechanism of synaptic transmission

- **Synaptic Transmission** happens in the following way: (As shown figure)

(1) Calcium Gats Open: When action **potential** arrives at **synaptic knobs**, calcium gates in **presynaptic membrane** open.

For Information

- The higher the frequency of action potentials in the presynaptic axon, the more **neurotransmitters** are released.

(2) Calcium ions present in synaptic cleft diffuse rapidly into **presynaptic axon.**

(3) Due to the diffusion of calcium ions into **presynaptic axon**, its synaptic vesicles fuse with its membrane. This fusion causes the release of **neurotransmitters** from vesicles by **exocytosis.**

(4) The released neurotransmitters **diffuse** rapidly in the cleft and bind to **postsynaptic** membrane at receptor proteins.

(5) The binding of **neurotransmitters** acts as a massage for postsynaptic membrane. Its Na^+gates open and an action potential is generated in postsynaptic membrane.

(6) After their action, the **neurotransmitters** do not remain in the synaptic cleft indefinitely.
At many synapses, the used **neurotransmitters** are reabsorbed by the presynaptic neuron. At other synapses, they are broken down by enzymes.

Topic: Types of Neurotransmitters:

Q.26 What are neurotransmitters & name two types of neurotransmitter also give one example of each type? S/Q

Ans. Neurotransmitters:

- **Definition:** The chemical substances, which are **released by nerve cells** (neurons) to pass the signals across a synapse (gap) to other neuron, muscle or gland are called **neurotransmitters.**
- Types of Neurotransmitters:
  (1) Excitatory Neurotransmitters. **Example:** Acetylcholine.
  (2) Inhibitory Neurotransmitters. **Example:** Gamma-amino butyric acid (GABA).

Check Understanding!

Q.9 Which biogenic amine neurotransmitter regulates sleep patterns, focus, and alertness in the central nervous system?
(A) Dopamine. (B) Norepinephrine.
(C) Acetylcholine. (D) Serotonin.

Q.27 Classify neurotransmitters as inhibitory and excitatory and list some common examples. Exercise L/Q.8
OR Define & discuss the excitatory & inhibitory neurotransmitters with their common examples. L/Q

Ans. Types of Neurotransmitters:

(i) Excitatory Neurotransmitters:

- The **neurotransmitters** which generate nerve impulse (action potential) in postsynaptic neurons by increasing membrane permeability to Na^+ are called **excitatory neurotransmitters.**

Examples of Excitatory Neurotransmitters:

(a) Acetylcholine: It acts between motor neurons and skeletal muscle fibres, and between many neurons.
(b) Glutamate: It acts in the CNS.
(c) Biogenic Amines: Biogenic amines are **excitatory** but they can also act as **inhibitory** neurotransmitters depending on the receptor they bind.

- They also function as **hormones.** These include:
  (i) Nor-epinephrine: It is made in CNS and sympathetic nerves. It regulates sleep patterns, focus and alertness.
  (ii) Epinephrine: It is released in **adrenal glands** and the brainstem. It plays a role in sleep. It also enables to become and stay alert.
  (iii) Dopamine: It is a neurotransmitter in **brain.** It controls body movements, pleasures related to motivation and also emotional stimulation.

For Information

- Degeneration of dopamine-releasing neurons produces the muscle tremors of Parkinson's disease.
- Insufficient activity of serotonin-releasing neurons may cause depression.
- Many antidepressant drugs block the elimination of serotonin from the synaptic cleft. So, serotonin remains in the synaptic cleft and reduces depression.

CamScanner

(iv) Serotonin: It is produced mainly by special endocrine cells of the **intestine (~90%)** and by neurons in the **CNS (~10%)**. It regulates appetite, sleep, memory and learning, temperature, mood, behaviour, muscle contraction etc.

(ii) Inhibitory Neurotransmitters:

- The neurotransmitters which decrease the **chance of transmission** of nerve impulse to the postsynaptic neuron are called as **inhibitory neurotransmitters.**
- When they bind to the **receptors** on **postsynaptic neuron, channels for chloride ions open** instead of opening sodium channels (which would excite the cell). As a result, **chloride ions** diffuse into neuron and make the inside of the membrane even **more negative** than RMP. This hyperpolarization causes **inhibitory effect.**

For Information

Sedative Drugs:

- Many sedative drugs enhance the binding of GABA to its receptors and so increase the effectiveness of GABA at the synapse.

For Information

Opium and its derivatives, morphine and heroin, have an analgesic (pain reducing) effect because they are similar in chemical structure to endorphins. So, they easily bind to the receptors of endorphins.

Check Understanding!

Q.10 Explain how inhibitory neurotransmitters such as GABA affect the postsynaptic membrane potential.

Examples of inhibitory Neurotransmitters:

(a) Gamma - aminobutyric acid (GABA):

- It is the chief inhibitory neurotransmitter in CNS.
- It **reduces** the neural excitability throughout the nervous system.
- It helps to control and regulate various physiological and behavioural processes.
- It reduces anxiety, stress, and fear, and promotes relaxation and sleep.

(b) Glycine:

- It is an inhibitory **neurotransmitter** especially in the spinal cord, brainstem, and retina.

(c) Endorphins: These are inhibitory **neurotransmitters** released by **neurons in brain.**

- They reduce the release of excitatory neurotransmitters responsible for transmitting **pain messages.**
- In this way, they block the pain signals to reach the concerned part of the brain.

Effect of Nerve Gas on Neurotransmitter Acetylcholine:

- The excitatory neurotransmitter acetylcholine is released by motor neurons at neuromuscular junctions. It stimulates the skeletal muscles to contract.
- Then, it is broken down by acetylcholinesterase enzyme.
- A **nerve gas** (e.g., sarin, tabun, soman) is a highly toxic chemical that inhibits this enzyme.
- This inhibition leads to the accumulation of acetylcholine, causing overstimulation of skeletal muscle and cause muscles to remain contracted.
- If the **diaphragm** muscle remains contracted, the person is not be able to breathe. Other effects may include muscle twitching, convulsions, respiratory distress, and ultimately death.

Multiple Choice Questions (MCQs)

		Key
1.	**A synapse is the junction between the axon terminal of one neuron and:** (A) Another neuron or an effector. (B) A dendrite only. (C) The cell body only. (D) A Schwann cell.	1.(A)
2.	**The transmitting cell in a synapse is called the:** (A) Postsynaptic cell. (B) Presynaptic cell. (C) Sensory cell. (D) Receptor cell.	2.(B)
3.	**The narrow gap between two communicating cells at a synapse is known as the:** (A) Node of Ranvier. (B) Neural canal. (C) Axon hillock. (D) Synaptic cleft.	3.(D)
4.	**A motor neuron-to-muscle synapse is called a:** (A) Reflex arc. (B) Neuromuscular junction. (C) Ganglion. (D) Neural plexus.	4.(B)
5.	**Arrival of an action potential at the presynaptic terminal opens voltage-gated _____ channels.** (A) Sodium. (B) Potassium. (C) Calcium. (D) Chloride.	5.(C)
6.	**Calcium present in:** (A) Dendrite. (B) Synaptic knob. (C) Cell body. (D) Axon hillock.	6.(B)

		Key
7.	**Neurotransmitters are released from synaptic vesicles by:** (A) Diffusion. (B) Active transport. (C) Osmosis. (D) Exocytosis.	7.(D)
8.	**After release, neurotransmitters diffuse across the:** (A) Synaptic cleft. (B) Myelin sheath. (C) Cell membrane. (D) Node of Ranvier.	8.(B)
9.	**Which neurotransmitter is the major excitatory neurotransmitter in the central nervous system (CNS)?** (A) GABA. (B) Glycine. (C) Glutamate. (D) Endorphins.	9.(C)
10.	**Which neurotransmitter is the chief inhibitory neurotransmitter in much of the CNS?** (A) Acetylcholine. (B) Dopamine. (C) GABA. (D) Serotonin.	10.(C)
11.	**A higher frequency of action potentials usually strengthens synaptic transmission because it causes:** (A) A fewer neurotransmitters to be released. (B) More synaptic vesicles to release neurotransmitter (C) Closure of calcium channels. (D) Inhibition of exocytosis of neurotransmitters.	11.(B)
12.	**Excitatory neurotransmitters increase the probability of an action potential mainly by:** (A) Increasing Na^+ permeability. (B) Increasing K^+ leakage. (C) Closing sodium channels. (D) Increasing Cl^- leakage.	12.(A)
13.	**Which neurotransmitter primarily reduces neural excitability and helps regulate anxiety and sleep?** (A) Glutamate. (B) Acetylcholine. (C) GABA. (D) Dopamine.	13.(C)
14.	**Which process normally helps to terminate the action of a neurotransmitter?** (A) DNA replication. (B) Potassium secretion. (C) Continuous calcium entry. (D) Enzymatic breakdown.	14.(D)

BASIC ORGANIZATION OF HUMAN NERVOUS SYSTEM

Q.28 Name the different components of human nervous system. S/Q

Ans. Components of Human Nervous System:

- **The human nervous system consists of:**

(1) Central Nervous System (CNS): The CNS consists of: (a) Brain. (b) Spinal cord.

(2) Peripheral Nervous System (PNS): The PNS consists of:

(a) Cranial Nerves: Which arise from brain.

(b) Spinal Nerves: Which arise from brain spinal cord.

- The nerves make **sensory** and **motor** pathways.
- There are two motor pathways:

(i) Voluntary (Somatic) Nervous System: Which controls voluntary (skeletal) muscles.

(ii) Autonomic Nervous System: Which controls involuntary muscles and glands.

- The autonomic system consists of:

(a) Sympathetic Nervous System.

(b) Parasympathetic Nervous Systems.

Check Understanding!

Q.11 Which thin middle layer of the meninges acts as a barrier between the cerebrospinal fluid and the blood in the dura mater?

(A) Dura mater. (B) Pia mater (C) Arachnoid. (D) Cerebral cortex.

Q.29 Show the basic organization of nervous system in the form of flow sheet. S/Q

Ans. Organization of Nervous System:

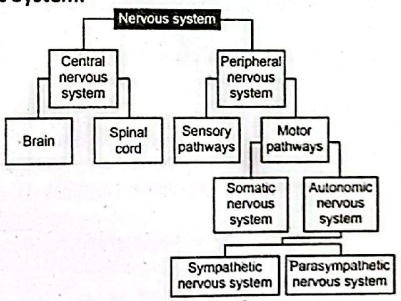


Figure: Basic organization of nervous system

CamScanner

Topic: Central Nervous System - Brain and Spinal Cord:

Q.30 What is CNS?

Ans. CNS:

- The nervous system which is composed of brain & spinal cord is said as CNS.
- The CNS (brain and spinal cord) is made of **inter-neurons** and **neuroglia.**

Q.31 How are brain & spinal cord protected?

Ans. Protection of Brain & Spinal Cord:

- Brain & Spinal Cord both are protected by the **two ways.**

Protection of Brain	Protection of Spinal Cord
• Brain is enclosed for protection within the **cranium.** • Protected by meninges which consists of **three layers** of membranes.	• **Spinal cord** is enclosed for protection within vertebral column. • Also protected by meninges which consists of **three layers of membranes.**

Q.32 Name the three layers of meninges also give their importance for CNS.

Ans. Three Layers of Meninges:

(i) Dura Matter:

- The outermost thick layer (below skull and vertebrae) is called dura mater.
- **Importance For CNS:** It contains larger blood vessels.

(ii) Arachnoid:

- The **second layer** (below dura mater) of meninges is thin and is called **arachnoid.**
- **Importance For CNS:** It **acts as a barrier** between the **cerebrospinal** fluid present below it and the blood in the dura mater.

Check Understanding!

Q.12 Identify the four lobes of each cerebral hemisphere and state the primary function of the frontal lobes.

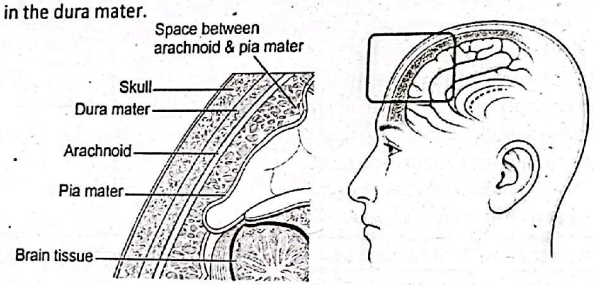


Figure: The meninges of brain

(iii) Pia Mater:

- The third layer is very delicate membrane called **pia mater.**
- **Importance For CNS:** It adheres to the surfaces of brain and spinal cord and has blood capillaries that nourish the brain and spinal cord.

For Information

- In Grade X, you have studied the traditional divisions of brain structure i.e., **forebrain, midbrain,** and **hindbrain.**
- Here, you would study the **structure of brain** according to the **latest defined divisions.**

Topic: Structure of Brain:

- The average adult human brain **weighs 1.4 kg** (about 2 percent of total body weight).
- It contains **86-100 billion neurons (90-99% of which are inter-neurons).**

Q.33 Draw the diagram of human brain & name its major parts. S/Q

Ans. Diagram of Human Brain & Name its Major Parts:

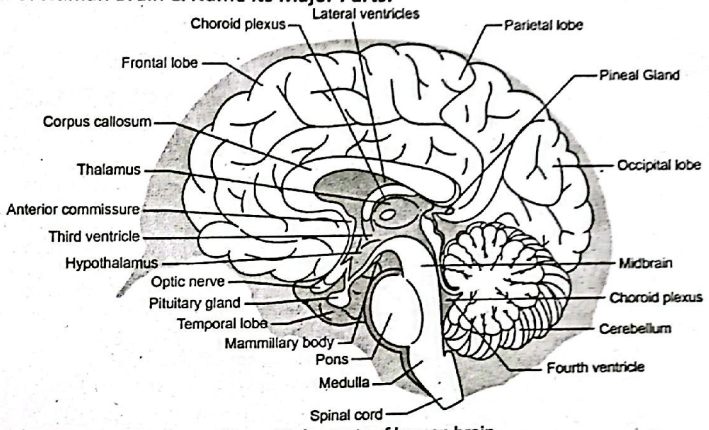


Figure: Major parts of human brain

Q.34 Write the names of four main parts of human brain. Exercise L/Q.9

Ans. Main Parts of Human Brain:

- The human brain consists of the following major parts.
  (1) Cerebrum. (2) Brainstem. (3) Diencephalon. (4) Cerebellum.

Topic: (1) Cerebrum:

Q.35 What is cerebrum, discuss its detailed structure, especially cerebral hemispheres, carpus callosum & lobes of hemisphere. Exercise L/Q.9

Ans. Cerebrum:

- Cerebrum is the **largest portion of human brain.**
- Its outer layer is highly folded.

Tidbit

- Damage to one hemisphere results in a loss of sensation and paralysis on the opposite side of body.

➢ **Cerebral Hemisphere:**

- Cerebrum is divided by a **deep groove** (fissure) into two parts called left and right cerebral hemispheres.
- **Corpus Callosum:** At the base of deep groove, **both cerebral hemispheres** are connected by the **corpus callosum.**
- Corpus callosum is a band of axons.
- Each hemisphere receives sensory information from the opposite side of the body and sends motor commands to that side.

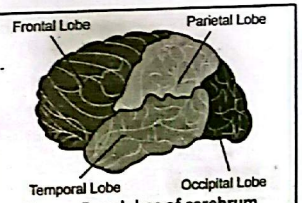


Figure: Four lobes of cerebrum

➢ **Lobes of Hemisphere: (Four Lobes in Each Hemisphere)**

- Each cerebral hemisphere is divided into four lobes:

(i) Frontal Lobes: The frontal lobes are associated with executive functions including **self-control, planning, reasoning,** and abstract thought.

(ii) Parietal Lobes: The parietal lobes process sensory information, give awareness of position of the body and the **environment, control attention, plan** and **execute motor movements.**

Check Understanding!

Q.13 What specific cortical area within the temporal lobe deals with different sound frequencies?

(A) Visual cortex. (B) Motor area.
(C) Auditory cortex. D. Sensory area

CamScanner

(iii) **Temporal Lobe:** The temporal lobes are involved in processing sensory input for appropriate retention of visual memory, **language comprehension**, and **emotions.**

(iv) **Occipital Lobe:** It controls vision.

Q.36 What is cerebral cortex, name its three areas and discuss their importance? Exercise L/Q.9

Ans. Cerebral Cortex:

- It is the folded outer **layer of cerebrum.** It is made of grey **matter** (containing cell bodies and non-myelinated axons).
- It is densely packed with interneurons (about 10% of all neurons in brain).

➢ **Three Area of Cerebral Cortex:**

- It contains the following areas.

(i) Motor Areas:

- **Importance:** The motor areas send impulses to the **voluntary** (skeletal) muscles.

(ii) Sensory Areas:

- **Importance:** The sensory areas receive information from different parts.
- **Auditory Cortex:** A specialized area called auditory cortex within the **temporal lobe** deal with different sound frequencies.
- **Visual Cortex:** The visual cortex in the occipital lobe deals with information from the eye.

(iii) Association Areas:

- **Importance:** Association areas of the **cortex** are the sites of higher mental activities. Some functions are associated with **one side,** such as language in the left and **visual-spatial ability** in the right.

Tidbit

Q. What are gyri also define sulcus & fissure.

Ans. The ridges in cerebral hemispheres are called **gyri** (singular, gyrus).

- Gyri are separated by grooves.
- A shallow groove is called **sulcus** (plural, sulci).
- A deep groove is called **fissure.**

Check Understanding!

Q.14 Describe the anatomical location and primary emotional role of the amygdalae within the limbic system.

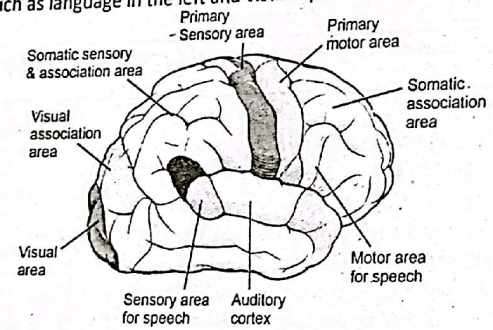


Figure: Sensory, motor and association areas in cerebral region

- Below cerebral cortex is the **white matter** (composed of myelinated axons).
- It links specific regions of the cortex with each other and with other neural centres.

Topic: (2) Brainstem: (Midbrain, Pons, Medulla Oblongata)

Q.37 What is brainstem, where is it located & describe its three components? Exercise L/Q.9

Ans. Brainstem:

- The cerebrum is connected to the spinal cord **through** brainstem.
- **Location:** The brainstem lies below the **cerebrum.**

Components of Brainstem:

- It consists of **three main divisions:**

(i) Midbrain: It relays visual and auditory information. It also contains reticular formation, which connects hindbrain with forebrain.

(ii) Pons: It transmits impulses between the cerebral hemispheres and cerebellum.

(iii) Medulla Oblongata: It serves as both a relay centre and a control centre for heart rate, respiration rate, and other homeostatic activities.

Topic: (3) Diencephalon: (Thalamus, Hypothalamus)

Q.38 Where is diencephalon located, write names and describe its two major parts. Exercise L/Q.9

Ans. Diencephalon:

- **Location of Diencephalon:** It is **present** deep within the **brain's center, above** the brainstem and **beneath** the cerebrum (specifically between the cerebral hemispheres).

➢ **Parts of Diencephalon:**

- It consists of two major parts:

(i) Thalamus:

- It is a relay centre between sensory information and the cerebrum.

(ii) Hypothalamus:

- It integrates the visceral activities.
- It regulates body temperature, hunger and satiety, thirst, and various emotional states.
- It also controls the pituitary gland, which in turn regulates many of the other endocrine glands.

Pineal Gland

- The pineal gland is located where the two halves of the thalamus join.
- It produces a hormone melatonin which controls sleep patterns.

Topic: Limbic System: (Hypothalamus, Amygdala, Hippocampus)

Q.39 What is limbic system give its location in brain and describe its three major parts? Exercise L/Q.9

Ans. Limbic System:

- Limbic system is a group of **linked structures** and is a functional network.
- **Location of Limbic System:** It lies on both sides of the **thalamus,** just under the **cerebrum.**

➢ **Parts of Limbic System:**

- Limbic system includes three main parts:

(i) Hypothalamus. (ii) Amygdala. (iii) Hippocampus.

- Also has several other nearby areas.

(i) Hypothalamus:

- The hypothalamus through its hormone production and neural connections acts as a major coordinating centre controlling **body temperature, hunger,** the **menstrual cycle,** water balance the **sleep-wake cycle** etc.

(ii) Amygdala:

- The **amygdalae** (singular: amygdala) are two almond shaped structures present deep within the temporal lobes.
- They control feeling and **emotions** of love, hate, anger, fear, rage and sexual arousal.

(iii) Hippocampus:

- The hippocampus consists of two "**horns**" that curve back from the amygdala.
- It plays role in the consolidation of information from **short-term memory** to **long-term memory.**

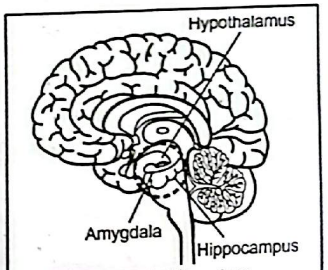


Figure: Limbic system

Topic: (4) Cerebellum: Exercise L/Q.9

Q.40 Write a short note on cerebellum.

Ans. Cerebellum:

- It is the second major **structure** in brain.
- **Location:** It lies below and behind the cerebral hemispheres. It coordinates muscle actions.
- It consists of a tightly folded layer of cortex, with white matter underneath.

CamScanner

- It receives sensory impulses from muscles, tendons, joints, eyes, and ears.
- It also receives information from other brain centres.
- It processes information about body position and controls posture.
- The cerebellum coordinates rapid and ongoing movements.
- It acts with the brainstem and with the cerebral cortex to coordinate skeletal muscles.

Topic: Ventricles of Brian:

Q.41 What are ventricles, discuss the ventricles in brain? S/Q

Ans. Ventricles of Brain:

- The brain and spinal cord are hollow structure. It means that they contain fluid filled cavities called ventricles.

➢ **Four Ventricles in Brian:**

- There are four ventricles in human brain.

(i) Two Lateral Ventricles: There are two large lateral ventricles in cerebrum.

(ii) Third Ventricle: The third ventricle is in diencephalon between the right and left thalamus.

(iii) Fourth Ventricle: The fourth ventricle is located between the cerebellum and the brainstem, and it is continuous with the central canal of spinal cord.

(iv) Function of Ventricles: The main function of ventricles is the production and circulation of cerebrospinal fluid.

Topic: Structure of Spinal Cord:

Q.42 Discuss the structure of spinal cord also draw its labelled diagram. L/Q

Ans. Structure of Spinal Cord:

- The spinal cord is a cable of neurons extending from the medulla oblongata of brain down through the backbone.

➢ **Protection of Spinal Cord:**

- It is enclosed and protected by the vertebral column and layers of meninges.
- Like brain, the neurons and neuroglia of spinal cord make grey and white matter, but the arrangement of grey and white matter in spinal cord is opposite to that of brain.

Check Understanding!

Q.15 What is the arrangement of grey and white matter within the spinal cord?

(A) Inner white matter and outer grey matter.
(B) Uniform distribution of grey and white matter.
(C) Grey matter enclosing the vertebral column.
(D) Inner H-shaped grey matter and outer white matter.

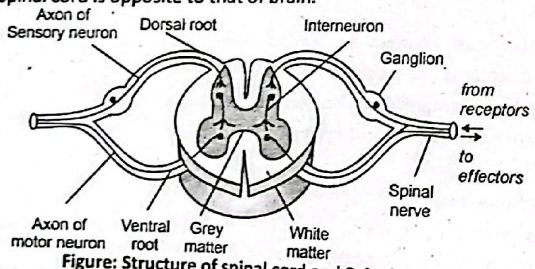


Figure: Structure of spinal cord and Spinal nerves

➢ **Zones in Spinal Cord:**

- There are two zones inside spinal cord.

(i) Inner Zone:

- The inner of spinal cord is H-shaped or butterfly-shaped zone is made of grey matter.
- It contains cell bodies of inter-neurons and motor neurons.
- It also contains neuroglia cells and non-myelinated axons.

(ii) Outer Zone:

- The outer zone of spinal cord is made of white matter.

Tidbit

- The diameter of spinal cord is between 0.25 to 0.5 inch.
- It is wider in cervical and lumbar regions.
- In cervical region, it deals with sensory input and motor output for arms and trunk.
- In lumbar region, it handles sensory input and motor output for legs.

- It contains myelinated axons. The inner zone also contains a central fluid-filled canal.
- It is a continuation of the fourth ventricle of brain.
- Spinal cord acts as information highway on which messages are transmitted between body and the brain.

Topic: Peripheral Nervous System - Cranial and Spinal Nerves:

- The peripheral nervous system consists of nerves and ganglia.
- Nerves are cable-like collections of axons.
- Ganglia are aggregations of cell bodies located outside CNS. The nerves which arise from brain are called cranial nerves.
- While those which arise from spinal nerves are called spinal nerves

Topic: Cranial Nerves:

Q.43 What are cranial nerves, name the nature and function of each cranial nerve. L/Q

Ans. Cranial Nerves:

- There are 12 pairs of cranial nerves. The first two pairs of cranial nerves (olfactory nerve and optic nerve) arise from cerebrum.
- The other 10 cranial nerve pairs arise from the brainstem.
- Some of cranial nerves are sensory, some are motor and others are mixed nerves (contain axons of sensory and motor neurons).

Check Understanding!

Q.16 List the nature and major functions of Cranial Nerve I and Cranial Nerve II.

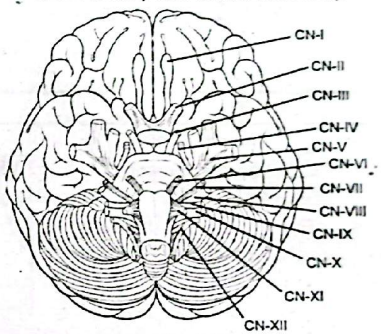


Figure: Cranial nerves

Table: Twelve Pairs of Cranial Nerves (CN) & their Functions

Cranial Nerve	Nature	Major Function
I	Sensory	• Sense of smell.
II	Sensory	• Sense of vision.
III	Motor	• Movement of eye.
IV	Motor	• Movement of the superior oblique muscle of eye.
V	Mixed	• Sensation in the face; control of the muscles involved in chewing.
VI	Motor	• Movement of the lateral muscles of eye which are responsible for outward gaze.
VII	Mixed	• Facial expressions and the sense of taste in the front of the tongue.
VIII	Sensory	• Hearing and balance.
IX	Mixed	• Sense of taste in the back of tongue; movement of the muscles involved in swallowing.
X	Mixed	• Controls many organs, including heart, lungs, and digestive system.
XI	Motor	• Controls the muscles in the neck and shoulders.
XII	Motor	• Controls the muscles of the tongue.

CamScanner

Topic: Spinal Nerves: (31-Pairs)

- There are **thirty-one pairs of spinal nerves. All spinal nerves are mixed.**
- They transmit sensory and motor information between the spinal cord and the rest of the body.
- Each **spinal nerve** emerges from the spinal cord by two short branches or roots.
  - **(i) Dorsal Root:** The dorsal root contains the axons and dendrites of sensory neurons.
  - **(ii) Ventral Root:** The ventral root contains the axons of motor neurons.
- The two roots join just before a **spinal nerve** leaves the vertebral column.
- The cell bodies of sensory neurons are **grouped together** outside spinal cord in the dorsal root ganglia.
- The cell bodies of somatic motor neurons are located within the spinal cord and so are not located in ganglia.
- **The 31 pairs of spinal nerves include: (5-Regions of Spinal Nerves)**
  (i) 8 pairs of cervical nerves. (ii) 12 pairs of thoracic nerves.
  (iii) 5 pairs of lumbar nerves. (iv) 5 pairs of sacral nerves.
  (v) 1 pair of coccygeal nerves.

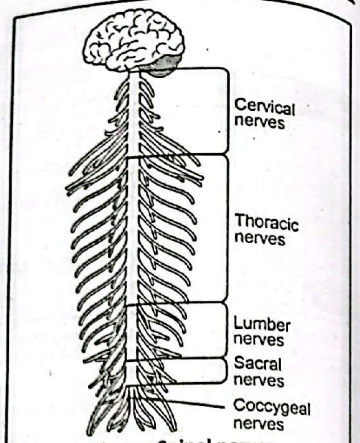


Figure: Spinal nerves

Topic: Divisions of the PNS:

S/Q

Q.44 Name & define the two major pathways of PNS.

Ans. Pathways or Divisions of PNS:

- The PNS makes two major types of **pathways or divisions:**
  (A) Sensory Pathways. **(B) Motor Pathways.**

(A) Sensory Pathways: The sensory pathways contain the sensory neurons of spinal and cranial nerves that connect the receptors of body to CNS.

(B) Motor Pathways: The motor pathways contain the motor neurons of spinal and cranial nerves that connect the CNS the effectors of body.

Check Understanding!

Q.17 How many pairs of thoracic nerves are present within the human spinal nerves?
(A) 8 pairs. (B) 12 pairs.
(C) 5 pairs. (D) 1 pair.

Q.45 Discuss the two systems formed by motor-path way also discuss two sub-divisions of autonomic nervous system. Exercise L/Q.11

Ans. Two Systems Formed by Motor-Path Way:

- The motor pathways make of two systems:
  (1) Somatic Nervous System. **(2) Autonomic Nervous System.**

(1) Somatic Nervous System:

- It consists of those **motor neurons** of spinal and cranial nerves which control **skeletal muscles.**
- The somatic system is voluntary. It means that skeletal muscles can be moved at will.
- For reflex action, the somatic system operates without **conscious control.**

(2) Autonomic Nervous System:

- It consists of those motor neurons of spinal and cranial nerves which control smooth muscles and glands.
- The autonomic system is involuntary and it controls internal body conditions by regulating smooth muscles.

Importance of Autonomic Nervous System:

- It controls respiration, **heartbeat, digestion,** and other functions.

Sub-Divisions of Autonomic Nervous System:

- The autonomic system has two subdivisions:
  (a) Sympathetic Division. **(b) Parasympathetic Division.**

(a) Sympathetic Nervous System:

- It prepares the body under physical or emotional stress.
- The motor neurons of sympathetic nervous system originate from the thoracic and lumbar regions of spinal cord.
- The axons of these neurons reach different visceral organs (smooth muscles and glands).

Functions of Sympathetic Nervous System:

- When the sympathetic nervous system is activated, its motor neurons stimulate various smooth muscles and glands to prepare the body for fight or flight.
- **Example:** The heart beats faster and stronger, blood glucose concentration increases, blood flow is diverted to the muscles and heart, and the bronchioles dilate.

(b) Parasympathetic Nervous System:

- This system antagonises **(opposite in action)** the response of sympathetic nervous system after the threat or stress has passed.
- The motor neurons of parasympathetic nervous system originate from the brain and sacral regions of spinal cord.
- Many of these motor neurons are in **vagus** (the tenth cranial) nerve.
- These motor neurons reach the internal organs.
- These neurons bring the internal organs to their **normal conditions.**
- **Example:** Heart beat slows down, blood flow to heart and skeletal muscles decreases, digestive organs increase secretion and other activities, and so on.

Q.46 Compare the functions or effects of sympathetic nervous system and parasympathetic nervous system on our body parts, given as: Exercise L/Q.11
(i) Pupil of eye. **(ii) Salivary glands.** **(iii) Gastric glands.** **(iv) Liver.**
(v) Digestive tract. **(vi) Urinary bladder.** **(vii) Heart muscle.** **(viii) Bronchioles.**
(ix) Blood vessels in muscles. **(x) Blood vessels in skin.**

Ans. Effects of Autonomic Nervous System on Body Parts:

Body Parts	Effect of Sympathetic Nervous System	Effect of Parasympathetic Nervous System
(i) Pupil of eye.	• Dilation.	• Constriction.
(ii) Salivary glands.	• Decreased secretion.	• Increased secretion.
(iii) Gastric glands.	• Inhibition of secretion.	• Stimulation of secretion.
(iv) Liver.	• Stimulation of glucose secretion.	• Inhibition of glucose secretion.
(v) Digestive tract.	• Decreased motility.	• Increased motility.
(vi) Urinary bladder.	• Relaxation.	• Contraction.
(vii) Heart muscle.	• Increased rate and strength.	• Decreased rate.
(viii) Bronchioles.	• Dilation.	• Constriction.
(ix) Blood vessels in muscles.	• Dilation.	• No effect.
(x) Blood vessels in skin.	• Constriction.	• No effect.

Multiple Choice Questions (MCQs)	Key
1. What two primary components make up the central nervous system (CNS)? (A) Cranial nerves. (B) Brain & spinal cord. (C) Spinal nerves. (D) Somatic muscles.	1.(B)
2. Which protective meninges layer is the thickest outermost membrane containing larger blood vessels? (A) Pia mater. (B) Arachnoid layer. (C) Dura mater. (D) Central canal.	2.(C)
3. If a physician observes a membrane that acts as a barrier between cerebrospinal fluid and blood in the dura mater, which layer is it? (A) Dura mater. (B) Arachnoid layer. (C) Pia mater. (D) Vertebral column	3.(B)

CamScanner

4. What is the average weight of an adult human brain as stated in the text?
(A) 2.0 kg. (B) 1.4 kg. (C) 0.5 kg. (D) 3.0 kg.

5. How are the two cerebral hemispheres structurally linked at the base of the deep groove (fissure)?
(A) Cerebral cortex. (B) Brainstem region.
(C) Corpus callosum. (D) Diencephalon center.

6. Which specific lobes of the cerebrum control human vision?
(A) Frontal lobes. (B) Temporal lobes. (C) Parietal lobes. (D) Occipital lobes.

7. Why are the association areas of the cerebral cortex considered critical for human brain function?
(A) Reflex coordination. (B) Higher mental activities.
(C) Heart rate control. (D) Vision processing.

8. If a patient loses the ability to integrate visual-spatial skills associated with the right side of the cortex, which specific region is primarily affected?
(A) Motor cortex. (B) Association areas. (C) Auditory cortex. (D) Visual cortex.

9. Which specific division of the brainstem serves as a control centre for heart rate and respiration rate?
(A) Midbrain region. (B) Pons structure. (C) Medulla oblongata. (D) Thalamus center.

10. What region acts as a major relay centre between incoming sensory information and the cerebrum?
(A) Hypothalamus. (B) Thalamus. (C) Cerebellum. (D) Amygdala.

11. If a person experiences a disturbance in body temperature regulation, hunger, and thirst, which specific part of the diencephalon is likely involved?
(A) Thalamus. (B) Hypothalamus. (C) Pons. (D) Cerebellum.

12. Which specific part of the limbic system plays a role in consolidating information from short-term memory to long-term memory?
(A) Amygdala. (B) Hypothalamus. (C) Hippocampus. (D) Thalamus.

13. Why are the amygdalae important structures within the temporal lobes?
(A) Regulating thirst. (B) Controlling emotions.
(C) Relaying sensory data. (D) Producing melatonin.

14. What is the primary function of the second major brain structure, the cerebellum?
(A) Processing smell. (B) Coordinating muscle actions.
(C) Regulating hunger. (D) Producing melatonin.

15. How many fluid-filled ventricles are present within the human brain?
(A) Two ventricles. (B) Three ventricles. (C) Four ventricles. (D) Five ventricles.

16. If a cross-section of the spinal cord is examined, what is the shape of its inner zone of grey matter?
(A) Circular ring. (B) H-shaped zone. (C) Straight line. (D) Spiral band.

17. How many total pairs of cranial nerves arise from the brain?
(A) Ten pairs. (B) Thirty-one pairs. (C) Twelve pairs. (D) Twenty pairs.

18. How many pairs of spinal nerves emerge from the human spinal cord?
(A) Twelve pairs. (B) Eight pairs. (C) Thirty-one pairs. (D) Five pairs.

19. What structural feature distinguishes the dorsal root from the ventral root in spinal nerves?
(A) Motor axons. (B) Sensory axons. (C) Ganglia absence. (D) White matter.

20. Which motor pathway division specifically controls skeletal muscles?
(A) Autonomic system. (B) Somatic system.
(C) Sympathetic system. (D) Parasympathetic system.

21. Which system controls internal body conditions like respiration and heartbeat involuntarily?
(A) Somatic system. (B) Autonomic system.
(C) Skeletal system. (D) Sensory system.

22. If an individual faces sudden physical or emotional stress requiring a "fight or flight" response, which system is activated?
(A) Parasympathetic system. (B) Sympathetic system.
(C) Somatic system. (D) Sensory system.

23. How do the sympathetic and parasympathetic divisions function relative to each other?
(A) Antagonistic response. (B) Identical action.
(C) Synergistic growth. (D) Parallel control.

24. Why are parasympathetic motor neurons originating in the vagus nerve crucial after stress?
(A) Speeds heart. (B) Normalizes organs.
(C) Increases glucose. (D) Dilates bronchioles.

25. If a novel drug blocked the sympathetic nervous system's ability to stimulate visceral organs, what hypothetical change would occur during physical stress?
(A) Impaired fight-or-flight. (B) Accelerated heartbeat.
(C) Increased glucose. (D) Pupil dilation.

4.	(B)
5.	(C)
6.	(D)
7.	(B)
8.	(B)
9.	(C)
10.	(B)
11.	(B)
12.	(C)
13.	(C)
14.	(B)
15.	(C)
16.	(B)
17.	(C)
18.	(C)
19.	(B)
20.	(B)
21.	(B)
22.	(B)
23.	(A)
24.	(B)
25.	(A)

RECEPTORS IN HUMAN BODY

Q.47 What are receptors, give examples. S/Q

Ans. Receptors:

- The organs, tissues, cells or **parts of cells** that detect changes (stimuli) in external or internal environment and create nerve impulses in the associated sensory neurons are called **receptors.**
- **Examples:** Receptors for Taste, Smell, Touch, and Pain.

Topic: Receptors of Taste:

Q.48 What are chemoreceptors? Discuss number, location & structure of taste receptors. Exercise L/Q.13

Ans. Chemoreceptors:

- The receptors which sense the taste are called **chemoreceptors.**

➢ **Types of Chemoreceptors:**

- **No. of Taste Receptors:** On average, the human tongue has **2,000-8,000** taste buds.

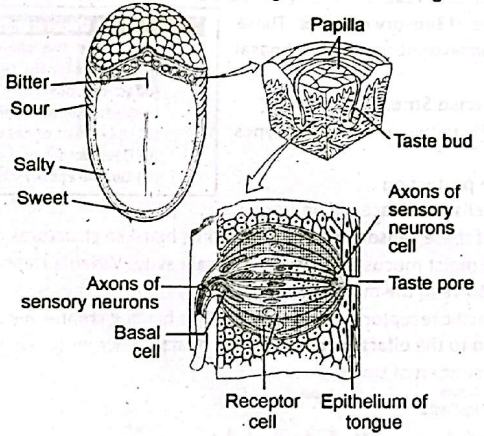


Figure: Receptors of taste

Check Understanding!
Q.18 Contrast the effects of the sympathetic and parasympathetic nervous systems on heart rate and strength.

- **Location of Taste Receptors:**
  - Most of them are embedded between bumps called **papillae on the tongue.**
  - Some taste buds are present in the **throat** and on the **roof of oral cavity.**
- **Structure of Taste Bud:**
  - A taste bud is **bulb-shaped** and is made up of many receptor cells with **hair-like** structures and basal cells (for making new receptor cells).
  - A taste bud opens out into the mouth through a **taste pore.**

Q.49 How do chemoreceptors work to perceive the taste, also give types of teste buds? L/Q

Ans. Working of Chemoreceptors For Teste Perception:

- When the chemoreceptor cells of **taste buds** are stimulated by the chemicals present in food or drink, they produce nerve impulses in associated sensory neurons.
- The **nerve impulses** travel along nerves **(cranial nerve VII, IX, and X)** and reach **brainstem.**
- From brainstem, the impulses are transmitted to the **taste-sensing** areas of cerebral cortex.
- The cortex processes this information with other sensory information, such as **smell** and **texture,** to create the complete perception of taste.

CamScanner

Types of Taste Buds:

- Humans have five kinds of taste buds which respond to:
  (i) Salty. (ii) Sweet. (iii) Sour.
  (iv) Bitter tastes. (v) Umami (Savoury, brothy, or meaty).
- Each taste bud can detect all five basic tastes.
- It means that every part of the tongue that contains taste buds can detect all five basic tastes.
- But some areas of the tongue may be slightly more sensitive to certain tastes.

Distribution of Taste Buds:
(i) Sweet at the **tip.**
(ii) Sour at the **sides.**
(iii) Bitter at the **back.**
(iv) Salty over most of the tongue's surface.

Topic: Receptors of Smell:

Q.50 What are Olfactory receptors or smell receptors, where these are located in our body, also discuss their working to sense smell. Exercise L/Q.12

Ans. Receptors of Smell: (Olfactory Receptors)

- The receptors which are **responsible** for the sense of smell **(olfaction)** are called olfactory or smell receptors.
- These are also chemoreceptors which are located in the upper part of **nasal cavities.**
- These receptors are actually the ends of **sensory neurons.** These sensory neurons are present in a thin layer of tissue called **nasal epithelium.**

Check Understanding!
Q.19 Where are the chemoreceptors responsible for the sense of smell (olfaction) located?
(A) Surface of the tongue.
(B) Upper part of nasal cavities.
(C) Deep dermis of the skin.
(D) Quadriceps muscle tendon.

Working of Olfactory Receptors to Sense Smell:

- Olfactory receptors are packed tightly between two other **types of cells named below:**
  (a) Supporting Cells: Which provide protection.
  (b) Basal Cells: Which act as **stem cells** to replace old neurons.
- The dendrites (the receiving ends) of these sensory **neurons** have tiny, hair-like structures called **cilia.**
- These cilia project outward into the moist mucus that lines the nasal cavity. When air enters the nasal cavities, the air-borne chemicals dissolve in the mucus.
- These dissolved chemicals bind to specific receptor sites on the cilia. This binding **creates nerve impulse** in sensory neurons, which is transmitted to the **olfactory bulb** through olfactory nerves (cranial nerve I).
- The olfactory **bulb produces** the perception of smell.

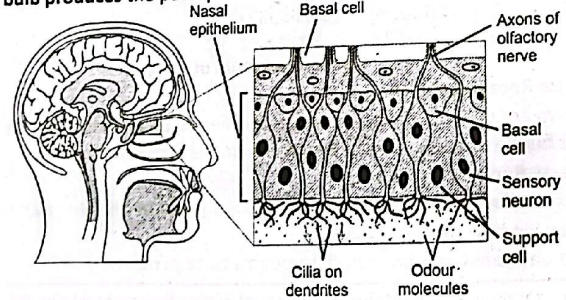


Figure: Olfactory receptors

Topic: Receptors of Pain and Touch:

Q.51 What are cutaneous receptors & name the stimuli, detected by cutaneous receptors? SIC

Ans. Cutaneous Receptors:

- The receptors which are present in **skin** are called cutaneous receptors.

Stimuli For Cutaneous Receptors:

- Touch, pressure, heat, cold, and pain.

Topic: Nociceptors:

Q.52 What are nociceptors, how do different nociceptors show response for different stimuli? Exercise L/Q.14

Ans. Nociceptors:

- The receptors which **detect pain** are called **nociceptors.**
- Pain is defined as a **stimulus** that causes or is about to cause tissue damage.
- **Structure of Nociceptors:** Nociceptors consist of **free nerve** endings.
- **Location of Nociceptors:** Located throughout the body, **especially near surfaces.**
- **Different nociceptors** may respond to extremes in:
  (i) Temperature. (ii) Very Intense Pressure.
  (iii) Specific chemicals (including some that are released by injured cells).

Check Understanding!
Q.20 Describe the structure and function of nociceptors in the human body.

Topic: Touch Receptors:

- The skin contains a variety of **touch receptors.**
- They are **mechanoreceptors** that respond to different physical stimuli.

Q.53 What are mechanoreceptors, name & briefly describe the five types of mechanoreceptors located in skin or dermis? Exercise L/Q.14

Ans. Mechanoreceptors:

- The receptors related to touch are called mechanoreceptors.

Types of Mechanoreceptors:

(i) Meissner's Corpuscles:
- They are endings of sensory neurons surrounded by a capsule.
- They are found in the **upper layer** of the skin (especially in lips, fingertips, palm, and soles).
- They **detect light touch** and vibration.

(ii) Hair Follicle:
- The receptors which are **endings** of neurons and are located around the base of hair follicles.
- They detect the **movement of hairs,** which occur due to mechanical or thermal stimuli.

(iii) Merkel Cells:
- They are oval-shaped receptors in the deepest layer of epidermis.
- They **detect light touch** and are present in highly touch-sensitive areas like fingertips.

(iv) Pacinian Corpuscles:
- These are sensory neuron endings, surrounded by a capsule.
- They are located deeper in the skin.
- They **detect deep** pressure and vibration.

(v) Ruffini Endings:
- They are also sensory neuron endings enclosed in capsule.
- They are located in the dermis.
- They detect **sustained** pressure and stretching.

For Information
Q. Define thermoreceptors & differentiate between warm & cold receptors in reference to their location in skin.
Ans. Thermoreceptors: The receptors which are naked dendrite endings of sensory neurons detect fall and rise in temperature.
- Cold receptors are located immediately below the epidermis, while warm receptors are located slightly deeper, in the dermis.
- **Thermoreceptors** are also found within the hypothalamus of the brain, where they detect the temperature of the blood and thus monitor the body's internal (core) temperature.

CamScanner

Q.54 Draw the diagram of skin & label 5-types of mechanoreceptors present in skin. S/Q

Ans. Label 5-type of Mechanoreceptors:

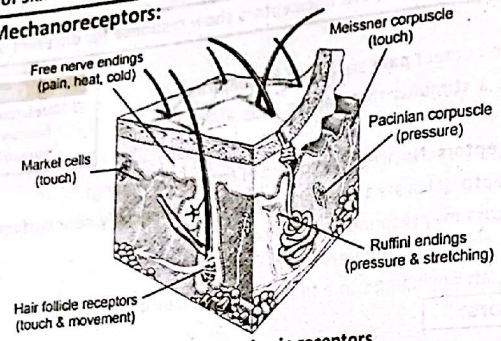


Figure: Touch and pain receptors

- These touch receptors generate and transmit impulses via sensory neurons to the spinal cord and then to brain, where the signals are processed to create the sensations of touch.

Multiple Choice Questions (MCQs)

		Key
1.	**Receptors generate impulses in association with:** (A) Motor neurons. (B) Sensory neurons. (C) Inter-neurons. (D) Schwann cells.	1.(B)
2.	**Taste buds are classified as:** (A) Mechanoreceptors. (B) Thermoreceptors. (C) Chemoreceptors. (D) Photoreceptors.	2.(C)
3.	**Approximately how many taste buds are present in the human body?** (A) 2,000 – 8,000. (B) 5,000 – 8,000. (C) 8,000 – 10,000. (D) 10,000 – 20,000.	3.(A)
4.	**Taste buds are found mainly in the papillae of the:** (A) Nose. (B) Tongue. (C) Pharynx. (D) Oesophagus.	4.(B)
5.	**Chemicals that stimulate taste receptor cells first dissolve in:** (A) Blood. (B) Lymph. (C) Saliva. (D) Mucus.	5.(C)
6.	**Taste impulses travel mainly through cranial nerves:** (A) X, XI and XII. (B) V, VI and VIII. (C) VII, IX and X. (D) I, II and III.	6.(D)
7.	**The five principal taste qualities are:** (A) Sweet, sour, salty bitter, Umami. (B) Sweet, umami, salty, bitter brothy. (C) Sour, spicy, sweet and salty, savoury. (D) Bitter, spicy, sour and umami, meaty.	7.(A)
8.	**Olfactory chemoreceptors are located in the:** (A) Lower nasal cavity. (B) Upper nasal cavity. (C) Tongue papillae. (D) Pharynx.	8.(B)
9.	**Olfactory receptor cells are specialized:** (A) Motor neurons. (B) Multipolar neurons. (C) Bipolar sensory neurons. (D) Inter-neurons.	9.(C)
10.	**Odour molecules initiate nerve impulses after they:** (A) Enter the bloodstream. (B) Bind to receptor proteins. (C) Reach the tongue. (D) Stimulate the optic nerve.	10.(B)
11.	**Flavour depends not only on taste but also on:** (A) Blood pressure and heartbeat. (B) Smell, texture and temperature. (C) Vision and hearing. (D) Body posture and balance.	11.(B)
12.	**What type of specialized cutaneous receptors are responsible for detecting pain?** (A) Mechanoreceptors. (B) Nociceptors. (C) Thermoreceptors. (D) Merkel cells.	12.(B)
13.	**Where are cold thermoreceptors located relative to the skin layers?** (A) Deep dermis. (B) Hypodermis layer. (C) Below epidermis. (D) Core hypothalamus.	13.(C)
14.	**If a person touches a textured surface and experiences light touch and vibration via encapsulated neuron endings in the upper layer of the skin, which receptors are activated?** (A) Pacinian corpuscles. (B) Ruffini endings. (C) Meissner's corpuscles. (D) Hair receptors.	14.(C)
15.	**How do Merkel cells differ from Pacinian corpuscles in terms of their physical location within the skin layers?** (A) Epidermis base. (B) Dermis layer. (C) Hypodermis base. (D) Surface hair.	15.(A)

		Key
16.	**Why are thermoreceptors also located within the hypothalamus of the brain in addition to the skin?** (A) Monitor core temperature. (B) Detect external cold. (C) Sense skin pressure. (D) Process deep vibration.	16.(A)
17.	**If a sensory neuron ending located deep in the dermis is designed to detect sustained pressure and skin stretching, what type of receptor has been simulated?** (A) Ruffini endings. (B) Nociceptor cells. (C) Merkel receptors. (D) Meissner corpuscles.	17.(A)

EFFECTS OF DRUGS ON NERVOUS COORDINATION

Q.55 Define the term drugs & give its effects. L/Q

Ans. Drug:

- A **substance** (other than food) that is used to **prevent, diagnose, treat,** or relieve symptoms of a disease or **abnormal condition is called drug.**

For Information
- All narcotics are psychoactive drugs, but all psychoactive drugs are not narcotics.

➢ **Effects of Drugs:**

- Drugs can also affect the working of **brain** and **cause** changes in mood, **awareness, thoughts, feelings,** or **behavior.**

Q.56 Differentiate between psychoactive drug & narcotic drugs also give their examples. S/Q

Ans.

Psychoactive Drug	Narcotic Drug
• A type of **drug** that **alters brain functions,** resulting in changes in **mood, perception, consciousness,** and **behaviour.**	• A narcotic drug (or simply narcotic) is a type of **opioid** drug that is used for **pain relief** and has a **high potential for addiction** and abuse.
• **Examples:** Alcohol, caffeine, nicotine, and illicit drugs such as cocaine, heroin etc.	• **Examples:** Such as morphine, codeine, and oxycodone.

Topic: Addiction, Tolerance and Withdrawal Symptoms:

Q.57 Discuss the following terms: Exercise L/Q.16

(i) Drug dependence. **(ii) Drug Addiction.** **(iii) Drug Tolerance.**
(iv) Increased Addiction **(v) With-drawl symptoms.**

Ans. The abuse of psychoactive drugs often leads to dependence.

(i) Drug Dependence:

- A **state** in which a person relies **on a drug** physically or emotionally in order to function. Dependence often results in addiction.

(ii) Drug Addiction:

- It means the **disorder of uncontrollable drug desire** and use despite its negative effects.

(iii) Drug Tolerance:

- As a person continues to use a drug, the body **becomes adaptive** and less sensitive to its effects. This condition is called **drug tolerance.**

(iv) Increased Addiction:

- After drug tolerance, the person may **require higher doses** to achieve the same level of response. This leads to an increased addiction.

(v) With-drawl Symptoms:

- When addicts stop taking an **addictive drug,** they experience withdrawal symptoms. Withdrawal symptoms may include **vomiting, headache, insomnia, breathing difficulties, depression, mental instability,** and **seizures.**

Check Understanding!
Q.21 What type of touch receptors found in the upper layer of the skin detect light touch and vibration?
(A) Pacinian corpuscles.
(B) Ruffini endings.
(C) Meissner's corpuscles.
(D) Merkel cells.

CamScanner

Q.58 How can you justify that addictive drugs are the source of pleasure & motivation & what are disadvantages of continuous uses. S/Q

Ans. Changes in Nervous System during Addiction and Tolerance:

Addictive Drugs As Source of Pleasure & Motivation:

- **Addictive drugs affect the regions of brain which regulate pleasure and motivation.**
- **(i) Produce Dopamine (Source of Pleasure):** When these drugs reach brain, the **presynaptic neurons release dopamine** neurotransmitter, which produces feelings of pleasure and reward.
- **(ii) Block Dopamine Reabsorption Receptors:** The drug molecules block the **dopamine** reabsorption receptors in presynaptic neuron. So, large amount of dopamine accumulates in synaptic cleft.

➢ **Disadvantages of Addictive Drugs:**

- **Brain adapts** and reduces the number of **dopamine** receptors on postsynaptic neuron. This leads to tolerance i.e.; the user requires higher doses of drug to achieve the same pleasure or reward.
- When the drug is **stopped abruptly**, dopamine release becomes normal but due to less receptors, the postsynaptic neuron is less-stimulated and it leads to withdrawal **symptoms.**

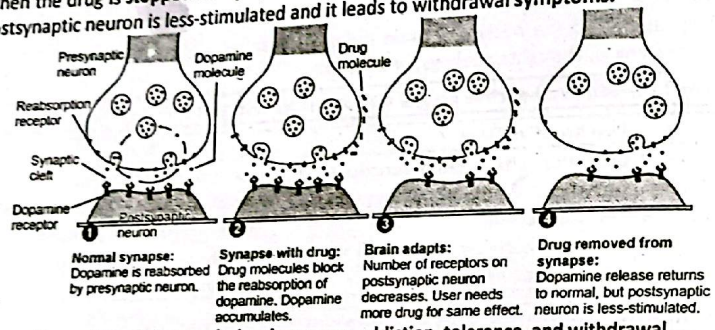


Figure: Neural changes during drug usage, addiction, tolerance, and withdrawal

Topic: Addiction and Tolerance of Caffeine:

Q.59 What are the sources of caffeine, how does it effect our body also write its withdrawal symptoms? S/Q

Ans. Sources of Caffeine:

- Caffeine is found in **many common beverages**, such as **coffee, tea,** and **energy drinks.**

Effects of Caffeine:

- It can **block the action** of a **neurotransmitter** called adenosine, which promotes sleep and relaxation.
- As a result, caffeine increases **alertness** and energy levels.
- Regular caffeine use can lead to tolerance. So, the user requires higher doses to achieve the same level of alertness.

Check Understanding!
Q.22 Explain how addictive drugs cause tolerance at the cellular level within brain synapses.

Withdrawal Symptoms of Caffeine:

- If caffeine use is **stopped abruptly**, withdrawal symptoms such as headaches and fatigue can occur.

Topic: Addiction and Tolerance of Nicotine:

Q.60 Discuss nicotine with reference to: L/Q
(a) Sources of Nicotine **(b) Mode of action of Nicotine** **(c) Effects of use**
(d) Withdrawal Symptoms **(e) Effects of long term use.**

Ans. (a) Sources of Nicotine:

- Nicotine is **highly addictive** stimulant present in tobacco products (cigarettes, cigars, and smokeless tobacco).

(b) Mode of Action of Nicotine:

- It binds to nicotine receptors in brain. These receptors release dopamine and other neurotransmitters to produce pleasurable feelings.

(c) Effects of Use of Nicotine:

- Regular nicotine use leads to tolerance. So, the user requires higher doses to achieve the same level of pleasure.

(d) Withdrawal Symptoms of Nicotine:

- When nicotine use is stopped abruptly, the user experiences withdrawal symptoms, such as irritability, anxiety, and cravings.

(e) Effects of Long Term Use:

- Long-term nicotine use is also associated with a variety of negative health effects, including an increased risk of cancer, heart disease, and respiratory problems.

Topic: Use and Abuse of Drugs:

Q.61 How can you differentiate use of drugs and abuse of drugs? Exercise L/Q.15

Ans.

Use of Drugs	Abuse of Drugs
• The term "use" refers to the **appropriate** or prescribed use of drugs for medical purposes.	• The term "**abuse**" generally refers to the **inappropriate** use of psychoactive drugs.

Q.62 Write names of 5-drugs which are common for abuse of drugs. Exercise L/Q.15

Ans. 5-Common Drugs known as Abuse Drugs:
(1) Heroin. (2) Cannabis. (3) Nicotine. (4) Alcohol. (5) Inhalants.

Topic: (1) Heroin:

Q.63 Discuss the source, mode of usage, side effects & negative physical & mental health issues of Heroin. Exercise L/Q.15

Ans. Heroin:

- **Source of Heroin:** It is a highly addictive opioid drug that is **derived** from the opium poppy plant.
- **Mode of Use:** It is injected, smoked, or snorted.
- **Side Effects:** It produces false senses of euphoria (intense excitement and happiness) and relaxation.
- Its use quickly leads to dependence and addiction.
- **Negative Physical & Mental Health Effects:** It has a range of negative physical and mental health effects, including respiratory depression, infections, and mental health disorders.

Check Understanding!
Q.23 What psychoactive drug is made from the dried flowering tops, leaves, and stem of the Indian hemp plant Cannabis sativa?
(A) Nicotine. (B) Heroin.
(C) Alcohol. (D) Cannabis.

Topic: (2) Cannabis:

Q.64 How cannabis is produced, discuss its mode of use, harmful effects also give its effects of long term use. Exercise L/Q.15

Ans. Cannabis:

- **Source of Cannabis:** Cannabis is a psychoactive drug that is made **from dried flowering tops,** leaves and stem of Indian hemp plant Cannabis sativa.
- **Examples:** It includes drugs like marijuana and hashish.
- **Mode of Usage:** It can be smoked, vaporized, or consumed in edibles.
- **Harmful Effects:** The use of cannabis produces sense of relaxation, euphoria, altered perception, and increased appetite.
- **Effects of Long Terms Use:** Its long-term use leads to negative effects, such as impaired cognitive function, respiratory problems, and mental health disorders.

Topic: (3) Nicotine:

Q.65 How is nicotine used? Also discuss its effects on health. Exercise L/Q.15

Ans. Nicotine:

- **Source of Nicotine/Usage of Nicotine:** Nicotine is a highly addictive drug found in tobacco products, including cigarettes, cigars, and smokeless tobacco.

CamScanner

- **Harmful Health Effects:** Its use leads to addiction and dependence, as well as a range of negative physical and mental health effects, including respiratory problems, cancers, cardiovascular disease, and mental health disorders.

Topic: (4) Alcohol:

Q.66 What is alcohol, name its different forms, discuss it common as well as negative effects. Exercise L/Q.15

Ans. Alcohol:

- Alcohol is a psychoactive drug.
- **Different Forms of Alcohol:** It is commonly consumed in various forms, such as beer, wine, and spirits.
- **Common Effects:** It produces feelings of relaxation and euphoria (intense happiness or excitement).
- **Negative Effects:** Its negative effects include impaired cognitive and motor functions, liver diseases, cardiovascular diseases, and mental health disorders.

Topic: (5) Inhalants:

Q.67 What are inhalants, what are its negative health effects? Exercise L/Q.16

Ans. Inhalants:

- Inhalants, such as nail polish remover and glue, are psychoactive substances that are inhaled to produce senses of euphoria, relaxation, and altered perception.
- **Health Negative Effects:** They can produce a range of negative health effects, such as respiratory problems, cognitive impairment, and neurological damage.

Q.68 Discuss the withdrawal symptoms of drug abuse. Exercise L/Q.17

Ans. Withdrawal Symptoms of Drug Abuse:

- The withdrawal symptoms of drug abuse include anxiety, depression, fatigue, agitation and mood swings.
- It also includes shakiness or tremors, headache, sweating, nausea, loss of appetite, insomnia, rapid heart rate, high blood pressure, hallucinations (visual, auditory, or tactile), and seizures.

Multiple Choice Questions (MCQs)	Key
1. What type of drug specifically alters brain functions, resulting in changes in mood, perception, and consciousness? (A) Antibiotic pill. (B) Nutrient food. (C) Psychoactive drug. (D) Vitamin liquid.	1.(C)
2. Which type of opioid drug is used for pain relief and has a high potential for addiction and abuse? (A) Caffeine drink. (B) Narcotic drug. (C) Plant vitamin. (D) Mineral salt.	2.(B)
3. If a statement claims that all narcotics belong to a broader category of drugs that alter brain function, which rule applies? (A) All are psychoactive. (B) None are psychoactive. (C) Only some are. (D) They are unrelated.	3.(A)
4. How does drug dependence fundamentally differ from drug addiction based on the text definitions? (A) Reliance versus desire. (B) Same exact meaning. (C) Physical versus mental. (D) Medical versus illegal.	4.(A)
5. Why must a person take higher doses of a drug over time to achieve the same initial effect? (A) Body develops tolerance. (B) Drug potency drops. (C) Liver stops working. (D) Blood pressure falls.	5.(A)
6. If an addict abruptly stops taking an addictive drug, what collection of negative physical and mental reactions will they experience? (A) Enhanced energy. (B) Perfect stability. (C) Withdrawal symptoms. (D) Immediate recovery.	6.(C)
7. Which neurotransmitter is released by presynaptic neurons into the synaptic cleft to produce feelings of pleasure and reward? (A) Acetylcholine chemical. (B) Dopamine neurotransmitter. (C) Serotonin molecule. (D) Adrenaline hormone.	7.(B)
8. What do addictive drug molecules specifically block at the presynaptic neuron to cause dopamine to accumulate? (A) Reabsorption receptors. (B) Release channels. (C) Enzyme sites. (D) Synaptic clefts.	8.(A)
9. When the brain adapts to excessive dopamine by reducing postsynaptic receptors, what condition directly develops? (A) Complete immunity (B) Drug tolerance. (C) Normal health. (D) Rapid recovery.	9.(B)

10. How does caffeine increase alertness and energy levels in the central nervous system? (A) Blocks adenosine. (B) Releases insulin. (C) Stimulates dopamine. (D) Destroys synapses.	10.(A)
11. Why do regular coffee or tea drinkers experience headaches and fatigue when they abruptly stop consuming caffeine? (A) Withdrawal symptoms occur. (B) Energy levels peak. (C) Adenosine increases. (D) Tolerance disappears.	11.(A)
12. If a stimulant binds to specific brain receptors to release dopamine and cause physical dependence from tobacco use, what substance is it? (A) Caffeine product. (B) Nicotine stimulant. (C) Alcohol drink. (D) Heroin opiate.	12.(B)
13. What does the term "use" specifically refer to regarding medical substances? (A) Inappropriate abuse. (B) Appropriate prescribed use. (C) Illegal trafficking. (D) Accidental ingestion.	13.(B)
14. From which plant source is the highly addictive opioid drug heroin derived? (A) Cannabis plant. (B) Tobacco plant. (C) Opium poppy plant. (D) Hemp plant.	14.(C)
15. If a psychoactive drug is made from the dried flowering tops and leaves of the Indian hemp plant, what is it called? (A) Heroin drug. (B) Nicotine chemical. (C) Alcohol liquid. (D) Cannabis substance.	15.(D)
16. What unique physical symptom is typically produced alongside relaxation and euphoria when using cannabis? (A) Increased appetite. (B) Decreased hunger. (C) Respiratory paralysis. (D) Permanent amnesia.	16.(A)
17. Why is long-term nicotine use considered severely detrimental to human health beyond mere psychological addiction? (A) Causes heart disease. (B) Improves immune function. (C) Enhances brain volume. (D) Reduces blood pressure.	17.(A)
18. If a person consumes fermented beverages like beer, wine, or spirits to produce feelings of relaxation and euphoria, what drug have they ingested? (A) Nicotine product. (B) Cannabis plant. (C) Heroin opiate. (D) Alcohol drink.	18.(D)
19. What major body organ is notoriously prone to severe disease from the long-term abuse of alcohol? (A) Liver organ. (B) Lung tissue. (C) Kidney cell. (D) Stomach lining.	19.(A)
20. Which psychoactive substances include household items like nail polish remover and glue? (A) Narcotic drugs. (B) Inhalant substances. (C) Opioid formulas. (D) Stimulant compounds.	20.(B)
21. If someone chronically inhales volatile industrial solvent vapors, what type of permanent injury can result? (A) Neurological damage. (B) Enhanced memory. (C) Stronger muscles. (D) Better vision.	21.(A)
22. How do autonomic nervous signs manifest during acute drug withdrawal phases according to the text? (A) Slow pulse rate. (B) Rapid heart rate. (C) Decreased blood pressure. (D) Complete calmness.	22.(B)
23. Why are sensory disturbances such as visual or auditory phenomena categorized as severe withdrawal signs? (A) Indicate brain imbalance. (B) Show high intelligence. (C) Prove total recovery. (D) Represent normal health.	23.(A)

DISORDERS OF NERVOUS SYSTEM

Topic: Vascular Disorders:

Q.69 Define vascular disorders of nervous system & give its two examples. S/Q

Ans. Vascular Disorders of Nervous System:

- The conditions in which the blood vessels of brain and spinal cord are affected are called vascular the disorders of nervous system.
- **Examples:** Stroke, Cerebral venous thrombosis.

Q.70 What is stroke? Discuss causes, symptoms & treatment of brain stroke. Exercise L/Q.17

Ans. Stroke:

- A stroke means damage in brain cells due to interruption in the blood supply to a part of brain. Such interruption may be due to a blockage or a rupture of a blood vessel of brain.

CamScanner

➢ **Causes of Stroke:**
- These include high blood pressure, **smoking, diabetes, high cholesterol, obesity,** and family history of stroke.

➢ **Symptoms of Stroke:**
- The symptoms of a stroke vary **depending** on the area of brain affected.
- Paralysis occurs on the side of body opposite the cerebral infarction (death of tissue).
- Other common symptoms are aphasia (inability to express through words); sudden trouble in seeing and walking, dizziness, loss of balance; and severe headache

➢ **Treatment of Stroke:**
- Treatment should be **given as soon** as possible to minimize damage to brain.
- Treatment may include:
  - (i) **Medications:** Such as blood thinners, clot-dissolving drugs, or antihypertensive drugs.
  - (ii) **Surgery** to remove a blood clot or repair a ruptured blood vessel.
  - (iii) **Rehabilitation:** To help patients recover physical and cognitive function.

Check Understanding!
Q.24 Define a stroke and outline its primary vascular causes within the brain.

For Information
Q. Causes of three types of brain stroke.
Ans. Three types of Brian Stroke:
i. **Ischemic Stroke:** It occurs when the brain's blood vessels become narrowed or blocked
ii. **Haemorrhagic Stroke:** It occurs when a blood vessel in brain leaks or ruptures.
iii. **Transient Ischemic attack (ministroke):** It occurs by a temporary decrease in blood supply to part of brain, which may last as little as five minutes.

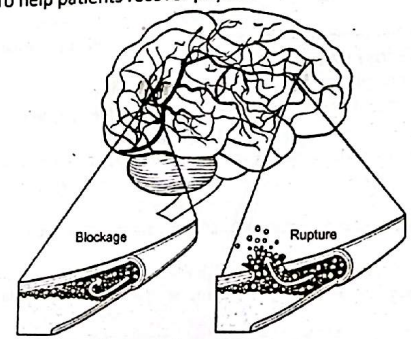


Figure: Main types of strokes

Topic: Infectious Disorders of Nervous System:

➢ **Causes of Infectious Disorders of Nervous System:**
- **Infections of the central nervous system** can be caused by **almost any infectious agent,** including viruses, **bacteria, fungi, protozoa,** and **flatworms.**

Topic: Meningitis:

Q.71 What is meningitis, describe causes, symptom & treatment of meningitis? Exercise L/Q.17

Ans. **Meningitis:**
- A inflammation (swelling) of the meninges due to **infection** is called **meningitis.**

➢ **Causes of Meningitis:**
(i) **Bacterial Meningitis:** It is the most severe and **life-threatening.**
(ii) **Viral Meningitis:** It is usually less severe.
(iii) **Fungal Meningitis:** It is rare and usually occurs in people with weak immune systems.
(iv) Other causes include parasitic infections.

Check Understanding!
Q.25 Which type of meningitis caused by bacterial infection is considered the most severe and life-threatening?
(A) Viral meningitis.
(B) Bacterial meningitis.
(C) Fungal meningitis.
(D) Parasitic meningitis.

➢ **Symptoms of Meningitis:**
- Include stiffness in the **neck, headache,** and **fever.**
- In **severe cases,** meningitis may also cause paralysis, or coma.

➢ **Treatment of Meningitis:**
- **Bacterial** meningitis requires **immediate** treatment with antibiotics.
- **Viral meningitis** is usually self-limiting, although antiviral medications may be used.
- **Fungal meningitis** requires long-term treatment with antifungal medications.
- **Vaccines** are available for some of the bacterial meningitis, which can prevent infection.

Topic: Structural Disorders of Nervous System:

➢ **Causes of Structural Disorders of Nervous System:**
- **Structural disorders of nervous system** result from **abnormalities** or damage to the **physical structure** of nervous system.
- **Examples: (i) Brain Tumour. (ii) Spinal Cord Injuries.**

Topic: Brain Tumour:

Q.72 What is brain tumour, name its two types, also discuss its causes, symptoms & treatment. Exercise L/Q.17

Ans. **Brain Tumour:**
- An **abnormal** growth or mass of cells in brain.

➢ **Types of Brain Tumour:**
(i) **Brain Tumors Can Be:** Benign non-cancerous.
(ii) **Malignant:** Cancerous.
- **Brain tumour** can arise from glial cells or from the neurons themselves.

➢ **Causes of Brain Tumour:**
- The exact cause of brain tumors is unknown, but **risk factors include exposure to radiation,** family history, and certain genetic mutations.

➢ **Symptoms of Brain Tumour:**
- Depend on the location of tumour. These may include headaches, severe nerve pain, paralysis, seizures, and coma.

➢ **Treatment of Brian Tumour:**
- Common treatments include surgery, radiation therapy, and chemotherapy.

Topic: Functional Disorders f Brain:

➢ **Effects of Functional Disorders:**
- **Functional disorders are the conditions** that affect the normal functioning of the nervous system without any **apparent** structural or **organic cause.**

Topic: Headache:

Q.73 What is headache? Differentiate between primary headache & secondary headache. Exercise L/Q.17

Ans. **Headache:**
- Headache is a common **condition** characterized by **pain** or **discomfort** in head or neck.

Primary Headache	Secondary Headache
• **Primary headaches** are due to headache itself and not due to another cause e.g., migraine, tension headache.	• **Secondary headaches** are due to an underlying structural problem in head or neck such as bleeding in the brain, tumour, meningitis etc.

For Information
Q. What is migraine? Discuss its causes & treatment.
Ans. **Migraine:** Migraine is a type of headache that is characterized by **intense,** throbbing pain on one side or in one region of head.
Causes of Migraine: Migraines are **caused** by changes in the brain and blood vessels, which lead to inflammation and pain.

CamScanner

➢ **Treatment of Migraine:**
- Treatments include pain-killing (analgesic) medicines, and reducing stress, getting regular exercise, and improving sleep habits.

Topic: Degenerative Disorders of Nervous System:

Q.74 Define degenerative disorders & briefly describe the following degenerative disorders. Exercise Q.17
(a) Parkinson's Disease (b) Huntington's Disease (c) Multiple Sclerosis

Ans. Degenerative Disorders:
- The conditions of progressive deterioration of nerve cells in brain, spinal cord, or peripheral nerves are called degenerative disorders.

(a) Parkinson's Disease:
- The progressive death or weakening of the neurons in brain that produce dopamine leading to movement issues and cognitive changes.

(b) Huntington's Disease:
- The progressive damage to neurons in the brain, leading to movement disorders, cognitive decline, and psychiatric symptoms.

(c) Multiple Sclerosis:
- An autoimmune disease of the CNS in which myelin sheath is damaged leading to vision loss, pain, fatigue, and impaired coordination).

Q.75 Write a short note on characteristics, causes, symptoms, & treatment of Alzheimer disease. Exercise Q.17

Ans. Alzheimer Disease:
- Alzheimer's disease is a progressive degenerative brain disorder that affects memory, thinking, and behaviour.
- It leads to dementia in older adults. Its onset usually occurs in aged people, but it is not particularly associated with aging.

Check Understanding!
Q.26 Outline the underlying causes and symptoms associated with Alzheimer's disease.

➢ **Causes of Alzheimer Disease:**
- It is due to a combination of genetic, environmental, and lifestyle factors.

➢ **Symptoms Alzheimer Disease:**
- Typically begin with mild memory loss and confusion and progress to more severe cognitive impairment, including difficulty with language, problem-solving, and completing familiar tasks.

➢ **Treatment Alzheimer Disease:**
- There is no cure for Alzheimer's disease, but there are medicines to slow its progression and to improve memory and cognitive function.

Multiple Choice Questions (MCQs)	Key
1. What type of nervous system disorders affect the blood vessels of the brain and spinal cord? (A) Infectious disorders. (B) Vascular disorders. (C) Functional disorders. (D) Structural disorders.	1.(B)
2. What specific type of stroke occurs when a blood vessel in the brain leaks or ruptures? (A) Ischemic stroke. (B) Transient attack. (C) Haemorrhagic stroke. (D) Venous thrombosis.	2.(C)
3. If a patient suffers a stroke resulting in the inability to express themselves through words, which specific symptom are they experiencing? (A) Aphasia. (B) Paralysis. (C) Dizziness. (D) Insomnia.	3.(A)
4. How does a transient ischemic attack (mini-stroke) differ fundamentally from a standard stroke in terms of duration and blood supply? (A) Permanent damage. (B) Temporary decrease. (C) Complete blockage. (D) Vessel rupture.	4.(B)
5. Which infectious nervous system disorder is characterized by an inflammation of the protective meninges due to an infection? (A) Brain tumour. (B) Meningitis. (C) Alzheimer's. (D) Parkinson's.	5.(B)
6. Which specific type of meningitis is described as the most severe and life-threatening? (A) Viral meningitis. (B) Fungal meningitis. (C) Bacterial meningitis. (D) Parasitic meningitis.	6.(C)

7. If a patient presents with neck stiffness, headache, and fever due to a bacterial pathogen, what immediate medical intervention is required? (A) Antibiotics. (B) Antifungals. (C) Antivirals. (D) Surgery only.	7.(A)
8. Why does fungal meningitis typically occur predominantly in individuals with weak immune systems rather than healthy populations? (A) Rare occurrence. (B) Weak immunity. (C) Viral mutation. (D) Bacterial toxin.	8.(B)
9. What causes structural disorders of the nervous system, such as a brain tumour? (A) Functional shift. (B) Physical damage. (C) Dietary habits. (D) Sleep loss.	9.(B)
10. What type of brain tumors are classified as non-cancerous abnormal growths? (A) Malignant mass. (B) Benign tumour. (C) Glial lesion. (D) Secondary cyst.	10.(B)
11. If a patient suffers from headaches caused by an underlying structural problem such as bleeding in the brain, how are these headaches classified? (A) Primary headaches. (B) Secondary headaches. (C) Tension attacks. (D) Migraine events.	11.(B)
12. How do primary headaches differ from secondary headaches in terms of their root origin? (A) Due to head itself. (B) Tumor bleeding. (C) Brain infection. (D) Meningitis swelling.	12.(A)
13. Why are analgesic medicines combined with lifestyle changes like stress reduction and sleep improvement recommended for headaches? (A) Relieve discomfort. (B) Cure tumors. (C) Stop stroke. (D) Prevent bacteria.	13.(A)
14. What pathological process defines degenerative disorders of the nervous system? (A) Progressive deterioration. (B) Sudden blood leak. (C) Bacterial invasion. (D) Temporary blockage.	14.(A)
15. Which specific disease involves the progressive death or weakening of dopamine-producing neurons leading to movement issues? (A) Alzheimer's disease. (B) Parkinson's disease. (C) Huntington's disease. (D) Multiple sclerosis.	15.(B)
16. If an autoimmune disease of the CNS damages the myelin sheath and leads to vision loss and fatigue, what condition is present? (A) Multiple sclerosis. (B) Brain tumour. (C) Bacterial meningitis. (D) Transient attack.	16.(A)
17. What primary cognitive function is predominantly affected first in the early stages of Alzheimer's disease? (A) Motor coordination. (B) Mild memory loss. (C) Heart rate control. (D) Visual processing.	17.(B)
18. Why is Alzheimer's disease considered a progressive degenerative brain disorder rather than a normal consequence of aging? (A) Not bound to aging. (B) Caused by bacteria. (C) Cured easily. (D) Temporary disorder.	18.(A)
19. If a pharmaceutical researcher develops a novel drug aimed at slowing the progression of dementia and improving memory in older adults, what condition are they treating? (A) Alzheimer's disease. (B) Bacterial meningitis. (C) Haemorrhagic stroke. (D) Primary headache.	19.(A)

DIAGNOSTIC TESTS FOR NERVOUS DISORDERS

Q.76 Name three important diagnostic tests for nervous disorders. S/Q

Ans. Important Diagnostic Tests for Nervous Disorders:
- A number of tests have been developed to diagnose the disorders of nervous disorders, three of them are named below.
  (1) Electroencephalography (EEG). (2) Computed Tomography (CT).
  (3) Magnetic Resonance Imaging (MRI).

Topic: Electro-encephalography (EEG):

Q.77 What is EEG, describe its principle, procedure, & uses. Exercise Q.18

Ans. Electroencephalography (EEG):
- EEG is a test which measures the electrical activity of brain.

➢ **Principle of EEG:**
- Its basic principle is based on detecting the electrical nerve impulses being transmitted among the neurons.

➢ **Procedure of EEG:**
- During EEG, metal electrodes are attached to the scalp. These electrodes are connected to an amplifier.

Check Understanding!
Q.27 Which brain wave frequency detected during an EEG test is associated with deep sleep involving dreams and reduced consciousness?
(A) Beta waves. (B) Alpha waves.
(C) Theta waves. (D) Gamma waves

CamScanner

- The amplifier magnifies the electrical signals detected by the electrodes.
- The signals are then recorded and displayed as a series of waveforms on a computer screen or paper.

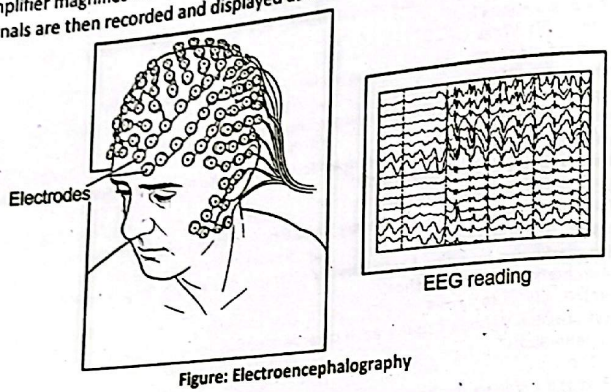
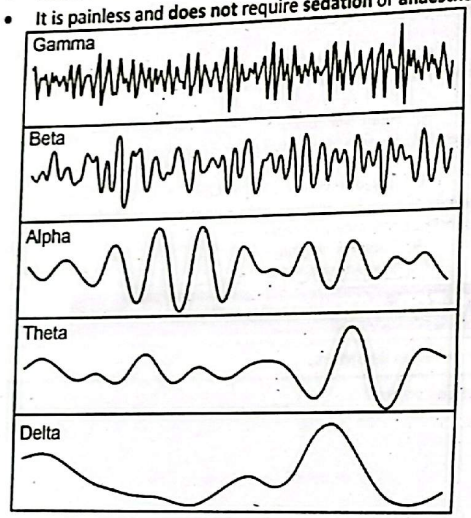


Figure: Electroencephalography

➢ **Uses of EEG:**

- EEG is done to evaluate various **neurological conditions,** including **seizures, epilepsy,** and **brain tumors.**
- It is painless and **does not require sedation or anaesthesia.**



For Information

Each wave of EEG is associated with different states of brain activity.

- Gamma waves are associated with high perception, learning, problem-solving activities.
- **Beta waves** are associated with normal alert state and active thinking.
- **Alpha waves** show physically and mentally relaxed state.
- **Theta waves** show light sleep/drowsiness.
- **Delta waves** show deep, dreamless sleep.

Note that dreaming occurs during REM (Rapid Eye Movement) during which Theta waves dominate, mixed with Beta waves.

Topic: Computed Tomography (CT):

Q.78 Define the term CT scan, describe its principle, procedure, & uses. Exercise L/Q.18

Ans. Computed Tomography (CT): (Commonly known As CT-Scan)

- An imaging technique that uses X-rays and computer processing to generate detailed images of body's internal structures is called **CT scan.**

➢ **Principle of CT Scan:**

- The basic principle of CT is based on the fact that different tissues in body have varying degrees of X-ray absorption.
- These differences can be used to create detailed images of internal structures.

➢ **Procedure of CT Scan:**

- During a **CT scan,** the patient is on a motorized table that slides into a doughnut-shaped machine called a gantry.
- The **gantry** contains an **X-ray** tube that rotates around the patient.
- Multiple detectors on the opposite side of gantry record the absorption of X-rays through different tissues. This information is then used by a computer to construct a detailed, cross-sectional image of the internal structures.

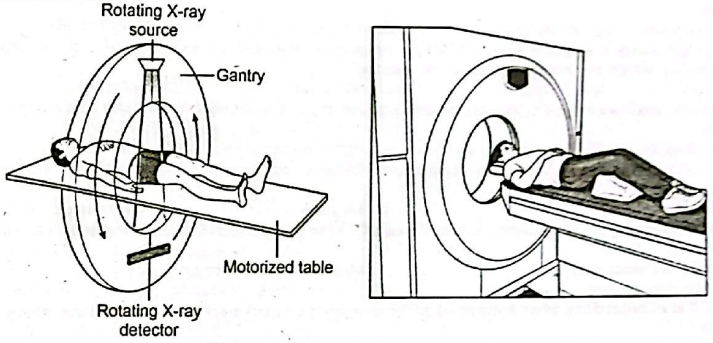


Figure: Computed tomography scan

➢ **Uses of CT Scan:**

- CT scans are **useful** for imaging soft tissues, such as **brain, lungs,** and **abdomen,** as well as for detecting abnormalities in bone structure.
- CT scans are used to diagnose **cancers, infections,** and **injuries.**

Topic: Magnetic Resonance Imaging (MRI):

Q.79 What is MRI? Describe principle, procedure, & uses of MRI. Exercise L/Q.18

Ans. Magnetic Resonance Imaging: (MRI)

- An imaging technique uses a strong magnetic field and radio waves to produce detailed images of body's internal structures is called **MRI.**

Check Understanding!

Q.28 Describe the basic operational principle and medical uses of Magnetic Resonance Imaging (MRI).

➢ **Principle of MRI:**

- The basic principle of MRI is based on the fact that different tissues in the body have varying amounts of hydrogen atoms, which have magnetic properties.

➢ **Procedure of MRI:**

- The patient is on a motorized table that slides into a large tube-like machine called a **scanner.**
- The scanner contains a powerful magnet that creates a strong magnetic field around the patient's body.
- Radio waves are then used to cause the hydrogen atoms in the body to produce a signal.
- These signals are then detected by a receiver. This information is used by a computer to construct a detailed, three-dimensional image of the internal structures.

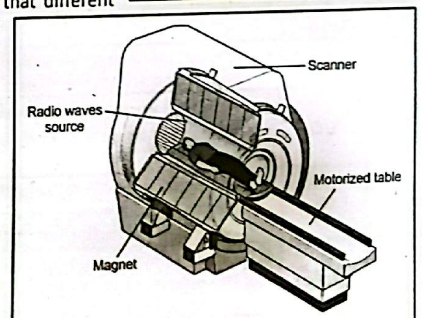


Figure: Magnetic Resonance Imaging

➢ **Uses of MRI:**

- MRI is used for imaging soft tissues, such as brain, spinal cord, and internal organs, as well as for detecting abnormalities in blood vessels and certain types of tumors.

Multiple Choice Questions (MCQs)

1. What physical parameter does an Electroencephalography (EEG) test measure in the brain?
(A) Blood flow. (B) Electrical activity. (C) Oxygen level. (D) Tissue weight.

2. What device is used during an EEG procedure to magnify the electrical signals detected by the scalp electrodes?
(A) Scanner gantry. (B) X-ray tube. (C) Amplifier machine. (D) Motorized table.

3. If a neurologist wants to evaluate a patient for epilepsy and seizures using a painless test that requires no anaesthesia, which diagnostic procedure is selected?
(A) EEG test. (B) CT scan. (C) MRI scan. (D) Biopsy test.

4. Which specific brain wave type is associated with a physically and mentally relaxed state according to the text?
(A) Gamma waves. (B) Beta waves. (C) Alpha waves. (D) Delta waves.

5. What core technology does a Computed Tomography (CT) scan combine with computer processing to generate images?
(A) Sound waves. (B) X-rays. (C) Magnetic fields. (D) Radio waves.

6. What is the underlying physical principle that allows a CT scan to differentiate between various internal body tissues?
(A) Varying X-ray absorption. (B) Magnetic hydrogen count.
(C) Electrical impulse rate. (D) Thermal energy emission.

7. During a CT scan procedure, what is the name of the doughnut-shaped machine containing the rotating X-ray tube?
(A) Scanner tube. (B) Gantry machine. (C) Electrode cap. (D) Receiver box.

8. Why are CT scans particularly useful for medical diagnostics involving soft tissues and bone structures?
(A) Detects blood gas. (B) Measures currents.
(C) Shows abnormalities. (D) Records sound.

9. What physical forces are utilized by a Magnetic Resonance Imaging (MRI) technique to produce detailed internal images?
(A) X-rays and heat. (B) Magnetic field and radio waves.
(C) Electrical currents and amplifiers. (D) Sound waves and pressure.

10. Which specific atomic component inside body tissues possesses the magnetic properties utilized by an MRI scan?
(A) Carbon atoms. (B) Hydrogen atoms. (C) Oxygen atoms. (D) Nitrogen atoms.

11. Why is MRI preferred over standard X-ray techniques for producing detailed three-dimensional images of the spinal cord and brain?
(A) Uses strong magnets. (B) Avoids radiation.
(C) Faster procedure. (D) Cheaper cost.

Key
1.(B)
2.(C)
3.(A)
4.(C)
5.(B)
6.(A)
7.(B)
8.(C)
.(B)
10.(B)
11.(B)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(B)	• The provided material states that receptors are organs, tissues, or cells that detect stimuli and act as transducers.
2.	S/Q	• Dendrites are membrane-bounded extensions of the cell body that receive information from other neurons or cells, convert it into nerve impulses, and carry it toward the cell body.
3.	(C)	• The provided material specifies that oligodendrocytes produce myelin sheaths in the central nervous system, whereas Schwann cells produce them in the peripheral nervous system.
4.	S/Q	• Tapping the patellar tendon is sensed by a receptor in the quadriceps muscle, sending a nerve impulse via a sensory neuron to the spinal cord, which transfers it directly to a motor neuron that causes the quadriceps to contract and the lower leg to kick forward.
5.	(D)	• The provided material indicates that the resting membrane potential of a polarized neuron is about -70 millivolts (-70 mV).

6.	S/Q	• During depolarization, the sodium gates of the membrane open and sodium ions rush into the cell, reducing the inner negative charge and changing the electrical potential from -70 mV up to +50 mV.
7.	(B)	• The provided material explains that action potentials jumping from one node of Ranvier to another while skipping myelinated regions is called saltatory conduction.
8.	S/Q	• When an action potential arrives at the synaptic knobs, calcium gates open allowing calcium ions to diffuse rapidly into the presynaptic axon, which causes synaptic vesicles to fuse with the membrane and release neurotransmitters via exocytosis.
9.	(B)	• The provided material notes that norepinephrine is made in the CNS and sympathetic nerves where it regulates sleep patterns, focus, and alertness.
10.	S/Q	• Inhibitory neurotransmitters bind to postsynaptic receptors and open channels for chloride ions instead of sodium channels, causing chloride ions to diffuse inward and make the inside of the membrane even more negative than the resting potential through hyperpolarization.
11.	(C)	• The provided material states that the second layer below the dura mater is the thin arachnoid layer, which acts as a barrier between the cerebrospinal fluid and blood.
12.	S/Q	• The four lobes are the frontal, parietal, temporal, and occipital lobes; the frontal lobes are associated with executive functions including self-control, planning, reasoning, and abstract thought.
13.	(C)	• The provided material specifies that a specialized area called the auditory cortex within the temporal lobe deals with different sound frequencies.
14.	S/Q	• The amygdalae are two almond-shaped structures present deep within the temporal lobes that control feelings and emotions such as love, hate, anger, fear, rage, and sexual arousal.
15.	(D)	• The provided material states that the inner H-shaped or butterfly-shaped zone of the spinal cord is made of grey matter while the outer zone is made of white matter, which is opposite to the brain.
16.	S/Q	• Cranial Nerve I (olfactory nerve) is sensory and controls the sense of smell, while Cranial Nerve II (optic nerve) is sensory and controls the sense of vision.
17.	(B)	• The provided material lists the 31 pairs of spinal nerves as including 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal pair.
18.	S/Q	• The sympathetic nervous system increases the rate and strength of heart contractions to prepare the body for stress, whereas the parasympathetic nervous system decreases the heart rate to restore normal body conditions after the threat has passed.
19.	(B)	• The provided material states that chemoreceptors located in the upper part of nasal cavities within the nasal epithelium are responsible for the sense of smell.
20.	S/Q	• Nociceptors consist of free nerve endings located throughout the body, especially near surfaces, and are designed to detect pain caused by extremes in temperature, intense pressure, or specific chemicals released by injured cells.
21.	(C)	• The provided material specifies that Meissner's corpuscles are sensory neuron endings surrounded by a capsule found in the upper layer of skin that detect light touch and vibration.
22.	S/Q	• Addictive drugs cause large amounts of dopamine to accumulate in the synaptic cleft by blocking reabsorption, prompting the brain to adapt by reducing the number of dopamine receptors on the postsynaptic neuron, which leads to tolerance.
23.	(D)	• The provided material states that cannabis is a psychoactive drug made from dried flowering tops, leaves, and stems of the Indian hemp plant Cannabis sativa.
24.	S/Q	• A stroke means damage in brain cells due to an interruption in blood supply caused by either the blockage or the rupture of a blood vessel in the brain.
25.	(B)	• The provided material states that bacterial meningitis is the most severe and life-threatening form of meningitis.

CamScanner

26.	S/Q	• Alzheimer's disease is caused by a combination of genetic, environmental, and lifestyle factors leading to progressive deterioration of nerve cells, with symptoms starting with mild memory loss and confusion and progressing to severe cognitive impairment.
27.	(C)	• The provided material indicates that theta waves show deep sleep characterized by dreams and reduced consciousness.
28.	S/Q	• MRI uses a strong magnetic field and radio waves to cause hydrogen atoms in different body tissues to produce signals, which a computer constructs into detailed three-dimensional images used for imaging soft tissues like the brain and spinal cord.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQS

1. **Neurotransmitter receptors are located on:**
   (a) Nuclear membrane. (b) Nodes of Ranvier.
   (c) Postsynaptic membrane. (d) Myelin sheath.
2. **Which neurotransmitter is released by all motor neurons at their synapses with skeletal muscles?**
   (a) Acetylcholine. (b) GABA (c) Norepinephrine. (d) Dopamine.
3. **Which part of the nervous system prepares the body during emergency?**
   (a) Central nervous system. (b) Sympathetic nervous system.
   (c) Parasympathetic nervous system. (d) Sensory pathway.
4. **Which of these is closest to the brain tissue?**
   (a) Dura mater. (b) Arachnoid. (c) Pia mater. (d) Cranium.
5. **In meninges, the cerebrospinal fluid is present between:**
   (a) Skull and dura mater. (b) Dura mater and arachnoid.
   (c) Arachnoid and pia mater. (d) Pia mater and brain or spinal cord.
6. **Which is NOT a function of cerebrospinal fluid?**
   (a) Cushions brain. (b) Produces hormones.
   (c) Transport nutrients to brain. (d) Protects the spinal cord.
7. **During saltatory conduction, the nerve impulse jumps from one ___ to another.**
   (a) Axon. (b) Synapse. (c) Myelin sheath. (d) Node of Ranvier.
8. **In a resting neuron, which of these ions has the highest permeability?**
   (a) Chloride. (b) Sodium. (c) Potassium. (d) Calcium.
9. **If nerve impulses in a neuron 'a' are travelling faster than the impulses in neuron 'b', what might be the reason?**
   (a) Hyperpolarization in neuron 'a'. (b) Neuron 'a' is myelinated.
   (c) There is a high concentration of sodium ions inside neuron 'a'.
   (d) Neuron 'a' is thicker than neuron 'b'.
10. **Dorsal root of spinal nerve contains:**
    (a) Sensory neurons. (b) Inter-neurons.
    (c) Motor neurons. (d) Sensory and motor neurons
11. **Which ions cause the presynaptic vesicles to fuse with the presynaptic membrane and release a neurotransmitter into the synaptic area?**
    (a) Sodium. (b) Potassium. (c) Calcium. (d) Iodine.
12. **The most common cause of dementia is:**
    (a) Alzheimer's disease. (b) Brain tumour. (c) Stroke. (d) Meningitis.
13. **Nociceptors are specialized receptors that detect:**
    (a) Light touch. (b) Deep pressure. (c) Pain. (d) Taste.
14. **Which receptor detects deep pressure and vibration?**
    (a) Meissner's corpuscles. (b) Pacinian corpuscles. (c) Merkel cells. (d) Ruffini endings.

15. **Which of the following is a narcotic drug used for pain relief?**
    (a) Caffeine. (b) Morphine. (c) Alcohol. (d) Nicotine.
16. **Withdrawal symptoms of drug abuse include:**
    (a) Improved concentration. (b) Headache, nausea, and anxiety.
    (c) Increased euphoria. (d) Faster drug metabolism.
17. **Caffeine increases alertness by:**
    (a) Increasing dopamine receptors. (b) Blocking adenosine receptors.
    (c) Stimulating nociceptors. (d) Enhancing serotonin degradation.

Answer Key with Explanations

Sr. No.	Option	Answer	Explanations
1.	(c)	Postsynaptic membrane.	• Neurotransmitter receptors are embedded in the postsynaptic membrane to detect chemical signals arriving across the synaptic cleft.
2.	(a)	Acetylcholine.	• Acetylcholine is the primary excitatory neurotransmitter released at the neuromuscular junction to stimulate skeletal muscle contraction.
3.	(b)	Sympathetic nervous system.	• The sympathetic division controls the fight-or-flight response to prepare the body for emergency situations.
4.	(c)	Pia mater.	• The pia mater is the innermost meningeal layer that adheres directly to the surface of the brain and spinal cord tissue.
5.	(c)	Arachnoid and pia mater.	• The subarachnoid space, which contains cerebrospinal fluid, lies strictly between the arachnoid mater and the pia mater.
6.	(b)	Produces hormones.	• Cerebrospinal fluid acts as a shock absorber, physical cushion, and nutrient carrier, but it is not an endocrine gland that produces hormones.
7.	(d)	None of Ranvier.	• Saltatory conduction involves action potentials jumping rapidly from one node of Ranvier to the next along myelinated axons.
8.	(c)	Potassium.	• Resting neuronal membranes are significantly more permeable to potassium ions via leak channels than to sodium ions.
9.	(b)	Neuron 'a' is myelinated.	• Myelination insulates the axon and allows saltatory conduction, which dramatically increases the speed of nerve impulse propagation.
10.	(a)	Sensory neurons.	• The dorsal root of a spinal nerve exclusively contains afferent fibers transmitting sensory information into the spinal cord.
11.	(c)	Calcium.	• The influx of calcium ions into the axon terminal triggers the exocytosis of synaptic vesicles containing neurotransmitters.
12.	(a)	Alzheimer's disease.	• Alzheimer's disease accounts for the vast majority of all global dementia cases in aging populations.
13.	(c)	Pain.	• Nociceptors are specialized free nerve endings that function specifically to detect noxious or painful stimuli.
14.	(b)	Pacinian corpuscles.	• Pacinian corpuscles are encapsulated mechanoreceptors specialized for sensing deep pressure, high-frequency vibrations, and touch.
15.	(b)	Morphine.	• Morphine is a powerful opiate narcotic derived from opium used clinically for severe pain management.
16.	(b)	Anxiety and tremors.	• Cessation of drug abuse disrupts neurochemistry, causing distressing physical and psychological withdrawal effects like anxiety and tremors.
17.	(b)	Blocking adenosine receptors.	• Caffeine acts as a central nervous system stimulant by competitively blocking adenosine receptors, which prevents drowsiness.

CamScanner

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Enlist the basic elements of nervous coordination.

Ans. Basic Elements of Nervous Coordination:

- It comprises three primary elements:
  (i) Receptors. (ii) Control Center (brain and spinal cord). (iii) Effectors.

Q.2 Define receptors and effectors with examples.

Ans.
- **Receptors:** Specialized cells or organs that detect specific environmental stimuli.
- **Example:** Photoreceptors in eyes detecting light.
- **Effectors:** Organs, muscles, or glands that receive messages from the control center and produce response.
- **Example:** Skeletal muscles contracting.

Q.3 State the path of a message transmitted through the nervous system.

Ans. Path of a Message Transmitted Through the Nervous System:

- Stimulus ⟶ Receptor ⟶ Sensory Neuron ⟶ Control Center (Interneuron) ⟶ Motor Neuron ⟶ Effector ⟶ Response.

Q.4 Define nerve impulse.

Ans. Nerve Impulse (Electrochemical Wave):

- An electrical potential wave of depolarization and repolarization that travels rapidly along the axon membrane of a neuron.

Q.5 Name the factors responsible for the resting membrane potential of neuron.

Ans. Factors Responsible for the Resting Membrane Potential of Neuron: (Primary Determinants)

(i) The action of the sodium-potassium pump (Na^+/K^+ ATPase).
(ii) Differential membrane permeability.
(iii) Higher concentration of potassium ions inside relative to sodium ions outside.

Q.6 What are the main components of the nervous system?

Ans. Main Components of the Nervous System:

- **Central Nervous System (CNS):** It consists of the brain and spinal cord.
- **Peripheral Nervous System (PNS):** It consists of cranial and spinal nerves connecting the CNS to the rest of the body.

Q.7 Define narcotic drugs and give examples.

Ans. Narcotic Drugs:

- A habit-forming analgesic substances that depress central nervous system activity and relieve severe pain.
- **Examples:** Cannabis, Heroin.

Q.8 Briefly describe the effects of drug addiction and tolerance on the functioning of nervous system.

Ans. Effects of Drug Addiction and Tolerance on the Functioning of Nervous System:

- **Effects of Addiction:** It causes chemical dependency and restructuring of neural pathways, driving compulsive drug-seeking behavior.
- **Effects of Tolerance:** It down-regulates receptor sensitivity, requiring progressively larger doses of the drug to elicit the same physiological response.

Q.9 State the causes, symptoms and treatment of stroke and meningitis.

Ans. Causes, Symptoms and Treatment of Stroke and Meningitis:

(i) **Stroke:**
- Caused by blocked or ruptured cerebral blood vessels.
- Symptoms include sudden paralysis or speech deficits.
- Treated with clot-dissolving medications or surgery.

(ii) **Meningitis:**
- Caused by viral or bacterial infection of the meninges.
- Symptoms include severe headache, fever, and stiff neck.
- Treated with targeted antibiotics or antivirals.

Q.10 State the causes, symptoms and treatment of brain tumor.

Ans. Causes, Symptoms and Treatment of Brain Tumor:

- **Causes:** Uncontrolled, abnormal cellular proliferation within the brain or cranial tissues.
- **Symptoms:** Persistent headaches, epileptic seizures, and neurological or cognitive impairment.
- **Treatment:** Surgical resection, radiotherapy, and chemotherapy.

Q.11 State the causes, symptoms and treatment of Alzheimer disease.

Ans. Causes of Alzheimer Disease:

- It is due to a combination of genetic, environmental, and lifestyle factors.

Symptoms Alzheimer Disease:

- Typically begin with mild memory loss and confusion and progress to more severe cognitive impairment, including difficulty with language, problem-solving, and completing familiar tasks.

Treatment Alzheimer Disease:

- There is no cure for Alzheimer's disease, but there are medicines to slow its progression and to improve memory and cognitive function.

Q.12 Differentiate between:

- Axon and dendrite.
- Myelinated and nonmyelinated neurons.
- Cranial and spinal nerves.
- Resting membrane potential and active membrane potential.
- Polarization and depolarization
- Presynaptic and postsynaptic neuron.
- Somatic and autonomic nerves system.
- Sensory neuron, inter-neuron, and motor neurons.
- White matter and grey matter.
- Repolarization and hyperpolarization.
- Synaptic knob and synaptic vesicles.
- Drug addiction and drug tolerance.

Ans. Axon and Dendrite:

Axon	Dendrite
• An axon transmits nerve impulses away from the cell body.	• Dendrites carry impulses toward the cell body.

Sensory Neuron, Inter-neuron, and Motor Neurons:

Sensory Neuron	Inter-neuron	Motor Neurons
• Sensory neurons relay signals from receptors to the CNS.	• Interneurons integrate signals within the CNS.	• Motor neurons transmit signals from the CNS to effectors.

Myelinated and Nonmyelinated Neurons:

Myelinated	Non-myelinated Neurons
• Myelinated neurons feature an insulating myelin sheath facilitating fast saltatory conduction.	• Non-myelinated neurons lack myelin sheath.

White Matter and Grey Matter:

White Matter	Grey Matter
• White matter consists largely of myelinated axonal tracts.	• Grey matter comprises neuronal cell bodies and unmyelinated fibers.

CamScanner

Cranial and Spinal Nerves:

Cranial	Spinal Nerves
• Cranial nerves originate directly from the brain.	• Spinal nerves emerge directly from the spinal cord.

Resting Membrane Potential and Active Membrane Potential:

Resting Membrane Potential	Active Membrane Potential
• Resting potential is the stable baseline polarization of an inactive neuron (-70 mV).	• Active potential is the sudden reversal of voltage during excitation (+50mV).

Polarization and Depolarization:

Polarization	Depolarization
• Polarization maintains a negative internal charge relative to the exterior.	• Depolarization involves the influx of sodium ions reducing this charge difference.

Repolarization and Hyperpolarization:

Repolarization	Hyperpolarization
• Repolarization restores the original resting potential via potassium efflux.	• Hyperpolarization temporarily dips past the resting baseline into a more negative state

Presynaptic and Postsynaptic Neuron:

Presynaptic	Postsynaptic Neuron
• The presynaptic neuron sends neurotransmitters across the synapse.	• The postsynaptic neuron receives neurotransmitters.

Synaptic Knob and Synaptic Vesicles:

Synaptic Knob	Synaptic Vesicles
• The synaptic knob is the terminal swelling of an axon branch.	• Synaptic vesicles are micro-sacs inside the knob storing neurotransmitters.

Somatic and Autonomic Nerves System:

Somatic	Autonomic Nerves System
• The somatic system controls voluntary skeletal movements.	• The autonomic system regulates involuntary visceral and cardiac functions.

Drug addiction and Drug Tolerance:

Drug	Drug Tolerance
• Addiction is a psychological and physical dependence leading to compulsive use.	• Tolerance is a physiological adaptation reducing sensitivity to a fixed drug dose.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Explain the structure of a neuron.
Ans. See Page No. 44 (Q.8)

Q.2 Explain the function of the three types of neurons with the help of a reflex arc.
Ans. See Page No. 47 (Q.16)

Q.3 Describe the generation and transmission of nerve impulse.
Ans. See Page No. 49 (Q.20)

Q.4 Describe polarization, depolarization and hyperpolarisation of neuron membrane.
Ans. See Page No. 49 (Q.20)

Q.5 Describe the saltatory conduction of nerve impulse.
Ans. See Page No. 51 (Q.23)

Q.6 Describe the structure of synapse.
Ans. See Page No. 52 (Q.24)

Q.7 Explain synaptic transmission of nerve impulse.
Ans. See Page No. 52 (Q.25)

Q.8 Classify neurotransmitters as inhibitory and excitatory and list some common examples.
Ans. See Page No. 53 (Q.27)

Q.9 Explain briefly the functions of major parts of brain.
Ans. See Page No. 57-59 (Q.34, Q.35, Q.36, Q.37, Q.38, Q.39, Q.40)

Q.10 Describe the structure of human brain and compare it with that of spinal cord.
Ans. **Structural Comparison Between the Human Brain and the Spinal Cord:**

	Structure of Human Brain	Structure of Spinal Cord
1. Internal Organization of Gray and White Matter:	• Gray matter (neuronal cell bodies) forms the outer surface layer (cortex) of the cerebrum and cerebellum, while white matter (myelinated axons) lies deep within.	• The internal arrangement is inverted; the white matter forms the outer tract layer, while the gray matter is positioned centrally in a characteristic butterfly or H-shape.
2. Protective Bony Encasement	• Encased within the rigid, protective bony vault of the cranium (skull). • Cranium shields it from direct physical trauma.	• Protected within the flexible, segmented vertebral canal formed by the vertebrae of the spinal column, allowing for spinal movement and bending.
3. Anatomical Complexity and Regional Specialization	• Highly convoluted and structurally complex, divided into two cerebral hemispheres, the cerebellum, and the brainstem.	• Long, relatively uniform, and cylindrical in shape.
4. Nerve Root and Segmental Organization	• Connects directly with 12 pairs of cranial nerves that primarily serve sensory and motor functions of the head, neck, and facial regions.	• Gives rise to 31 pairs of spinal nerves arranged segmentally (cervical, thoracic, lumbar, sacral, and coccygeal) that supply the rest of the body.

Q.11 Explain the types and functions of autonomic nervous system.
Ans. See Page No. 62-63 (Q.45 ⟶ Q.46)

Q.12 Write a detailed note on the receptors for smell.
Ans. See Page No. 66 (Q.50)

Q.13 Explain the structure of the receptors for taste.
Ans. See Page No. 65 (Q.48)

Q.14 Describe the receptors for touch and pain.
Ans. See Page No. 67 (Q.52 ⟶ Q.53)

Q.15 Describe the use and abuse of narcotic drugs with examples.
Ans. See Page No. 71-72 (Q.61 ⟶ Q.68)

CamScanner

Q.16 What is meant by drug addiction and drug tolerance? Explain with reference to caffeine and nicotine.

Ans. See Page No. 69 (Q.57)

Q.17 Explain the classification of nervous disorders with examples.

Ans. See Page No. 73-76 (Q.70 ⟶ Q.75)

Q.18 Explain the principles and use of EEG, CT scan and MRI.

Ans. See Page No. 77-79 (Q.77 ⟶ Q.79)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Predict from every day experience what kinds of receptors are found in human body.

Ans. (i) **Meissner's Corpuscles:** They detect light touch and vibration.
(ii) **Hair Follicle:** They detect the movement of hairs, which occur due to mechanical or thermal stimuli.
(iii) **Merkel Cells:** They detect light touch and are present in highly touch-sensitive areas like fingertips.
(iv) **Pacinian Corpuscles:** They detect deep pressure and vibration.
(v) **Ruffini Endings:** They detect sustained pressure and stretching.

Q.2 Conceptualize the activity of brain, which can be recorded using magnets and tomography.

Ans.
- **Neural Impulses:** Brain cells (neurons) communicate using tiny electrical signals that generate weak magnetic fields.
- **Magneto-encephalography (MEG):** Uses sensitive detectors to record these magnetic fields and map active brain areas.
- **Brain Tomography:** Imaging techniques like EEG and CT scans track blood flow and energy use to show which brain parts are working.

Q.3 Justify the way nervous system helps to coordinate complex and intricate movements of hand to play a piano, or write alphabets.

Ans. **Way Nervous System Helps to Coordinate Complex and Intricate Movements:**
- **Motor Cortex Commands:** The brain sends rapid electrical messages via motor nerves to specific hand and finger muscles.
- **Cerebellum Fine-Tuning:** The cerebellum coordinates balance, rhythm, and muscle timing for smooth and accurate actions.
- **Sensory Feedback:** Eyes and touch receptors send instant updates back to the brain to correct speed and pressure continuously.

Q.4 Justify that the development of a modern computer is in fact a product of the understanding of the way nervous coordination occurs in complex organisms like humans.

Ans.
- **Input-Processing-Output:** Both computers and the nervous system follow the same basic steps of receiving data, processing it, and giving a response.
- **On/Off Signals:** Computer binary codes (0s and 1s) mimic how neurons fire using all-or-none electrical impulses.
- **Neural Networks:** Advanced computing and artificial intelligence are directly modeled after human brain networks to learn and solve problems.

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. (1 x 6 = 06)

(i) **How do the two types of effectors differ in their responses?**
(A) Contracting vs secreting. (B) Electrical vs chemical.
(C) Internal vs external. (D) Sensory vs motor.

(ii) **In myelinated axons, action potentials occur mainly at the:**
(A) Schwann cells. (B) Axon terminals. (C) Nodes of Ranvier. (D) Cell body.

(iii) **A motor neuron-to-muscle synapse is called a:**
(A) Reflex arc. (B) Neuromuscular junction. (C) Ganglion. (D) Neural plexus.

(iv) **If a physician observes a membrane that acts as a barrier between cerebrospinal fluid and blood in the dura mater, which layer is it?**
(A) Dura mater. (B) Arachnoid layer. (C) Pia mater. (D) Vertebral column.

(v) **Approximately how many taste buds are present in the human body?**
(A) 2,000 – 8,000. (B) 5,000 – 8,000. (C) 8,000 – 10,000. (D) 10,000 – 20,000.

(vi) **What type of brain tumors are classified as non-cancerous abnormal growths?**
(A) Malignant mass. (B) Benign tumour. (C) Glial lesion. (D) Secondary cyst.

Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) State the path of a message transmitted through the nervous system.
(ii) What are Schwann cells & oligodendrocytes, how they play different role in neurons?
(iii) Differentiate between Polarization and Depolarization.
(iv) Which factors can effect the velocity of the nerve impulse?
(v) What are neurotransmitters & name two types of neurotransmitter also give one example of each type?
(vi) How are brain & spinal cord protected?
(vii) Differentiate between psychoactive drug & narcotic drugs also give their examples.
(viii) Differentiate between primary headache & secondary headache.

Q.3 Extensive Questions. (4 x 2 = 8)

(a) Describe the structure of human brain and compare it with that of spinal cord.
(b) Explain the principles and use of EEG, CT scan and MRI.

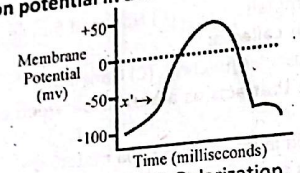
CamScanner

ENTRANCE TEST MDCAT

1. **Neurotransmitter secreted at synapse outside the central nervous system is:** (UHS 2015) (SGD 2023 Gi)
   A. Dopamine. B. Androgen. C. Polypeptide. D. Acetylcholine.

2. **Conduction of action potentials from one node of Ranvier to another in myelinated neurons is through:** (UHS 2015)
   A. Hyperpolarization. B. Depolarization. C. Resting membrane potential. D. Saltatory conduction.

3. **In the following diagram of action potential in a neuron, "x" depicts:** (UHS 2015)



   A. Depolarization. B. Repolarization. C. Polarization. D. Hyperpolarization.

4. **Humans have homeostatic thermostat present in a specified portion of the brain that is:** (UHS 2016)
   A. Lateral ventricle. B. Spinal cord. C. Thalamus. D. Hypothalamus.

5. **A neurological disorder characterized by the decline in brain function is _____. Its symptoms are smilar to those diseases that cause dementia:** (UHS 2016)
   A. Parkinson's disease. B. Alzheimer's disease. C. Epilepsy. D. Diabetes.

6. **Part of hind brain responsible for the balance and equilibrium of body is called:** (UHS 2016)
   A. Medulla. B. Pons. C. Cerebellum. D. Thalamus.

7. **Brain is protected and enclosed in:** (UHS 2016)
   A. Lumbar vertebrae. B. Vertebral column. C. Coccyx. D. Cranium.

8. **The nerve impulse which jumps from node to node in myelinated neurons is:** (UHS 2017)
   A. Resting membrane potential. B. Threshold stimulus.
   C. Saltatory nerve impulse. D. Initial nerve impulse.

9. **The CNS is protected by:** (UHS 2017)
   A. Three layers of meninges. B. Four layers of meninges.
   C. One layer of meninx. D. Two layers of meninges.

10. **White matter of spinal cord is made up of:** (UHS 2017)
    A. Sensory nerve fibres. B. Motor nerve fibres. C. Myelinated nerve fibres. D. Mixed nerve fibres.

11. **In nervous system chemical messengers are called:** (UHS 2018)
    A. Neurotransmitters. B. Chemoreceptors. C. Hormones. D. Enzymes.

12. **How many sodium ions are pumped out in response to two potassium ions transported into the membrane:** (UHS 2018)
    A. 2 B. 4 C. 3 D. 1

13. **In an action potential, the permeability of sodium ions in the neurons increases due to:** (UHS 2019)
    A. Repolarization. B. The opening of sodium channels/gates.
    C. The action of the acetylcholinesterase enzyme. D. Sodium ions forming an ionic bonding.

14. **The reflex action is the phenomena which only involves:** (UHS 2019)
    A. Brain, receptors, spinal cord. B. Receptors, neurons, brain.
    C. Receptors, effectors and spinal cord. D. Receptors ad effectors.

ANSWERS KEY

1. D	2. D	3. B	4. D	5. B	6. C	7. D	8. C	9. A	10. C	11. A	12. C	13. B	14. C

CHAPTER 16

HUMAN ENDOCRINE SYSTEM

Student Learning Outcomes (SLOs)

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

- State the role of hormones as chemical messengers.
- Describe the chemical nature of hormones and correlate it with important hormones.
- Locate the endocrine glands in human body and name the hormones they release and their functions; (pituitary, thyroid, parathyroid, pancreas, adrenal, gonads).
- Relate the problems associated with the imbalance of these hormones.
- Explain the neurosecretory role of hypothalamus.
- Outline the concept of feedback mechanism of hormones and describe positive feedback with reference to Oxytocin and negative feedback with reference to Insulin and Glucagon.

CamScanner

Human Endocrine System — Concept Map

1. HORMONES – CHEMICAL MESSENGERS

(a) Chemical Nature

- **Peptide & Protein** (Water-soluble, cell-surface receptors; e.g., Insulin, Glucagon, GH, Oxytocin).
- **Glycoprotein** (Large, complex, polar; e.g., TSH, FSH, LH)
- **Amino Acid Derivatives** (Tyrosine/Tryptophan-derived; e.g., Epinephrine/Norepinephrine, Thyroxine/Triiodothyronine).
- **Steroid** (Lipid-soluble from cholesterol, direct nuclear access; e.g., Cortisol, Aldosterone, Testosterone, Estrogen, Progesterone).

- Path of Message → Endocrine secretion → Blood transport → Specific target cell receptors → Cellular response.

2. ENDOCRINE SYSTEM OF MAN

(a) Hypothalamus (Neurosecretory)

- Posterior Control → Oxytocin & ADH storage/release via axonal transport.
- Anterior Control → Releasing/Inhibiting hormones via portal blood vessels (TRH, GHRH, Somatostatin, GnRH, Dopamine/PIF).

(b) Pituitary Gland:

- Anterior Lobes → GH, ACTH, TSH, LH, FSH, Prolactin (Imbalances: Gigantism, Acromegaly, Dwarfism, Diabetes Insipidus).
- Posterior Lobes → ADH, Oxytocin.
- Intermediate Lobe → Melanocyte Stimulating Hormone (MSH).

(c) Thyroid Gland:

- Hormones → Thyroxine (T4), Tri-iodothyronine (T3), Calcitonin.
- Imbalances → Hypothyroidism (Cretinism, Myxoedema, Goitre), Hyperthyroidism (Graves' disease).

(d) Parathyroid Glands:

- Hormone → Parathormone (Raises blood Ca^{2+}).
- Imbalances → Hypercalcemia/Tetany.

(e) Pancreas:

- Islets of Langerhans → Insulin (β cells lower glucose) vs. Glucagon (α cells raise glucose) | Imbalance: Diabetes Mellitus / Hypoglycaemia.

(f) Adrenal Glands:

- Medulla → Epinephrine & Norepinephrine (Fight or flight response)
- Cortex → Glucocorticoids (Cortisol) & Mineralocorticoids (Aldosterone) | Imbalances: Cushing disease, Addison's disease.

(g) Gonads:

- Ovaries → Estrogen & Progesterone (Cycle regulation, secondary sex traits).
- Testes → Testosterone via interstitial cells (Androgen / Male traits).

(h) Other Tissues:

- Thymus (Thymosin), Pineal (Melatonin), Stomach/Intestine (Gastrin, Secretin, CCK), Kidneys (Renin, Erythropoietin, Calcitriol), Brain (Endorphins), Local Prostaglandins

3. FEEDBACK MECHANISM

(a) Positive Feedback:

- Product/response accelerates the controlling action (e.g., Oxytocin during childbirth contractions).

(b) Negative Feedback:

- End product stops the initial step (e.g., Insulin stopping when blood glucose normalizes).

INTRODUCTION

Chapter's Intro:

- In this chapter we will study the **hormones of endocrine glands, and their functions.**

Q.1 What is the importance of human endocrine system & why is coordination through endocrine system called chemical coordination? S/Q

Ans. Importance of Endocrine System:

- While our nervous system **carries out** high-speed nervous coordination, the **endocrine system** controls long-term processes like **growth, metabolism,** and **reproduction.**

Coordination via Endocrine System:

- A chemical coordination performs its job by sending chemical instructions, in the form of hormones, to the target body parts that's why it is called **chemical coordination.**

Check Understanding!

Q.1 Which type of glands are ductless and secrete their secretions called hormones directly into the blood or tissue fluid?

(A) Endocrine glands. (B) Exocrine glands. (C) Salivary glands. (D) Sweat glands.

HORMONES - THE CHEMICAL MESSENGERS

Q.2 What are hormones, & why are they called chemical messengers or signaling molecules? S/Q

Ans. Hormone:

- A hormone is a regulatory chemical that is secreted into the blood or tissue fluid by an endocrine gland.
- The blood **carries** the hormone to every cell in body, but it shows its effects only in its specific target cells.

➢ **Hormones As Chemical Messengers or Signaling Molecules:**

- When the **target cells** receive a hormone, they respond in specific way. That's why, hormones are referred to as **chemical messengers or signaling molecules.**

For Information

Q. What are glands & define its two types.

Ans. Glands:

These are the tissues that produce and release secretions.

There are **two types** of glands in body.

(i) **Exocrine glands** secrete their secretion in ducts attached with them.

(ii) **Endocrine glands** are ductless. They secrete their secretions called hormones directly in blood or tissue fluid.

Topic: Chemical Nature of Hormones:

Q.3 Name the main chemical categories of hormones. Exercise L/Q.2

Ans. Main Chemical Categories of Hormones:

- We can group hormones into **four main** chemical categories:
  - **(1) Peptide and Protein Hormones.**
  - **(2) Glycoprotein Hormones.**
  - **(3) Amino Acid Derivatives Hormones.**
  - **(4) Steroid Hormones.**

Check Understanding!

Q.2 Differentiate between the chemical structures and membrane permeability of peptide/protein hormones versus steroid hormones.

Topic: (1) Peptide and Protein Hormones:

Q.4 What are peptide & protein hormones discuss their characteristics & give their examples with their sources & role in our body. Exercise L/Q.2

Ans. Peptide & Protein Hormones:

- The hormones which are made of **chains of amino acids** are called **peptide & Protein hormones.**

➢ **Characteristics of Peptide & Protein Hormones:**

- They are water-soluble, meaning they dissolve easily in blood.
- They cannot pass through cell membranes. So, they bind to receptors on the cell surface.

CamScanner

➢ **Examples + Sources + Functions of Peptide & Protein Hormones:**

Hormone	Source (Gland)	Main Function
(i) Insulin	• Pancreas.	• Lowers blood glucose levels.
(ii) Glucagon	• Pancreas.	• Raises blood glucose levels.
(iii) Growth Hormone	• Anterior Pituitary.	• Stimulates growth and cell reproduction.
(iv) Oxytocin	• Hypothalamus (released by Posterior Pituitary)	• Stimulates muscle contractions during childbirth.

Topic: (2) Glycoprotein Hormones:

Q.5 What are glycoprotein hormones, give their characteristics. Exercise L/Q.2

Ans. Glycoprotein Hormones:

- The hormones which are "conjugated proteins" and consist of a protein combined with a carbohydrate (sugar) group are called **glycoprotein hormones.**

➢ **Characteristics of Glycoprotein Hormones:**

- They are large, complex, and polar molecules. So, they also cannot pass through the cell membrane.
- Examples include;

Q.6 Give three examples of hormones which are glycoprotein in nature also give their source & main functions in human body. Exercise L/Q.2

Ans. Hormones are Glycoprotein in Nature:

Hormone	Source (Gland)	Main Function
(i) Thyroid Stimulating Hormone.	• Anterior Pituitary.	• Stimulates the thyroid gland to produce thyroxine.
(ii) Follicle Stimulating Hormone.	• Anterior Pituitary.	• Stimulates sperm production or egg development.
(iii) Luteinizing Hormone.	• Anterior Pituitary.	• Triggers ovulation in females and secretion of testosterone in males.

Topic: (3) Amino Acid Derivatives Hormones:

Q.7 What are amino acid derivatives hormones? Discuss their characteristics give examples with source & major functions of such hormones? Exercise L/Q.2

Ans. Amino Acid Derivatives Hormones:

- The hormones which are small molecules **derived** from a single **amino acid** (usually **Tyrosine or Tryptophan**) are called **amino acid derivative hormones.**
- Their ability to pass through cell membranes depends on whether they behave more like a protein or more like a lipid.
- **Epinephrine** and nor-epinephrine cannot cross **membranes** while thyroxine and tri-iodothyronine can cross.

Tidbit

- In 1902, two British scientists, **Bayliss** and **Starling**, discovered hormone during their research on digestive system.
- They found that when acidic gastric juice comes in small intestine, a substance (which they called "secretin") was released into blood.
- Secretin reaches the pancreas and stimulates it to secrete pancreatic juice.

➢ **Examples of Amino Acid Derivative Hormones:**

Amino Acid Derivative Hormone	Source (Gland)	Main Function
(i) Epinephrine (Adrenaline).	• Adrenal Medulla.	• Immediate "fight or flight" response.
(ii) Nor-epinephrine (nor-adrenaline).	• Adrenal Medulla.	• Increases blood pressure and alertness.
(iii) Thyroxine (T_4).	• Thyroid Gland.	• Controls the speed of metabolism.
(iv) Triiodothyronine (T_3).	• Thyroid Gland.	• Regulates body temperature and heart rate.

Topic: (4) Steroid Hormones:

Q.8 What are steroid hormones, write their characteristics give examples, source glands, & main functions of these hormones. Exercise L/Q.2

Ans. Steroid Hormones:

- The hormones which are derived from **cholesterol** (a type of lipid) are known as steroid hormones.

➢ **Characteristics of Steroid Hormone:**

- Unlike proteins, steroids are lipid-soluble (fat-soluble).
- Thus they can move through the cell membrane to give instructions directly to the nucleus.
- Examples include:

Check Understanding!

Q.3 Which chemical category of hormones includes molecules derived from a single amino acid, such as tyrosine or tryptophan?
(A) Amino Acid Derivatives Hormones.
(B) Peptide and Protein Hormones.
(C) Glycoprotein Hormones.
(D) Steroid Hormones.

Hormone	Source (Gland)	Main Function
(i) Cortisol.	• Adrenal Cortex.	• Regulates metabolism and helps the body respond to stress.
(ii) Aldosterone.	• Adrenal Cortex.	• Helps the kidneys manage salt and water balance.
(iii) Testosterone.	• Testes.	• Regulates male reproductive tissues and traits.
(iv) Estrogen / Progesterone.	• Ovaries.	• Regulate the female reproductive system and cycle.

Q.9 What path of the chemical message carried by hormones? S/Q

Ans. Path of the Chemical Message Carried by Hormones:

- The endocrine glands **secrete** their hormones on receiving **particular stimuli.** They release hormones in blood, which carries the hormone to all cells.
- **Each hormone** affects only its target cells. Target cells have receptors.
- Each **receptor binds** to a specific hormone. When a hormone binds to a receptor, the binding **triggers events** that lead to changes within the cell.
- Receptors can be found on the cell membrane, in the **cytoplasm**, or in the **nucleus of a cell.**

Tidbit

Q. Write one similarity & two differences between hormones & neurotransmitters.

Ans. Difference between Hormones & Neurotransmitters:

Hormones: Hormones are part of endocrine system. Hormones are often slower acting and have longer effects.

Neurotransmitters: Neurotransmitters are fast acting & have shorter effects.

Neurotransmitters are part of nervous system.

Hormones and neurotransmitters are both chemical messengers.

Multiple Choice Questions (MCQs)

		Key
1.	**A hormone is a regulatory chemical secreted by a(n):** (A) Exocrine gland. (B) Endocrine gland. (C) Sweat gland. (D) Salivary gland.	1.(B)
2.	**Hormones are commonly called:** (A) Structural proteins. (B) Antibodies. (C) Digestive enzymes. (D) Chemical messengers.	2.(D)
3.	**Endocrine glands are characterized by being:** (A) Ductless. (B) Connected to ducts. (C) Muscle tissue. (D) Located in the brain.	3.(A)
4.	**Peptide and protein hormones bind to receptors on the cell surface because they are:** (A) Lipid-soluble. (B) Water-soluble. (C) Derived from cholesterol. (D) Stored in the nucleus.	4.(B)
5.	**Which hormone lowers blood glucose levels?** (A) Glucagon. (B) Epinephrine. (C) Cortisol. (D) Insulin.	5.(D)
6.	**Thyroid Stimulating Hormone (TSH) is secreted by the:** (A) Thyroid gland. (B) Adrenal cortex. (C) Anterior pituitary. (D) Pancreas.	6.(C)
7.	**Which hormone triggers ovulation in females and stimulates testosterone secretion in males?** (A) Luteinizing Hormone. (B) Follicle Stimulating Hormone. (C) Growth Hormone. (D) Oxytocin.	7.(A)
8.	**Which amino acid derivative hormone controls the speed of metabolism?** (A) Epinephrine. (B) Norepinephrine. (C) Thyroxine (T_4). (D) Cortisol.	8.(C)
9.	**Steroid hormones are derived from:** (A) Amino acids. (B) Glucose. (C) Glycogen. (D) Cholesterol.	9.(D)

CamScanner

10. Aldosterone primarily helps the kidneys to regulate:
(A) Blood glucose. (B) Salt and water balance.
(C) Body temperature. (D) Muscle contraction.

11. A hormone is carried by the blood to all body cells but affects only certain cells because:
(A) Specific receptors. (B) Muscle cells. (C) Endocrine glands. (D) Target organs.

12. Which pair of hormones can cross the cell membrane?
(A) Epinephrine & norepinephrine. (B) Insulin & glucagon.
(C) Thyroxine (T_4) & Triiodothyronine (T_3). (D) Follicle Stimulating Hormone & Luteinizing Hormone.

13. Steroid hormones can directly influence the nucleus because they are:
(A) Water-soluble. (B) Lipid-soluble. (C) Large protein molecules. (D) Glycoproteins.

14. Bayliss and Starling discovered the hormone while studying the:
(A) Circulatory system. (B) Respiratory system. (C) Nervous system. (D) Digestive system.

15. Which sequence correctly describes the pathway of hormonal communication?
(A) Hormone → Target cell → Endocrine gland → Blood.
(B) Endocrine gland → Blood → Target cell receptor → Cellular response.
(C) Blood → Receptor → Endocrine gland → Cell.
(D) Receptor → Hormone → Blood → Target cell.

10.(B) 11.(A) 12.(C) 13.(B) 14.(D) 15.(B)

ENDOCRINE SYSTEM OF MAN

Q.10 What is endocrine system? S/Q

Ans. Endocrine System:

- The system of human beings which consists of glands and organs that produce and secrete hormone for regulating various body functions is called **endocrine system.**

Q.11 Show the location of endocrine glands with the help of diagram. S/Q

Ans. Locations of Different Endocrine Glands in Human Body:

- The locations of major endocrine glands have been shown below.

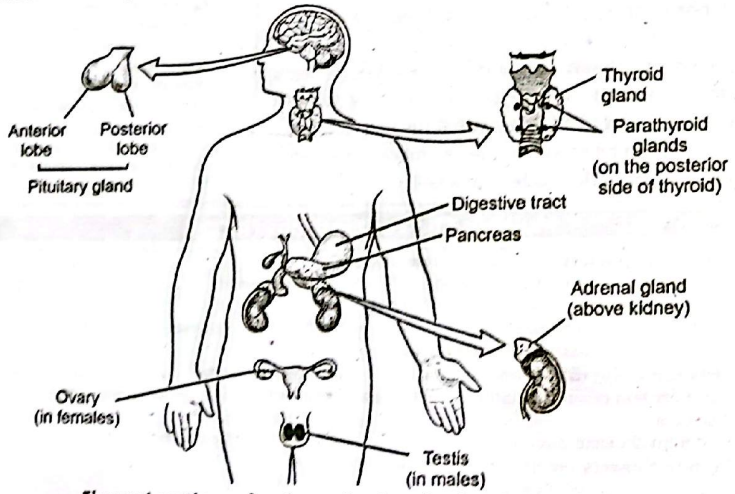


Figure: Locations of major endocrine glands in human body

Topic: Neurosecretory Role of Hypothalamus:

Q.12 What are "Neurosecretory Cell", discuss the role of "Hypothalamus" as "Neurosecretory Organ"? Exercise Q.4

Ans. Neurosecretory Cell:

- The cells which not only conduct nerve impulses but also secrete hormones are called **neurosecretory ce**

➢ **Neurosecretory Role of Hypothalamus:**

- Many endocrine glands of the body are controlled by the master gland i.e., pituitary gland.
- The master gland is itself controlled by a part of the brain i.e., hypothalamus. Hypothalamus contains special neurosecretory cells.

Check Understanding!
4. Explain the dual nature and function of the neurosecretory cells located within the hypothalamus.

(i) Control of Posterior Pituitary:

- Two hormones i.e., **oxytocin** and **antidiuretic hormone (ADH)** are made by neurosecretory cells of **hypothalamus.**
- The axons of **neurosecretory cells** transport oxytocin and ADH to the **posterior lobe of pituitary gland.**
- Where they are stored for **eventual** release into blood.

(ii) Control of Anterior Pituitary:

- Blood vessels connect hypothalamus with the anterior pituitary.
- **Neurosecretory cells** of hypothalamus secrete hormones that travel to the anterior pituitary through these blood vessels. These hormones are of two kinds

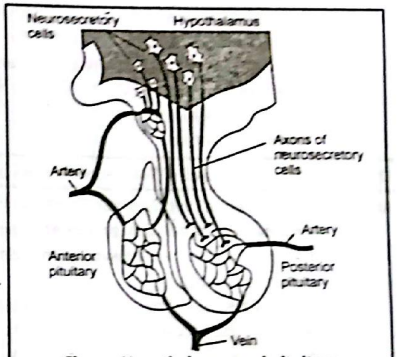


Figure: Hypothalamus and pituitary

(a) Releasing Hormones of Hypothalamus:

- These hormones stimulate the anterior pituitary to make and secrete hormones.

Releasing Hormones of Hypothalamus	Effect on Anterior Pituitary
(i) Growth Hormone Releasing-Hormone.	• Secretion of growth hormone.
(ii) Thyrotropin releasing hormone (TRH).	• Secretion of thyroid stimulating hormone (TSH).
(iii) Adreno-corticotropin releasing hormone.	• Secretion of adrenocorticotrophic hormone.
(iv) Gonadotropin releasing hormone.	• Secretion of FSH and LH.

(b) Inhibiting Hormones of Hypothalamus:

- These hormones **inhibit production** and secretion of anterior pituitary hormones.

Inhibiting Hormones of Hypothalamus	Effect on Anterior Pituitary
(i) Somatostatin.	• Inhibition of growth hormone.
(ii) Prolactin inhibiting factor - which is actually dopamine.	• Inhibits secretion of prolactin.

Topic: Pituitary Gland:

Q.13 Why pituitary gland is called master gland? S/Q

Ans. Pituitary Gland As Master Gland:

- The secretions of many endocrine glands is controlled by pituitary gland, that's why it is called "Master Gland".

Q.14 What is infundibulum & name three lobes of pituitary gland? S/Q

Ans. Infundibulum:

- Pituitary gland is attached to hypothalamus by a stalk called infundibulum.

➢ **Lobes of Pituitary Glands:**

- Pituitary gland is divided into three lobes:
  (1) Anterior Pituitary Lobe. (2) Posterior and Pituitary.
  (3) Intermediate / Median Pituitary.

Check Understanding!
Q.5 Which anterior pituitary hormone stimulates the thyroid gland to produce thyroxine, which in turn stimulates oxidative respiration?
(A) Thyroid-stimulating Hormone.
(B) Adrenocorticotropic Hormone.
(C) Luteinizing Hormone.
(D) Growth Hormone.

CamScanner

Topic: Anterior Pituitary:

Q.15 Name the hormones produced from "Anterior Pituitary". Exercise L/Q.2

Ans. Hormones of Pituitary Gland:

- Anterior pituitary secretes many hormones, many of which regulate the activity of other endocrine glands.

1. Growth Hormone (GH, or Somatotropin).
2. Adrenocorticotropic Hormone (ACTH, or Corticotropin).
3. Thyroid-stimulating Hormone (TSH, or Thyrotropin).
4. Luteinizing Hormone (LH) In Females & Males.
5. Follicle-stimulating Hormone (FSH).
6. Prolactin Hormone.

Q.16 Describe the role of different hormones produce from anterior pituitary. Exercise L/Q.2

Ans. Role of Different Hormones Produce from Anterior Pituitary:

1. **Growth Hormone (GH, or Somatotropin):**
   - It stimulates the growth of muscles, bones (indirectly), and other tissues.
   - It is also essential for proper metabolic regulation.
2. **Adrenocorticotropic Hormone (ACTH, or Corticotropin):**
   - It stimulates the adrenal cortex for the secretion of corticosteroids, chiefly cortisol, which regulates glucose homeostasis.
3. **Thyroid-stimulating Hormone (TSH, or Thyrotropin):**
   - It stimulates the thyroid gland to produce thyroxine, which in turn stimulates oxidative respiration.
4. **Luteinizing Hormone (LH) In Females & Males:**
   - **In Females:** It stimulates ovaries to produce progesterone and estrogen hormones. It also initiates ovulation.
   - **In Males:** It stimulates testes for testosterone production.
5. **Follicle-stimulating Hormone (FSH) in Females & Males:**
   - **In Females:** This hormone stimulates the development of ovarian follicles.
   - **In Males:** It stimulates the development of sperms.
   - FSH and LH are both referred to as gonadotropins.
6. **Prolactin Hormone:**
   - It stimulates the mammary glands to produce milk.
   - It is produced in both male and female but functions only in female.

Tidbit

Growth Hormone Treatment

- GH treatment is given to children have short stature due to GH deficiency. It improves their growth rate.
- However, every dwarf person does not have GH deficiency. So, GH therapy may not be appropriate for everyone.
- Some people use GH because they believe it will build muscle or slow aging. However, doctors do not support the use of GH for these purposes.

Topic: Posterior Pituitary:

Q.17 What is posterior pituitary? Discuss the hormones stored in posterior pituitary. Exercise L/Q.3

Ans. Posterior Pituitary:

- The posterior pituitary contains axons that originate in hypothalamus and extend to posterior pituitary.
- Posterior pituitary does not synthesize any hormone but only stores and releases the hormones made by hypothalamus.

➢ **Hormones Stored & Released From Posterior Pituitary:**

- The following are the hormones released by posterior pituitary.
  - (i) **Antidiuretic Hormone (ADH or vasopressin):** It stimulates water retention by the kidneys.
  - (ii) **Oxytocin:** It stimulates the milk-ejection by stimulating the contraction of smooth muscles of mammary glands. It also stimulates uterine contractions in women during childbirth.

Check Understanding!

Q.6 Evaluate why the posterior pituitary does not synthesize its own hormones despite releasing oxytocin and antidiuretic hormone.

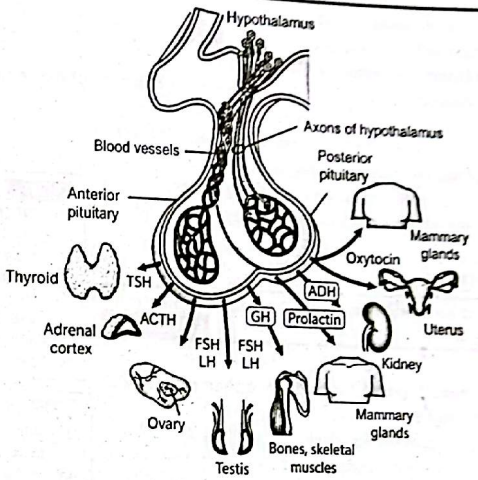


Figure: Hormones of anterior & posterior pituitary and their target sites

Topic: Intermediate Pituitary:

Q.18 What is intermediate pituitary? Name the hormone produces from intermediate pituitary also give its role. Exercise S/Q.3

Ans. Intermediate Pituitary:

- In humans, **intermediate pituitary** is a thin layer of cells between the anterior and posterior pituitary.

➢ **Hormones Produces From Intermediate:**

- **(i) Melanocyte Stimulating Hormone (MSH):**
  - MSH stimulates the production and release of melanin by melanocytes in skin and hair.

For Information

- During embryonic development, posterior pituitary is formed from an outgrowth of neural tissue. That's why, hypothalamus of brain and posterior pituitary remain interconnected by a tract of axons.

For Information

- Oxytocin secretion continues after childbirth in breast-feeding mothers. That's why, the uterus of a nursing mother returns to its normal size after pregnancy more quickly than the mothers who do not breast-feed.

Topic: Imbalance of Pituitary Hormones:

Q.19 Discuss the problems produced due to imbalance of pituitary hormones. Exercise L/Q.3

Ans. Problems Due to Imbalance of Pituitary Hormones:

- **(1) Problems Due to Over-Secretion of Growth Hormone:**
  - **(a) Over Secretion: (During Early Age)**
    - **Gigantism:** If there is an over-secretion of growth hormone (GH) in a growing child, it causes gigantism i.e., height that is well above average, enlarged hands, feet, and facial features.
  - **(b) Over-Secretion (In Later Age):**
    - Over-secretion of GH in adult life causes acromegaly.
    - Acromegaly is a condition in which bones are no longer capable of increasing in length but grow in thickness.
    - Acromegaly is characterised by enlarged hands, feet, skull, nose and jawbone.
- **(2) Problems Due to Under secretion of Growth Hormone:**
  - **(a) Dwarfism:** Deficiency of GH results in dwarfism in which development is much slower and individual has short stature. However, the body parts stay in proportion and brain development and IQ are unaffected.
- **(3) Problems Due to Over secretion of TSH:**
  - **Hyperthyroidism** causes due to excess of thyroxine.

CamScanner

(4) **Problems Due to Under Secretion of TSH:**
- **Hypothyroidism** lack of thyroxine.

(5) **Problems Due to Under Secretion of ADH:**
- **Diabetes insipidus** it is characterized by excessive production of dilute urine and frequent thirst.

(6) **Problems Due to Over Secretion of ADH:**
- May lead to water retention and lower blood sodium level.

(7) **Problems Due to Over-Secretion of Oxytocin:**
- Over secretion of **oxytocin** causes rupturing of uterine wall while under secretion of oxytocin inhibits normal labour process.

Topic: Thyroid Gland:

Q.20 Where is thyroid gland located? Discuss the homes with their roles secreted by thyroid gland. Exercise L/Q.4

Ans. Thyroid Gland:
- It is a butterfly-shaped gland located on **either side** of the trachea in the **front of neck.**
- It is composed of two **connected lobes.**
- Thyroid secretes following hormones;

➢ **Hormones with Their Functions, Secreted By Thyroid Gland:**

(1) Tetra-iodothyronine (T_4) or Thyroxine and Tri-iodothyronine (T_3):
- Thyroid produces **much more T_4,** which eventually converts **into T_3,** which is the more **"active"** and powerful hormone.

(i) Increase Heart Rate: T_3 & T_4 hormones increase heart rate and breathing rate.

(ii) Stimulate Cellular Respiration: They stimulate **cellular** respiration.

(iii) Glucose Catabolism + Cholesterol Balance: They also enhance **glucose catabolism** and uptake of cholesterol by liver. Their net effect is to lower plasma cholesterol.

(iv) Growth of Skeleton + Brain Development: In children, they promote growth of the **skeleton** and the **development of brain.**

(2) Calcitonin Hormone:
- **Maintains Calcium Level in Blood:** It plays a role in maintaining **proper levels** of calcium in blood.
- It inhibits bone breakdown (osteoclast activity), promoting calcium deposition in bone and lowering blood calcium.

Check Understanding!
Q.7 What specific medical condition results from severe hypothyroidism during fetal and childhood development, characterized by stunted growth and mental retardation?
(A) Cretinism. (B) Gigantism.
(C) Acromegaly. (D) Myxoedema.

Tidbit
Q. Why thyroid gland is called "Master Controller of Metabolism".
Ans. Thyroid gland is often called the body's **"Master Controller of Metabolism"** because its hormones dictate how fast or slow every cell in body works.

For Information
Q. What are the causes, symptoms & effects of Graves Disease?
Ans. Cause of Graves Disease:
- Graves' disease is an autoimmune disease that causes **hyperthyroidism.** It also often results in an enlarged thyroid.
- **Symptoms of Graves Disease:** Its symptoms include irritability, muscle weakness, sleeping problems, fast heartbeat, poor tolerance of heat, diarrhoea, weight loss, thickening of skin on the shins.
- **Effects of Graves Disease:** Exophthalmia (protrusion of the eyeballs) may also result from Graves' disease.

Topic: Imbalance of Thyroid Hormones:

Q.21 Discuss the problems caused due to imbalance of thyroid hormones. Exercise L/Q

Ans. Problem Due to Imbalance of Thyroid Hormones:

(1) Problem Due to Deficiency of Thyroid Hormone (Hypothyroidism):
- **Hypothyroidism:** The deficiency of thyroid hormones **(hypothyroidism)** is called hypothyroidism.
- A condition which causes **growth retardation,** lethargy, weight gain, constipation, high cholesterol and low heart rate and body temperature.

(a) Problem Due to Deficiency of Thyroid Hormone At Foetal Stage:
- If the hypothyroidism occurs during foetal and childhood development, it causes cretinism.
- **Cretinism:** A condition of **stunted growth** and **mental retardation.**

(b) Problem Due to severe Deficiency of Thyroid Hormone:
- **Causes Myxoedema:** Severe **hypothyroidism** result in is a rare, life-threatening complication known as **myxoedema.**
- **Myxoedema:** It is characterized **build-up** of **mucopolysaccharides** in the connective tissues, which causes swelling and thickening of the skin and tissues.

(c) Problems Due Iodine Deficiency:
- If hypothyroidism is caused by **iodine deficiency,** it results in **goitre** i.e., swelling of thyroid gland.

(2) Problems Due to Excessive Secretions of Thyroid Gland:
- **Hyperthyroidism:** Excessive secretion of thyroid hormones is called **hyperthyroidism.**
- This condition causes weight loss; and high blood pressure, heart rate, and body temperature.

Q.22 Differentiate between the two terms hypothyroidism and hyperthyroidism.

Ans.

Hypothyroidism	Hyperthyroidism
• The **lower secretion** or deficiency of thyroid hormone is called **hypothyroidism.**	• The **higher or excessive** secretion of thyroid hormone is called hyperthyroidism.

Topic: Parathyroid Glands:

Q.23 What is parathyroid gland & discuss its role in maintaining calcium level in blood? L/Q

Ans. Parathyroid Glands:
- These are **four small glands** attached to the **posterior** surface of thyroid gland.
- Parathyroid glands **secrete** hormone **parathormone.**

Check Understanding!
Q.8 Describe how parathormone restores blood calcium levels when they fall below normal.

➢ **Role in Maintaining Blood Calcium:**
- When blood **calcium level** falls, parathormone **is released.**
- **Parathormone** stimulates the **osteoclasts** (bone cells) to dissolve the **calcium crystals** of bone matrix and **release** calcium **into the blood.**
- It also stimulates the kidneys to **reabsorb calcium** from the urine.
- It **causes** the activation of **vitamin D,** needed for the absorption of **calcium from** food in the intestine.

Q.24 Discuss the problems due to imbalance of parathyroid hormone. L/Q

Ans. Problems Due to Imbalance of Parathyroid Hormone:

(i) Over Secretion of Parathormone:
- Over secretion may be due to **parathyroid gland tumour** results in excessive release of calcium from bones.
- It leads to bones **deformation** and **soft bones.**
- Blood calcium level elevates **(hypercalcemia)** which depresses nervous system and causes weakness of muscles.

(ii) Under Secretion of Parathormone:
- It causes **hypocalcaemia.** This increases the **excitability** of neurons. Also, it can lead to tetany in which muscles remain in contracted state.

Q.25 Differentiate between the term hypercalcemia & hypocalcemia. S/Q

Ans.

Hypercalcemia	Hypocalcemia
• The higher level of calcium in blood is called **hypercalcemia.**	• The lower level of calcium in blood is called **Hypocalcemia.**

Multiple Choice Questions (MCQs)

Key
1.(B)
2.(D)

1. **The master gland of the endocrine system is the:** (A) Thyroid gland. (B) Pituitary gland. (C) Adrenal gland. (D) Pancreas.
2. **The pituitary gland is directly controlled by the:** (A) Cerebellum. (B) Pineal gland. (C) Medulla oblongata. (D) Hypothalamus.

CamScanner

3. The pituitary gland is attached to the hypothalamus by a stalk called the:
(A) Infundibulum. (B) Corpus callosum. (C) Nephron. (D) Optic chiasma. — 3.(A)

4. Oxytocin and ADH are synthesized in the:
(A) Posterior pituitary. (B) Anterior pituitary. (C) Hypothalamus. (D) Thyroid gland. — 4.(C)

5. Which hormones stimulate the anterior pituitary to produce and secrete hormones?
(A) Inhibiting hormones. (B) Releasing hormones. (C) Steroid hormones. (D) Tropic hormones. — 5.(B)

6. Growth Hormone (GH) is secreted by the:
(A) Posterior pituitary. (B) Hypothalamus. (C) Anterior pituitary. (D) Intermediate pituitary. — 6.(D)

7. Which anterior pituitary hormone stimulates the thyroid gland to produce thyroxine?
(A) ACTH. (B) FSH. (C) TSH. (D) LH. — 7.(C)

8. Which hormone released from the posterior pituitary stimulates water retention by the kidneys?
(A) Oxytocin. (B) ADH (Vasopressin). (C) Prolactin. (D) MSH. — 8.(B)

9. Melanocyte Stimulating Hormone (MSH) is produced by the:
(A) Intermediate pituitary. (B) Posterior pituitary. (C) Anterior pituitary. (D) Adrenal cortex. — 9.(A)

10. Which hormone stimulates the mammary glands to produce milk?
(A) Oxytocin. (B) Prolactin. (C) FSH. (D) ACTH. — 10.(B)

11. Why is the posterior pituitary not considered a true hormone-producing gland?
(A) Single hormone. (B) Hormone storage. (C) Childhood only. (D) Digestive enzymes. — 11.(B)

12. A growing child develops excessive height with enlarged hands and feet due to over-secretion of Growth Hormone. This condition is called:
(A) Acromegaly. (B) Dwarfism. (C) Gigantism. (D) Diabetes insipidus. — 12.(C)

13. A patient passes excessive amounts of dilute urine and experiences frequent thirst. The most likely cause is:
(A) Over-secretion of TSH. (B) Under-secretion of LH. (C) Over-secretion of GH. (D) Under-secretion of ADH. — 13.(D)

14. Gonadotropin Releasing Hormone (GnRH) from the hypothalamus stimulates the anterior pituitary to secrete:
(A) TSH and ACTH. (B) GH and Prolactin. (C) FSH and LH. (D) ADH and Oxytocin. — 14.(C)

15. Over-secretion of Growth Hormone in an adult causes enlargement of the hands, feet, skull, nose and jaw because:
(A) Bone thickening. (B) Bone elongation. (C) Muscle replacement. (D) Thyroxine stimulation. — 15.(A)

Topic: Pancreas:

Q.26 Why is pancreas called double gland? Exercise L/Q.6

Ans. Pancreas As Double Gland:

- Pancreas mostly contains **exocrine cells**, which produce and secrete **pancreatic juice** in pancreatic duct but pancreas also has specialized cells, which function as an **endocrine gland.**
- Due to its **exocrine & endocrine** functions pancreas is called as **double gland.**

Q.27 What are Islets of Langerhans give name of its two types of cells? Exercise L/Q.6

Ans. Islets of Langerhans:

- These cells are distributed in the form of **patches** in the pancreas. These patches are called Islets of Langerhans.
- Each islet is composed of two types of cells.
  - (I) **Beta (β) Cells:** Which are **larger in number** and they secrete **insulin hormone.**
  - (ii) **Alpha (α) Cells:** Which are **lesser in number** & secrete **glucagon hormone.**

Q.28 How is the secretion of insulin stimulated? Also give its role in lowering, the glucose level in blood. Exercise L/Q.6

Ans. Stimulation of Secretion Insulin:

- Insulin is one of the most important **hormones of human body.**
- **Stimulus for Secretion:** It is secreted when the level of blood glucose **rises**, so it reduces the blood sugar (glucose) level.

Role of Insulin in Lowering Glucose level in Blood:

(i) It **increases** the rate of **glucose** uptake by body cells (e.g., skeletal muscles and fat cells).
(ii) It also promotes **glycogenesis** which is conversion of glucose to glycogen in liver.
(iii) It increases the **use of glucose** in cellular respiration.
(iv) It promotes the **conversion of excess glucose** to fats.
(v) Insulin inhibits **gluconeogenesis** (glucose synthesis).

Check Understanding!
Q.9 Which cells within the Islets of Langerhans secrete insulin, and what primary metabolic effect do they produce?
(A) Alpha cells; raise blood glucose levels.
(B) Beta cells; lower blood glucose levels.
(C) Exocrine cells; secrete pancreatic juice.
(D) Interstitial cells; secrete testosterone.

Q.29 Differentiate glycogenesis & gluconeogenesis. Exercise L/Q.6

Ans.

Glycogenesis	Gluconeogenesis
• The process of glycogen synthesis from **glucose** is called Glycogenesis.	• The process of **synthesizing new glucose** from non-carbohydrate precursors (such as lactate, glycerol, and amino acids) is called gluconeogenesis.

Q.30 How does glucagon increase the glucose level in blood? Exercise L/Q.6

Ans. Role of Glucagon in Increasing Glucose Levels:

- **Glucagon** raises the blood glucose level.
- **Stimulus for Glucagon Secretion:** It is secreted when **blood glucose** level is below normal.

(i) It mainly promotes the **hydrolysis** of stored glycogen in liver. As a result, glucose is released into blood and can be taken up by cells and used for energy.

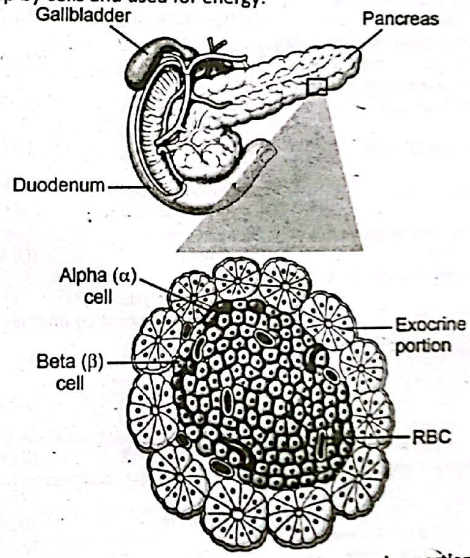


Figure: Islets of Langerhans (surrounded by exocrine portions)

Topic: Imbalance of Pancreas Hormone:

Q.31 Discuss the problem/effects due to imbalance of pancreatic hormones. Exercise L/Q.6

Ans. Imbalance of Pancreas Hormones:

(i) **Problems Due to Under Secretion of Insulin:**

- The under secretion of insulin leads to **diabetes mellitus (Hyper-Glycaemia).**

CamScanner

- In diabetes mellitus cells are unable to obtain glucose from blood.
- It results in above normal blood glucose level. This excess glucose in blood inhibits water reabsorption by the kidneys.
- So large amounts of urine are produced.
- It leads to dehydration and kidney damage.

(ii) Problems Due to Over secretion of Insulin:

It causes Hypglycaemia:

- The over secretion of insulin results below normal blood glucose level i.e., **hypoglycaemia.**
- **Symptoms of hypoglycaemia include lethargy, dizziness, nervousness,** and in extreme cases, unconsciousness.

For Information

Q. Differentiate between diabetes type-I & Diabetes type-II.

Ans. In **Type I diabetes** (insulin-dependent diabetes mellitus), the patients lack insulinsecreting β cells. It is generally is treated with daily injections of insulin (because insulin is a peptide hormone, it would be digested if taken orally and must be injected into blood). This injectable insulin is produced by genetically engineered bacteria.

- The patients of **Type II diabetes** (noninsulin dependent diabetes mellitus) have normal levels of insulin in their blood, but their cells have a reduced sensitivity to insulin. These patients do not require insulin. They control their diabetes through other medicines, diet and exercise.

Q.32 Differentiate between hypoglycaemia and hyperglycaemia. SQ

Ans.

Hypoglycaemia	Hyperglycaemia
• A condition characterized by an abnormally **low level of blood glucose** (blood sugar).	• A condition characterized by an **abnormally high level of blood glucose** (blood sugar).

Multiple Choice Questions (MCQs)

	Key
1. The exocrine cells of the pancreas secrete: (A) Insulin. (B) Glucagon. (C) Pancreatic juice. (D) Thyroxine.	1.(C)
2. The endocrine patches of the pancreas are called: (A) Nephrons. (B) Islets of Langerhans. (C) Alveoli. (D) Follicles.	2.(B)
3. Which cells of the Islets of Langerhans secrete insulin? (A) Alpha (α) cells. (B) Acinar cells. (C) Delta cells. (D) Beta (β) cells.	3.(D)
4. Glucagon is secreted by: (A) Alpha (α) cells. (B) Beta (β) cells. (C) Acinar cells. (D) Duct cells.	4.(A)
5. Insulin is secreted when: (A) Blood glucose falls below normal. (B) Blood glucose rises. (C) Blood calcium rises. (D) Blood pressure falls.	5.(B)
6. Insulin promotes the conversion of glucose into: (A) Glycogen. (B) Urea. (C) Protein. (D) Cholesterol.	6.(A)
7. Glucagon mainly raises blood glucose by promoting the: (A) Formation of glycogen. (B) Glycogenolysis. (C) Conversion of glucose into fats. (D) Uptake of glucose by muscles.	7.(B)
8. Which process is inhibited by insulin? (A) Gluconeogenesis. (B) Cellular respiration. (C) Glycogenesis. (D) Glucose uptake.	8.(A)
9. Under-secretion of insulin results in: (A) Hypoglycaemia. (B) Diabetes mellitus. (C) Goitre. (D) Tetany.	9.(B)
10. Over-secretion of insulin causes: (A) Hyperglycaemia. (B) Hypercalcaemia. (C) Hypoglycaemia. (D) Hyperthyroidism.	10.(C)
11. A person's blood glucose level suddenly falls below normal. Which pancreatic hormone is expected to increase? (A) Insulin. (B) Glucagon. (C) Thyroxine. (D) Calcitonin.	11.(B)
12. Why does insulin lower blood glucose levels? (A) Inhibits uptake. (B) Glucose uptake. (C) Glycogen breakdown. (D) Less respiration.	12.(B)
13. A diabetic patient produces excessive amounts of urine because excess glucose in the blood: (A) Water reabsorption. (B) ADH secretion. (C) No urine. (D) Inhibits reabsorption.	13.(D)
14. Which symptom is most likely associated with hypoglycaemia caused by excessive insulin secretion? (A) Lethargy and dizziness. (B) Weight gain. (C) Goitre. (D) Tetany.	14.(A)
15. Which statement correctly compares insulin and glucagon? (A) Lower glucose. (B) Reversed roles. (C) Opposite effects. (D) Same cells.	15.(C)

Topic: Adrenal Glands:

Q.33 Where is adrenal gland located, also name its two portions. Exercise L/Q.5

Ans. Location of Adrenal Glands:

- One adrenal gland is located just above each kidney.

➢ **Names of Two Portions:**

- Each gland is composed of:
  - **(a) An inner portion,** the adrenal medulla.
  - **(b) An outer layer,** the adrenal cortex.

Check Understanding!

Q.10 Outline the physiological role of mineralocorticoids like aldosterone produced by the adrenal cortex.

Q.34 Write a detailed note on adrenal glands mentioning the hormones of adrenal context and adrenal medulla and their functions. Exercise L/Q.5

Ans. Adrenal Gland:

- Two adrenal gland are present in human on present on each kidney.
- Each adrenal gland has two portion discussed below:

(A) Adrenal Medulla:

- The inner portion of adrenal gland is called **adrenal medulla.**

Hormones of Adrenal Medulla:

- The adrenal medulla produces two hormones:
  (i) Epinephrine (Adrenaline). (ii) Nor-epinephrine (nor-adrenaline).

Effects of Adrenaline & Non-Adrenaline:

- When a person is stressed, the **medulla** secretes **epinephrine** and **norepinephrine.**
- These hormones prepare the body for **"fight or flight".**
- In fight & flight response, there is **increased heart rate,** increased blood pressure, dilation of the bronchioles, elevation in blood glucose, and reduced blood flow to skin and **digestive organs.**

(B) Adrenal Cortex:

- The outer layer of adrenal gland called **adrenal cortex.**

Hormones of Adrenal Cortex:

- The hormones from adrenal cortex are called **corticosteroids.** These include:

(i) Glucocorticoids: (Examples: Cortisol & Steroids)

- Cortisol and related steroids are examples of glucocorticoids hormones which maintain glucose homeostasis.
- **Increase Protein Breakdown:** They **stimulate** the breakdown of muscle protein into amino acids, which are carried by blood to liver.
- **Stimulate Glycogenosis:** They also **stimulate liver** for gluconeogenesis (conversion of amino acids into glucose).

(ii) Mineralocorticoids: (Example: Aldosterone)

- Aldosterone is an example of mineralocorticoid which helps to regulate mineral balance in blood.
- **Helps in Reabsorption of Sodium:** It stimulates the kidneys to reabsorb sodium from urine. In this way, water is also reabsorbed from urine. Thus, normal blood volume and pressure is maintained.
- **Stimulates Kidneys for Potassium Secretion:** Aldosterone also stimulates the kidneys to secrete the excess of potassium into urine.

Topic: Imbalance of Adrenal Gland Hormones:

Q.35 Discuss the problems due to imbalance of adrenal hormones. Exercise L/Q.5

Ans. Imbalance of Adrenal Gland Hormones:

(1) Problems Due to Secretion of Adrenal Medulla:

- **(a) Over Secretion:** It may cause **hypertension** and **aggressive** behaviour during routine life.
- **(b) Under Secretion:** It causes failure to combat with emergency situation.

CamScanner

(2) Problems Due to Secretions of Adrenal Cortex:

(I) Problems Due to Over secretion of Cortisol (Causes ⟶ Cushing Disease)

- It occurs when pituitary gland produces too much ACTH, which causes the adrenal glands to produce cortisol in high levels.

Effects of Cushing Disease:

- In Cushing disease there is excessive **protein breakdown.**
- It results in high **blood sugar,** high blood pressure, thin bones, muscle loss, thin and fragile skin, depression, and too much **facial hair** (in women).

(ii) Problems Due to Under Secretion of Cortisol: (Causes ⟶ Addison's Disease)

- **Addison's Disease:** A disease caused du to Under secretion of cortisol.

Effects of Addison's Disease:

- Addison's is characterized by general **metabolic disturbance,** weakness of muscles and loss of salts. The symptoms usually happen slowly.

Multiple Choice Questions (MCQs)	Key
1. Each adrenal gland is located: (A) Below each kidney. (B) Above each kidney. (C) Behind the liver. (D) Inside the pancreas.	1.(B)
2. The adrenal medulla secretes: (A) Cortisol and aldosterone. (B) Insulin and glucagon. (C) Epinephrine and norepinephrine. (D) Thyroxine and calcitonin.	2.(C)
3. Epinephrine and norepinephrine prepare the body for the: (A) Rest-and-digest response. (B) Fight-or-flight response. (C) Sleep cycle. (D) Growth phase.	3.(B)
4. During the fight-or-flight response, the bronchioles: (A) Constrict. (B) Become blocked. (C) Collapse. (D) Dilate.	4.(D)
5. Hormones secreted by the adrenal cortex are collectively called: (A) Catecholamines. (B) Corticosteroids. (C) Gonadotropins. (D) Thyroid hormones.	5.(B)
6. Which hormone is a glucocorticoid secreted by the adrenal cortex? (A) Cortisol. (B) Aldosterone. (C) Epinephrine. (D) Glucagon.	6.(A)
7. Aldosterone primarily stimulates the kidneys to reabsorb: (A) Glucose. (B) Potassium. (C) Sodium. (D) Calcium.	7.(C)
8. Aldosterone also stimulates the kidneys to secrete excess: (A) Sodium. (B) Potassium. (C) Glucose. (D) Calcium.	8.(B)
9. Which pituitary hormone stimulates the adrenal cortex to produce high levels of cortisol in Cushing disease? (A) TSH. (B) FSH. (C) ACTH. (D) LH.	9.(C)
10. During a stressful situation, which combination of changes is expected? (A) Fight-or-flight. (B) Slow heartbeat. (C) Active digestion. (D) Bronchoconstriction.	10.(A)
11. Cortisol helps maintain glucose homeostasis by stimulating: (A) Glycogen formation. (B) Gluconeogenesis. (C) Calcium absorption. (D) Insulin secretion.	11.(B)
12. Under-secretion of cortisol causes Addison's disease, which is characterized by: (A) Facial hair. (B) Metabolic disturbance. (C) High calcium. (D) Excess insulin.	12.(B)
13. Which statement correctly compares the adrenal medulla and adrenal cortex? (A) Same hormones. (B) Identical hormones. (C) Insulin only. (D) Different hormones.	13.(D)

Topic: Gonads:

Q.36 What are gonads? S/Q

Ans. Gonads:

- Gonads are gametes producing organs.
  - **Gonads in Female:** Ovaries.
  - **Gonads in Males:** Testes.
  - **Gonads also produce sex hormones under the influence of LH and FSH of anterior pituitary.**

Check Understanding!

Q.11 Which hormone is produced by the corpus luteum during the menstrual cycle and placenta during pregnancy to inhibit further FSH secretion and maintain the uterine wall?
(A) Testosterone. (B) Estrogen. (C) Progesterone. (D) Oxytocin.

Topic: Ovaries:

Q.37 What are ovaries? Name the hormones produced by ovaries & discuss the role of each hormone in human female? L/Q

Ans. Ovaries:

- The female gonads, which produce **sex cells or eggs** and **sex hormones** are called **ovaries.**

Hormones of Ovaries:

- Ovaries secrete two important female sex hormones: **(1) Estrogen. (2) Progesterone.**

(1) Estrogen:

- It is secreted by **Graafian** follicle in response to FSH.

Role of Estrogen:

(i) Develops Secondary Sex Characteristics: Its functions include development of **secondary sexual characteristics** (e.g., breast development, widening of the pelvis, fat distribution in hips and thighs etc.).

(ii) Maintains Menstrual Cycle: It help in regulation of the **menstrual cycle,** repair of the uterine lining after menstruation, ovulation (release of an egg from ovary).

(iii) Estrogen also helps in **maintenance** of **bone density,** lowering "bad" **cholesterol (LDL).**

(iv) It maintains and healthy **blood pressure,** regulation of mood and memory.

For Information

- **Puberty** is the adolescent stage during which the sex organs mature and secondary sex characteristics appear.
- **In Males:** During puberty in males, sperm production begins, the voice deepens, the chest broadens, and hair grows on the body and face.
- **In females,** the menstrual cycle begins, the breasts grow, and the hips widen.

(2) Progesterone:

- It is produced by **corpus luteum** in response to LH during menstrual cycle.
- It is also produced and released from **placenta** during pregnancy.

Role of Progesterone:

- It inhibits **further FSH secretion** from pituitary, thus preventing more follicles from ripening.
- It also causes **further thickening** and **vascularisation** of the uterus wall for maintaining pregnancy. Progesterone suppresses ovulation.

For Information

- Small amounts of estrogen and testosterone are also released by adrenal glands.
- A very small amount of testosterone is produced in females.

Topic: Testes:

Q.38 What are testes, name their hormones with role? S/Q

Ans. Testes:

- The male gonads which **produce sperms & sex hormones** are the testes.
- **LH stimulates** the testes to secrete a group of sex hormones called **androgens.**

➢ **Testosterone: (Androgen Hormone)**

- It is an androgen which is secreted by the **interstitial** cells among seminiferous tubules of testes.
- It initiates the maturation of male reproductive organs and appearance of **secondary sex characteristics** and sex drive.
- **Sperm Production:** Testosterone is also necessary for normal **sperm production.**

Q.39 What problems can be faced due to imbalance production of hormones of gonads? S/Q

Ans. Problems Due to Imbalance of Hormones of Gonads:

(A) Imbalance of Hormones of Ovaries:

(I) Imbalance of Estrogen:

(a) Under-Secretion of Estrogen: Due to estrogen deficiency in the **young females,** they fail to mature sexually. Deficiency of estrogen in adults leads to sterility.

(b) Over-secretion of Estrogen: It over-secretion may lead to the development of **fibroids** (abnormal growth) in uterus and **polycystic ovaries.**

CamScanner

(ii) **Imbalance of Progesterone:**
- **Under secretion** of progesterone during menstrual cycle, decreases the chance of pregnancy and may cause early menstruation.
- **Under secretion during pregnancy** may lead to the **miscarriage.**

(B) Imbalance of Hormones of Testes:
- **Testosterone:** Under secretion of testosterone in males causes the development of feminine (female like) characteristics and male sterility.

Topic: Artificially Synthesized Steroids:

Q.40 What are anabolic steroid? What are their importance for athletes? S.Q

Ans. Artificially Synthesized Steroids: (Anabolic Steroids)
- Artificially synthesized steroids, also known as **anabolic steroids**, have been widely used by athletes to enhance performance in sports.
- These steroids are synthetic versions of the testosterone.

➢ **Importance of Anabolic Steroids For Athletes:**
- They increase muscle mass, strength, and endurance.
- However, the use of anabolic steroids in sports is illegal and banned.

Q.41 What are harmful effects of synthetic or anabolic steroids? S.Q

Ans. Harmful Effects of Synthetic Steroids:
- Use of synthetic steroids can lead to **long-term health problems** including:
  - Anabolic steroids can cause **damage** to liver, leading to hepatitis and liver tumors.
  - They can increase the risk of **heart disease**, stroke, and blood clots.
  - Prolonged use of can **disrupt the body's natural** hormone balance, **leading to infertility,** impotence, and breast development in men.
  - Their use can also cause mental health issues such as depression, anxiety, and aggressive behaviour.

Multiple Choice Questions (MCQs)

		Key
1.	Gonads are organs that produce: (A) Hormones only. (B) Gametes only. (C) Gametes and sex hormones. (D) Digestive enzymes.	1.(C)
2.	The secretion of sex hormones by gonads is mainly controlled by: (A) LH and FSH. (B) ADH and Oxytocin. (C) TSH and ACTH. (D) Insulin and Glucagon.	2.(A)
3.	Estrogen is secreted by the _____ in response to FSH. (A) Corpus luteum. (B) Placenta. (C) Seminiferous tubules. (D) Graafian follicle.	3.(D)
4.	Which hormone is produced by the corpus luteum in response to LH? (A) Estrogen. (B) Progesterone. (C) Testosterone. (D) Oxytocin.	4.(B)
5.	During pregnancy, progesterone is also secreted by the: (A) Placenta. (B) Thyroid gland. (C) Pituitary gland. (D) Adrenal cortex.	5.(A)
6.	Progesterone inhibits the secretion of: (A) LH. (B) TSH. (C) FSH. (D) ACTH.	6.(C)
7.	Testosterone is secreted by the: (A) Seminiferous tubules. (B) Interstitial cells. (C) Sertoli cells. (D) Corpus luteum.	7.(B)
8.	Testosterone belongs to the group of hormones called: (A) Estrogens. (B) Corticosteroids. (C) Glycoproteins. (D) Androgens.	8.(D)
9.	Testosterone is essential for normal: (A) Ovulation. (B) Sperm production. (C) Milk production. (D) Menstruation.	9.(B)
10.	Which hormone helps in the repair of the uterine lining after menstruation? (A) Progesterone. (B) Testosterone. (C) Estrogen. (D) Oxytocin.	10.(C)
11.	Which hormone suppresses ovulation and helps maintain pregnancy by thickening and vascularizing the uterine wall? (A) Progesterone. (B) Estrogen. (C) Testosterone. (D) LH.	11.(A)

		Key
12.	A woman experiences repeated miscarriages due to insufficient secretion of a reproductive hormone during pregnancy. The deficient hormone is: (A) Estrogen. (B) Progesterone. (C) FSH. (D) Testosterone.	12.(B)
13.	Deficiency of estrogen in young females primarily results in: (A) Early menopause. (B) Increased blood glucose. (C) Excessive facial hair. (D) Failure of sexual maturation.	13.(D)
14.	Under-secretion of testosterone in males may lead to: (A) Gigantism. (B) Hyperthyroidism. (C) Male sterility. (D) Diabetes mellitus.	14.(C)
15.	Which statement correctly compares estrogen and progesterone? (A) Ovulation roles. (B) Female functions. (C) Pregnancy only. (D) Testes production.	15.(B)

Topic: Other Endocrine Glands/Tissues:

Q.42 Describe the functions of the hormones secreted by thymus glands, pineal gland, kidneys, and walls of digestive tract. Exercise L/Q.7 L/Q

OR Discuss the role of the following structures or cells as special Endocrine Glands.
(1) Thymus Gland. (2) Pineal Gland. (3) Endocrine Cell of Digestive Organs.
(4) Kidneys. (5) Brain. (6) Body Cells.

Ans. Endocrine Glands/Tissues:
- There are several other glands in the endocrine system.
- There are also **specialized endocrine cells** in **brain, stomach, small intestine, liver,** and **other organs.**

(1) Thymus Gland:
- **Location:** It is located beneath the **sternum** and **between the lungs.**
- **Hormone:** It secretes **thymosin** hormone that stimulates **maturation of T cells,** which help to defend the body from pathogens.

(2) Pineal Gland:
- **Location:** It is present near the **centre/posterior of brain.**
- **Hormone:** It secretes **melatonin** hormone. It regulates **sleep patterns.**

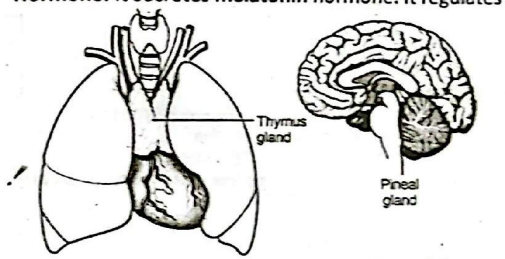


Figure: Locations of thymus and pineal glands

Check Understanding!
Q.12 State the specific source and physiological function of thymosin and melatonin within the human body.

(3) Endocrine Cells of Digestive Organ:
- **Location:** Endocrine cells within the walls of some **digestive organs.**
- These cells secrete **hormones** that control digestive processes.

Hormones of Endocrine Cells of Digestive Organs:

(i) Gastrin Secretion:
- When food is eaten, endocrine cells in the stomach walls secrete **gastrin** hormone.
- Gastrin stimulates the gastric glands to release gastric juice.

(ii) Secretin Secretion:
- Endocrine cells of the small intestine wall release **secretin** hormone.
- **Secretin** Stimulates the pancreas to release pancreatic juice.

(iii) Cholecystokinin Secretion:
- The small intestine wall also secretes **cholecystokinin** hormone.
- **Cholecystokinin** which stimulates gallbladder to release bile.

CamScanner

(4) Kidneys As Endocrine Gland:

(i) Renin Hormone: Kidneys produce **renin** hormone that controls the production of **aldosterone** in adrenal glands.

(ii) Erythropoietin Hormone: Kidneys also produce **erythropoietin** hormone that stimulates bone marrow for the production of RBCs.

(iii) Calcitriol Hormone: Another hormone of kidneys, calcitriol increases blood calcium level by absorption of calcium from intestines.

(5) Brain As Endocrine Gland:

- **Endorphins Hormone:** Brain produces hormones called **endorphins.**
- Endorphins bind to **pain receptors** and so block sensation of pain.

(6) All Body Cells As Gland:

- **Prostaglandins are hormone-like substances** that are produced by **almost all cells of the body.**
- They are powerful, locally-acting vasodilators and are involved in **inflammation.**

Multiple Choice Questions (MCQs)	Key
1. The thymus gland is located: (A) Above the kidneys. (B) Beneath sternum & between lungs. (C) Behind the thyroid gland. (D) Above the pancreas.	1.(B)
2. The hormone secreted by the thymus gland is: (A) Melatonin. (B) Renin. (C) Gastrin. (D) Thymosin.	2.(D)
3. Thymosin mainly stimulates the maturation of: (A) T cells. (B) B cells. (C) Red blood cells. (D) Platelets.	3.(A)
4. The pineal gland secretes: (A) Calcitriol. (B) Endorphins. (C) Melatonin. (D) Secretin.	4.(C)
5. Melatonin primarily regulates: (A) Blood glucose level. (B) Sleep patterns. (C) Blood calcium level. (D) Blood pressure.	5.(B)
6. Which hormone is secreted by endocrine cells of the stomach wall? (A) Secretin. (B) Renin. (C) Cholecystokinin. (D) Gastrin.	6.(D)
7. Secretin stimulates the pancreas to release: (A) Bile. (B) Gastric juice. (C) Pancreatic juice. (D) Insulin.	7.(C)
8. Cholecystokinin stimulates the: (A) Liver to produce glycogen. (B) Gallbladder to release bile. (C) Stomach to release gastric juice. (D) Pancreas to secrete insulin.	8.(B)
9. Which kidney hormone stimulates bone marrow to produce red blood cells? (A) Erythropoietin. (B) Calcitriol. (C) Renin. (D) Aldosterone.	9.(A)
10. Calcitriol increases blood calcium levels by promoting calcium absorption from the: (A) Kidneys. (B) Bones. (C) Intestines. (D) Liver.	10.(C)
11. A person suffers from a disease that reduces T-cell maturation. Which endocrine gland is most likely affected? (A) Pineal gland. (B) Thymus gland. (C) Pancreas. (D) Adrenal gland.	11.(B)
12. After eating a meal, pancreatic juice secretion increases due to the action of: (A) Gastrin. (B) Endorphins. (C) Melatonin. (D) Secretin.	12.(D)
13. Which hormone produced by the kidneys helps regulate aldosterone production in the adrenal glands? (A) Erythropoietin. (B) Calcitriol. (C) Renin. (D) Gastrin.	13.(C)
14. Endorphins reduce the sensation of pain because they: (A) Stimulate T-cell production. (B) Bind to pain receptors. (C) Increase blood calcium. (D) Stimulate gastric glands.	14.(B)
15. Which statement correctly compares gastrin and cholecystokinin? (A) Digestive roles. (B) Pancreatic juice. (C) Reversed functions. (D) Kidney secretion.	15.(A)

FEEDBACK MECHANISM IN ENDOCRINE SYSTEM

Q.43 What is feedback mechanism? Discuss the types of feedback mechanism with the help of examples from endocrine system. L/Q

Ans. Feedback Mechanism in Endocrine System:

- **Definition:** A phenomenon in which a **controlling** mechanism is **itself controlled** by the product of the process it is controlling is called feedback mechanism.

- Endocrine system also has feedback mechanisms, which control it.

Types of Feedback Mechanism:

- There are two types of feedback mechanism.

(1) Positive Feedback:

- **Definition:** A types of feedback mechanism in which the product or response made by the controlling system speeds up the action of controlling system.

Example of Positive Feedback Mechanism:

- Release of **oxytocin** hormone by posterior pituitary is an example of **positive feedback.**
- During **childbirth** when uterus begins to contract, the sensory neurons send signals to hypothalamus.
- Hypothalamus triggers the release of oxytocin from posterior pituitary.

Flow Sheet of Positive Feedback Mechanism of Oxytocin:

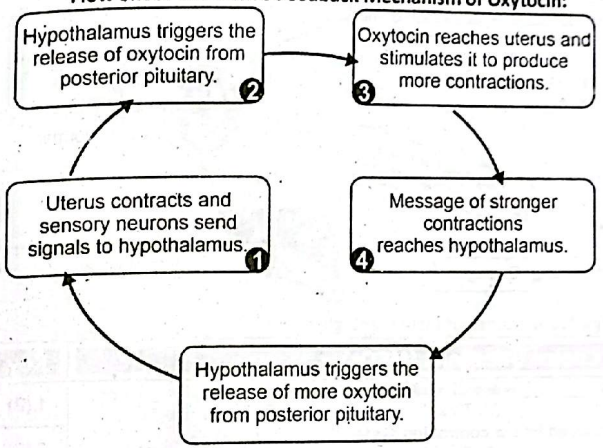


Figure: Positive feedback of oxytocin

Check Understanding!

Q.13 How does positive feedback differ fundamentally from negative feedback within endocrine systems?

(A) Positive feedback speeds up the action of the controlling system, whereas the end product stops the initial step in negative feedback.

(B) Positive feedback lowers blood glucose, whereas negative feedback triggers uterine contractions.

(C) Positive feedback is exclusively controlled by the pancreas, whereas negative feedback relies on the adrenal medulla.

(D) Positive feedback operates via neural pathways only, whereas negative feedback uses hormonal pathways exclusively.

- Oxytocin **stimulates uterus** to produce more and **stronger contractions.**
- When hypothalamus receives message of **stronger contractions**, it triggers the release of more **oxytocin.** This series of positive feedback **continues** until the **birth of baby.**

(2) Negative Feedback:

- **Definition:** A type of feedback mechanism in which the end **product stops** or **inhibits** the initial **step of the process.**
- Negative feedback is common in **endocrine system.**

Example of Negative Feedback Mechanism: (Insulin & Glucagon Secretions)

(i) Mechanism of Insulin Release:

- When blood **glucose goes** above from normal value the **beta cells** of the islets of Langerhans sense this and **release insulin.**
- Insulin lowers blood **glucose** by doing different actions. Due to these actions, blood glucose level **falls to normal.**
- This result i.e., normal blood glucose level stimulates the **beta cells to stop releasing insulin.**

(ii) Mechanism of Glucagon Release:

- The release of **glucagon** is also controlled by **negative feedback mechanism.**
- When blood glucose **level goes low,** the alpha cells of the islets of Langerhans secrete glucagon. This hormone takes actions to raise blood glucose.
- Due to **these actions,** blood glucose level rises to normal. This result i.e., normal blood glucose level stimulates the alpha cells to stop releasing glucagon.

CamScanner

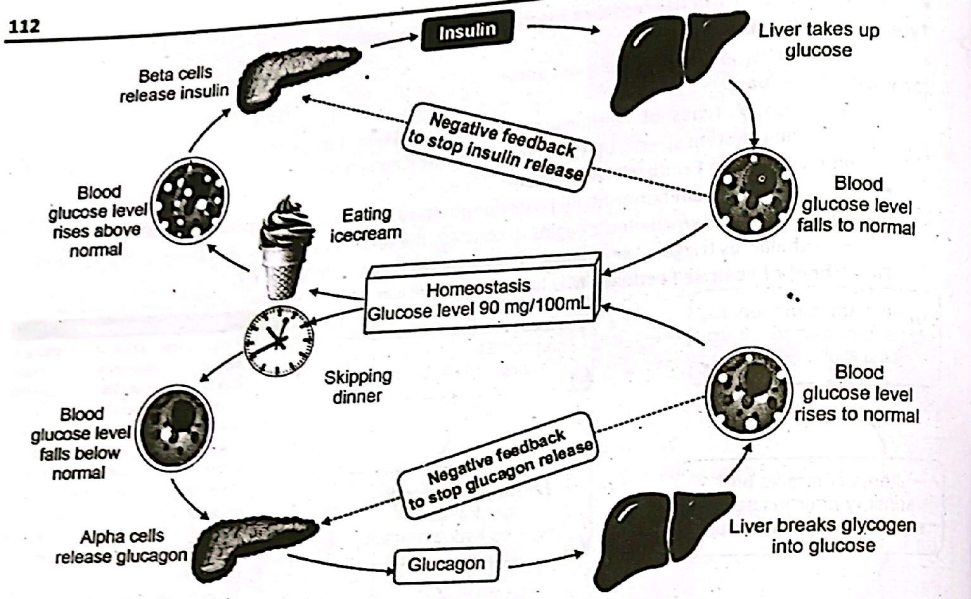


Figure: Negative feedback of insulin and glucagon

Multiple Choice Questions (MCQs)	Key
1. The endocrine system mainly exhibits _____ types of feedback mechanisms. (A) One. (B) Two. (C) Three. (D) Four.	1.(B)
2. In positive feedback, the response produced by the controlling system: (A) Stops mechanism. (B) Slows mechanism. (C) Speeds mechanism. (D) No effect.	2.(C)
3. Which hormone provides the example of positive feedback during childbirth? (A) Insulin. (B) Glucagon. (C) ADH. (D) Oxytocin.	3.(D)
4. During childbirth, sensory neurons send signals to the: (A) Hypothalamus. (B) Thyroid gland. (C) Pituitary gland. (D) Adrenal gland.	4.(A)
5. Oxytocin is released from the: (A) Anterior pituitary. (B) Posterior pituitary. (C) Hypothalamus. (D) Thyroid gland.	5.(B)
6. Oxytocin directly stimulates the: (A) Ovaries. (B) Kidneys. (C) Uterus. (D) Pancreas.	6.(C)
7. Negative feedback is illustrated by the regulation of: (A) Blood glucose level. (B) Blood groups. (C) Skin colour. (D) Body height.	7.(A)
8. When blood glucose rises above normal, _____ cells of the Islets of Langerhans release insulin. (A) Alpha (α). (B) Beta (β). (C) Delta. (D) Acinar.	8.(B)
9. Glucagon is secreted when blood glucose level is: (A) Above normal. (B) Normal. (C) Below normal. (D) Unchanged.	9.(C)
10. Why does oxytocin release increase continuously during childbirth until the baby is born? (A) Inhibits contractions. (B) Insulin stimulation. (C) Rising glucose. (D) Positive feedback.	10.(D)
11. Which statement best describes negative feedback in blood glucose regulation? (A) Continuous insulin. (B) Secretion stops. (C) Rising glucose. (D) Constant glucagon.	11.(B)
12. Which of the following is an example of positive feedback? (A) Postmeal insulin. (B) Fasting glucagon. (C) Labour contractions. (D) Insulin stop.	12.(C)
13. Which statement correctly distinguishes positive and negative feedback? (A) Reversed roles. (B) Normal restoration. (C) More hormones. (D) Less hormones.	13.(B)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(A)	• The text states that exocrine glands secrete their secretion in attached ducts, while endocrine glands are ductless and secrete their secretions called hormones directly in blood or tissue fluid.
2.	S/Q	• Peptide and protein hormones are made of water-soluble amino acid chains that cannot pass through cell membranes and must bind to surface receptors, whereas steroid hormones are lipid-soluble derived from cholesterol and move directly through the cell membrane to give instructions to the nucleus.
3.	(A)	• The text specifies that amino acid derivatives hormones are small molecules derived from a single amino acid, usually tyrosine or tryptophan.
4.	S/Q	• Hypothalamus contains special neurosecretory cells which not only conduct nerve impulses but also secrete hormones, transporting oxytocin and ADH to the posterior pituitary via axons and releasing regulatory releasing/inhibiting hormones into blood vessels for the anterior pituitary.
5.	(A)	• The text outlines that thyroid-stimulating hormone (TSH, or thyrotropin) stimulates the thyroid gland to produce thyroxine, which in turn stimulates oxidative respiration.
6.	S/Q	• During embryonic development, the posterior pituitary is formed from an outgrowth of neural tissue, remaining interconnected by a tract of axons that only store and release hormones made by the hypothalamus.
7.	(A)	• The text states that if hypothyroidism occurs during fetal and childhood development, it causes cretinism, a condition of stunted growth and mental retardation.
8.	S/Q	• Parathormone stimulates osteoclasts to dissolve calcium crystals of the bone matrix, stimulates kidneys to reabsorb calcium from urine, and causes the activation of vitamin D needed for intestinal calcium absorption.
9.	(B)	• The text specifies that beta cells secrete insulin, which is one of the most important hormones reducing blood sugar levels by increasing glucose uptake and promoting glycogenesis.
10.	S/Q	• Aldosterone helps regulate mineral balance by stimulating kidneys to reabsorb sodium from urine (which causes water reabsorption to maintain normal blood volume and pressure) and stimulating kidneys to secrete excess potassium into urine.
11.	(C)	• The text explains that progesterone is produced by the corpus luteum in response to LH and placenta during pregnancy, inhibiting further FSH secretion and causing further thickening and vascularization of the uterus wall.
12.	S/Q	• Thymosin is secreted by the thymus gland to stimulate the maturation of T cells for pathogen defense, while melatonin is secreted by the pineal gland to regulate sleep patterns.
13.	(A)	• The text explicitly defines positive feedback as a response where the product speeds up the action of the controlling system (e.g., oxytocin), and negative feedback as a process where the end product stops the initial step (e.g., insulin and glucagon).

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. Which of the following pair of hormones has antagonistic (opposing) effects?
(a) Parathyroid hormone and calcitonin. (b) Growth hormone and epinephrine.
(c) Estrogen and progesterone. (d) Cortisol and aldosterone.

2. Which gland produces hormones that control other endocrine glands?
(a) Anterior pituitary. (b) Posterior pituitary.
(c) Thyroid. (d) Intermediate pituitary.

CamScanner

3. Which of the following is NOT released by anterior pituitary?
(a) Prolactin (b) ADH (c) FSH (d) TSH

4. Antidiuretic and oxytocin hormones are produced by:
(a) Anterior pituitary. (b) Posterior pituitary.
(c) Intermediate pituitary. (d) Hypothalamus.

5. Which of the following hormones binds to the receptors located inside the cell?
(a) FSH. (b) Testosterone. (c) Insulin. (d) Growth hormone.

6. Which of the following is a function of a hormone released by the posterior pituitary?
(a) Maturation of egg and sperm. (b) Decrease in calcium levels
(c) Water retention. (d) Increase in thyroid hormone level.

7. Which of the following hormones would be expected to increase if you were studying all day for a te and skipped breakfast and lunch?
(a) Glucagon. (b) Insulin. (c) Growth hormone. (d) Calcitonin.

8. Which of the following is both an endocrine and exocrine gland?
(a) Anterior pituitary. (b) Pancreas. (c) Thyroid. (d) Adrenal medulla.

9. Which hormone increases basal metabolic rate in the body?
(a) Thyroxine. (b) Parathormone. (c) Glucagon. (d) Secretin.

10. Which of the following is NOT a site of action of insulin?
(a) Smooth muscles. (b) Skeletal muscles. (c) Adipose tissue. (d) Liver.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(a)	Parathyroid hormone and calcitonin.	• Parathyroid hormone raises blood calcium levels while calcitonin lowers them, operating in a classic antagonistic feedback loop.
2.	(a)	Anterior pituitary.	• The anterior pituitary secretes tropic hormones that directly regulate the activity of several other major endocrine glands.
3.	(b)	ADH.	• Antidiuretic hormone is synthesized by the hypothalamus and released via the posterior pituitary, not the anterior pituitary.
4.	(d)	Hypothalamus.	• Both ADH and oxytocin are synthesized in specialized neurosecretory cells of the hypothalamus and stored in the posterior pituitary.
5.	(b)	Testosterone.	• As a lipid-soluble steroid hormone, testosterone easily crosses the cell membrane to bind with intracellular receptors.
6.	(c)	Water retention.	• Antidiuretic hormone, released from the posterior pituitary, promotes water reabsorption in the kidneys to reduce urine volume.
7.	(a)	Glucagon.	• Fasting and prolonged studying deplete blood glucose, prompting the pancreas to release glucagon to stimulate glycogen breakdown.
8.	(b)	Pancreas.	• The pancreas functions as an exocrine gland by secreting digestive enzymes and an endocrine gland by producing insulin and glucagon.
9.	(a)	Thyroxine.	• Thyroxine stimulates cellular respiration and metabolic activity across target tissues, directly increasing the basal metabolic rate.
10.	(a)	Smooth muscles.	• Insulin primarily promotes glucose uptake in skeletal muscles, liver cells, and adipose tissue, rather than in smooth muscles.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 State the role of hormones as chemical messengers.

Ans. Role of Hormones as Chemical Messengers:
- **Signal Transmission:** Hormones are organic chemical messengers secreted by endocrine glands directly into the blood to regulate target cell activities.
- **Metabolic Coordination:** They control and coordinate slow, long-term physiological responses such as growth, metabolism, development, and homeostasis.

Q.2 Where are receptors located in amino acid-based hormones and steroid hormones?

Ans. Receptors Located in Amino acid-based Hormones and Steroid Hormones:

a) Amino Acid-Based Hormones:
- Their receptors are located on the plasma membrane of the target cell surface because these hormones cannot pass through the lipid bilayer.

b) Steroid Hormones:
- Their receptors are located inside the target cell (in the cytoplasm or nucleus) because they are lipid-soluble and easily diffuse across the cell membrane.

Q.3 What are neurosecretory cells?

Ans. Neurosecretory Cells:
- **Specialized Neurons:** They are specialized nerve cells that receive neuronal signals and secrete hormones into the blood instead of neurotransmitters.
- **Hypothalamic Link:** Found notably in the hypothalamus, they serve as a direct physical and chemical bridge between the nervous and endocrine systems.

Q.4 Name the hormones of anterior pituitary gland.

Ans. Hormones of Anterior Pituitary Gland:
- **Major Hormones:** Include Growth Hormone (GH), Thyroid-Stimulating Hormone (TSH), Adrenocorticotropic Hormone (ACTH), and Prolactin (PRL).
- **Gonadotropins:** Also include Follicle-Stimulating Hormone (FSH) and Luteinizing Hormone (LH).

Q.5 Why the pituitary gland is called master gland?

Ans. Pituitary Gland As Master Gland:
- **Hormone Secretion:** It secretes multiple tropic hormones that directly control and regulate the secretory activity of several other endocrine glands in the body, that's why it is called master gland.
- **Hypothalamic Control:** Although it acts as a master gland, its own secretions are closely regulated by releasing and inhibiting hormones from the hypothalamus.

Q.6 How is the secretion of ADH controlled?

Ans. Control of ADH Secretion:
- Secretion of ADH is primarily controlled by **hypothalamic** osmoreceptors that monitor the osmotic pressure and water concentration of the blood.

Feedback Mechanism:
- High blood osmolarity (dehydration) **stimulates** Antidiuretic Hormone (ADH) release to conserve water.
- Excess hydration (more water in blood) inhibits its release.

Q.7 Write a note on parathyroid glands.

Ans. Parathyroid Glands:
- **Anatomy:** They are four small, pea-sized endocrine glands embedded in the posterior surface of the thyroid gland.
- **Function:** They secrete parathormone (PTH), which plays a crucial role in regulating blood calcium and phosphate levels.

CamScanner

Q.8 Write the names and functions of hormones secreted by ovaries and testes.

Ans. Functions of Hormones Secreted by Ovaries and Testes:

(a) Ovarian Hormones:

(i) Estrogen hormone which drives female secondary sexual characteristics and uterine lining growth.

(ii) Progesterone hormone which maintains the uterine lining for pregnancy.

(b) Testicular Hormones Secretes:

- **Testosterone** hormone which drives male secondary sexual characteristics, sperm production, and libido.

Q.9 Differentiate between;

- **Exocrine and endocrine glands.**
- **Parathormone and calcitonin.**
- **Insulin and glucagon.**
- **Estrogen and progesterone.**
- **Hypothyroidism and hyperthyroidism.**
- **Beta and alpha cells of pancreas.**
- **Diabetes insipidus and diabetes mellitus.**
- **Positive and negative feedback.**

Ans. Exocrine and Endocrine Glands:

Exocrine Glands	Endocrine Glands
• Exocrine glands secrete products through ducts onto body surfaces or into cavities.	• Endocrine glands are ductless and secrete hormones directly into the bloodstream.

Hypothyroidism and Hyperthyroidism:

Hypothyroidism	Hyperthyroidism
• Hypothyroidism results from under secretion of thyroid hormones causing low metabolic rate and lethargy.	• Hyperthyroidism results from over secretion causing high metabolic rate and weight loss.

Parathormone and Calcitonin:

Parathormone	Calcitonin
• Parathormone raises blood calcium levels by bone resorption and kidney reabsorption.	• Whereas calcitonin lowers blood calcium levels by depositing calcium into bones.

Beta and Alpha Cells of Pancreas:

Beta Cells Pancreas	Alpha Cells of Pancreas
• Beta cells secrete insulin to lower blood glucose levels.	• Alpha cells secrete glucagon to raise blood glucose levels.

Insulin and Glucagon:

Insulin	Glucagon
• Insulin promotes the uptake and storage of glucose into cells.	• Glucagon stimulates the breakdown of glycogen into glucose to increase blood sugar.

Diabetes Insipidus and Diabetes Mellitus:

Diabetes Insipidus	Diabetes Mellitus
• Diabetes insipidus is caused by a deficiency of ADH resulting in excessive dilute urine.	• Diabetes mellitus is caused by insulin deficiency or resistance resulting in high blood glucose.

Estrogen and Progesterone:

Estrogen	Progesterone
• Estrogen develops and maintains female secondary sexual characteristics and endometrial proliferation.	• Progesterone prepares and maintains the endometrium for gestation.

Positive and Negative Feedback:

Positive	Negative Feedback
• Positive feedback amplifies or accelerates a physiological response away from a set point.	• Negative feedback reverses a change to maintain homeostatic balance.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Explain the neurosecretory role of hypothalamus.

Ans. See Page No. 96 (Q.12)

Q.2 Describe the chemical nature of hormones.

Ans. See Page No. 93 – 95 (Q.3 ⟶ Q.8)

Q.3 State the names of the hormones secreted by pituitary gland. Write the function of each hormone and state the major abnormalities caused by the imbalance of pituitary hormones.

Ans. See Page No. 98 – 99 (Q.15 ⟶ Q.19)

Q.4 Describe the functions of thyroid hormones. What are major diseases due to their imbalance?

Ans. See Page No. 100 (Q.20 ⟶ Q.21)

Q.5 Write a detailed note on adrenal glands mentioning the hormones of adrenal cortex and adrenal medulla and their functions.

Ans. See Page No. 105 (Q.33 ⟶ Q.35)

Q.6 Write a note on pancreas as an endocrine gland.

Ans. See Page No. 102 – 104 (Q.26 ⟶ Q.31)

Q.7 Describe the functions of the hormones secreted by thymus gland, pineal gland, kidneys, and walls of digestive tract.

Ans. See Page No. 109 (Q.42)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 State the role of artificially synthesized steroids in sports and their long-term effects on its users.

Ans. Role of Artificially Synthesized Steroids in Sports and Their Long-term Effects on Its Users:

(a) Role in Sports:

- Athletes misuse anabolic steroids (synthetic testosterone derivatives) to artificially increase muscle mass, enhance physical strength, and speed up recovery times between intense workouts.

(b) Long-term Effects on Its Users:

- **Cardiovascular Damage:** Long-term use causes high blood pressure, artery damage, elevated LDL cholesterol, and a significantly higher risk of heart attacks and strokes.
- **Hormonal and Organ Failure:** Chronic abuse leads to severe liver damage, hormonal imbalances (such as testicular shrinkage and infertility in men, and masculine traits in women), alongside psychological issues like severe mood swings and aggression.

Q.2 Explain on what grounds some companies claim that growth is possible in people having short heights.

Ans. Some Companies Claim that Growth is Possible in People having Short Heights:

(i) Targeting Open Growth Plates: Companies often market their products to teenagers or children, claiming growth is possible because young individuals still have active cartilage growth plates in their long bones.

(ii) Hormone Supplement Marketing: Many products claim to stimulate **natural human growth** hormone (HGH) production through amino acids, vitamins, or secretagogues to promote bone elongation.

(iii) Scientific Limitations: While **legitimate synthetic HGH** can treat **medical deficiencies** in children before growth plates fuse, most over-the-counter commercial supplements lack medical proof and are unable to increase height in adults whose bones have fully matured.

CamScanner

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. (1 x 6 = 06)

(i) Which of the following hormones would be expected to increase if you were studying all day for a test and skipped breakfast and lunch?
(A) Glucagon. (B) Insulin. (C) Growth hormone. (D) Calcitonin.

(ii) Which hormone lowers blood glucose levels?
(A) Glucagon. (B) Epinephrine. (C) Cortisol. (D) Insulin.

(iii) Which anterior pituitary hormone stimulates the thyroid gland to produce thyroxine?
(A) ACTH. (B) FSH. (C) TSH. (D) LH.

(iv) Glucagon is secreted by:
(A) Alpha (α) cells. (B) Beta (β) cells. (C) Acinar cells. (D) Duct cells.

(v) Aldosterone also stimulates the kidneys to secrete excess:
(A) Sodium. (B) Potassium. (C) Glucose. (D) Calcium.

(vi) The secretion of sex hormones by gonads is mainly controlled by:
(A) LH and FSH. (B) ADH and Oxytocin. (C) TSH and ACTH. (D) Insulin and Glucagon.

Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) Name the main chemical categories of hormones.
(ii) What is endocrine system?
(iii) Differentiate between the term hypercalcemia & hypocalcemia.
(iv) What are testes, name their hormones with role?
(v) What are anabolic steroid? What are their importance for athletes?
(vi) What are neurosecretory cells?
(vii) Why the pituitary gland is called master gland?
(viii) Differentiate between Insulin and glucagon.

Q.3 Extensive Questions. (4 x 2 = 8)

(a) Explain the neurosecretory role of hypothalamus.
(b) Write a note on pancreas as an endocrine gland.

ENTRANCE TEST MDCAT

1. Thyroxine deficiency in adults results in a condition called: (UHS 2015)
A. Cretinism. B. Thyrotoximia. C. Hypothyroidism. D. Myxoedema.

2. α-cells of pancreas secrete a hormone known as: (UHS 2015)
A. Glucagons. B. Gastrin. C. Insulin. D. Rennin.

3. Over-secretion of cortical hormone causes a disease called: (UHS 2015)
A. Cushing's disease. B. Hypoglycemia. C. Diabetes mellitus. D. Addison's disease.

4. Ejection of milk from mammary glands is under the control of which one of the following hormones? (UHS 2015)
A. Androgen. B. Progesterone. C. Oxytocin. D. Estrogen.

5. Hormone is antagonistic to insulin and causes increase in blood glucose level. (UHS 2016)
A. Glucagon. B. Calcitonin. C. Nor-epinephrine. D. Thyroxine.

6. Beta cells of islets of Langerhans produce _____ hormone. (UHS 2016)
A. Glucagon. B. Pancreatic juice. C. Insulin. D. Parathormone.

7. The central portion of adrenal gland (adrenal medullA. produces ____ hormone. (UHS 2016)
A. Aldosterone. B. Androgen. C. Epinephrine. D. Corticosterone.

8. Hormones are called fight and flight hormones as they prepare an organism to face stressful situation. (UHS 2016)
A. Adrenaline, aldosterone. B. Cortisone, oxytocin.
C. Epinephrine, nor-epinephrine. D. Thyroxine, nor-epinephrine.

9. There is evidence that high levels of aluminium may contribute to the onset of: (UHS 2017)
A. Parkinson's disease. B. Lesch-Nyhan syndrome.
C. Alzheimer's disease. D. Fragile X-syndrome.

10. The thyroxine hormone of thyroid gland acts directly on: (UHS 2017)
A. Iodine metabolism. B. Glucose metabolism. C. Protein metabolism. D. Basal metabolic rate.

11. All the hormone released by anterior pituitary are tropic EXPECT: (UHS 2017)
A. Thyroid stimulating hormone. B. Adrenocorticotrophic hormone.
C. Somatotrophin hormone. D. Gonadotrophic hormone.

12. Which one of the followings is exocrine as well as endocrine? (UHS 2017)
A. Liver. B. Thyroid. C. Adrenals. D. Pancreas.

13. When a nerve impulse jumps from one node of Ranvier to the next in a myelinated neuron, its called _____: (UHS 2018)
A. Synapses. B. Reusing potential. C. Saltatory conduction. D. Membrane potential.

14. Parathormone hormone production is controlled by the blood: (UHS 2018)
A. Ca level. B. Na level. C. Sugar level. D. Mg level.

15. Blood solute potential is controlled by following hormone: (UHS 2018)
A. Estrogen. B. Thyroxin. C. Epinephrine. D. Vasopressin.

16. Taste buds on the tongue are example of: (UHS 2018)
A. Pressure receptors. B. Thermoreceptors. C. Chemoreceptors. D. Photoreceptors.

17. If stimulation is above _____, impulse travel to the brain along the sensory neuron: (UHS 2019)
A. Action potential. B. Resting potential. C. Threshold. D. Recovery period.

18. The main neurotransmitter for synapses is _____ which lie outside the central nervous system: (UHS 2019)
A. Choline. B. Acetaldehyde. C. Acetylcholine. D. Phosphatidylcholine.

19. Acetylcholine and Noradrenaline are two types of _____ used in our nervous system: (UHS 2019)
A. Hormones. B. Channel and carrier proteins in the cell membrane of a neuron
C. Enzyme. D. Neurotransmitters.

ANSWERS KEY

1. D	2. A	3. A	4. C	5. A	6. C	7. C	8. C	9. C	10. D	11. C	12. D
13. C	14. A	15. D	16. C	17. C	18. C	19. D					

CamScanner

FIND US ON
Facebook
LIKE OUR PAGE TODAY
@SCHOLARPUBLICATIONS.PK

SCHOLAR PUBLICATIONS

17 CHAPTER

HUMAN REPRODUCTIVE SYSTEM

Student Learning Outcomes (SLOs)

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

- Describe the structures of the male reproductive system and identify their functions.
- Define male reproductive hormones and explain their functions
- Explain the structures of female reproductive system and describe their functions
- Describe the menstrual cycle and the hormones involved.

CamScanner

Human Reproductive System — Concept Map

1. REPRODUCTIVE SYSTEMS

(a) Male Reproductive System

- **Gonads (Testes) →** Scrotum (34°C); Seminiferous tubules (Germline & Sertoli cells); Leydig cells.
- Accessory Ducts → Rete testis → Epididymis (maturation/motility) → Vas deferens → Ejaculatory duct → Urethra → Penis.
- **Accessory Glands →** Seminal vesicles (fructose), Prostate gland (60% fluid), Bulbourethral glands (lubrication/neutralization).
- Spermatogenesis → Spermatogonia → Primary spermatocyte (2n) → Meiosis-I → Secondary spermatocyte (1n) → Meiosis-II → Spermatid → Sperm (Head with acrosome, Midpiece with mitochondria, Tail).
- Hormonal Control → Hypothalamus (GnRH) → Anterior Pituitary (FSH stimulates spermatogenesis & Inhibin; LH stimulates Leydig cells for testosterone).

(b) Female Reproductive System

- **Gonads (Ovaries) →** Ovarian follicles, Ovulation of secondary oocyte, Corpus luteum.
- **Oviducts (Fallopian tubes) →** Cilia-assisted transport & site of fertilization.
- **Uterus →** Fundus, Body, Cervix; Layers: Perimetrium, Myometrium, Endometrium (basal & functional layers, placenta formation).
- **Vagina →** 8-10 cm birth canal and menstrual passageway.
- Oogenesis → Oogonia → Primary oocyte (stops in Prophase-I until puberty) → Secondary oocyte + 1st polar body (stops in Metaphase-II) → Fertilization completes Meiosis-II to form Ovum + 2nd polar body.

(c) Female Reproductive Cycle (Menstrual Cycle - 28 days)

- **Menstrual Phase (Days 1–5) →** Shedding of functional endometrium due to low estrogen & progesterone; rising FSH.
- **Proliferative Phase & Ovulation (Days 6–14) →** Graafian follicle growth driven by FSH; estrogen thickens endometrium; estrogen surge triggers LH peak causing Ovulation on Day 14.
- **Secretory / Post-Ovulatory Phase (Days 15–28) →** Corpus luteum secretes estrogen & progesterone; maintenance of vascular endometrium; degeneration leads to menstruation unless rescued by hCG from embryo (pregnancy).

INTRODUCTION

Chapter's Intro:

- We know that **reproduction** means the ability of an **organism** to produce new offspring of its own type.
- In this chapter, we will learn about the human **reproductive system** in more detail.

REPRODUCTIVE SYSTEMS

Q.1 What are the functions of reproductive system? S/Q

Ans. Functions of Reproductive System:

- The functions of reproductive systems include.
- The production of reproductive cells (gametes) and the preparation of **gametes** for fertilization.
- The male reproductive system delivers the **gametes** to the female reproductive system.
- The female **reproductive** system nourishes the fertilized egg cell and provides an **environment** for its **development** into baby.

For Information

- **The reproductive system is different from other organ systems in two aspects.**

i. The reproductive system is quite different in male and female. While, the other organ systems are almost the same in male and female.

ii. The reproductive system does not become functional until puberty. In contrast, all other body systems are functional since or shortly after birth.

Topic: Male Reproductive System:

Q.2 Name the major components of human male reproductive system. Exercise L/Q.1

Ans. Major Components of Human Male Reproductive System:

(i) Gonads (Testes): Two testes are **located** outside the abdomen in a skin pouch called **scrotum.**

(ii) Accessory Ducts: From seminiferous tubules, the **spermatozoa** enter into a network of tubules called rete testis.

(iii) Accessory Glands: These are the glands that add fluids to sperms to form semen.

(iv) Copulatory Organ (Penis): The male copulatory organ is called penis. It contains urethra, erectile tissue, an artery and two veins.

Q.3 Describe the structure of human male reproductive system. Identify the function of each part. Exercise L/Q.1

OR Name the components of human male reproductive system and write the structure & function of each part. L/Q

Ans. Structure of Human Male Reproductive System:

- The components of the male reproductive system and their functions are described below:

(1) Gonads (Testes):

Structure of Gonads:

- Two testes are located outside the abdomen in a skin pouch called **scrotum.**
- Each testis is oval-shaped and measures about 3-5 cm in length and 2-3 cm in width.
- A testis **is composed** of highly convoluted **seminiferous tubules.**
- The wall of the seminiferous tubules i.e., **germinal epithelium** contains **two types** of cells:
  - **(a) Germline Cells:** Germinal cells make sperms (spermatozoa) by meiosis.
  - **(b) Sertoli Cells:** Sertoli cells nourish the developing sperms.

Check Understanding!

Q.1 Which two unique features distinguish the human reproductive system from all other body organ systems?

(A) Structural dimorphism and puberty activation.

(B) Uniform morphology and lifelong functionality.

(C) Endocrine independence and embryonic arrest.

(D) Somatic constancy and continuous mitosis.

CamScanner

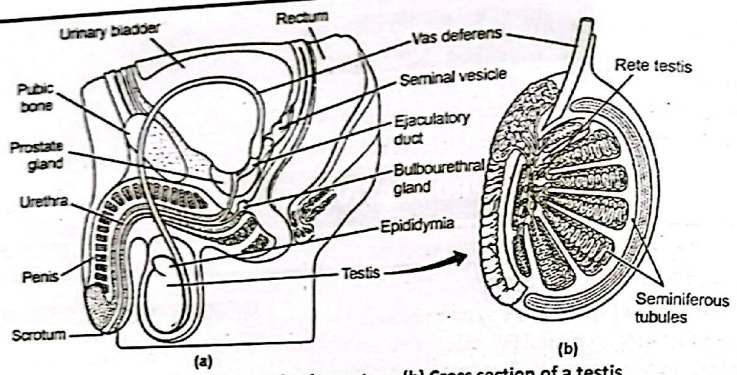


Figure: (a) Male reproductive system; (b) Cross section of a testis

(2) Accessory Ducts:

Structure & Functions of Accessory Ducts:

- From seminiferous tubules, the spermatozoa enter into a network of tubules called **rete testis.**
- From rete testis, sperms enter into a long, coiled tube called the **epididymis.**
- In epididymis the spermatozoa are **still non-motile.** They remain in epididymis for a few days. Then, they become motile and enter another long tube, the **vas deferens.**
- The vas deferens passes into the abdominal cavity via the **inguinal canal.**
- The **vas deferens** from each testis joins with a duct from a seminal **vesicle** (a gland). After joining, the tube is called the **ejaculatory duct.** The two ejaculatory ducts coming from two testes pass through a **prostate gland.**
- They open into the **urethra,** which **comes** from the urinary bladder.
- The urethra opens out of the body through the penis.

For Information

- During development, the testes are formed within the abdominal cavity. Shortly before birth, they descend through an opening into the scrotum.
- The scrotum maintains the testes at **around 34°C.** This temperature is slightly lower than the core body **temperature (37°C).**
- This lower temperature is required for the **development of sperms.**

(3) Accessory Glands:

Structure & Functions of Accessory Glands:

- These are the glands that add fluids to sperms to form semen:

Types of Accessory Glands:

i. Seminal Vesicles:

- There are two seminal vesicles in humans males.
- **Importance:** They releases a **fluid rich** in fructose (sugar) into the vas deferens through a duct.
- This fluid makes **60-70%** volume of the semen and provides energy for the sperm.
- Semen is a mixture of sperms and fluids from the seminal vesicles and the prostate gland.

Check Understanding!

Q.2 Deduce why the testes must be located outside the abdominal cavity within the scrotum during human development.

ii. Prostate Gland:

- The **prostate gland** lies just below the urinary bladder.
- It is soft and spongy and produces about 25-30% fluid of the semen.
- Semen contains nutrients and enzymes for sperm health.

iii. Bulbourethral Glands:

- There are two small **bulbourethral glands.**
- **Importance:** They secrete a clear fluid that lubricates the urethra for sperm passage and provides a protective neutral environment for sperms to survive.

(4) Copulatory Organ (Penis):

- The male copulatory organ is called **penis.**
- Penis contains urethra, three erectile tissue columns and a rich supply of blood vessels and nerves.

Topic: Spermatogenesis:

Q.4 What is spermatogenesis? Discuss the mechanism of formation of spermatogenesis. L/Q

Ans. Spermatogenesis (Production of Sperm):

- The process by which sperm are formed inside the **seminiferous tubules** of the testes is called **spermatogenesis.**

Mechanism of Formation of Spermatogenesis:

- In the walls of **seminiferous tubules,** special cells called **germline cells (2n)** divide by **mitosis.** Some of the new cells become **spermatogonia** (2n), while others remain as **germline cells** for future use.
- The spermatogonia continue to **divide** and form **primary spermatocytes (2n).** Primary spermatocytes move toward the inner space (lumen) of the tubules.

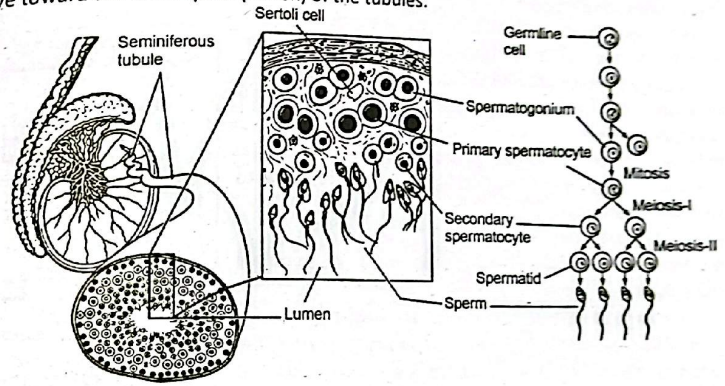


Figure: Spermatogenesis

- Each primary spermatocyte divides by **meiosis-I** to form two **secondary spermatocytes (1n).**
- These cells quickly undergo **meiosis-II** to produce spermatids (1n).
- In this way, **one spermatogonium (2n)** produces **four spermatids (1n).** Each spermatid matures into an **elongated sperm.**
- The mature spermatozoa present in the lumen of seminiferous tubules are non-motile.
- They enter the **epididymis** with the help of the fluid secreted by Sertoli cells. In the epididymis, they gain motility.

Q.5 Name the three parts of sperm & discuss each part separately. L/Q

Ans. Structure of Sperm:

- A sperm consists of **three parts:**

(a) **A Head:** The genetic material is present within its head. About two-thirds of the head is surrounded by a thick cap called the **acrosome.** The acrosome is formed mainly of **Golgi Body.**

(b) **A Midpiece:** It contains enzymes that later help the sperm to fertilize the ovum. The **Midpiece** contains mitochondria and a centriole.

(c) **A Tail:** The **tail** is formed of microtubules (axial filament) which arise from the centriole of Midpiece.

Check Understanding!

Q.3 **Which cellular organelle primarily forms the thick acrosome cap surrounding about two-thirds of a sperm's head?**

(A) Golgi body.
(B) Endoplasmic reticulum.
(C) Lysosomal vacuole.
(D) Centriole complex.

CamScanner

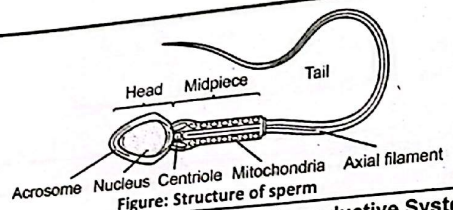


Figure: Structure of sperm

Check Understanding!
Q.4 Analyze the negative feedback loop mechanism that regulates testosterone and LH levels in the male reproductive system.

Topic: Hormonal Control of Male Reproductive System:

Q.6 Explain the major reproductive hormones of human male and explain their role. Exercise L/Q.2
OR Discuss the hormonal control of male reproductive system.

Ans. Hormonal Control of Male Reproductive System:

- Spermatogenesis is controlled by hormones of **hypothalamus** and **pituitary gland.**
- The hypothalamus releases:
  - **(i) Role of GnRH: Gonadotropin-releasing hormone (GnRH):** It stimulates the anterior pituitary to release **follicle-stimulating hormone (FSH)** and **luteinizing hormone (LH).**
  - **(ii) Role of FSH:** FSH stimulates seminiferous tubules for **spermatogenesis.**
  - **(iii) Role of LH:** LH stimulates **Leydig cells** (located in the interstitial tissue between the seminiferous tubules) to **secrete testosterone.**
  - **(iv) Role of Testosterone:**
    - Testosterone **stimulates** the development of **germinal epithelium.**
    - It also maintains **male secondary** sexual characteristics.
    - When **FSH is released** by the anterior pituitary, it causes the Sertoli cells to release a **peptide hormone** called **inhibin** that **inhibits further FSH secretion.**
    - Similarly, when **LH stimulates Leydig cells** to secrete testosterone, the release of **testosterone** inhibits the release of LH and GnRH.

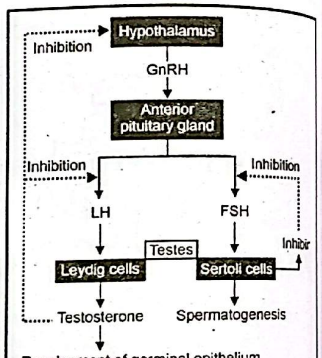


Figure: Hormonal control of male reproductive system

Multiple Choice Questions (MCQs)

		Key
1.	The testes are located inside a skin pouch called the: (A) Epididymis. (B) Scrotum. (C) Prostate. (D) Urethra.	1.(B)
2.	Sperms are produced in the: (A) Epididymis. (B) Vas deferens. (C) Seminiferous tubules. (D) Prostate gland.	2.(C)
3.	Which cells of the seminiferous tubules nourish developing sperms? (A) Leydig cells. (B) Germline cells. (C) Spermatogonia. (D) Sertoli cells.	3.(D)
4.	Sperms become motile in the: (A) Epididymis. (B) Rete testis. (C) Seminiferous tubules. (D) Vas deferens.	4.(A)
5.	The lower temperature of the scrotum mainly helps in: (A) Testosterone secretion. (B) Spermatogenesis. (C) Urine formation. (D) Semen production.	5.(B)
6.	The seminal vesicles secrete a fluid rich in: (A) Proteins. (B) Fructose. (C) Calcium. (D) Cholesterol.	6.(B)
7.	Approximately what percentage of semen fluid is produced by the prostate gland? (A) 20%. (B) 40%. (C) 60%. (D) 80%.	7.(C)
8.	The bulbourethral glands mainly secrete a fluid that: (A) Lubricates. (B) Produces sperms. (C) Stores testosterone. (D) Nourishes Leydig cells.	8.(A)

		Key
9.	The enzyme-containing cap covering the head of a sperm is called the: (A) Centriole. (B) Acrosome. (C) Axial filament. (D) Midpiece.	9.(B)
10.	The Midpiece of a sperm is rich in: (A) Ribosomes. (B) Golgi bodies. (C) Mitochondria. (D) Lysosomes.	10.(C)
11.	One primary spermatocyte (2n) undergoes meiosis to produce: (A) Two spermatids. (B) Four spermatids. (C) Two spermatogonia. (D) Four primary spermatocytes.	11.(B)
12.	Which sequence correctly represents the pathway followed by sperm after leaving the seminiferous tubules? (A) Rete testis → Epididymis → Vas deferens → Ejaculatory duct → Urethra. (B) Epididymis → Rete testis → Vas deferens → Urethra. (C) Vas deferens → Epididymis → Rete testis → Urethra. (D) Seminiferous tubules → Vas deferens → Rete testis → Urethra.	12.(A)
13.	Which hormone directly stimulates the seminiferous tubules for spermatogenesis? (A) LH. (B) Testosterone. (C) FSH. (D) GnRH.	13.(C)
14.	LH stimulates Leydig cells to secrete: (A) Inhibin. (B) Testosterone. (C) FSH. (D) Progesterone.	14.(B)
15.	During hormonal regulation of spermatogenesis, inhibin helps maintain hormonal balance by: (A) Stimulating LH secretion. (B) Stimulating GnRH release. (C) Increasing testosterone. (D) Inhibiting FSH.	15.(D)

Topic: Female Reproductive System:

Q.7 Name the major parts of female reproductive system. Exercise L/Q.3

Ans. Major Parts of Female Reproductive System:

- The female reproductive system consists of following **four major parts:** **(i) Gonads (Ovaries). (ii) Oviducts. (iii) Uterus. (iv) Vagina.**
- The **oviducts, uterus** and **vagina** are called accessory organs of the female reproductive system.

Q.8 Explain the structures of human female reproductive system. Identify the function of each part. Exercise L/Q.3

Ans. Structure & Function of Female Reproductive System:

- The female reproductive system is composed of following **four major parts,** discussed below:

(1) Gonads (Ovaries):

- Ovaries **produce egg cells** (ova or oocytes) and release hormones.
- There are **two ovaries** - each present on the side of the uterus.
- An **oval-shaped** ovary is **3-5 cm** long and **2-3 cm** wide.

Importance of Ovaries:

- Ovary contains many tiny sac-like structures called **ovarian follicles** which are the functional units of ovary.
- Follicles nurture immature eggs. In adult female, one of the **ripening follicles** ejects its egg cell **each month.**
- **Ovulation:** The event of release of egg is called **ovulation.**
- **Corpus Luteum:** After ovulation, the ruptured follicle is transformed into a glandular structure called the **corpus luteum.**

Check Understanding!
Q.5 **Which pituitary hormone surge directly triggers the release of the ovum from the Graafian follicle into the oviduct on day 14?**
(A) Follicle-stimulating hormone.
(B) Luteinizing hormone.
(C) Gonadotropin-releasing hormone.
(D) Progesterone hormone.

(2) Oviducts (Fallopian Tubes):

- The oviducts also called **fallopian tubes** or **uterine tubes. Oviducts** are two tubes leading from the **ovaries into the uterus.**
- When an **ovum matures,** the ovarian follicle and ovary wall rupture to release it. The ovum enters an oviduct and travels toward the uterus. This movement is **facilitated** by the movements of cilia on the inner lining of oviduct.

CamScanner

Importance of Oviduct:

- **Fertilization** of the ovum also occurs in **oviduct**. The resulting zygote undergoes several mitotic divisions while still in oviduct.

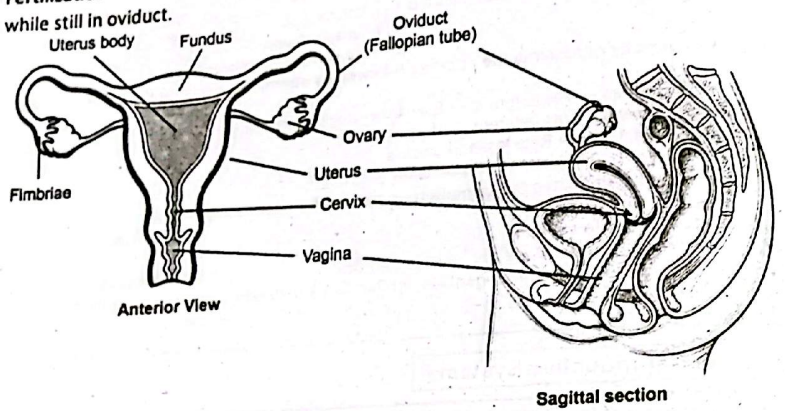


Figure: Human female reproductive system

(3) Uterus:

- The **two oviducts** enter into a **hollow and muscular** organ called **uterus.**
- **Uterus** consists of three parts:
  - **(a) Fundus: Fundus** is the uppermost rounded portion above the openings of oviducts.
  - **(b) Body:** The **body** of the uterus makes its major portion.
  - **(c) Cervix:** The lower narrow part of uterus is called **cervix**. The opening of cervix leads to the vagina.

Structure of Uterus:

- The wall of the uterus is composed of **three layers:**
  - **(i) Perimetrium:** It is the outermost thin layer.
  - **(ii) Myometrium:** It is the middle thick layer composed of smooth muscles.
  - **(iii) Endometrium:** It is the inner spongy lining. It has a basal layer and a functional layer.

Importance of Uterus:

- The **basal layer** has the **stem cells** which regenerate the functional layer.
- The **functional layer** thickens and is shed during the **menstrual cycle.**
- During pregnancy, it further thickens to implant the embryo. Its vascular spaces fuse and become interconnected, forming the placenta (made of maternal endometrium + embryonic chorion).
- Placenta **supplies oxygen** and **nutrition** to the **embryo** and **foetus.**

(4) Vagina:

- It is a thin-walled **8-10 cm long** tube leading from the outside to the cervix of uterus.

Importance of Vagina:

- It provides a passageway for **delivery** of infant and for **menstrual flow** to vagina is also used to transfer the male sperm into female's body through **copulatory organ.**

Topic: Oogenesis:

Q.9 What is oogenesis, discuss the mechanism of oogenesis & explain your answer with the help of diagram. U/A

Ans. Oogenesis: (Production of Ovum)

- The process of production of ovum is called **oogenesis.**

Mechanism of Oogenesis:

- The process of oogenesis starts during the **embryonic development** of female when female is present in **mother's uterus.**
- In that period, the **oogonia (2n)** present in follicle divide by mitosis to produce **primary oocytes (2n).** These primary oocytes begin the **first meiotic** division, but stop in **prophase-I.** They remain in **prophase-I** all through **childhood** (for at **least 10 to 14 years**).
- At puberty, **only one** of the many **primary oocytes** present in ovary resumes **meiosis-I** and produces two dissimilar haploid cells. The larger cell is the secondary oocyte (1n) while **smaller one** is called the first polar body (1n).
- The secondary oocyte stops division in **metaphase-II** and it is released from the **ovary.**

For Information
At birth, a female's ovaries contain some 2 million follicles, each with a primary oocyte.

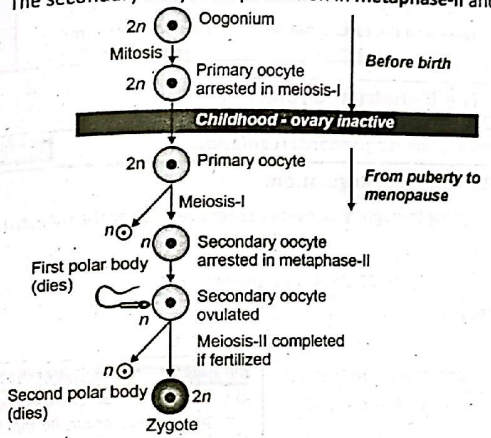


Figure: Oogenesis

Check Understanding!
Q.7 What structural layer of the uterus contains stem cells within its basal layer that regenerate the functional layer shed during menstruation?
(A) Perimetrium.
(B) Myometrium.
(C) Endometrium.
(D) Cervix.

When Secondary Oocyte is not fertilized:

- If an **ovulated** secondary oocyte is not fertilized by a sperm, it dies & menstrual phase starts in female.

When Secondary Oocyte is fertilized:

- If a **sperm fuses** with the secondary oocyte, it quickly **completes meiosis II** (in oviduct). It produces two new cells i.e., one large ovum (1n) and a small second polar body (1n).

Multiple Choice Questions (MCQs)

1. **The functional units of the ovary are called:**
(A) Corpus luteum. (B) Ovarian follicles. (C) Oviducts. (D) Endometrium.
2. **The monthly release of an egg from the ovary is called:**
(A) Ovulation. (B) Menstruation. (C) Fertilization. (D) Implantation.
3. **After ovulation, the ruptured follicle transforms into the:**
(A) Endometrium. (B) Placenta. (C) Corpus luteum. (D) Cervix.
4. **Fertilization normally occurs in the:**
(A) Uterus. (B) Oviduct (Fallopian tube). (C) Vagina. (D) Ovary.
5. **The movement of the ovum through the oviduct is mainly facilitated by:**
(A) Blood flow. (B) Smooth muscles only. (C) Cilia on the inner lining. (D) Gravity.
6. **The uppermost rounded portion of the uterus is called the:**
(A) Cervix. (B) Body. (C) Endometrium. (D) Fundus.
7. **Which uterine layer is composed mainly of smooth muscles?**
(A) Myometrium. (B) Endometrium. (C) Perimetrium. (D) Functional layer.
8. **The functional layer of the endometrium is shed during:**
(A) Pregnancy. (B) Ovulation. (C) The menstrual cycle. (D) Fertilization.

Key
1.(B)
2.(A)
3.(C)
4.(B)
5.(C)
6.(D)
7.(A)
8.(C)

CamScanner

9. During pregnancy, the vascular spaces of the functional layer fuse to form the:
(A) Corpus luteum. (B) Placenta. (C) Cervix. (D) Ovary.

10. If fertilization does not occur, the secondary oocyte:
(A) Immediately forms an ovum. (B) Continues meiosis-II and forms two ova.
(C) Dies while arrested in metaphase-II. (D) Returns to the ovary.

11. During embryonic development, primary oocytes remain arrested in:
(A) Metaphase-I. (B) Prophase-I. (C) Metaphase-II. (D) Telophase-II.

12. Completion of meiosis-II in the secondary oocyte occurs only when:
(A) Ovulation takes place. (B) Puberty begins.
(C) A sperm fuses secondary oocyte. (D) The menstrual cycle ends.

13. Which sequence correctly describes the stages of oogenesis?
(A) Oogonium → Secondary oocyte → Primary oocyte → Ovum.
(B) Secondary oocyte → Primary oocyte → Oogonium → Ovum.
(C) Primary oocyte → Oogonium → Ovum → Secondary oocyte.
(D) Oogonium → Primary oocyte → Secondary oocyte → Ovum.

14. Which statement correctly compares the basal layer and the functional layer of the endometrium?
(A) Both shed. (B) Layer functions. (C) Ova production. (D) Placenta formation.

9.(B) 10.(C) 11.(B) 12.(C) 13.(D) 14.(B)

Topic: Female Reproductive Cycle - The Menstrual Cycle:

Q.10 Describe the events of a menstrual cycle and explain its hormonal regulation. Exercise Q.

Ans. Events of a Menstrual Cycle & Explain its Hormonal Regulation:

- The female reproductive system functions by going through cyclic events, collectively called the menstrual cycle.

➢ **Phases of Menstrual Cycle:**

- The menstrual cycle lasts approximately one month (28 days on average).
- It can be divided into the **following phases:**

(1) Menstrual Phase (Days 1-5):

- In this phase, the functional layer of **endometrium** is shed. The detached tissue and blood move out of the body. This step is called **menstruation.**
- **Menstruation** continues for **3 – 5 days.**

Check Understanding!
Q.6 Evaluate the precise meiotic arrest points that occur during human oogenesis from embryonic development through fertilization.

Hormonal Control of Menstrual Phase:

- It occurs due to low levels of estrogen and progesterone hormones.
- The **gonadotropins** (especially **FSH**) begin to rise in **this phase.**

(2) Proliferative Phase & Ovulation (Days 6-14):

- Due to the **rise in FSH**, a few ovarian follicles begin **growing.** But, only one follicle grows full and the others degenerate.
- **Graafian Follicle:** The mature follicle, called the **Graafian follicle,** rises to the **surface** of the ovary.
- **Proliferative Phase is also called follicular phase.**

Hormonal Control of Proliferative & Ovulation Phase:

- **Role of FSH:** FSH stimulates the **Graafian follicle** to secrete estrogen hormones.
- **Role of Estrogen:** Estrogen causes the initial vascularization of endometrium **and makes** it velvet and thick again. When estrogen **reaches a high level,** it **switches** to positive feedback.
- On the **anterior pituitary, causing a sudden surge of LH.**
- It happens at the end of the proliferative phase (day 14).
- **Role of LH:** The sudden release of LH stimulates Graafian follicle to release the ovum into the oviduct. This phase is known as **ovulation.**

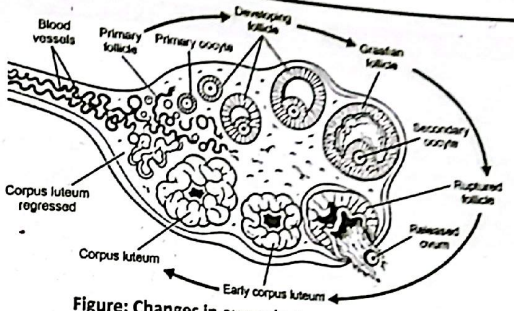


Figure: Changes in ovary during menstrual cycle

(3) Secretory/Post-Ovulatory Phase (Days 15-28):

- **Formation of Corpus Luteum:** After ovulation, **LH stimulates** the ruptured **Graafian follicle** to develop into a yellow structure called the **corpus luteum.**

Hormonal Control of Secretory Phase:

- **Hormones Production from Corpus Luteum: Corpus luteum** secretes estrogen and progesterone hormones which make the endometrium more vascular and glandular.
- **If No Fertilization Occurs:**
  - If fertilization **does not occur,** rising estrogen/progesterone from the corpus luteum suppress LH.
  - As LH declines, the corpus luteum degenerates.
  - Degeneration of corpus luteum results in an abrupt fall in **estrogen** and **progesterone.**
  - It causes the thick endometrium to be shed with bleeding, so the **menstruation** phase starts on **day 28.**

For Information
Q. Define Menopause.
Ans. In human females, menstrual cycle stops around 50 years of age and it is termed as menopause.

Q. What is hCG? How is it important in pregnancy?
Ans. When the ovulated oocyte is fertilized, the tiny embryo secretes **human chorionic gonadotropin** (hCG). This hormone maintains the **corpus luteum.** So, the levels of estrogen and progesterone keep high and menstruation is prevented.
Use to Test Pregnancy: Because hCG comes from the **embryonic chorion** and not the mother, it is the **hormone that is tested for in all pregnancy tests.**

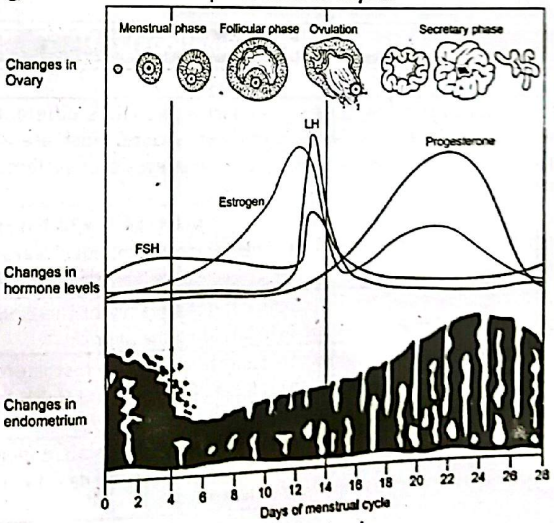


Figure: Menstrual cycle

CamScanner

Multiple Choice Questions (MCQs)

		Key
1.	The average duration of the menstrual cycle is: (A) 14 days. (B) 21 days. (C) 28 days. (D) 35 days.	1.(C)
2.	Menstruation normally occurs during: (A) Days 1–5. (B) Days 6–14. (C) Days 15–21. (D) Days 22–28.	2.(A)
3.	Menstruation occurs due to low levels of: (A) FSH and LH. (B) Estrogen and progesterone. (C) hCG and LH. (D) GnRH and FSH.	3.(B)
4.	During the proliferative phase, FSH stimulates the growth of the: (A) Corpus luteum. (B) Graafian follicle. (C) Endometrium only. (D) Cervix.	4.(B)
5.	The mature ovarian follicle is called the: (A) Graafian follicle. (B) Primary follicle. (C) Corpus luteum. (D) Oogonium.	5.(A)
6.	Ovulation is directly triggered by a sudden release of: (A) FSH. (B) Estrogen. (C) LH. (D) Progesterone.	6.(C)
7.	Ovulation usually occurs on approximately: (A) Day 5. (B) Day 10. (C) Day 28. (D) Day 14.	7.(D)
8.	After ovulation, the ruptured Graafian follicle develops into the: (A) Placenta. (B) Corpus luteum. (C) Endometrium. (D) Oocyte.	8.(B)
9.	During the secretory phase, the corpus luteum secretes: (A) Estrogen and progesterone. (B) FSH and LH. (C) GnRH and hCG. (D) Testosterone and estrogen.	9.(A)
10.	Menopause generally occurs around the age of: (A) 30 years. (B) 40 years. (C) 50 years. (D) 60 years.	10.(C)
11.	If fertilization does not occur, what causes menstruation at the end of the cycle? (A) LH increase. (B) Continuous progesterone. (C) hCG increase. (D) Corpus degeneration.	11.(D)
12.	Why does the level of FSH decrease during the proliferative phase? (A) Progesterone rise. (B) Estrogen feedback. (C) hCG secretion. (D) Corpus degeneration.	12.(B)
13.	Which hormone secreted by the embryo prevents menstruation during pregnancy? (A) Human chorionic gonadotropin (hCG). (B) Progesterone. (C) Estrogen. (D) LH.	13.(A)
14.	Pregnancy tests detect which hormone because it is secreted by the embryonic chorion? (A) LH. (B) FSH. (C) hCG. (D) Estrogen.	14.(C)
15.	Which sequence correctly represents the normal menstrual cycle? (A) Secretory phase → Menstrual phase → Ovulation. (B) Menstrual phase → Proliferative phase → Ovulation → Secretory phase. (C) Ovulation → Menstrual phase → Secretory phase. (D) Proliferative phase → Secretory phase → Menstrual phase → Ovulation.	15.(B)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(A)	• The text states that the human reproductive system is different because it is quite different in males and females (unlike other systems which are almost the same) and does not become functional until puberty, whereas other systems are functional since or shortly after birth.
2.	S/Q	• The scrotum maintains the testes at approximately 34°C, which is slightly lower than the core body temperature of 37°C, a cooler environment specifically required for normal sperm development.
3.	(A)	• The text specifies that the acrosome is formed mainly of the Golgi body and contains enzymes that later assist the sperm in fertilizing the ovum.
4.	S/Q	• LH stimulates Leydig cells to secrete testosterone; when testosterone levels rise, it acts via negative feedback to inhibit the release of both LH and GnRH from the pituitary and hypothalamus, thereby stabilizing hormone concentrations.
5.	(B)	• The text states that as estrogen rises, FSH falls due to negative feedback, prompting the anterior pituitary to release a sudden surge of LH at day 14, which stimulates the Graafian follicle to release the ovum (ovulation).
6.	S/Q	• Primary oocytes arrest in prophase-I throughout childhood; at puberty, one resumes meiosis-I but arrests again at metaphase-II until fertilization stimulates it to rapidly complete meiosis-II.
7.	(C)	• The text explains that the endometrium is the inner spongy lining possessing a basal layer with stem cells that regenerate its functional layer, which thickens and is shed during the menstrual cycle.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. Fertilization of the ovum occurs in:
(a) Oviduct. (b) Uterus. (c) Cervix. (d) Vagina.
2. Which cells of the testis secrete testosterone hormone?
(a) Sertoli cells. (b) Germline cells. (c) Spermatogonia. (d) Leydig cells.
3. The site of the production of sperm is:
(a) Seminiferous tubules. (b) Epididymis. (c) Seminal vesicle. (d) Vas deferens.
4. Which part produces fructose-rich fluid for the sperm?
(a) Prostate gland. (b) Seminal vesicles. (c) Testis. (d) Bulbourethral gland.
5. In males, which hormone initiates spermatogenesis?
(a) Luteinizing hormone. (b) Follicle stimulating hormone.
(c) Gonadotropin-releasing hormone. (d) Testosterone.
6. During ovulation which cell is actually released from ovary?
(a) Oogonium. (b) Primary oocyte. (c) Secondary oocyte. (d) Mature ovum.
7. Which hormone stimulates the Graafian follicle to release ovum?
(a) LH (b) FSH (c) Estrogen. (d) Progesterone.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(a)	Oviduct.	• Fertilization typically takes place in the ampulla of the fallopian tube (oviduct) where the sperm meets the secondary oocyte.
2.	(d)	Leydig cells.	• Leydig cells (interstitial cells) located adjacent to the seminiferous tubules are responsible for synthesizing and secreting testosterone.
3.	(a)	Seminiferous tubules.	• Spermatogenesis occurs within the specialized epithelial lining of the seminiferous tubules inside the testes.
4.	(b)	Seminal vesicles.	• The seminal vesicles secrete a thick, alkaline fluid rich in fructose, prostaglandins, and proteins that nourishes and activates sperm.
5.	(b)	Follicle stimulating hormone.	• FSH directly acts on the seminiferous tubules and Sertoli cells to stimulate and maintain the process of spermatogenesis.
6.	(c)	Secondary oocyte.	• The human ovary releases an egg arrested at metaphase II of meiosis, which is structurally a secondary oocyte.
7.	(a)	LH.	• A surge of Luteinizing Hormone (LH) triggers ovulation by causing the rupture of the mature Graafian follicle.

CamScanner

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Briefly describe the function of seminal vesicles, prostate gland, and bulbourethral glands.

Ans. a) Function of Seminal Vesicles:
- Each of these glands releases a **fluid rich** in fructose (sugar) into the vas deferens through a duct. This fluid provides energy for the sperm.

b) Function of Prostate Gland:
- It is soft and spongy and produces about 60% fluid of the semen. Semen is a mixture of sperms and fluids from the seminal vesicles and the **prostate gland.**

c) Function of Bulbourethral Glands:
- They secrete a clear fluid that lubricates the urethra for sperm passage and provides a protective neutral environment for sperms to survive.

Q.2 When do the ova in females begin meiosis? When do they complete the first meiotic division?

Ans. Start of Meiosis in Ova + Completion of First Meiotic Division:
- **Beginning of Meiosis:** Oogenesis begins during embryonic development in the female fetus, where oogonia transform into primary oocytes and arrest in prophase-I & stays here for 10 – 14 years.
- **Completion of First Meiotic Division:** The first meiotic division is completed just prior to **ovulation** in each respective ovarian cycle after puberty.

Q.3 Write a brief note on the role of FSH, LH and testosterone in man.

Ans. (a) Role of FSH (Follicle-Stimulating Hormone):
- It stimulates the Sertoli cells to support and nourish developing sperm cells during spermatogenesis.

(b) Role of LH (Luteinizing Hormone):
- It stimulates the Leydig cells in the testes to synthesize and secrete testosterone.

(c) Role of Testosterone:
- It drives primary and secondary male sexual characteristics, supports spermatogenesis, and regulates libido.

Q.4 List the structures of female reproductive system.

Ans. Structures of Female Reproductive System:
- The female reproductive system consists of following **four major parts:**
  (i) Gonads (Ovaries). (ii) Oviducts. (iii) Uterus. (iv) Vagina.
- The **oviducts, uterus and vagina** are called accessory organs of the female reproductive system.

Q.5 What changes occur in ovulation and menstruation during the gestation period?

Ans.
- **Changes Occur in Ovulation during Gestation Period:** Ovulation ceases entirely during gestation due to high levels of estrogen and progesterone providing negative feedback to the pituitary gland.
- **Changes Occur in Menstruation during Gestation Period:** Menstruation stops completely as the thickened uterine endometrium is maintained to support the developing embryo and placenta.

Q.6 What is the role of the corpus luteum in a menstrual cycle?

Ans. Role of the Corpus Luteum in a Menstrual Cycle:
- **Hormone Secretion:** It secretes large amounts of progesterone and some estrogen to maintain and thicken the uterine endometrium for potential implantation.
- **Cycle Regulation:** If pregnancy does not occur, it degenerates into the corpus albicans, causing hormone levels to drop and menstruation to begin.

Q.7 Differentiate between:
- Primary and secondary spermatocytes
- Sertoli cell and Leydig cell
- Primary oocyte and secondary oocyte
- Spermatogenesis and oogenesis
- Spermatids and spermatozoa

Ans. Primary and Secondary Spermatocytes:

Primary Spermatocytes	Secondary Spermatocytes
• Primary spermatocytes are diploid cells that undergo the first meiotic division.	• Secondary spermatocytes are haploid cells resulting from that division which undergo meiosis II.

Spermatogenesis and Oogenesis:

Spermatogenesis	Oogenesis
• Spermatogenesis is the continuous process of producing four viable haploid sperm cells in males.	• Oogenesis is the discontinuous process in females that yields a single functional haploid ovum and polar bodies.

Sertoli Cell and Leydig Cell:

Sertoli Cell	Leydig Cell
• Sertoli cells nourish and support developing sperm cells within the seminiferous tubules.	• Leydig cells are interstitial cells that produce testosterone.

Spermatids and Spermatozoa:

Spermatids	Spermatozoa
• Spermatids are non-motile, round haploid cells just emerging from meiosis.	• Spermatozoa are fully mature, flagellated, motile sperm cells.

Primary Oocyte and Secondary Oocyte:

Primary Oocyte	Secondary Oocyte
• A primary oocyte is a diploid cell arrested in prophase-I prior to birth.	• A secondary oocyte is a haploid cell resulting from the first meiotic division that is released during ovulation.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Describe the structure of human male reproductive system. Identify the function of each part.

Ans. **See Page No. 123 – 124 (Q.2 ⟶ Q.3)**

Q.2 Explain the major reproductive hormones of human male and explain their role.

Ans. **See Page No. 126 (Q.6)**

Q.3 Explain the structures of human female reproductive system. Identify the function of each part.

Ans. **See Page No. 127 – 128 (Q.7 ⟶ Q.8)**

Q.4 Describe the events of a menstrual cycle and explain its hormonal regulation.

Ans. **See Page No. 130 (Q.10)**

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 List the structures in order, through which a sperm passes on its way from the seminiferous tubules to the outside.

Ans. Pathway of Sperm from Seminiferous Tubules to the Outside:
- Seminiferous Tubules ⟶ Rete Testis ⟶ Efferent Ductules ⟶ Epididymis ⟶ Vas Deferens ⟶ Ejaculatory Duct ⟶ Urethra ⟶ Outside of the Body

CamScanner

Q.2 Describe the effect of endocrine disrupting contaminants on the reproductive abilities.

Ans. Endocrine Disrupting Contaminants on the Reproductive Abilities:

(i) **Hormone Mimicry:** Endocrine disruptors mimic or block natural sex hormones like estrogen testosterone, disrupting the delicate chemical signaling needed for reproduction.

(ii) **Reduced Fertility:** They can cause a significant decline in sperm count and quality in males, and d normal ovulation and menstrual cycles in females.

(iii) **Developmental Abnormalities:** Exposure can lead to structural malfunctions in reproductive organs increase the risk of reproductive system cancers.

Q.3 Why are so many sperms produced in the male and so few ova produced in the female?

Ans. Reasons of Many Sperms Produced in the Male + Few Ova Produced in the Female:

- **Probability and Competition:** Millions of sperm are produced to overcome a high mortality rate in female tract and to engage in intense competition to fertilize the egg.
- **Biological Investment:** Sperms are tiny cells with minimal energy investment, allowing the male body produce them continuously and in massive quantities.
- **Limited Ova Production:** Females produce few ova because eggs are large, resource-heavy cells require significant energy, and biological strategy focuses on quality and internal embryo development rather than sheer numbers.

SELF-ASSESSMENT

Total Mark

Q.1 Encircle the correct option. (1 x 6 =

(i) **Approximately what percentage of semen fluid is produced by the prostate gland?**
(A) 20%. (B) 40%. (C) 60%. (D) 80%.

(ii) **LH stimulates Leydig cells to secrete:**
(A) Inhibin. (B) Testosterone. (C) FSH. (D) Progesterone.

(iii) **The site of the production of sperm is:**
(A) Seminiferous tubules. (B) Epididymis. (C) Seminal vesicle. (D) Vas deferens.

(iv) **Fertilization normally occurs in the:**
(A) Uterus. (B) Oviduct (Fallopian tube). (C) Vagina. (D) Ovary.

(v) **Which statement correctly compares the basal layer and the functional layer of the endometrium?**
(A) Both shed. (B) Layer functions. (C) Ova production. (D) Placenta formation.

(vi) **Menopause generally occurs around the age of:**
(A) 30 years. (B) 40 years. (C) 50 years. (D) 60 years.

Q.2 Write short answers of the following questions. (2 x 8 =

(i) How is human reproductive system different from other organ systems in two aspects?
(ii) Define Menopause.
(iii) What is hCG? How is it important in pregnancy?
(iv) Briefly describe the function of seminal vesicles, prostate gland, and bulbourethral glands.
(v) Differentiate between Spermatogenesis and oogenesis.
(vi) What changes occur in human female if no fertilization occurs during secretory phase?
(vii) Differentiate between Sertoli cell and Leydig cell.
(viii) List the structures in order, through which a sperm passes on its way from the seminiferous tubules to outside.

Q.3 Extensive Questions. (4 x 2 =

(a) Explain the major reproductive hormones of human male and explain their role.
(b) Describe the events of a menstrual cycle and explain its hormonal regulation.

ENTRANCE TEST MDCAT

1. In human testis, which structure is responsible for carrying sperm from inside the testis? (UHS 2015)
A. Seminiferous tubules. B. Seminal vesicle. C. Urinogenital duct. D. Vasa efferentia.

2. In which part of female reproductive system fertilization takes place? (UHS 2015)
A. Proximal part of oviduct. B. Placenta. C. Uterus. D. Vagina.

3. In females, FSH stimulates the ovary to produce (UHS 2015)
A. Progesterone. B. Oestrogen. C. Lactin. D. Oxytocin.

4. In which phase of human female menstrual cycle, endometrium prepares for the implantation of embryo? (UHS 2015)
A. Proliferative phase. B. Secretary phase. C. Menstrual phase. D. Ovulation phase.

5. Events of menstrual cycle are regulated by the: (UHS 2016)
A. Ethylene. B. Auxins. C. Gonadotropins. D. Gibberellins.

6. Decrease of FSH and increase of estrogen cause pituitary gland to secrete: (UHS 2016)
A. Somatotropin. B. Testosterone. C. Luteinizing Hormone. D. Spermatogonium.

7. _____ is structure in female reproductive system where fertilization takes place: (UHS 2017)
A. Ovaries. B. Cervix. C. Uterus. D. Oviduct.

8. Which one of the followings directly develops into sperms: (UHS 2017)
A. Primary spermatocytes. B. Secondary spermatocytes.
C. Spermatids. D. Spermatogonia.

9. FSH stimulates the production of estrogen hormone which has two targets _____ and _____: (UHS 2017)
A. Uterus, posterior pituitary. B. Uterus, anterior pituitary.
C. Ovaries, uterus. D. Ovaries, hypothalamus.

10. Ovulation is suppressed by progesterone via: (UHS 2017)
A. Only by inhibition of LH. B. Inhibition of LH and stimulation of FSH.
B. Inhibition of FSH and stimulation of LH. D. Inhibition of FSH and inhibition of LH.

11. In human female egg is fertilized in: (UHS 2018)
A. Ovary. B. Oviduct. C. Vagina. D. Uterus.

12. Which hormone is released in female in response to FSH from pituitary gland? (UHS 2018)
A. Oestrogen. B. Oxytocin. C. ADH. D. Progesterone.

13. Which hormone causes the contraction walls of uterus during the process of birth? (UHS 2018)
A. FSH. B. Oxytocin. C. STH. D. LTH.

14. Which of the following hormone acts on the uterus wall for thickening? (UHS 2018)
A. Progesterone. B. Follicle stimulating hormone.
C. Zona pellucida. D. Oxyntic.

15. Inside ovary, primary oocyte divides through first meiotic division forming two haploid cells, secondary oocyte and: (UHS 2019)
A. Polar body. B. Follicle cell. C. Oogonium. D. Ovum.

16. Which hormonal pair would maintain the endometrium and make it receptive for implantation of embryo? (UHS 2019)
A. Luteinizing Hormone and Progesterone.
B. Estrogen and Follicle Stimulating Hormone.
C. Luteinizing Hormone and Follicle Stimulating Hormone.
D. Estrogen and Progesterone.

17. During spermatogenesis, the _____ which are haploid cells eventually mature into spermatozoa/mature sperms: (UHS 2019)
A. Secondary spermatocytes. B. Spermatogonia.
C. Primary spermatocytes. D. Spermatids.

CamScanner

18. Process ensuring the survival of species over long periods of time, even though individual members of the species die: (UHS 2018)
A. Reproduction. B. Mitosis. C. Adaptability. D. Respiration.

19. Which of the following hormone stimulates the ovulation from the follicle into oviduct? (UHS 2019)
A. Luteinizing hormone. B. Estrogen.
C. Follicle stimulating hormone. D. Progesterone

20. Which hormonal pair would maintain the endometrium and make it receptive for implantation of embryo? (UHS 2019)
A. Luteinizing Hormone and Progesterone.
B. Estrogen and Follicle Stimulating Hormone.
C. Luteinizing Hormone and Follicle Stimulating Hormone.
D. Estrogen and Progesterone.

21. During spermatogenesis, the _____ which are haploid cells eventually mature into spermatozoa/mature sperms: (UHS 2019)
A. Secondary spermatocytes. B. Spermatogonia.
C. Primary spermatocytes. D. Spermatids.

ANSWERS KEY

1. D	2. A	3. B	4. B	5. C	6. C	7. D	8. C	9. B	10. A	11. B	12. A
13. D	14. A	15. A	16. D	17. D	18. A	19. A	20. D	21. D			

18 CHAPTER

INHERITANCE

Student Learning Outcomes (SLOs)

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

- Define gene.
- Explain the law of segregation and independent assortment, using a suitable example related to the pea plants.
- Relate the Law of independent assortment to random orientation of chromosomes during meiosis.
- Express limitations of independent assortment and its usefulness.
- Show that independent assortment leads to variation in the gametes.
- Evaluate that inheritance of genes and their mixing during fertilization is based on mathematical probabilities.
- Describe the exceptions to the Mendel's laws of inheritance.
- Explain incomplete dominance and exemplify it through the inheritance of flower color in 4 O' clock plant.
- Differentiate between incomplete dominance and codominance.
- Define alleles and multiple alleles.
- State the alleles responsible for the trait of ABO blood groups.
- Explain the case where two alleles have equal dominance through the genetics of human blood group AB.
- Name the various human blood group systems.
- Investigate the reasons for O –ve individual as the Universal donor and AB +ve as the Universal recipient.
- Describe the occurrence of some other blood group systems.
- Associate the positive and negative blood groups with the presence and absence of Rh factor.
- Justify why Rh incompatibility could be a danger to the developing fetus and mother.
- Explain Erythroblastosis fetalis in the light of antigen-antibody reaction.
- Suggest measures to counter the problem of Erythroblastosis fetalis before it occurs.
- Define and relate the terms; polygenic and epistasis.
- Describe polygenic inheritance using suitable examples from plants (grain color in wheat) and animals (skin color in man).
- List at least five polygenic traits discovered in humans.
- Give one example of epistasis from mammals (coat color inheritance in Labrador retrievers) and one from plants (pigment phenotype in foxgloves) and justify modified Mendelian ratios.
- Describe the terms gene linkage and crossing over.
- Explain that gene linkage counters independent assortment and crossing-over modifies the progeny.
- Suggest that linkage can be observed / evaluated only if the number of progeny is quite large.
- Explain the XX-XY mechanism of sex determination in mammals.
- Identify male and female individuals from the karyotype of man.
- Solve the genetics problems related to XX-XY, sex determination.
- Describe the concept of sex-linkage.
- Explain the inheritance of sex-linked traits (eye color) in Drosophila.
- Describe the sex-linked inheritance of male characters due to Y-chromosome and the effect of Holandric genes.
- Describe the X-linked disorders with reference to the patterns of inheritance.
- Name some of the sex-linked disorders of man (Red green color blindness, Hemophilia)
- Explain the techniques employed for embryonic screening e.g., Amniocentesis and Chorionic Villus Sampling.

CamScanner

Inheritance — Concept Map

1. LAW OF SEGREGATION
- **Monohybrid Cross** → Seed shape cross yielding 3:1 phenotype (disguised 1:2:1 genotype).
- **Interpretation** → Genes/alleles, homozygous/heterozygous, locus, genotype (blueprint) vs phenotype.
- **Testcross** → Crossing dominant phenotype with recessive (rr) to test zygosity.

2. LAW OF INDEPENDENT ASSORTMENT
(a) Limitations:
- Linked genes, chromosome crossover, epistasis, pleiotropy, and environmental effects.

(b) Probabilities
- Basic rule, Product rule (multiplying independent events), Sum rule (adding mutually exclusive events).

3. DOMINANCE RELATIONS & MULTIPLE ALLELES
- **Incomplete Dominance** → Blended intermediate phenotype (Japanese 4-o'clock, 1:2:1 ratio).
- **Co-dominance** → Both alleles fully expressed (MN blood group).
- **Multiple Alleles** → Genes with >2 forms in population (ABO blood group system).

4. BLOOD GROUP SYSTEMS
- **ABO System** → Antigens A/B, Landsteiner's rule, universal donor (O) & recipient (AB), Bombay phenotype (hh).
- **Rh System** → Rh factor (D gene), O-negative universal donor & AB-positive universal recipient.
- **Erythroblastosis Foetalis** → Rh incompatibility between Rh-negative mother and Rh-positive foetus.

5. POLYGENIC INHERITANCE & EPISTASIS
- **Polygenic Inheritance** → Additive multiple genes causing continuous variation (skin/wheat color).
- **Epistasis** → Non-allelic gene masking/modification (Labrador coat 9:3:4, Foxglove flowers 12:3:1).

6. GENE LINKAGE & CROSSING OVER
- **Gene Linkage** → Genes on same chromosome inherited together (Morgan's Drosophila studies).
- **Crossing Over** → Exchange of DNA between homologous chromatids during meiosis-I, causing genetic recombination.

7. SEX DETERMINATION
1. **XX-XY System** → Mammals & Drosophila (females XX, males XY).
2. **XX-XO System** → Insects/grasshopper (males lack Y chromosome, have nullo gametes).
3. **ZW-ZZ System** → Birds (females ZW, males ZZ).

8. SEX LINKAGE & TRAITS
- **Human Sex-Linked Traits** → X-linked recessive, X-linked dominant, Y-linked (holandric).
- **Sex-Linked Disorders** → Haemophilia (A, B, C), Colour-blindness (dichromacy/monochromacy), Duchenne muscular dystrophy.
- **Sex-Limited & Influenced Traits** → Sex-limited (expressed in one sex: beard, milk) & Sex-influenced (hormone-dependent dominance: male-pattern baldness).

INTRODUCTION

- You have studied the basics of **Mendelian genetics** in Grade X.

Chapter Intro:
- This chapter carries the concept forward to **post-Mendelian research.**
- It also gives an insight into the **inherited diseases** and their symptoms and treatment.

Recalling

Q. Who was Gregor Johann Mendel & what was his contributions in the field of genetics?

Ans. Gregor Johann Mendel was the "Austrian" monk.

Gregor Johann Mendel Contributions in the Field of Genetics:
- He first to explain the mechanism of inheritance.
- He developed **true-breeding** (pure-breeding) varieties of pea plants. A plant which is **true-breeding** for a particular trait produces all the offspring with the same trait upon **self-fertilization.**

LAW OF SEGREGATION

Q.1 Discuss the working of Mendel, before he established law of segregation. LIQ

Ans. **Working of Mendel and Establishment of Law of Segregation:**
- Mendel performed **monohybrid** crosses in pea plant.
- In the first monohybrid crosses, he observed the inheritance of **"seed shape".**
- When he crossed a **true-breeding round-seeded** (RR) plant with **wrinkled-seeded (rr) plant, all plants of** F1 generation produced round seeds. (See figure)
- **Dominant Form of Trait:** He called the trait that was expressed in the **F1 plants** (round seeds, Rr) as **dominant.**
- **Recessive Form of Trait:** The alternative trait that was not expressed in the F1 plants **(wrinkled seeds)** called as **recessive** trait.
- When **F1 plants** were self-pollinated (Rr × Rr) the 1/4 of F2 seed were wrinkled (rr).
- In other words, the **dominant-recessive ratio** among the F2 seeds was **3 dominant : 1 recessive.**
- His results suggested that the **3:1 ratio in F2 generation** was really a disguised 1:2:1 ratio (Genotype Ratio).
- In **F2 generation.**
  - 1/4 were pure-breeding dominant (RR).
  - 2/4 were not pure-breeding dominant (Hybrid) (Rr).
  - 1/4 were pure-breeding recessive (rr).

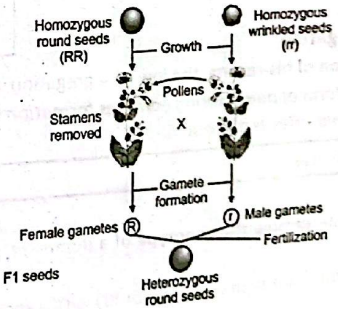
Check Understanding!

Q.1 What underlying phenotypic ratio is disguised by the 3:1 dominant-to-recessive ratio observed in the F2 generation of Mendel's monohybrid cross?

(A) 1:2:1 ratio (B) 9:3:3:1 ratio
(C) 1:1 ratio (D) 12:3:1 ratio

Mendel's Conclusion:
- From his experiments, Mendel **concluded** that for each pair of **alternative traits,** one trait was **not expressed** in the **F1 hybrids,** although it reappeared in **1/4 of F2 seeds.**
- The trait that **"disappeared"** must therefore be disguised (masked, hidden) in the **F1 seeds.**

Step-I (True Breeding Cross):



➢ **Step-II (Mono-Hybrid Self Cross):**

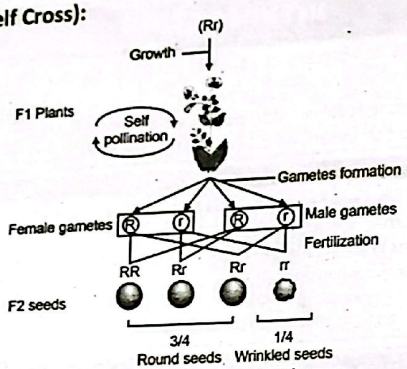


Figure: Mendel's monohybrid cross

➢ **Interpretation of the Results:**

(i) Traits Controlled By Factors (Now Named As Genes): Mendel explained that the characters (traits) of organisms are controlled by special **"factors"** (which are now called **genes**).

(ii) Each Trait Has Two Genes: Each individual is diploid and has two **genes** for a character.

(iii) Genes Present on Chromosome: Genes are present on chromosomes.

(iv) One Gamete Has One Gene: When the individual forms haploid gametes (eggs or sperms), each gamete receives one **gene** for each **character**.

(v) Allele As Alternative Form: All copies of a gene may not be identical. The alternative forms of a gene, leading to alternative.traits, are called **alleles.**

(vi) Homozygous Gene-pair (RR, rr): When two haploid gametes containing the **same alleles** fuse, the offspring receives the gene-pair with similar alleles. Such offspring is called **homozygous** for that gene pair or trait.

(vii) Heterozygous Gene-pair (Rr): When the two haploid gametes with different alleles fuse, the offspring is **heterozygous.**

➢ **Mendel's Present Concept of Gene & Locuss:**

- A gene is **"A sequence of nucleotides as part of DNA, which codes for the formation of a polypeptide".**
- **Locus:** The particular location of a gene on a chromosome is called the **gene's locus.**
- When the individual forms gametes, each **gamete receives** just one gene copy (allele), which is selected randomly. This is known as the law of **segregation.** When gametes join, they form a **new individual,** whose genotype consists of the alleles contained in the gametes.

For Information

- In heterozygous individuals, only one allele (dominant) is expressed, while the other allele (recessive) is present but unexpressed.
- **Genotype:** The combination of alleles in an individual is its **genotype.**
- **Phenotype:** It is the observable character or trait.
- In other words, the genotype is the blueprint, and the phenotype is the **visible outcome.**

➢ **Statement of Law of Segregation:**

- After Mendel's **explanation of his results,** the low of segregation was **stated as:**
- ***Genes are present in the form of pairs, during gametes formation each gamete receives only one allele, the pair is again completed after fertilization.***

Q.2 What is test cross? What is its use? S/Q

Ans. Testcross:

- A cross which is used to **determine the genotype** of a dominant phenotype whether it is homozygous or heterozygous.
- It involves crossing the **dominant** phenotype (RR or Rr) with a **recessive phenotype (rr).**

- **Use:** Test cross is used to find out the genotype of a trait.

Example:

- A round-seeded plant may be **RR (homozygous)** or Rr (heterozygous).
- The **wrinkled-seeded** plants are always rr.
- To determine the genotype of RR or Rr, the round-seeded plant is crossed with a wrinkled-seeded plant (rr), two times.
- **Case-I:** If it is **RR,** all offspring will be **round (Rr).**
- **Case-II:** If it is **Rr,** the offspring will be **round and wrinkled in a 1:1 ratio.**

Check Understanding!

Q.2 Deduce why an organism's phenotype cannot always be used to definitively determine its genotype without performing a testcross.

Multiple Choice Questions (MCQs)

		Key
1.	**Mendel demonstrated the Law of Segregation through a:** (A) Dihybrid cross. (B) Back cross. (C) Monohybrid cross. (D) Testcross.	1.(C)
2.	**In his monohybrid cross, Mendel studied the inheritance of:** (A) Seed shape. (B) Plant height. (C) Flower colour. (D) Pod colour.	2.(A)
3.	**In the F_1 generation obtained from crossing round- and wrinkled-seeded pea plants, all seeds were:** (A) Wrinkled. (B) Round. (C) Half round and half wrinkled. (D) Oval.	3.(B)
4.	**Mendel called the trait expressed in the F_1 generation the:** (A) Recessive trait. (B) Intermediate trait. (C) Hybrid trait. (D) Dominant trait.	4.(D)
5.	**The phenotypic ratio of dominant to recessive traits in the F_2 generation is:** (A) 1 : 1. (B) 2 : 1. (C) 3 : 1. (D) 1 : 2 : 1.	5.(C)
6.	**The genotypic ratio in the F_2 generation is:** (A) 3 : 1. (B) 1 : 2 : 1. (C) 2 : 2. (D) 1 : 1.	6.(B)
7.	**Genes are located on:** (A) Chromosomes. (B) Mitochondria. (C) Ribosomes. (D) Lysosomes.	7.(A)
8.	**Alternative forms of the same gene are called:** (A) Loci. (B) Chromatids. (C) Alleles. (D) Codons.	8.(C)
9.	**The specific position of a gene on a chromosome is called its:** (A) Genome. (B) Locus. (C) Chromatid. (D) Centromere.	9.(B)
10.	**A homozygous individual possesses:** (A) Two different alleles. (B) Only one allele. (C) No alleles. (D) Two identical alleles.	10.(D)
11.	**If a round-seeded plant (unknown genotype) is test-crossed with a wrinkled-seeded plant and all offspring are round, the genotype of the round-seeded plant is:** (A) Rr. (B) rr. (C) RR. (D) rR.	11.(C)
12.	**Why did Mendel conclude that the recessive trait had not disappeared in the F_1 generation?** (A) Always visible. (B) F_2 reappearance. (C) Only pollen. (D) Permanent change.	12.(B)
13.	**Which statement best explains Mendel's Law of Segregation?** (A) Alleles together. (B) Recessives only. (C) Dominants together. (D) Alleles separate.	13.(D)

LAW OF INDEPENDENT ASSORTMENT

➢ **Simplest Difference Between Law of Segregation & Law of Independent Assortment:**

- The **law of segregation** explains the inheritance of **one trait.**
- While the **law of independent assortment** explains the inheritance of **more than one traits** simultaneously.

Q.3 Explain Mendel's experiment which led to the formulation of the law of independent assortment. Exercise L/Q.1

Ans. Mendel's Experiments to the Formulation of Law of Independent Assortment:

- After showing that alleles of one character segregate independently, **Mendel studied** whether genes of different characters also **segregate independently.**

Check Understanding!

Q.3 What term is used to describe F1 plants that are heterozygous for two different pairs of genes being studied simultaneously?

(A) Testcrosses. (B) Homozygous.
(C) Dihybrids. (D) Recombinants.

CamScanner

- He examined two characters together: **seed shape - round (R) dominant and wrinkled (r) recessive**, and **seed colour - yellow (Y) dominant and green (y) recessive.**
- He established **pure-breeding** lines for these traits.
  - (i) Pure-breeding plants with both dominant traits i.e., round and yellow seeds (RRYY).
  - (ii) Pure-breeding plants with both recessive traits i.e., wrinkled and green seeds (rryy).
- **Step-I:** He crossed pure-breeding plants **(RRYY × rryy)**.
- **Step-II:** All F1 seeds showed both dominant traits (round and yellow) and were heterozygous with genotype **RrYy**.
- These F1 plants are called **dihybrids**, as they are heterozygous for both genes.
- To confirm the genotype of F1 plants, Mendel self-fertilized them to produce the F2 generation.
- Instead of a **3:1 ratio**, the F2 showed four phenotypes i.e., **round yellow, round green, wrinkled yellow,** and **wrinkled green** - in a **9:3:3:1** ratio respectively.

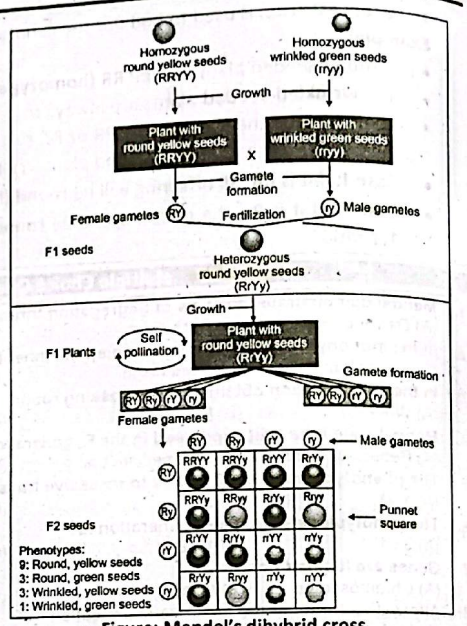


Figure: Mendel's dihybrid cross

➢ **Interpretation of the Results By Mendel:**

- In a F1 dihybrid plant **(RrYy)**, seed shape has alleles **R, r** and seed colour has **Y, y**. During gamete formation, four combinations are produced: **RY, Ry, rY, ry**. When these gametes combine (4 male × 4 female gametes), **16 combinations** are formed in the F2 generation. This results in four phenotypes in F2 in a **9:3:3:1 ratio**:
  - **(i) 9 round yellow.** **(ii) 3 round green.**
  - **(iii) 3 wrinkled yellow.** **(iv) 1 wrinkled green.**

For Information

- Independent assortment of different genes does not affect the segregation of individual allele pairs.
- Thus, round vs wrinkled seeds show a 3:1 ratio, and yellow vs green seeds also show a 3:1 ratio.

➢ **Conclusion:**

- The results showed that **genes for seed shape assort independently** from **genes for seed colour.**
- On these basis, Mendel proposed that "**Each pair** of alleles assorts independently of **other pairs of alleles** during gamete formation". It is referred to as Mendel's law of **independent assortment.**

Q.4 How can you justify that independent assortment of alleles is a source of variations? L/Q

Ans. Independent Assortment of Alleles as a Source of Variations:

(i) Allele For different Traits Present on Different Chromosomes:

- Independent assortment of alleles creates genetic diversity. It mixes alleles during the **formation of gametes** (sperm and egg cells).
- During gamete formation, alleles for different traits, which are on different chromosomes, separate independently of each other.
- This means one character (like eye colour) does not affect another character (like hair texture).

Tidbit

- A modern re-statement of Mendel's law of independent assortment would be that *"genes that are located on different chromosomes assort independently during meiosis"*.

(ii) Due to Random Line up of Homologous Chromosome:

- Independent **assortment** happens because **homologous chromosome** pairs line up **randomly during meiosis.** This random alignment causes different combinations of maternal and paternal alleles in gametes.

- In humans, it can produce over 8 million (2^{23}) possible allele combinations in one gamete. This reshuffling makes every gamete genetically unique.

(iii) Fertilization Increases Chances of Variations:

- The chances of variation increases further during **fertilization.** When a sperm and egg fuse, they combine their unique alleles to form a genetically unique zygote.
- This continuous mixing of alleles in a population creates genetic diversity, which helps species adapt to changing **environments.**

Check Understanding!

Q.4 Analyze how the random alignment of homologous chromosome pairs during meiosis-I directly generates genetic diversity through independent assortment.

Topic: Limitations to the Law of Independent Assortment:

Q.5 Discuss the limitations to the law of independent assortment. L/Q

Ans. Limitations to the Law of Independent Assortment:

- The law **of independent assortment** helps to explain **how genes are inherited, but it does not cover all genetic complexities.**
- Some of such complexities which are beyond the limit of independent assortment discussed below

(i) Linked Genes:

- Genes which are present close together on the **same chromosome** are called **linked genes.**
- The linked genes often inherited together and do not assort or separate **independently.** The phenomenon of staying together of alleles on the same chromosome is known as **gene linkage.**

(ii) Chromosome Crossover:

- The exchange of **genetic material** between homologous chromosomes during meiosis is called crossing over.
- Due to crossing over the ratio of gene combinations may not be as predicted by the law of **independent assortment.**

Check Understanding!

Q.5 Which genetic phenomenon occurs when one single gene controls multiple distinct characters?

(A) Epistasis. (B) Pleiotropy
(C) Gene linkage. (D) Crossing ove

(iii) Epistasis:

- It is phenomenon where the **effect** of one gene is modified or suppressed by one or more unrelated genes, present on other locus.
- Epistasis also changes the **expected ratio of gene combinations** and do not obey law of independent assortment.

(iv) Pleiotropy:

- The phenomenon where one gene **controls multiple** characters is called pleiotropy.
- It causes the characters to be **linked** and **controlled** by a **single gene.** Pleiotropy can distort or change the expected phenotypic ratios from **independent** assortment.

(v) Environmental effect:

- Many phenotypes can be affected by the environment.

Topic: Inheritance and Mathematical Probabilities:

- The transfer of genes from one generation to the other is **random.**
- The calculation of the possible new allelic combinations is based on **mathematical probability.**

Q.6 Define the term probability & how can it be calculated in heritance? S/Q

Ans. Probability:

- The chance of a particular event to occur is called **probability.**

Calculation of Probability in Inheritance:

- Probability of **inheritance of one or two alleles** (e.g., RrYy × RrYy) can be calculated by using a **Punnett square.**
- However, **for many genes** (e.g., AaBbCcDdEe × AaBbCcDdEe), Punnett squares become too complex. So, probability rules are used **instead** of punnet square.

CamScanner

Q.7 Name the three rules used to calculate probability.

Ans. Three Rules to Calculate of Probability:
(i) Basic Rule of Probability. (ii) Product Rule of Probability. (iii) Sum Rule of Probability.

Q.8 Define and discuss the basic rule, product rule & sum rule of probability by taking the example of each rule.

Ans. (i) Basic Rule of Probability:

- The rule through which probability is calculated by **dividing** the number of times an event occurs by the total number of possible outcomes is called **basic rule.**
- **Event Occurrence:**

$$\frac{\text{No. of Outcomes}}{\text{Total No. of Possible out comes}}$$

- **Example:** If wrinkled pea seeds appear 1,850 times out of 7,324 seeds. Thus the probability is $1850 \div 7324 = 0.253$, which is about **1 in 4 seeds.**

Performing and Recoding
- Use the rules of probability and calculate the probability of getting Sixes when you roll a dice 100 times.

(ii) Product Rule of Probability:

- The product rule of probability says that the **chance of two or more** independent events happening together is calculated by **multiplying their individual probabilities.**
- **Example:** Getting a six on one dice is 1/6. For two dice, the chance of getting **two sixes** is (1/6) × (1/6) = 1/36.
- The product rule can be used to predict **fertilization outcomes.**

Example 1 (Aa × Aa):

- Each parent has a $\frac{1}{2}$ chance of giving gamete with allele ***a***.
- So, probability of aa offspring = $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

Example 2(RrYy × RrYy):

- Probability of **Round seed** = $\frac{3}{4}$, Probability of yellow seed = $\frac{3}{4}$
- So, probability of round yellow offspring = $\frac{3}{4} \times \frac{3}{4} = \frac{9}{16}$

(iii) Sum Rule of Probability:

- The rule which applies to mutually **exclusive** events (only one can happen at a time).
- The probability of either event is found by adding event's individual probabilities.
- **Example:** On a six-sided die (Plural dice), the chance of getting 1 is 1/6 and the chance of getting 6 is 1/6. So, getting either 1 or 6 will be $\frac{1}{6} + \frac{1}{6} = \frac{1}{3}$.

Example:
In a cross Aa × Aa, dominant phenotype (AA or Aa) can occur in three ways:
(a) A from male +A from female (AA)
(b) A from male + a from female (Aa)
(c) A from male + A from female (Aa)

- Each individual event has a probability of $\frac{1}{4}$.

So, total probability of dominant phenotype = $\frac{1}{4} + \frac{1}{4} + \frac{1}{4} = \frac{3}{4}$.

Check Understanding!
Q.6 Calculate the combined probability of having a recessive offspring for both phenylketonuria and albinism if both parents are heterozygous for both independently assorting traits.

Analyzing, Interpreting and Communication Solve the following genetic problems.

Genetic Problem 18.1:

- **Phenylketonuria and albinism are two recessive disorders which assort independently. If a mother and a father who both are heterozygous for both traits, produce a child.**
- **What is the chance of their having a child with (a) Phenylketonuria, (b) Albinism, and (c) Both traits?**

Solution:

(a) Chance of having a Child with Phenylketonuria: 1/4 (25%)

- Since both parents are heterozygous (Pp), a monohybrid cross (Pp × Pp) yields a 1/4 (pp) probability of inheriting the homozygous recessive (pp) genotype.

Monohybrid cross with phenylketonuria: (1/4)

Pp × Pp

	P	p
P	PP	Pp
p	Pp	pp

(b) Chance of having a Child with Albinism: 1/4 (25%)

- Similarly, for the independently assorting albinism trait (Aa × Aa), the chance of inheriting the homozygous recessive (aa) genotype is also 1/4.

Monohybrid cross with Albinism: (1/4)

Aa × Aa

	A	a
A	AA	Aa
a	Aa	aa

(c) Both traits:1/16 (6.25%)

- Because the two traits assort independently.
- Multiplying their individual probabilities using the product rule gives $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$

Genetic Problem 18.2:

- **A gene has two alleles i.e., dominant C and recessive c.**
- **What proportions of the offspring from a CC x Cc cross would be:**
  (a) Homozygous dominant (CC). (b) Homozygous recessive (cc). (c) Heterozygous (Cc)

Solution:

(a) Homozygous Dominant (CC): 2/4 (50%)

- Half of the offspring inherit a dominant **C** allele from both parents.

CC × Cc

	C	C
C	CC	CC
c	Cc	Cc

Homozygous Dominant: (2/4 or 50%)

(b) Heterozygous (Cc): 2/4 (50%)

- Half of the offspring inherit a dominant **C** from the first parent and a recessive **c** from the second parent.

CC × Cc

	C	C
C	CC	CC
c	Cc	Cc

Heterozygous: (2/4 or 50%)

(c) Homozygous Recessive (cc): 0(0%)

- Since the first parent (CC) does not carry the recessive **c** allele, inheriting two recessive alleles is impossible.

Genetic Problem 18.3:

- **A TtYy pea plant self-pollinates and one seed is picked at random for planting.**
  (a) What is the chance that the seed will produce a tall, green seeded plant?
  (b) If it turns out to be tall and yellow-seeded what is the chance that its genotype is TTYY?

Solution:

(a) Chance of a Tall Green Seed Plant (3/16 or 18.75%)

- **Height** (3/4 tall in monohybrid cross) and **seed color** (1/4 green, yy in monohybrid cross) after their monohybrid crosses.
- Multiplying the individual probabilities of two monohybrid crosses gives 3/4 × 1/4 = 3/16.

CamScanner

Monohybrid cross for height:

Tt × Tt

	T	t
T	TT	Tt
t	Tt	tt

Tall height = 3/4

Monohybrid cross for shape:

Yy × Yy

	Y	y
Y	YY	Yy
y	Yy	yy

Green colour = 1/4

Tall + Green Seed = 3/4 × 1/4 = 3/16

(b) Chance that Genotype is TTYY given a Tall and Yellow Seed (1/9 or 11.1%)

- Out of the 9/16 offspring that display the dominant tall and yellow phenotypes.
- Only 1 part has the homozygous TTYY genotype (1 TTYY : 2 TTYy : 2 TtYY : 4 TtYy), resulting in conditional probability of 1/9.

Multiple Choice Questions (MCQs)

1. **Mendel used a _____ to explain the Law of Independent Assortment.**
   (A) Monohybrid cross. (B) Testcross. (C) Backcross. (D) Dihybrid cross.
2. **In Mendel's dihybrid cross, the two characters studied were:**
   (A) Flower colour and stem height. (B) Seed shape and seed colour.
   (C) Pod shape and flower position. (D) Plant height and seed size.
3. **The genotype of the pure-breeding round yellow parent was:**
   (A) RRYY. (B) RrYy. (C) RRYy. (D) RrYY.
4. **The genotype of all F_1 dihybrid plants was:**
   (A) RRYY. (B) rryy. (C) RrYy. (D) RRYy.
5. **The F_1 plants in Mendel's dihybrid cross are called dihybrids because they are:**
   (A) Homozygous for both genes. (B) Heterozygous for both genes.
   (C) Homozygous dominant. (D) Homozygous recessive.
6. **The phenotypic ratio obtained in the F_2 generation of a dihybrid cross is:**
   (A) 3 : 1. (B) 1 : 2 : 1. (C) 1 : 1 : 1 : 1. (D) 9 : 3 : 3 : 1.
7. **A dihybrid plant with genotype RrYy produces _____ different types of gametes.**
   (A) Two. (B) Three. (C) Four. (D) Sixteen.
8. **Which of the following is not one of the gametes produced by an RrYy plant?**
   (A) rr. (B) Ry. (C) RY. (D) rY.
9. **The number of possible genotype combinations in the F_2 generation of a dihybrid cross is:**
   (A) 4. (B) 8. (C) 12. (D) 16.
10. **According to Mendel's Law of Independent Assortment, each pair of alleles:**
    (A) Always together. (B) Independent assortment.
    (C) Father only. (D) Always linked.
11. **Which F_2 phenotype appears in the greatest proportion in a dihybrid cross?**
    (A) Round green. (B) Wrinkled yellow. (C) Round yellow. (D) Wrinkled green.
12. **Independent assortment increases genetic diversity because:**
    (A) Independent segregation. (B) Identical gametes.
    (C) Dominants only. (D) No recombination.
13. **Independent assortment occurs because homologous chromosome pairs:**
    (A) Move together. (B) Random alignment. (C) Never separate. (D) Remain attached.
14. **Which statement correctly describes fertilization as a source of genetic variation?**
    (A) Identical offspring. (B) Unique zygote. (C) Prevents mixing. (D) Eliminates diversity.
15. **Probability means:**
    (A) The certainty of an event. (B) How often a particular outcome occurs.
    (C) The total number of chromosomes. (D) The number of alleles in a gene.
16. **A Punnett square is mainly used to calculate the probability of inheritance of:**
    (A) One or two genes. (B) Ten genes.
    (C) Chromosome mutations. (D) Protein synthesis.
17. **For crosses involving many genes (e.g., AaBbCcDdEe × AaBbCcDdEe), probabilities are usually calculated using:**
    (A) Microscope observations. (B) Probability rules.
    (C) DNA sequencing. (D) Pedigree charts.

18. **Probability is calculated by dividing:**
    (A) Total ÷ Success. (B) Success ÷ Total.
    (C) Dominant ÷ Recessive. (D) Genes ÷ Chromosomes.
19. **According to the worked example, the probability of obtaining wrinkled seeds was approximately:**
    (A) 1/2. (B) 1/3. (C) 1/4. (D) 3/4.
20. **The product rule is used when calculating the probability of:**
    (A) Two or more independent. (B) Mutually exclusive events.
    (C) Environmental effects. (D) Gene linkage.
21. **In the cross Aa × Aa, the probability of obtaining genotype aa is:**
    (A) 1/2. (B) 1/3. (C) 1/4. (D) 3/4.
22. **In the cross RrYy × RrYy, the probability of obtaining a round yellow offspring is:**
    (A) 3/16. (B) 9/16. (C) 1/4. (D) 3/4.
23. **The sum rule applies to:**
    (A) Mutually exclusive. (B) Independent events. (C) Linked genes. (D) Crossing over.
24. **Which probability rule should be used to calculate the chance of an offspring inheriting two independent traits simultaneously?**
    (A) Sum rule. (B) Product rule. (C) Segregation rule. (D) Assortment rule.
25. **In the cross Aa × Aa, the dominant phenotype appears as either AA or Aa. Which probability rule is used to determine the total probability of the dominant phenotype?**
    (A) Product rule. (B) Testcross rule. (C) Linkage rule. (D) Sum rule.
26. **Why do Punnett squares become impractical for crosses involving many genes?**
    (A) No dominance. (B) Many combinations. (C) Recessives only. (D) No genotypes.
27. **The probability of the dominant phenotype in the cross Aa × Aa is:**
    (A) 1/4. (B) 1/2. (C) 3/4. (D) 1.
28. **Which statement correctly distinguishes the product rule from the sum rule?**
    (A) Multiply, add. (B) Adds, multiplies. (C) Always same. (D) Punnett only.

18.	18.(B)
19.	19.(C)
20.	20.(A)
21.	21.(C)
22.	22.(B)
23.	23.(A)
24.	24.(B)
25.	25.(D)
26.	26.(B)
27.	27.(C)
28.	28.(A)

DOMINANCE RELATIONS AND MULTIPLE ALLELES

Topic: Complete Dominance:

Q.9 What is complete dominance? Give one example. S/Q

Ans. Complete Dominance:

- A relationship between **two alleles** in heterozygous condition in which one **allele completely** mask the effect of other allele is called **complete dominance.**
- **Example:** In pea plants (Yy), the dominant allele (Y) is fully expressed and the recessive allele (y) is not **expressed** at all. So no intermediate trait (green) appears in Yy. This is called **complete dominance.**
- Scientists tested Mendel's ideas and found that results were not always the same. Many traits do not show **complete dominance.** Moreover, some traits are controlled by more than two alleles.
- **Examples:** Y(yellow) masks the effect of y(green).

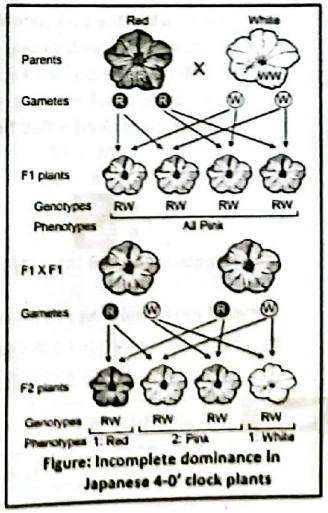


Figure: Incomplete dominance in Japanese 4-O' clock plants

Topic: Incomplete Dominance:

Q.10 Explain incomplete dominance and exemplify it through the inheritance of flower colour in 4 O' clock plant. Exercise L/Q 2

Ans. Incomplete Dominance:

- A dominance relationship between two alleles in heterozygous condition is which **none of two alleles** is fully dominant over the other is called **incomplete dominance.**

CamScanner

- Incomplete dominance in the heterozygous individual shows a phenotype that is **intermediate between** phenotypes of both parents.
- **Example:** In **Japanese four-o'clock** plants, when a **red flowered (RR)** is crossed with **white flowered (WW)**, it produces all heterozygous pink flowered (RW) offspring.
- This shows neither the alleles for red (R) nor of white (W) is completely dominant. When two pink flowered plants (RW × RW) are crossed, the result is red (RR), pink (RW), and white (WW) in a **1:2:1 ratio.**

Check Understanding!

Q.7 What phenotypic outcome occurs in the heterozygous offspring of Japanese four-o'clock plants during incomplete dominance?
(A) Codominant spotting.
(B) Fully dominant red.
(C) Pure white recessive.
(D) Intermediate phenotype.

...the following genetic problem:

Genetic Problem 18.4:

A pink flower four O'clock plant is crossed with a red flower plant. Find:

(a) **Probability of Red flower plant (RR).**
(b) **Probability of pink flower plant (RW).**
(c) **Ratio of pink flower to red flower plant.**

Solution:

Genetic Background

- 4 o'clock plants exhibit **incomplete dominance**, a genetic phenomenon where neither allele is completely dominant over the other. Instead of masking the recessive trait, the **heterozygous genotype (RW)** results in an intermediate, blended phenotype **(pink flower)**, while the homozygous RR genotype produces **red flowers** and **WW** genotype produces **white flowers.**
- Using the specified notation for incomplete dominance in four o'clock plants:
  - **RR** = Red flowers. • **WW** = White flowers. • **RW** = Pink flowers.
- The cross is between a red plant (RR) and a pink plant (RW).

(a) **Probability of Red flower plant (RR).**

- The red parent (RR) always contributes an R allele, while the pink parent (RW) has a 50% chance of contributing an R allele. Combining these gives a 2/4 probability for the homozygous RR red genotype.

Pink flower plant (RW) × Red flower plant (RR)

RW × RR

	R	W
R	RR	RW
R	RR	RW

Probability of Red (RR): (2/4 or 50%)

(b) **Probability of pink flower plant (RW).**

- The pink parent (RW) has a 50% chance of contributing the W allele. When paired with the mandatory R from the red parent, it creates a 2/4 probability for the heterozygous RW pink genotype.

Pink flower plant (RW) × Red flower plant (RR)

RW × RR

	R	W
R	RR	RW
R	RR	RW

Probability of Pink (RW): (2/4 or 50%)

(c) **Ratio of pink flower to red flower plant.**

- Because the offspring are split evenly between pink (50%) and red (50%), the simplified phenotypic ratio of pink to red plants is 1 : 1.

Topic: Co-dominance:

Q.11 **Define the term co-dominance & explain it with the help of MN-blood groups.** S/Q

Ans. **Co-dominance:**

- A type of inheritance relationship between two genes in heterozygous condition in which **both alleles** in a gene pair are fully express their effects is called **co-dominance.**

- In co-dominance, **both alleles** work without blending or one masking the other. So, the products or effects of **both alleles** appear together in the phenotype of heterozygous.

MN-Blood Group As Example of Co-dominance:

- The human **MN blood group** shows codominance, where both alleles are equally expressed. There are two alleles for this system.
- Allele L^M → Produces **M antigen.**
- Allele L^N → Produces **N antigen.**
- Both L^M and L^N are codominant. So, if both **are present**, both antigens appear on **red blood cells.**
- In this way, there are three possibilities i.e.,
  - **(i) M blood group (L^ML^M)** - individuals with only **M** antigens.
  - **(ii) N blood group (L^NL^N)** - individuals with only **N** antigens.
  - **(iii) MN blood group (L^ML^N)** - individuals with both **M and N antigens.**

For Information

- The "L" stands for **Landsteiner** and Levine, the scientists who discovered this system in 1927.
- It is also called the MNS system because the genes of MN group and the S/s group are physically "linked" on the same chromosome.

Check Understanding!

Q.8 Distinguish between incomplete dominance and codominance based on how alleles express themselves in the heterozygous state.

MN Blood Group System

Genotype	Antigen	Blood Group Phenotype
(i) L^ML^M	M	• M blood group
(ii) (L^NL^N)	N	• N blood group
(iii) (L^ML^N)	M & N	• MN blood group

Q.12 **How incomplete dominance is different from co-dominance?** S/Q

Ans. **Comparison between Incomplete Dominance and Codominance:**

Incomplete dominance	Co-dominance
• In this relationship, in heterozygous state, **both genes** blend their **phenotypic** effects.	• In heterozygous, both genes **fully express** their **effects.**
• The heterozygous show an **intermediate phenotype** between the two parental phenotypes.	• The heterozygous show both parental **phenotypes** at a time.
• **Example:** Flower colour in Japanese 4 O' clock plant.	• **Example:** Human **MN blood** group and human AB blood group.

Topic: Multiple Alleles:

Q.13 **What are multiple alleles? Give brief description with ABO blood group.** S/Q

Ans. **Multiple Allelic System:**

- A gene which has more than **two alternative** forms (alleles) in a population are called **multiple alleles** & this system is called **multiple allelic system.** This creates more variation in traits.

ABO-Blood Group System As Multiple Allelic System:

- Human **ABO blood group system** is controlled by **one gene (I gene)** with three alternative forms alleles: I^A, I^B, and **i.**
- Each person has only two of these alleles.
- Different combinations produce four following **blood groups:**

Phenotypes (Blood groups)	Genotypes
(i) A	I^AI^A or I^Ai
(ii) B	I^BI^B or I^Bi
(iii) AB	I^AI^B
(iv) O	ii

Check Understanding!

Q.9 **Which gene locus and chromosome control the multiple alleles of the human ABO blood group system?**
(A) Gene I on chromosome 9.
(B) Gene D on chromosome 7.
(C) Gene Se on chromosome 19.
(D) Gene W on chromosome 12.

For Information

- In human ABO blood group system, the alleles I^A and I^B also show co-dominance.

CamScanner

Multiple Choice Questions (MCQs)

1. In pea plants, the genotype Yy shows:
(A) Green seeds. (B) Yellow seeds.
(C) Yellow and green seeds together. (D) Intermediate seed colour.
2. The expression of only the dominant allele in a heterozygote is called:
(A) Incomplete dominance. (B) Co-dominance.
(C) Complete dominance. (D) Multiple allelism.
3. In incomplete dominance, the heterozygous individual shows:
(A) An intermediate phenotype. (B) Only the recessive phenotype.
(C) Only the dominant phenotype. (D) Both parental phenotypes separately.
4. In Japanese four-o'clock plants, crossing red-flowered (RR) with white-flowered (WW) plants produces:
(A) All red flowers. (B) All white flowers.
(C) Red and white flowers in equal numbers. (D) All pink flowers.
5. The genotype of pink flowers in Japanese four-o'clock plants is:
(A) RR. (B) WW. (C) RW. (D) RWw.
6. When two pink flowers (RW × RW) are crossed, the phenotypic ratio is:
(A) 3 : 1. (B) 1 : 2 : 1. (C) 9 : 3 : 3 : 1. (D) 1 : 1.
7. In co-dominance, the heterozygous individual expresses:
(A) Only the recessive allele. (B) Only the dominant allele.
(C) Both alleles fully. (D) Neither allele.
8. The MN blood group is an example of:
(A) Complete dominance. (B) Incomplete dominance. (C) Polygenic inheritance. (D) Co-dominance.
9. Allele L^M produces:
(A) M antigen. (B) N antigen. (C) O antigen. (D) AB antigen.
10. Which feature distinguishes incomplete dominance from complete dominance?
(A) Both expressed. (B) Intermediate phenotype. (C) Complete masking. (D) Homozygous only.
11. Which statement correctly explains co-dominance in the MN blood group?
(A) Antigen blending. (B) M only. (C) Both antigens. (D) Neither antigen.
12. A person has genotype L^ML^N. The blood group will be:
(A) M. (B) MN. (C) N. (D) O.
13. Which of the following is an example of incomplete dominance?
(A) Pink flowers. (B) Yellow seeds. (C) MN blood. (D) Round seeds.
14. Which statement correctly distinguishes incomplete dominance from co-dominance?
(A) Expressed, blended. (B) Intermediate, expressed. (C) Identical phenotypes. (D) Not plants.
15. A multiple allelic system occurs when a gene has:
(A) One allele. (B) Two alleles.
(C) More than two alleles in a population. (D) Two chromosomes.

Key: 1.(B) 2.(C) 3.(A) 4.(D) 5.(C) 6.(B) 7.(A) 8.(D) 9.(A) 10.(B) 11.(C) 12.(B) 13.(A) 14.(B) 15.(C)

BLOOD GROUP SYSTEMS

Q.14 What are blood group system & how many blood group systems are recognized in human? S/Q

Ans. Blood Group Systems:

- A blood group system is a **way of classifying** blood based on the presence of specific antigens on red **blood cells (RBCs).**
- The **International Society of Blood Transfusion** recognizes **43** blood group systems in humans. Each system has different blood groups.

Q.15 Name the first & second most important blood groups of human. S/Q

Ans. (i) First Most Important Blood Group System of Human:

- The most important is the **ABO system** (blood groups A, B, AB, O).

(ii) Second Most Important Blood Group System of Human:

- The second is the **Rh system** (blood groups **Rh-positive** and **Rh-negative**).
- For blood transfusion, the matching of **ABO and Rh-system** is necessary between donor and recipient's blood.

For Information

- In blood group systems, the antigens present on the surface of RBCs may be proteins, carbohydrates, glycoproteins, or glycolipids.

Q.16 Name the 5-blood group system with their antigens found in human other than ABO & Rh-blood systems. S/Q

Ans. 5-Blood Group System With Their Antigens Found In Human:

- The following are the other major blood group system, but these usually do not cause matching problems in the blood transfusions.

Blood Group System	Well-known antigens
(i) MNS.	• M, N, S, s, U.
(ii) Lutheran.	• Lu^a and Lu^b.
(iii) Kell.	• K, k, Kp^a, Kp^b, Js^a, Js^b.
(iv) Lewis system.	• Le^a and le^b.
(v) Duffy.	• Fy^a, Fy^b, Fy^3.

Topic: ABO Blood Group System:

Q.17 Discuss the role of Landsteiner & his students in the study of ABO-blood group system. S/Q

Ans. Work of Landsteiner to Study of ABO-blood Group System:

- The ABO system was discovered by **Landsteiner in 1901.**
- He **found two** antigens on **red blood cells** (RBCs): **antigen-A and antigen-B.**
- He observed some individuals have **antigen-A** on their RBCs while others have **antigen-B.**
- He also observed that many individuals do not have any of these antigens.
- **Landsteiner's students** discovered that some individuals have both **A and B antigens** on their RBCs. So, they named the different blood groups as:
  - **(i)** People with **antigen-A.** • Blood Group A.
  - **(ii)** People with **antigen-B.** • Blood Group B.
  - **(iii)** People with **both (antigen- A & antigen-B** • Blood Group AB.
  - **(iv)** People with neither of antigen-A & antigen-B • Blood Group O.

Check Understanding!

Q.10 Explain Landsteiner's rule of antigen-antibody relationship regarding blood plasma composition in individuals with blood group A.

Q.18 What is Landsteiner's rule of antigen-antibody relationship? S/Q

Ans. Landsteiner's Rule of Antigen-antibody Relationship:

- Each person's blood plasma **contains antibodies** against the antigen s/he does not have:
  - (i) Blood group A → anti-B antibodies.
  - (ii) Blood group B → anti-A antibodies.
- This is called **Landsteiner's rule of antigen-antibody relationship.**

For Information

- Some people secrete **antigens A and B** in body fluids.
- **Example:** Saliva, tears, urine. They possess a dominant secretor gene **"Se"** on their chromosome 19.

Topic: Inheritance of ABO Blood Group System:

Q.19 Discuss the inheritance and principle of transfusion of ABO Blood Groups. L/Q

Ans. Inheritance and Principle of Transfusion of ABO Blood Groups:

- **Control of ABO-Blood Group:** The ABO system is controlled by the **gene I** ("I" stands for iso-haemagglutinogen).
- **Location of I-Gene:** I-Gene is located on **chromosome 9** and has multiple alleles i.e., I^A, I^B **and i.**
- The alleles I^A and I^B are **co-dominant** over each other.
- While **allele i** is recessive to both of them.

CamScanner

- The I^A allele produces antigen- A , the I^B allele produces antigen-B. Allele i does not produce any antigen. Therefore;

(I) Blood Group-A (I^AI^A or I^Ai):
- Genotypes I^AI^A and I^Ai produce antigen-A. This phenotype is called **blood group A**. Individual's plasma contains **anti-B** antibodies.

(II) Blood Group-B (I^BI^B or I^Bi):
- Genotypes I^BI^B and I^Bi produce **antigen-B**. This phenotype is called **blood group-B**. Individual's plasma contains **anti-A antibodies.**

(iii) Blood Group AB (I^AI^B):
- Genotype I^AI^B produces both **antigen-A** and antigen-B. This phenotype is called **blood group AB.**
- Individual's plasma of blood group AB does not contain anti-A or anti-B antibodies.

(iv) Blood Group O (ii):
- Genotype **ii produces neither antigen-A nor antigen-B.** This phenotype is called **blood group O.**
- Individual's plasma of blood group O contains both anti-A and anti-B antibodies.

For Information
- In **ABO system**, the production of anti-A and anti-B antibodies does not require any exposure to antigens.
- Rather, these antibodies start forming from embryonic life and continue throughout life.

For Information
- In **pea plants**, each character that Mendel studied was controlled by a gene with two alleles.
- One allele was completely dominant over the other.
- But Incomplete dominance and co-dominance do not obey this rule of dominance.
- Similarly, in multiple allelic system, a gene has more than two alleles, any two of which work for producing a phenotype.

Solve the following genetic problem:

Genetic Problem 18.5:
- **A person has blood group A while his wife has B.**
- **They have four children each with different blood group. Explain that how is it possible?**

Solution:
- **Genetic Basis**
  - For parents with blood groups A and B to produce children with all four blood groups (A, B, AB, and O), both parents must be heterozygous carriers of the recessive I allele:
    - **Father (Blood Group A):** Genotype I^Ai
    - **Mother (Blood Group B):** Genotype I^Bi
- **Explanation:**
  - **Equal Probability per Birth:** The cross ($I^Ai \times I^Bi$) yields a 25% (1/4) chance for each of the four blood groups in every independent pregnancy:
  - **Independent Events:** Because each child's genetic inheritance is an independent event, statistical probability allows for every child to randomly inherit a different combination.
  - Therefore, having four children with four distinct blood groups is a completely valid and possible outcome.

$I^Ai \times I^Bi$

	I^B	i
I^A	I^AI^B (Blood Group AB)	I^Ai (Blood Group A)
i	I^Bi (Blood Group B)	ii (Blood Group O)

Genetic Problem 18.6:
- **A woman with blood group B has a child with blood group O.**
- **What are the genotypes of the mother and child? Which genotypes could the father not have?**

Solution:
- **Genotypes:**
  - **Child's Genotype:** ii (Blood Group O)
  - **Mother's Genotype:** I^Bi (Heterozygous Blood Group B)
- **Genotypes the Father Cannot Have:**
  - I^AI^A (Homozygous A)
  - I^BI^B (Homozygous B)
  - I^AI^B (AB)
- **Explanation:**
  - **Child's Genotype:** A child with blood group O must be homozygous **recessive (ii),** meaning they inherited one i allele from the mother and one i allele from the father.
  - **Mother's Genotype:** Because the mother has blood group B and successfully passed a recessive i allele to her child, she must be heterozygous (I^Bi).
  - **Father's Impossible Genotypes:** Since the child received an i allele from the father, the father must possess at least one i allele. Therefore, genotypes that lack an i allele (I^AI^A, I^BI^B, or I^AI^B) are impossible because they cannot donate the required I allele to produce an O-group child.

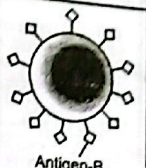
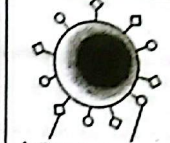
Genotypes	I^AI^A or I^Ai	I^BI^B or I^Bi	I^AI^B	ii
Antigens (on RBCs)	 Antigen-A	 Antigen-B	 Antigen-B Antigen-A	 No Antigens
Antibodies (in Plasma)	 Anti-B	 Anti-A	No Anti-A antibody No Anti-B antibody	 Anti-A Anti-B
Phenotypes (Blood Groups)	A	B	AB	O

Figure: ABO system genotypes and phenotypes

Principle of Transfusion in ABO System:

- During blood transfusions between two incompatible **(unmatching)** blood groups, the recipient's **antibodies attack the** antigens on donor's RBCs.
- It causes clumping (agglutination) of RBCs. It happens; if blood **group A** individual receives blood **group B** and vice versa.
- If **donor's blood** group is **AB** and the recipient is **A, B or O.**

Check Understanding!

Q.11 Why is blood group O considered the universal donor for the ABO system?
(A) Contains anti-A antibodies.
(B) Lacks A and B antigens.
(C) Possesses both A and B antigens.
(D) Lacks all plasma proteins.

Blood Group	Antigen	Antibody	Genotype	Donated to	Received from
• A	• A	• B	• I^AI^B, I^Ai	• A, AB	• A, O
• B	• B	• A	• I^BI^B, I^Bi	• B, AB	• B, O
• AB	• AB	• NIL	• I^AI^B	• AB	• AB, A, B, O
• O	• NIL	• A & B	• ii	• A, B, AB, O	• O

Exceptions:

- O blood group (donor) has **no antigen-A** and antigen-B. So, it can be given to A, B, AB, or O . That is why, people with O blood group are called **universal donors of ABO system.**
- AB blood group (recipient): has no anti-A or anti-B antibodies. So, it can receive all blood types. That is why, people with AB blood group are called **universal recipients of ABO system.**

Q.20 Differentiate between universal donors & universal recipients of ABO blood group system. S.Q

Ans.

Universal Donor	Universal Recipient
• A blood group which can be **donated** to all other blood groups (A, B, AB, O) is called **universal donor.**	• A blood group which can be **received** to all other blood groups (A, B, AB, O) is called **universal recipient.**
• **Example:** O Blood Group	• **Example:** AB-Blood Group.

Justify why a recessive blood group allele 'i' is more frequent in the population.

Reason that "I" is More Common in Populations:
- In a cross between blood group O (ii) and O (ii), all offspring will have blood group O (ii).
- In a cross between heterozygous I^Ai and I^Ai, 25% offspring will have blood group O (ii)
- In a cross between heterozygous I^Bi and I^Bi, 25% offspring will have blood group O (ii).
- In a cross between heterozygous I^A_i and I^Bi, 25% offspring will have blood group O (ii).

That's why blood group allele 'i' is more frequent in the population.

CamScanner

Multiple Choice Questions (MCQs)

		Key
1.	The ABO blood group system is controlled by: (A) Two genes. (B) One gene with three alleles. (C) Four genes. (D) Two genes with two alleles each.	1.(B)
2.	The three alleles of the ABO blood group gene are: (A) I^A, I^B and i. (B) A, B and O. (C) L^M, L^N and i. (D) R, r and i.	2.(A)
3.	Which genotype produces blood group AB? (A) I^AI^A. (B) I^BI^B. (C) ii. (D) I^AI^B.	3.(D)
4.	The ABO blood group system was discovered by: (A) Mendel. (B) Watson. (C) Landsteiner. (D) Morgan.	4.(C)
5.	The ABO gene is located on chromosome: (A) 1. (B) 9. (C) 7. (D) 19.	5.(B)
6.	Blood group A contains which antibodies in its plasma? (A) Anti-B. (B) Anti-A. (C) Both anti-A and anti-B. (D) No antibodies.	6.(A)
7.	Which blood group has neither antigen-A nor antigen-B on red blood cells? (A) A. (B) B. (C) AB. (D) O.	7.(D)
8.	Which blood group is called the universal donor in the ABO system? (A) A. (B) O. (C) B. (D) AB.	8.(B)
9.	Which blood group is called the universal recipient in the ABO system? (A) A. (B) B. (C) AB. (D) O.	9.(C)
10.	A person has blood group AB. Which antibodies are present in the plasma? (A) Anti-A only. (B) Anti-B only. (C) Both antibodies. (D) No antibodies.	10.(D)
11.	According to Landsteiner's rule, blood group B individuals possess: (A) A antigen. (B) B antigen. (C) A antigen, anti-B. (D) No antigens.	11.(B)
12.	Agglutination during blood transfusion occurs because: (A) Recipient antibodies. (B) Donor antibodies. (C) Platelet attack. (D) Plasma proteins.	12.(A)
13.	A woman with blood group B has a child with blood group O. The genotype of the mother must be: (A) I^BI^B. (B) I^Bi. (C) I^AI^B. (D) ii.	13.(B)
14.	Which statement best explains why the recessive allele i is common in the population? (A) Dominant allele. (B) Forms AB. (C) Heterozygous crosses. (D) Prevents antibodies.	14.(C)

Topic: Rh Blood Group System:

Q.21 Who discovered Rh-blood group system & why is it named as Rh? S/Q

Ans. Rh-blood Group System:

- It is the second most important blood group system in humans.

Name As Rh-Blood Group + Discovered By:

- The name of this system (Rh) is derived from Rhesus monkey, in which its antigen was first discovered by Landsteiner in 1930s.
- This system is based on the presence or absence of Rh-antigen (also called Rh factor or antigen-D) on RBCs.

Check Understanding!

Q.12 Assess the physiological mechanism that causes erythroblastosis foetalis when an Rh-negative mother carries an Rh-positive foetus.

.22 How is Rh +ve different from Rh –ve? S/Q

ns.

Rh +ve:	Rh –ve:
• The individuals having Rh-antigen are called Rh-positive.	• In which Rh-antigen is absent are called Rh-negative.

23 How are ABO and Rh (+ve, -ve) blood types determined in human? S/Q

is. Determination of Rh+ve & Rh–ve Blood Groups:

- Usually, the blood group of an individual mentions both ABO and Rh systems together.
- For instance, the individual who has antigen-A and Rh-antigen will have blood group A-positive.
- The individual who has antigen-A but lack Rh-antigen will have blood group A-negative.

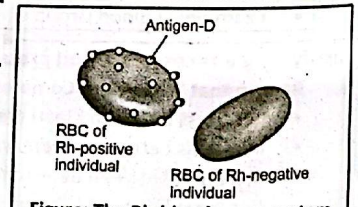


Figure: The Rh-blood group system

- Similar is the case with individuals of blood groups B, AB and O.

Genotype	Phenotype
• I^AI^A DD OR I^Ai Dd	• A-Positive
• I^AI^A dd OR I^Ai dd	• A-Negative

Q.24 Discuss the genetic basis & principle of transfusion in Rh-blood system. L/Q

Ans. Inheritance & Principle of Rh Blood Groups Transfusion:

- Rh blood group system is controlled a gene "D". It has two alleles (D and d).
- The dominant allele D forms the Rh-antigen, while the recessive allele d inhibits the formation of Rh-antigen.
- Therefore, individuals with genotypes DD or Dd have Rh-antigen and are Rh-positive. While the individuals with genotype dd do not have Rh-antigen and are Rh-negative.

Inheritance of Rh-Blood		Principle of Transfusion	
Genotype	Phenotype	Transfused to only	Transfused from
• DD or Dd	• Rh +ve Blood	Only Rh +ve	Rh +ve, Rh –ve
• dd	• Rh –ve Blood	Rh +ve, Rh –ve	Rh –ve

➢ Principle of Transfusion in Rh System:

- In ABO blood groups, the anti-A or anti-B antibodies are already present in plasma.
- But in Rh system, Rh-negative people do not naturally have anti-Rh antibodies. But, if Rh-negative person receives Rh-positive blood, his body start producing anti-Rh antibodies, which destroy the donated RBCs. These antibodies stay in the body for life.

➢ Actual Universal Donor (O^{-ve}):

- The blood group O-negative is the actual universal donor because neither has any antigen of ABO system nor has antigen of Rh system.

➢ Actual Universal Recipient (AB^{+ve}):

- The blood group AB-positive is the actual universal recipient because it has neither anti-A and anti-B nor anti-Rh antibodies. Therefore, it receives any donor's blood.

Topic: Erythroblastosis Foetalis:

Q.25 What are erythroblastosis foetalis? Discuss its reasons, complications, and treatments. Exercise L/Q.3

Ans. Erythroblastosis Foetalis:

- Erythroblastosis foetalis is a haemolytic disease of the foetus/new-born caused by Rh incompatibility between Rh-negative pregnant mother and Rh-positive foetus.

➢ Causes of Erythroblastosis Foetalis:

- It occurs when Rh-negative mother (dd) carries Rh-positive baby (DD or Dd).
- Foetal blood may enter the mother's blood. On exposure to Rh-antigens of feotus, mother will produce anti-Rh antibodies.
- These antibodies can cross the placenta and enter foetus blood.
- Here, mother's and anti-Rh antibodies will destroy foetal RBCs, leading to haemolytic anaemia and other serious complications in foetus.

CamScanner

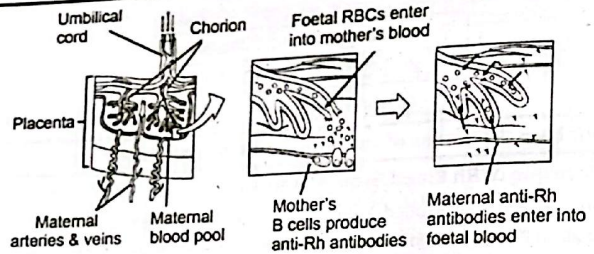


Figure: Erythroblastosis foetalis

➢ **Complications of Erythroblastosis:**

- In severe cases, destruction of foetal RBCs can cause **miscarriage or stillbirth.**

(i) Effect on Liver & Spleen: If the foetus survives, **the liver and spleen become** enlarged because they try to make more RBCs.

(ii) May Cause Jaundice: The breakdown of **RBCs** produces **bilirubin**, which builds up and causes jaundice (yellow skin and eyes) in foetus. High bilirubin can also damage brain cells.

Treatment of Erythroblastosis Foetalis Possibility:

- The **surviving baby's** blood is replaced by **Rh-negative blood** free of anti-Rh antibodies.

Tidbit

Q. In some cases, how ABO blood incompatibility protects the baby against Rh-incompatibility?

Ans. Role of ABO-Blood Group in Protection of Rh-incompatibility:

- Sometimes **ABO incompatibility** protects the baby against Rh incompatibility.
- If **O- negative mother** conceives **A-positive** or **B-positive** baby, any foetal RBCs entering the mother's blood are quickly destroyed by her already present anti-A or anti-B antibodies before she can form **anti-Rh antibodies.**

Tidbit

Q. How can the chances of erythroblastosis foetalis be inhibited?

Ans. When there are **chances of Rh-incompatibility**, the mother is given an injection of **Rh-antiserum** (serum containing anti-Rh antibodies) during **early pregnancy** and immediately after birth.

- This causes the **destruction** of any of the **baby's RBCs** that may have crossed into mother's blood before **sensitizing** the mother's immune **system.**

Solve the following genetic problem.

Genetic Problem 18.7:

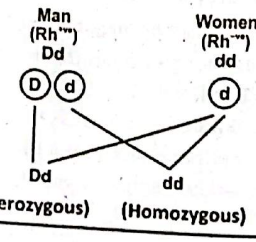
- **An Rh-negative woman is married to an Rh-positive man, whose father was also Rh-negative. What are the possible genotypes of each person in the family?**
- **What are the chances that their child will be affected with erythroblastosis foetalis?**

Solution:

Results:

- **50% offspring** will be Rh^+.
- **50%** will be Rh^-.

The probable risk of erythroblastosis foetalis among offspring is **½ or 50%.**



Multiple Choice Questions (MCQs)

		Key
1.	The Rh blood group system is the _____ most important blood group system in humans. (A) First. (B) Second. (C) Third. (D) Fourth.	1.(B)
2.	The name "Rh" is derived from the: (A) Rhesus monkey. (B) Rabbit. (C) Rat. (D) Chimpanzee.	2.(A)
3.	The Rh blood group system is based on the presence or absence of: (A) Antigen-A. (B) Antigen-B. (C) Rh antigen (antigen-D). (D) M antigen.	3.(C)
4.	Individuals having Rh antigen on their RBCs are called: (A) Rh-negative. (B) Rh-positive. (C) Universal donors. (D) Universal recipients.	4.(B)
5.	Which genotype results in an Rh-negative individual? (A) DD. (B) Dd. (C) dd. (D) DDD.	5.(C)
6.	The dominant allele responsible for Rh antigen production is: (A) d. (B) D. (C) I^A. (D) I^B.	6.(B)
7.	Rh-negative individuals naturally possess anti-Rh antibodies: (A) Always. (B) Only at birth. (C) Throughout childhood. (D) Never.	7.(D)
8.	The actual universal donor is: (A) AB-positive. (B) O-positive. (C) O-negative. (D) A-negative.	8.(C)
9.	The actual universal recipient is: (A) O-negative. (B) AB-positive. (C) A-positive. (D) B-positive.	9.(B)
10.	Erythroblastosis foetalis is caused by: (A) Rh incompatibility. (B) ABO incompatibility. (C) MN blood group incompatibility. (D) Kell blood group incompatibility.	10.(A)
11.	Erythroblastosis foetalis may develop when: (A) Rh^+ mother. (B) Rh^- mother. (C) Both Rh^-. (D) Both Rh^+.	11.(B)
12.	Why are anti-Rh antibodies dangerous to the foetus? (A) RBC stimulation. (B) Prevents bilirubin. (C) More oxygen. (D) Placental crossing.	12.(D)
13.	Which condition may develop in the foetus due to the breakdown of red blood cells? (A) Diabetes. (B) Hypertension. (C) Jaundice. (D) Osteoporosis.	13.(C)
14.	A Rh-negative person receives Rh-positive blood for the first time. What happens? (A) Immediate destruction. (B) Antibodies formed. (C) Antigen disappears. (D) No response.	14.(B)
15.	Which statement correctly explains why O-negative blood is called the actual universal donor? (A) No antigens. (B) All antigens. (C) Anti-Rh present. (D) A and B.	15.(A)

POLYGENIC INHERITANCE AND EPISTASIS

- Polygenic **inheritance** and **epistasis** are further examples of deviation from **Mendel's inheritance.**

Topic: Polygenic Inheritance:

Q.26 What are polygenic traits & how genes contribute to produce single trait? S/Q

Ans. Polygenes + Polygenic Traits:

- The **traits or characters** which are controlled by **many gene pairs,** not just one are called **polygenic traits** & these genes are called polygenes.
- In **polygenic inheritance,** all **alleles** of many **genes contribute** to the same trait in an **additive way** (some increase, some decrease the effect). The combined effect produces a **single trait.**
- Polygenic traits show a **range of differences** i.e., **continuous variation** in a population.
- **Examples of Polygenic Traits:** Height, skin colour, weight, intelligence in humans, and grain colour in plants.

Check Understanding!

Q.13 What type of variation is produced in a population by polygenic inheritance traits like human skin colour and height?

(A) Complete dominance.
(B) Discontinuous variation.
(C) Continuous variation.
(D) Sex-limited isolation.

Q.27 What are continuous variations? S/Q

Ans. Continuous Variations:

- The variations which have many alternative forms, have less differences and controlled by many genes called **continuous variations.**
- **Examples:** Human height, skin colour.

CamScanner

Q.28 Discuss the human skin colour as an example of polygenic inheritance.

Ans. Human Skin Colour as Polygenic Inheritance:

- In human, skin colour depends on the amount of melanin pigment.
- More melanin means darker skin; less melanin means lighter skin. This trait is controlled by polygenes (more than 100 genes), that's why its inheritance is said as polygenic inheritance.
- For understanding, we take 3 genes: A, B, C.
- Each of these genes has a dominant and a recessive allele.
  - Alleles A, B, and C produce more melanin.
  - Alleles a, b, and c produce less melanin.

Check Understanding!

Q.14 Evaluate how the additive contribution of alleles determines the phenotypic spectrum in wheat grain colour controlled by three polygenes.

➢ **When Parent's Genotype is AABBCC & aabbcc:**

- If the parents have genotypes AABBCC (very dark) and aabbcc (very light).
- All of their children will be AaBbCc (intermediate colour).
- If both parents are triple heterozygotes i.e., AaBbCc, their children will have wide range of skin colour from very dark to very light.
- The ratio of different skin colours will be 1 : 6 : 15 : 20 : 15 : 6 : 1 (from very dark to very light).
  - AABBCC → Darkest (Maximum melanin).
  - aabbcc → Lightest (Minimum melanin).

Q.29 Describe polygenic inheritance, using an example from grain colour in wheat. Exercise Q.

Ans. Wheat Grain Colour As Polygenic Inheritance:

- Wheat grain colour shows continuous variation, ranging from white to dark red.
- Wheat grain colour is controlled by three polygenes: A, B, and C.
- Each gene has a dominant allele (A, B, C) that produces red pigment and a recessive allele (a, b, c) that does not produce red pigment.

For Information

- Environmental factors like light, water and nutrients also influence the grain colour.

Genotype For Maximum Red Pigment:

- The genotype AABBCC produces the maximum red pigment, so the grains are dark red.

Genotype For White Colour:

- In contrast, aabbcc produces no pigment, so the grains are white. See the following cross.
- When dark red wheat (AABBCC) is crossed with white wheat (aabbcc), the F1 generation (AaBbCc) shows an intermediate red colour.
- In the F2 generation, during crossbreeding, a wide range of colours appears. Only one plant has darkest red grains (AABBCC), and one has white grains.
- While 62 plants will show different shades of red (moderate red to very light red).

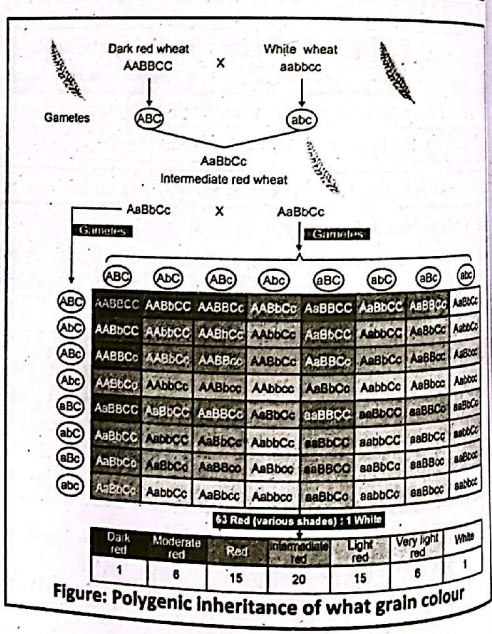


Figure: Polygenic Inheritance of what grain colour

Topic: Epistasis:

Q.30 Explain epistasis with the help of an example. Exercise Q.5

Ans. Epistasis:

- A gene interaction, in which an allele masks or modifies the effect of the alleles of other genes (present at other loci) is called epistasis.

➢ **Types of Epistasis:**

- Most traits appear due to interactions between different genes.
- These interactions are of two main types.

(i) Allelic Interactions:

- In allelic interactions, alleles of the same gene interact with each other.
- **Examples of Allelic Epistasis:** Incomplete dominance, codominance, and multiple alleles.

Check Understanding!

Q.15 What occurs during epistasis when an epistatic allele interacts with a hypostatic gene?

(A) Prevents meiosis division.
(B) Blends intermediate colors.
(C) Amplifies dominant ratios.
(D) Masks or modifies effect.

(ii) Non-Allelic Interactions:

- In non-allelic interactions, alleles of different genes (at different loci) interact with each other.
- **Example of Non-Allelic Epistasis:** Coat colour in Labrador, Bombay phenotype.

(a) Epistatic Allele: In this interaction, the allele which masks or modifies the effect is called epistatic.

(b) Hypostatic: The allele whose effect is masked or modified is called hypostatic.

- **Example:** In humans, the allele of baldness is epistatic to the alleles of black and blonde hair.

For Information

- Both polygenic inheritance and epistasis involve more than one gene, but they work differently.
- In polygenic inheritance, many genes act together, each having a small effect, to produce a trait. This results in continuous variation.
- In epistasis, one allele masks or modifies the effect of another gene. This usually produces discontinuous variation (distinct categories of traits).

Topic: Coat Colour in Labrador:

➢ **Example of Epistasis: Coat Colour in Labrador:**

- In many animals, coat colour is controlled by epistasis, where one gene affects another.
- **Example:** In Labrador dogs, coat colour (black, brown, yellow) depends on two genes.

(i) Role of Dominant "B" and Recessive "b" Genes:

- The B gene controls pigment colour. Its dominant allele B gives black colour. The recessive b gives brown.
- So, BB or Bb will be black, and bb will be brown.

(ii) Role of Dominant "E" & Recessive "e" Genes:

- The E gene controls the deposition of pigment in fur. The dominant E allows pigment,
- The recessive e is epistatic to B or b.
- Recessive "e" blocks pigment deposition in fur. So, EE or Ee will pigment in fur, but ee will have yellow coat, no matter if *B* or *b* is present.
- When two heterozygous black dogs (BbEe × BbEe) are crossed, the offspring show black, brown, and yellow colours in a 9:3:4 ratio.

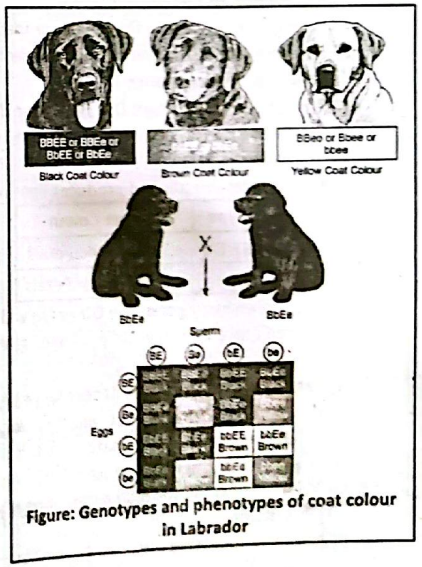


Figure: Genotypes and phenotypes of coat colour in Labrador

CamScanner

Topic: Bombay Phenotype:

Q.31 What is Bombay Phenotype? Discuss Bombay Phenotype as an example of epistasis & why this name is given? L/Q

Ans. Bombay Phenotype:

- **Definition:** A rare blood group caused by **recessive epistasis**, in which the **H-antigen** is absent on red blood cells due to the **hh genotype**.
- Since the **H-antigen** is required for the formation of **A & B antigens**, the person appears to have blood group but can **recessive** blood only from other Bombay phenotype person.

➢ **Bombay Phenotype As Example of Epistasis:**

- The expression of **ABO genotypes** also depends upon another **gene** i.e., H gene.
- **H gene** makes a **particular H substance**, which is a precursor to the A or B antigens.
- The alleles I^A and I^B produce enzymes which modify the **H substance** into **antigen-A** and **antigen-B** respectively.
- If an individual has I^A and I^B **alleles** but his genotype is hh, he will **not produce H substance**. So, his I^A and I^B alleles will **not produce A and B antigens.**
- In this way, he will have **O phenotype** (O-blood group) due to the lack of ***A*** and ***B*** antigens. This phenotype is called **Bombay phenotype** because it was discovered in **Bombay in 1952**. It is mostly found in the **India, Bangladesh, Pakistan,** and **Iran.**

Check Understanding!

Q.16 Analyze why an individual with the genotype I^AI^Bhh exhibits the Bombay phenotype (blood group **O**) despite carrying alleles for both A and B antigens.

Topic: Flower Colour in Foxglove Plants:

Q.32 Discuss the genetics of flower colour & foxglove plants. L/Q

Ans. Flower Colour in Foxglove Plants:

- In foxglove plants, the **flower colour** (dark red, light red, and white) is controlled by interaction in **two genes** (gene D and gene W).

(1) Role of Gene Dominant D & Recessive d:

- Gene D has a dominant allele D that produces dark red petals.
- Its recessive allele d produces light red petals.

Genotype	Flower Colour
• DD, Dd	• Dark Red Petals
• dd	• Light Red Petals

- Therefore, a **genotype DD** or Dd will have dark red and a genotype dd will have light red flower colour.

(2) Role of Dominant (W) & Recessive (w) Alleles:

- **Gene W** (present at another locus) has a **dominant allele** W that limits the distribution of red **pigment** (produced by D and d) in the form of **small spots so** petals appear white from **outside.**
- The recessive w allows uniform pigment distribution.

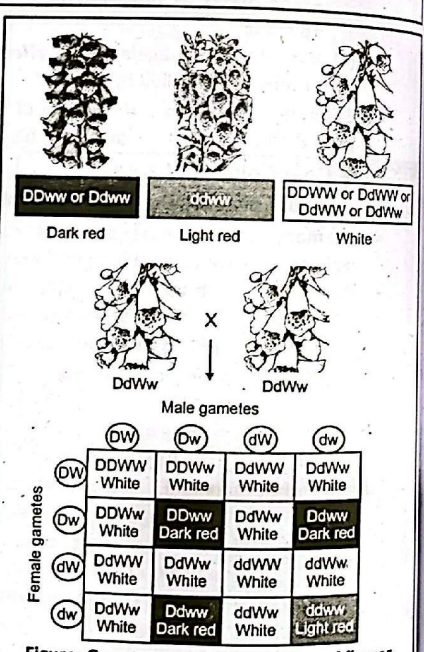


Figure: Genotypes and phenotypes of flower colour in foxglove

- The **heterozygous** plant **DdWw** will have **white flowers** (because the W allele limits the pigment in small spots in the inner side).
- If such **heterozygous** plant is self-fertilized, it produces plants with **white, dark red** and **light red** flowers in **12:3:1 ratio.**

Multiple Choice Questions (MCQs)

		Key
1.	**Polygenic inheritance is a type of:** (A) Complete dominance. (B) Mendelian inheritance. (C) Non-Mendelian inheritance. (D) Co-dominance.	1.(C)
2.	**In polygenic inheritance, a single trait is controlled by:** (A) Many gene pairs. (B) One gene pair. (C) Two gene pairs. (D) One chromosome.	2.(A)
3.	**In polygenic inheritance, the alleles of different genes contribute to a trait in a(n):** (A) Dominant manner only. (B) Recessive manner only. (C) Independent way. (D) Additive way.	3.(D)
4.	**Polygenic traits usually show:** (A) Discontinuous variation. (B) Continuous variation. (C) No variation. (D) Only dominant phenotypes.	4.(B)
5.	**Which of the following is a polygenic trait?** (A) Human height. (B) ABO blood group. (C) MN blood group. (D) Rh factor.	5.(A)
6.	**Human skin colour depends on the amount of:** (A) Haemoglobin. (B) Keratin. (C) Melanin. (D) Collagen.	6.(C)
7.	**Which alleles produce more melanin in the simplified model of skin colour inheritance?** (A) a, b and c. (B) A, B and C. (C) D, E and F. (D) R, Y and G.	7.(B)
8.	**Which genotype represents the darkest skin colour?** (A) AaBbCc. (B) AABBCC. (C) aabbcc. (D) AAbbCc.	8.(B)
9.	**Which genotype represents the lightest skin colour?** (A) AABBCC. (B) AaBbCc. (C) aabbcc. (D) AABbcc.	9.(C)
10.	**When AABBCC is crossed with aabbcc, all F_1 offspring have the genotype:** (A) AaBbCc. (B) AABBCC. (C) aabbcc. (D) AABbCc.	10.(A)
11.	**Why do polygenic traits show continuous variation in a population?** (A) Single gene. (B) Many genes. (C) Maternal inheritance. (D) Complete dominance.	11.(B)
12.	**In the F_2 generation of the skin colour cross (AaBbCc × AaBbCc), the phenotypic ratio from very dark to very light is:** (A) 3 : 1. (B) 9 : 3 : 3 : 1. (C) 1 : 2 : 1. (D) 1 : 6 : 15 : 20 : 15 : 6 : 1.	12.(D)
13.	**In wheat, the genotype AABBCC produces dark red grains because:** (A) All dominants. (B) All recessives. (C) No pigment. (D) One dominant.	13.(A)
14.	**When dark red wheat (AABBCC) is crossed with white wheat (aabbcc), the F_1 generation will have:** (A) White grains. (B) Dark red. (C) Intermediate red. (D) Equal numbers.	14.(C)
15.	**In the F_2 generation of the wheat grain colour cross, which statement is correct?** (A) All dark. (B) All white. (C) Different shades. (D) All intermediate.	15.(C)
16.	**Epistasis is an example of:** (A) Complete dominance. (B) Allelic interaction. (C) Non-allelic interaction. (D) Polygenic inheritance.	16.(C)
17.	**In allelic interactions, the interaction occurs between:** (A) Genes on different chromosomes. (B) Alleles of the same gene. (C) Different species. (D) Homologous chromosomes only.	17.(B)
18.	**Which of the following is an example of allelic interaction?** (A) Incomplete dominance. (B) Gene linkage. (C) Epistasis. (D) Polygenic inheritance.	18.(A)
19.	**In epistasis, the allele that masks or modifies the effect of another gene is called:** (A) Recessive allele. (B) Dominant allele. (C) Epistatic allele. (D) Hypostatic allele.	19.(C)
20.	**The allele whose effect is masked or modified is called:** (A) Epistatic allele. (B) Hypostatic allele. (C) Dominant allele. (D) Multiple allele.	20.(B)
21.	**In Labrador dogs, the B gene controls:** (A) Pigment colour. (B) Pigment deposition. (C) Hair length. (D) Eye colour.	21.(A)
22.	**In Labrador dogs, the recessive genotype ee produces:** (A) Black coat. (B) Brown coat. (C) Yellow coat. (D) White coat.	22.(C)
23.	**The dominant allele E in Labrador dogs:** (A) Blocks pigment deposition. (B) Allows pigment deposition. (C) Produces brown pigment. (D) Produces yellow pigment.	23.(B)

CamScanner

24. When two heterozygous black Labradors (BbEe × BbEe) are crossed, the phenotypic ratio is:
(A) 9 : 3 : 3 : 1. (B) 1 : 2 : 1. (C) 3 : 1. (D) 9 : 3 : 4.

25. In foxglove plants, gene D controls:
(A) Pigment distribution. (B) Petal colour. (C) Seed colour. (D) Flower size.

26. Why does a Labrador dog with genotype ee always have a yellow coat?
(A) Yellow pigment. (B) B recessive. (C) BB conversion. (D) Blocks pigment.

27. In foxglove plants, the dominant allele W produces white flowers because it:
(A) Stops pigment. (B) Limited distribution. (C) Changes pigment. (D) No pigment.

28. A heterozygous foxglove plant (DdWw) has which flower colour?
(A) Dark red. (B) Light red. (C) White. (D) Pink.

29. Self-fertilization of a DdWw foxglove plant produces white, dark red, and light red flowers in the ratio:
(A) 12 : 3 : 1. (B) 9 : 3 : 4. (C) 9 : 3 : 3 : 1. (D) 1 : 2 : 1.

30. Which statement correctly distinguishes allelic and non-allelic interactions?
(A) Same gene. (B) Different loci. (C) Plants only. (D) Allelic epistasis.

24.(D) 25.(B) 26.(D) 27.(B) 28.(C) 29.(A) 30.(B)

GENE LINKAGE AND CROSSING OVER

Q.33 Who was Karl Correns?

Ans. Karl Correns:

- He was a **German geneticist.**
- He rediscovered **Mendel's work** in **1900** and suggested the role of chromosomes in heredity.

Q.34 Who proposed the chromosomal theory of inheritance & state its two main points.

Ans. Chromosomal Theory of Inheritance:

- In 1902, American scientist Walter Sutton proposed the **chromosomal theory of inheritance.**

➢ **Two Main Points of Chromosomal Theory of Inheritance:**

(i) Genes are found at specific locations on chromosomes.

(ii) The behaviour of chromosomes during meiosis explains **Mendel's laws of inheritance.**

Check Understanding!

Q.17 What defines linked genes according to the chromosomal theory of inheritance?
(A) Genes on same chromosome.
(B) Alleles on different chromosomes.
(C) Genes controlling multiple traits.
(D) Recessive alleles on Y chromosome.

Q.35 Differentiate between gene-linkage & crossing over.

Ans.

Gene-linkage	Crossing over
• The phenomenon of staying together of genes on the same chromosomes is called **gene linkage.**	• The exchange of genetic material between non-sister chromatids of homologous chromosomes is called **crossing over.**

Topic: Gene Linkage:

Q.36 Explain how does gene linkage counter independent assortment and crossing-over modifies the progeny.
Exercise LO 7

Ans. Gene Linkage:

- In body cells, thousands of genes are present on **a limited number** of chromosomes.

Example:

(i) Humans have about **20,000 genes** on **23 chromosome** (present in two sets).

(ii) Fruit fly (*Drosophila*) has about **13,000 genes** on 4 chromosome (also present in two sets).

- This means many genes are arranged in a line on each chromosome, sometimes very close together.
- Genes present on the same chromosome are called linked genes, and this is known as **gene linkage.**

Check Understanding!

Q.18 Deduce how Thomas Hunt Morgan used phenotypic ratios in Drosophila crosses to distinguish between independent assortment and incomplete gene linkage.

- Closely linked genes tend to stay together and do not assort independently during gamete formation. However, genes on different chromosomes, or those far apart on the same chromosome, assort independently.

Detection of Gene Linkage:

➢
- Gene linkage and its frequency can be studied by performing crosses and observing how often different phenotypes appear in the offspring.
- The key idea is to compare parental combinations (same as parents) with recombinant or new combinations.

For Information

- Gene linkage can only be observed when a cross produces large number of offspring.
- Larger the progeny size, the more likely it is to represent the actual frequency of linkage in the population.

Modification in Progeny Due to Gene Linkage:

➢
(i) When No Linkage: If offspring show parental and new phenotypes in equal 1:1:1:1 ratio, it means the genes are not linked and assort **independently.**

(ii) When Linkage is Incomplete: If parental **combinations are more frequent** and **new combinations** are fewer, it indicates **incomplete linkage,** meaning genes are linked but can separate due to **crossing over.**

(iii) When Linkage is Complete: If only **parental** combinations appear and **no new** combinations are seen, it shows complete linkage, meaning the genes are very close and do not separate.

Q.37 Exemplify the concept of gene linkage by quoting the example of wing length and width of abdomen in *Drosophila melanogaster.*
Exercise LO 7

Ans. Concept of Gene Linkage through Examples of Wing Length & Abdomen Width of Drosophila Melanogaster:

- American biologist, **Thomas Hunt Morgan,** studied two traits in ***Drosophila*:**
  (i) Wing length. (ii) Abdomen width.
- He **observed** that allele for long wings (L) is **dominant** over short or **vestigial wing** (l).
- Similarly, he observed that allele for **broad abdomen** (B) is dominant over **narrow abdomen** (b).
- Morgan did the following cross in drosophila:

Parents	Broad abdomen Long wings	×	Narrow abdomen Vestigial wings
	BBLL	↓	bbll
F1	BbLl	Long wings Broad abdomens	

- Then, he crossed two of **F1 flies.**
- The **results** are shown in the following figure:

Check Understanding!

Q.19 During which meiotic phase does crossing over occur to recombine linked genes?
(A) Meiosis-I.
(B) Meiosis-II.
(C) Mitotic anaphase.
(D) Zygote fertilization.

➢ **Explanation of Result:**

- According to **Law of Independent Assortment.**
- The F2 generation should have the following 9:3:3:1 ratio:

F1 × F1	Long wings Broad abdomens	×	Long wings Broad abdomens
		↓	
F2	9 Long wings Broad abdomen (Parental combination)		1 Vestigial wing Narrow abdomen (Parental combination)
	3 Vestigial wings Broad abdomen (New combination)		3 Long-wings Narrow abdomen (New combination)

CamScanner

- **Results Were Unexpected:** But Morgan observed only parental combinations in **F2.**
- There were 3/4 flies with long wings-broad abdomen and 1/4 with vestigial wings-narrow abdomen.

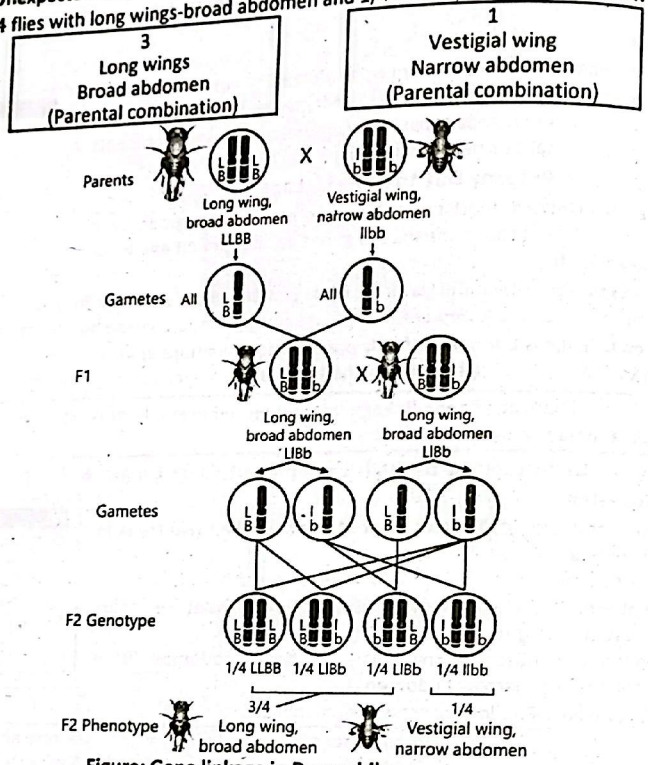


Figure: Gene linkage in Drosophila

➢ **Results & Conclusions of Thomas H. Morgan:**

- From this data, Morgan concluded that the genes for **wing length** and **abdomen width** were located on the **same chromosome** (Linked Genes) and they did no assort **independently,** it means the genes of **wing length & abdomen width** show **gene linkage.**

Topic: Crossing Over:

Q.38 Define & explain the concept of crossing over. Exercise L/Q.5

Ans. Crossing Over:

- **Definition:** Crossing over is the exchange of genetic material between non-sister chromatids of homologous chromosomes during prophase-I of meiosis, resulting in new combinations of alleles in the gametes.

➢ **Mechanism of Crossing Over:**

- During crossing over, the **chromatids of two homologous chromosomes** line up next to one another as shown in Figure.
- The chromatids (exchange) sections of DNA. In this process, DNA strands actually break and re-join.
- After **crossing over,** the homologous chromosomes separate from each other.
- The chromatids involved in **crossing over still** have the same genes in the same order, but the alleles have **been rearranged.** When these recombinant chromatids are distributed in different gametes, a wide variety is produced in gametes.

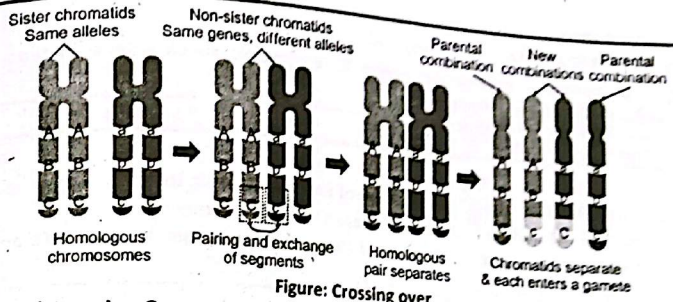


Figure: Crossing over

➢ **Importance of Crossing Over:**

- Crossing over leads to recombination of genes and thus responsible for genetic variability.

Multiple Choice Questions (MCQs)	Key
1. **Walter Sutton proposed the chromosomal theory of inheritance in:** (A) 1900. (B) 1901. (C) 1902. (D) 1930.	1.(C)
2. **According to the chromosomal theory of inheritance, genes are located:** (A) On chromosomes. (B) On ribosomes. (C) In the cytoplasm. (D) Inside mitochondria only.	2.(A)
3. **Genes present on the same chromosome are called:** (A) Multiple alleles. (B) Polygenes. (C) Codominant genes. (D) Linked genes.	3.(D)
4. **Gene linkage refers to the genes:** (A) Located on different chromosomes. (B) Present on the same chromosome. (C) Found only in plants. (D) Showing incomplete dominance.	4.(B)
5. **Closely linked genes generally:** (A) Stay together during gamete formation. (B) Assort independently. (C) Mutate rapidly. (D) Always undergo crossing over.	5.(A)
6. **If offspring appear in a 1 : 1 : 1 : 1 ratio, it indicates that the genes:** (A) Are completely linked. (B) Are incompletely linked. (C) Assort independently. (D) Are epistatic.	6.(C)
7. **If only parental combinations appear in the offspring, it indicates:** (A) Complete linkage. (B) Incomplete linkage. (C) Independent assortment. (D) Polygenic inheritance.	7.(A)
8. **Thomas Hunt Morgan performed his linkage experiments on:** (A) Pea plants. (B) Humans. (C) Mice. (D) Drosophila.	8.(D)
9. **Morgan studied linkage between the genes for:** (A) Seed colour and seed shape. (B) Flower colour and stem length. (C) Wing length and abdomen width. (D) Eye colour and blood group.	9.(C)
10. **Crossing over occurs during:** (A) Mitosis. (B) Meiosis-I. (C) Meiosis-II. (D) Fertilization.	10.(B)
11. **Morgan observed only parental combinations in the F_2 generation because the genes for wing length and abdomen width:** (A) Same chromosome. (B) Different chromosomes. (C) Recessive genes. (D) Gene mutation.	11.(A)
12. **During crossing over, what is exchanged between homologous chromosomes?** (A) Whole chromosomes. (B) Centromeres only. (C) DNA segments. (D) Ribosomes.	12.(C)
13. **Which statement best explains how crossing over increases genetic variation?** (A) New chromosomes. (B) Allele rearrangement. (C) Chromosome doubling. (D) Prevents meiosis.	13.(B)
14. **If parental combinations are more frequent than recombinant combinations, the genes are:** (A) Completely unlinked. (B) Independent assortment. (C) Incompletely linked. (D) Polygenic.	14.(C)
15. **Genes on different chromosomes or those far apart on the same chromosome generally:** (A) Always linked. (B) Assort independently. (C) No meiosis. (D) Parental only.	15.(B)

SEX DETERMINATION

Q.39 Define sex-determination & what is its base of determination? S/Q

Ans. Sex-Determination:

- It is **biological system** that determines the development of sexual characteristics in an organism. In this process, an **individual develops** into either a **male** or a female form.

CamScanner

➢ **Basis of Sex-Determination:**

- The sex of an animal is determined during its embryonic development. In most animals, sex is determined on the basis of karyotype.

Q.40 What is Karyotype? S/Q

Ans. Karyotype:

- Karyotype is a appearance of the **complete set of chromosomes** in the cells.
- Karyotype includes the **numbers, sizes, and shapes** of chromosomes.
- In the **karyotype** of most animals, all **pairs of chromosomes** are similar in **female** and **male animals**, except one pair.

Q.41 Differentiate between autosome & sex-chromosome. S/Q

Ans.

Autosome	Sex-chromosome
• The chromosomes which are **perfectly** similar in female and male, are called **autosomes.**	• One pair of chromosomes is different in female and male and it determines the gender are called **sex chromosomes.**
• **Example:** In human, **22-pairs** are autosome.	• **Example:** In human, only one pair is sex-chromosome.

- The following are the main sex-determination systems on the basis of karyotype.

Topic: (1) XX-XY System of Sex Determination:

Q.42 Explain the XX-XY mechanism of sex determination in Drosophila and Mammals. Exercise L/Q.8

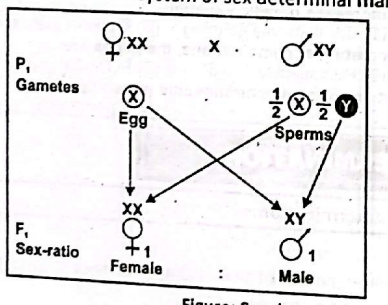
Ans. XX-XY System of Sex Determination: (Drosophila, Mammals, Most Vertebrates)

- In Drosophila, mammals and most other vertebrates, the sex chromosomes **pair consists** of a rod-shaped **X** chromosome and a **hook-shaped Y** chromosome.
- Females have **XX chromosomes** while males have XY. Drosophila has 3 pairs of autosomes and 1 pair of sex chromosomes. Humans have 22 pairs of autosomes and 1 pair of sex chromosomes.

Check Understanding!
Q.20 Contrast homogametic and heterogametic sexes within the XX-XY sex-determination system.

➢ **Pattern of Sex-Determination:**

- **Females Homogametic:** In these animals, females are **homogametic,** which means that they **produce all eggs with one X** chromosome.
- **Males Heterogametic:** Males are **heterogametic** in these animals, means that they produce **two types of sperm.**
- Half sperms carry one X chromosome and half carry one *Y* chromosome.
- If a **sperm with *X*** chromosome fertilizes the egg, the zygote will have XX chromosomes.
- This embryo will develop female sex organs and the baby will be a female.
- If a sperm with ***Y* chromosome** fertilizes the egg, the zygote will have XY chromosomes. This embryo will develop male sex organs and the baby will be a **male.**
- **Conclusion:** In XX-XY system of sex determinal **male sex** cells determine the gender of next generation.



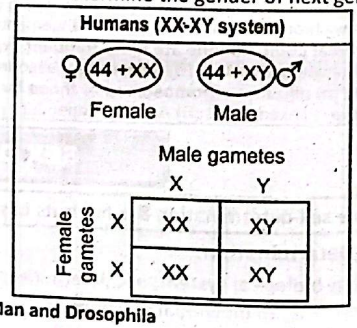


Figure: Sex determination in Man and Drosophila

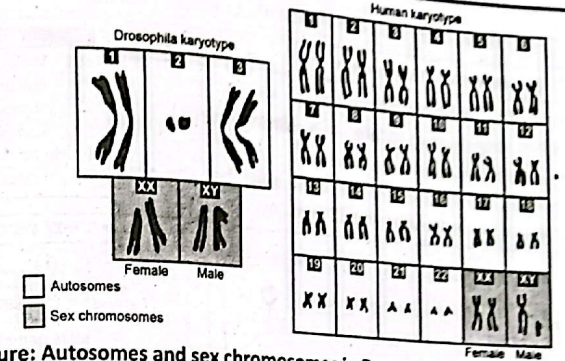


Figure: Autosomes and sex chromosomes in Drosophila and humans

Topic: (2) XX-XO System of Sex Determination: (Example: Grosshopper)

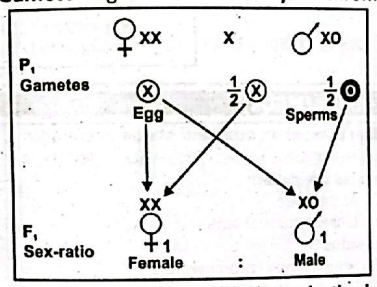
Q.43 Describe the XX-XO sex determination systems and evaluate by studying the karyotype. Exercise L/Q.9

Ans. XX-XO System of Sex Determination:

- This sex determination is found in some insects.
- **Example:** Grasshopper has **22 autosomes** (11 pairs).

➢ **Male Grosshopper: (Heterogametic)**

- Male has **total 23 chromosomes** because its **sex chromosome pair is XO** i.e., only X chromosome is present and there is no Y chromosome.
- Male forms two types of sperm; half containing X and half without any sex chromosome.
- **Nullo Gamete:** A gamete without **any sex chromosome** is called **nullo gamete.**



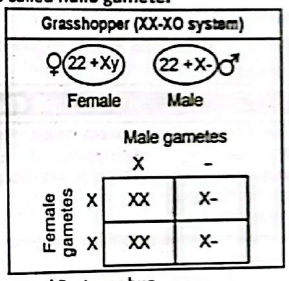


Figure: Sex determination in grasshipper and Protenor bug.

➢ **Female Grosshopper: (Homogametic)**

- Female has **24 chromosomes.** Its sex chromosome **pair is XX.**
- All eggs carry one X chromosome, so females are **homogametic.**
- If an X -carrying sperm fertilizes the egg, an XX female offspring is produced. If the nullo sperm fertilizes the egg, an XO male offspring is produced.

Q.44 Differentiate between the terms homogametic & heterogametic with one example of each. S/Q

Ans.

Homogametic	Heterogametic
• The organisms which produce only one type of gamete (All gametes carry the same sex chromosome).	• The organisms which produce two types of gametes (Gametes carry different sex chromosomes).
• **Examples:** Human females (XX), because every egg they produce carries an X chromosome.	• **Examples:** Human males (XY), because their sperm can carry either an X or a Y chromosome.

CamScanner

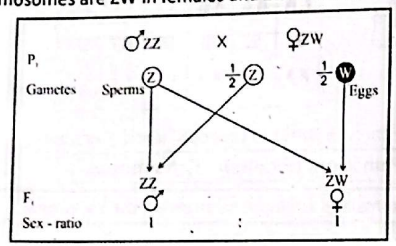
Topic: (3) ZW-ZZ System of Sex Determination: (Example: Birds)

Q.45 Describe the ZZ-ZW determination system. Exercise L/Q.9

Ans. ZW-ZZ System of Sex Determination:

(Female ⟶ Heterogametic) (Male ⟶ Homogametic)

- This sex determination is common in birds.
- The autosome number differs in different birds but the sex chromosomes are ZW in females and ZZ in males.



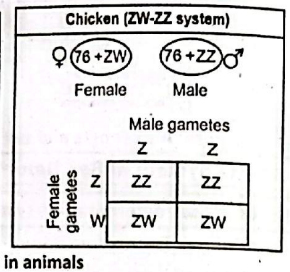


Figure: Sex determination in animals

Female Bird: (ZW-Heterogametic)

- It means that the female bird produces two kinds of eggs; half with Z chromosome and half with W chromosome.

Male Bird: (ZZ-Homogametic)

- While, the all sperms of the male have Z chromosome.
- When an **Z carrying egg** is fertilized by the sperm, offspring is male.
- When a **Y carrying egg** is fertilized by the sperm, offspring is female.

Check Understanding!

Q.21. Which sex-determination system features females with ZW chromosomes and males with ZZ chromosomes?
(A) Humans. (B) Birds.
(C) Grasshoppers. (D) Drosophila.

Check Understanding!

Q.22 Analyze why Thomas Hunt Morgan's F2 crosses involving Drosophila eye color yielded white-eyed flies exclusively among males.

Multiple Choice Questions (MCQs)

		Key
1.	The complete set of chromosomes arranged according to number, size, and shape is called: (A) Karyotype. (B) Genome. (C) Genotype. (D) Phenotype.	1.(A)
2.	Chromosomes that are similar in both males and females are called: (A) Sex chromosomes. (B) Autosomes. (C) Polygenes. (D) Linked chromosomes.	2.(B)
3.	Which chromosomes determine the gender of an individual? (A) Autosomes. (B) Homologous chromosomes. (C) Sex chromosomes. (D) Polytene chromosomes.	3.(C)
4.	In the XX–XY system, females have the chromosome pair: (A) XY. (B) XO. (C) ZZ. (D) XX.	4.(D)
5.	In humans, there are _____ pairs of autosomes. (A) 21. (B) 22. (C) 23. (D) 24.	5.(B)
6.	In the XX–XY system, males are called heterogametic because they produce: (A) Only X-bearing sperm. (B) Only Y-bearing sperm. (C) Two types of sperm (X and Y). (D) Only nullo gametes.	6.(C)
7.	In the XX–XO system, a gamete without any sex chromosome is called a: (A) Nullo gamete. (B) Haploid gamete. (C) Recombinant gamete. (D) Diploid gamete.	7.(A)
8.	In grasshoppers, the male sex chromosome pair is: (A) XX. (B) XY. (C) XO. (D) ZZ.	8.(C)
9.	In birds, the female sex chromosome combination is: (A) XX. (B) XY. (C) ZZ. (D) ZW.	9.(D)
10.	In the ZW–ZZ system, all sperms produced by the male contain: (A) X chromosome. (B) W chromosome. (C) Z chromosome. (D) Y chromosome.	10.(C)

11. In the XX–XY system, what determines whether the offspring will be male or female? (A) Egg chromosome. (B) Sperm type. (C) Autosome number. (D) Chromosome size. — 11.(B)
12. Why are females called homogametic in the XX–XY system? (A) X eggs. (B) XY eggs. (C) Nullo gametes. (D) One X. — 12.(A)
13. In the XX–XO system of grasshoppers, an XO male offspring is produced when: (A) X sperm. (B) Y sperm. (C) Nullo sperm. (D) Egg fusion. — 13.(C)
14. In birds, a male offspring develops when: (A) W + Z. (B) Z + Z. (C) X + Y. (D) Nullo gamete. — 14.(B)
15. Which statement correctly compares the three sex-determination systems described? (A) Males homogametic. (B) Grasshopper XY. (C) Birds only. (D) Correct comparison. — 15.(D)

SEX LINKAGE

Q.46 Define the term sex-linked traits & sex-linkage & why are the ratios of sex-linked traits different in males & females. S/Q

Ans. Sex-linked Traits & Sex-linkage:

- The traits which are controlled by alleles present on **sex chromosomes** are called **sex-linked traits** and this phenomenon is called **sex linkage.**
- **Ratio + Difference in Male & Female:** The sex-linked trait is actually **X-linked** because usually the Y **chromosome** carries almost no functional genes. That's why, the **ratio of sex-linked traits** is different in males and females.

Q.47 What are X-Y linked or pseudo-autosomal traits? S/Q

Ans. X-Y Linked or Pseudo-autosomal Traits:

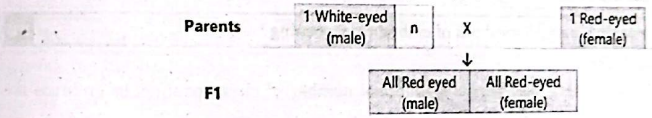
- A very few traits **whose alleles** are found on **both X and Y chromosomes.**
- Such traits are equally distributed among males and females and are called **X-Y-linked** or **pseudo-autosomal** traits.

Topic: Discovery of Sex-Linkage:

Q.48 Discuss the work of Thomas Hunt Morgan on drosophila to discover the sex linkage. Exercise L/Q.10, L/Q.14

Ans. Work of Thomas hunt Morgan on Drosophila Discovery of Sex-Linkage:

- In 1910, **Thomas Hunt Morgan** observed a **male Drosophila** fly that differed from normal flies.
- **Mutant Male:** This mutant male fly had white eyes instead of normal red.
- He crossed the mutant male to a normal (wild-type) female. All of the F1 progeny had red eyes.

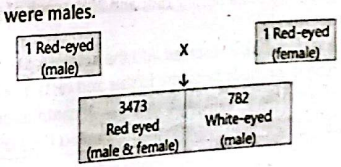


Conclusions After First Cross:

- He concluded that **red eye colour** was dominant over white.
- **Step-II:** He crossed the red-eyed flies from the F1 generation with each other.
- Out of 4252 flies in F2, there were 782(18%) **white eyed.** Although the ratio of red eyes to white eyes in the F2 was greater than 3:1, there was something important.

Conclusions After of Second Cross:

- All of the white-eyed F2 flies were males.



CamScanner

- **Interpretation of Morgan:** Morgan thought that perhaps it was impossible for a white-eyed female fly to exist.
- **Morgan Performed Test Cross:** To test this idea, he test-crossed the F1 red-eyed female with the white-eyed male. He obtained both white-eyed and red-eyed males and females in a 1:1:1:1 ratio.
- Hence, it was proved that a **female could have white eyes.**
- Why, then, were there no **white-eyed females** among the progeny of the first cross?
- He mated a **white-eyed female** with a red-eyed male.
- All **female** offspring had red eyes, and all male offspring had white eyes.

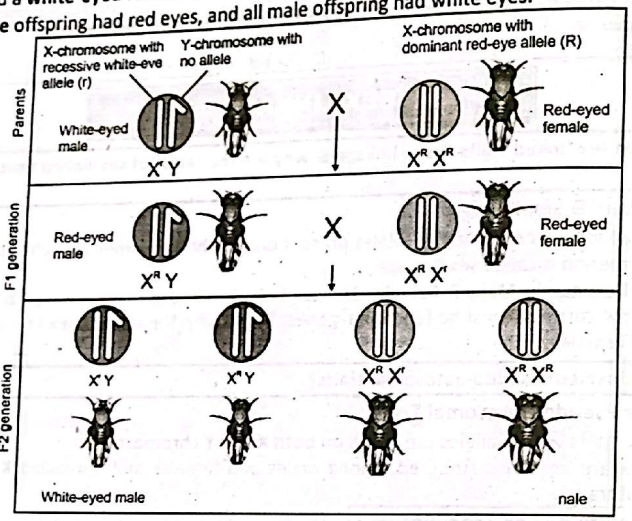


Figure: Inheritance of sex-linked trait (eye colour) in Drosophila

➢ **Morgan's Conclusion:**

- Morgan **concluded that the gene of white-eye** is present on **X chromosome.**
- He assumed that the **Y chromosome** did not have the allele of this gene. He called such genes as sex-linked genes and traits as sex-linked traits.

Topic: Embryonic Screening:

Q.49 What is embryonic screening, name 3-methods of embryonic screening? S/Q

Ans. Embryonic Screening (ES):

- The methods to check genetic **disorders** and **abnormal number** of chromosomes in embryos are called embryonic screening.

➢ **Methods of Embryonic Screening:**

- It includes methods like.

(i) Ultrasound scan. (ii) Chorionic villus sampling. (iii) Amniocentesis.

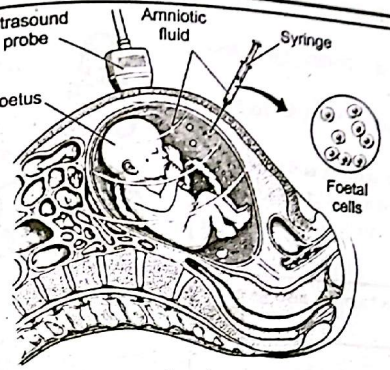
Q.50 What is Amniocentesis, discuss its brief procedure? S/Q

Ans. Amniocentesis:

- Amniocentesis is generally done **during 15th and 20th** week of pregnancy.

➢ **Procedure of Amniocentesis:**

- In its procedure, a long needle is inserted into the amniotic sac.
- During it, an ultrasound **probe locates the foetus** and tests any abnormality.
- The inserted needle sucks some amniotic fluid which contains **cells of the foetus.**
- The foetal cells are kept in culture medium and checked for abnormal **number of chromosomes.**



Amniocentesis

Check Understanding!

Q.23 What diagnostic procedure extracts amniotic fluid using a needle during weeks 15 to 20 of pregnancy to screen for chromosomal abnormalities?

(A) DNA chromatography.
(B) Electroporation.
(C) Amniocentesis.
(D) PCR amplification.

Topic: Sex-linked Traits in Humans:

Topic: X-linked Recessive Traits:

Q.51 Why are X-linked recessive traits more common in males than females? S/Q

Ans. X-linked Recessive Traits Common in Males than Females:

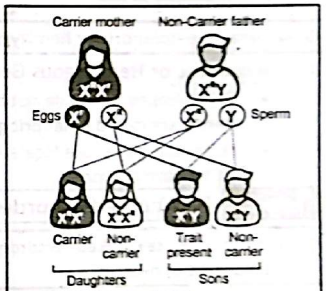
- The X-linked recessive traits are less common in females than males.
- It is because, **such trait** will appear in a **female only** when she has **two recessive alleles** on her two X chromosomes.
- While in males, this **X-linked recessive** trait will appear when only **one allele is present on X-chromosome** (because the Y - chromosome does not carry its allele).
- So, this trait will appear in all the males who possess its single **allele.**

Examples of X-linked Recessive Traits:

(i) **Muscular Dystrophy:** Muscle weakness and degeneration.
(ii) **Red-green Colour:** Blindness.
(iii) **Haemophilia:** Deficiency of clotting factors in the blood.

Check Understanding!

Q.24 Explain why X-linked recessive disorders manifest more frequently in human males than in females.



R: X-linked dominant allele
r: X-linked recessive allele

Figure: Inheritance of X-linked recessive traits

Q.52 Discuss the inheritance of X-linked recessive traits briefly. S/Q

Ans. Inheritance of X-linked Recessive Traits:

(i) If a mother has X-linked recessive trait, all of her sons will also have it.
(ii) If mother is a carrier (heterozygous) of the trait, **50%** of her sons can inherit it.
(iii) If such trait is present **in father,** all of his daughters will be carriers (daughters possess their father's Xchromosome) and **no son will** inherit this trait (sons do not inherit their father's X-chromosome).

Topic: X-linked Dominant Traits:

- Such traits are **in equal ratio in females and males.**

Examples include:

(i) **Vitamin D-resistant rickets** (inability to properly metabolize vitamin D, leading to softening and weakening of bones).
(ii) **Rett syndrome** (neuro-developmental disorder with loss of speech, repetitive hand movements, and problems with walking), Aicardi syndrome (abnormal development of brain).

CamScanner

➢ **Inheritance of X-linked Dominant Traits:**

- If a mother has X-linked dominant trait and is homozygous, she passes the trait to 100% of offspring.
- While a heterozygous dominant mother passes the trait to 50% of her offspring.
- If such trait is present in father, all of his daughters will inherit it (a daughter inherits her father's *X*-chromosome) and no son will inherit it (a son does not inherit his father's X-chromosome).

Topic: Y-Linked Traits:

Q.53 What are Y-linked traits & why are they rare in human, also give its examples. S/Q

Ans. Y-linked Traits:

- The traits whose genes are present on Y-chromosomes are called Y-linked traits.

➢ **Y-linked Traits-Rare in Human:**

- Y-chromosome contains relatively a few genes compared to X chromosome.
- The Y-linked genes do not have alleles on X-chromosome, thus Y-linked traits appear only in males and are inherited from father to son only. That's why Y-linked traits are relatively rare.

➢ **Examples of Y-linked Traits in Human:**

(i) **Hypertrichosis:** Growth of hair on the rim of pinna.
(ii) **Porcupine Man:** Straight hair on the body.
(iii) **Webbing of toes.**

Q.54 What are holandric or hemizygous genes? S/Q

Ans. Holandric or Hemizygous Genes:

- The Y-linked genes do not have alleles on X chromosome. Such genes are called holandric genes (or hemizygous genes).
- Holandric genes are located only on the non-homologous region of Y-chromosome.

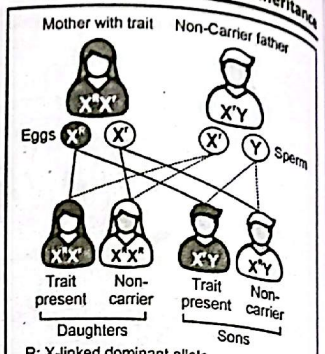


Figure: Inheritance of X-linked dominant traits

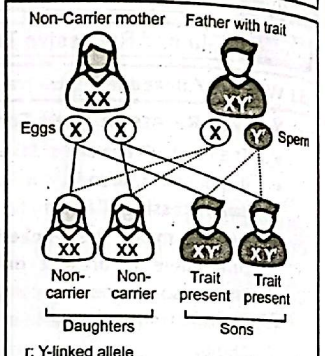


Figure: Inheritance of Y-linked traits

Topic: Sex Linked Disorders in Humans:

Q.55 What are sex-linked disorders & name the three sex-linked disorders in human? S/Q

Ans. Sex-Linked Disorders:

- The disorders, whose genes are present on x-chromosome are called sex-linked or x-linked disorders.
- **Examples:**
  (i) Haemophilia. (ii) Colour-Blindness. (iii) Muscular Dystrophy.

For Information

SRY-Gene & its Importance:

- In human males, there is a specific gene on Y-chromosome known as SRY (Sex-determining Region Y).
- It produces a protein which starts development of testes and prevents the development of female reproductive structures.

Topic: (1) Haemophilia: (X-Linked Recessive)

Q.56 What is haemophilia, give its identifying characteristics & name its types with causes? Exercise L/Q.12

Ans. Haemophilia:

- Haemophilia is a rare X-linked recessive trait.

➢ **Identifying Characteristics of Haemophilia:**

- In this disease, the blood fails to clot properly after an injury. It is due to the reduction, malfunctioning, or absence of blood clotting factors.

➢ **Types of Haemophilia:**

- Haemophilia is of three types i.e., A, B and C.

(i) Haemophilia A:

- It is caused due to abnormal blood clotting factors VIII.
- It is X-linked recessive trait.

(ii) Haemophilia B:

- It is caused due to blood clotting factors-IX.
- It is X-linked recessive trait.
- So, A & B are more common in males than females because there both are X-linked traits.

(iii) Haemophilia C:

- It is caused due to abnormal blood clotting factors XI. It is an autosomal recessive trait, so present in both genders equally.

Check Understanding!

Q.25 What specific clotting factor abnormality causes Haemophilia C, and how does its inheritance pattern differ from Haemophilia A and B?
(A) Factor XI; autosomal recessive.
(B) Factor VIII; X-linked recessive.
(C) Factor IX; Y-linked holandric.
(D) Factor D; X-linked dominant.

Solve the following genetic problem.

- **If two normal parents have a haemophiliac child, what could be the genotypes of the parents?**

Solution:

- **Parental Genotypes:**
  - **Mother:** $X^H X^h$ (Carrier female)
  - **Father:** $X^H Y$ (Normal male)
  - **Child:** $X^h Y$ (Hemophiliac male)
- **Explanation:**
  - **X-Linked Recessive:** Hemophilia is caused by a recessive allele (X^h) on the X chromosome.
  - **Child Must Be a Son:** A normal father ($X^H Y$) always passes his dominant X^H allele to daughters. Therefore, two normal parents cannot have a hemophiliac daughter.
  - **Mother Must Be a Carrier:** The hemophiliac son ($X^h Y$) receives his Y chromosome from the father and his X^h allele from the normal mother—proving she carries X^h alongside X^H.

(Carrier Normal Mother) X^HX^h × X^HY (Normal Father)

	X^H	X^h
X^H	X^HX^H (Normal Daughter)	X^HX^h (Carrier Normal Daughter)
Y	X^HY (Normal Son)	X^hY (Hemophilia Son)

➢ **Mechanism of Normal Blood Clotting (Coagulation):**

Blood clotting is a complex process that helps to prevent excessive bleeding when an injury occurs. The mechanism involves the following steps:

1. When an injury occurs, platelets adhere to the site of injury, forming a platelet plug.
2. Activated platelets as well as the damaged tissue release of clotting factors.
3. The clotting factors perform chemical reactions (clotting cascade), in which soluble protein fibrinogen is converted into an insoluble protein called fibrin.
4. Fibrin forms a mesh-like structure that entraps parts of the blood and makes a solid clot.
5. The clot is stabilized by the cross-linking of fibrin strands.

If the balance of clotting system is disrupted, it can lead to abnormal clotting, known as thrombosis, which can cause serious health problems such as stroke and heart attack.

Topic: (2) Colour-Blindness: (X-linked Recessive)

Q.57 Write a note on the inheritance of colour blindness in humans. Exercise L/Q.13

Ans. Colour Blindness:

- **Normal Colour Vision:** People with normal vision have trichromatic vision.
- In normal trichromatic colour vision there are three kinds of cone cells in the retina of eye - each sensitive for a specific primary colour.

CamScanner

➢ **Types of Cones For Three Colors:**

(i) Red-Sensitive Cones. (ii) Green-Sensitive Cones (iii) Blue-Sensitive Cones.

- **Opsins:** Each cone cell contains specific pigment proteins called **opsins.**
- **Genes for Red & Green Opsins:** The genes for **red and green opsins** are present on **X chromosome.**
- **Genes for Blue Opsins:** The gene for blue **opsin** is on **autosome 7.**

➢ **Types of Colour-Blindness:**

- The recessive alleles for opsins cause colour-blindness. It may be of following types.

(i) Dichromacy:

- It is the perception of **two primary** colours and **blindness** of the **third colour** whose opsin is missing.

Types of Dichromacy:

- It may be:
  - **(a) Red-blindness (Protanopia):** Normal vision for blue & green colours.
  - **(b) Green-blindness (Deuteranopia):** Normal vision for red & blue colours.
  - **(c) Blue-blindness (Tritanopia):** Normal vision for red & green colours.

Check Understanding!

Q.26 Assess the cellular basis of dichromacy in human color blindness with respect to retinal cone cells and gene locations.

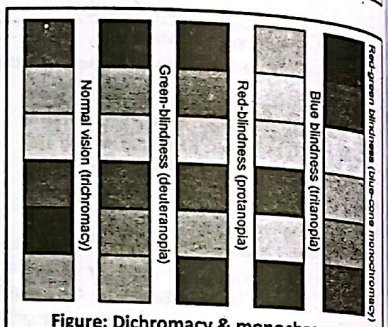


Figure: Dichromacy & monochromacy

(ii) Monochromacy (Total Colour Blindness i.e., Blindness of Two Primary Colours):

- It is the perception of a **single colour** and **blindness** of any two primary colours whose opsins are missing.

Blue-Cone Monochromacy: (Red-Green Blindness)

- In blue-cone monochromacy, **red** and **green opsins** are absent. It is also called red-green colour-blindness.
- It has normal opsins for blue colour.
- **Blue cone monochromacy** is only x-linked monochromacy.
- **Red-cone monochromacy** and **green-cone** monochromacy are very rare.

Treatment of Monochromacy:

- There is no **cure** for **colour blindness.**
- However, there are **assistive** technologies such as **colour-blind** glasses and special software that can help individuals to **differentiate between** colours.
- Additionally, some **colour-blind people** have found success with colour discrimination training.

Topic: (3) Muscular Dystrophy: (X-Linked Recessive)

Q.58 What is muscular dystrophy? Discuss effects and treatment of Duchenne muscular dystrophy as an example of muscular dystrophy. U-I

Ans. Muscular Dystrophy:

There are more than **30 disorders** classified as **muscular dystrophies.**

- **Duchenne Muscular Dystrophy:** it is the most common type of muscular dystrophy.
- It is X-linked **recessive** (so more common in males).
- About **two thirds cases** are inherited from a person's mother, while **one third** cases are due to a **new mutation.**

➢ **Causes & Symptoms of Duchenne Muscular Dystrophy:**

- **Lack of Dystrophin Protein:** If a male **receives** its **recessive allele,** he cannot make **muscle proteins** (dystrophin). It results in the death of **muscle fibres** and there is **weakness** and breakdown of skeletal muscles, especially those of the hips, pelvic area, thighs, and calves.

- It eventually progresses to the shoulders and neck, arms, respiratory and cardiac muscles, and other areas.

➢ **Effects of Duchenne Muscular Dystrophy:**

- Muscular dystrophy affects a child around the **age of four.**
- It becomes evident when the child **begins** walking.
- By **age 10,** the child may need **braces.** By **age 12,** most patients are unable to walk and need **wheelchair.**
- Typical lifespans range from **15 to 45.**

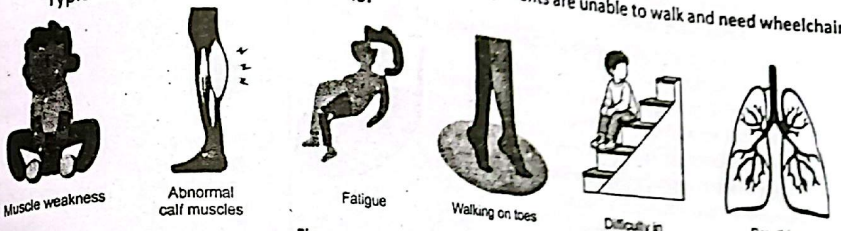


Figure: Symptoms of muscular dystrophy

➢ **Treatment of Duchenne Muscular Dystrophy:**

- **Has No Cure:** There is **no cure** for muscular dystrophy, but treatments are available to manage its symptoms and improve **quality** of life.
  - **(i) Physical Therapy:** Physical therapy is done to maintain **strength, flexibility,** and mobility.
  - **(ii) Corticosteroid Medicines:** Corticosteroid medicines can give short-term improvements in muscle strength and function.
  - **(iii) Use of Pain Killers:** Pain-killer medicines are used to relieve muscle pain.
  - **(iv) Surgery:** Surgery is done to correct **joint contractures.**

Topic: Sex-limited and Sex-influenced Traits:

Q.59 Describe sex-influenced and sex-limited traits with common examples from human genetics. Exercise Q.11

Ans. Sex-limited and Sex-influenced Traits:

- The traits which are **not sex-linked** (because their alleles are not present on **sex chromosomes**) but their ratio is different in males **and females.**
- There are two categories of such traits.

Check Understanding!

Q.27. How do sex-limited traits differ from sex-linked traits in their genetic basis and expression?

(A) Present in both, expressed in one.
(B) Located strictly on the Y chromosome.
(C) Controlled by autosomal codominance.
(D) Exhibited only during embryonic stages.

(1) Sex-limited Traits:

- The traits whose genes are present in **both sexes** but are **expressed in only one sex** due to anatomical or hormonal differences are called **sex-limited traits.**

Example of Sex-limited Trait:

(i) Horn Development Genes in Sheep:

- Both male and female **sheep** have the genes of **horn development.**
- These genes are only expressed in **male sheep.**

(ii) Milk Production in Mammals:

- The genes of **milk production** are present in both male and female mammals. But, these genes express **only in female mammals.**

(iii) Beard Growth In Human:

- The genes of the growth of **beard** in humans are present both in **male & females.**
- Bread growth genes are expressed in **males only.**

For Information

- Sex-limited genes are responsible for sexual dimorphism.
- Sexual dimorphism is phenotypic difference between males and females of the same species regardless of genotype.

CamScanner

(iv) Genes For Prostate Cancer:
- The genes of prostate cancer are expressed in males only.

(v) Genes for Ovarian Cancer:
- The genes of ovarian cancer are expressed in females only, although both these genes are present in males and females.

(2) Sex-influenced Traits:
- The traits in which the same gene shows different expression in different sex.
- Sex-influenced genes have alleles which are dominant in one sex but recessive in the other.
- This difference in expression is due to hormonal difference between the males and females.

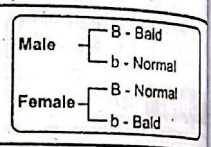
Example of Sex-Influenced Traits:

Body Hair + Baldness in Human:
- In humans, the traits of the amounts of body hair and baldness are sex-influenced traits.

Dominant Allele in Male & Recessive Allele Female:
- The allele of baldness is dominant in men but recessive in women.
- So, a man can be bald when he is homozygous (BB) or heterozygous (Bb) for baldness alleles.
- While a woman can be bald only when she inherits two recessive alleles (bb).

For Information
- Genetics has made significant progress. Now, it is more applied and practical science. For example:
- DNA sequencing and genetic engineering, have enabled researchers to manipulate genes.
- The completion of Human Genome Project has led to a deeper understanding of the genetic basis of various diseases and traits.
- Genetics plays important role in healthcare, helping doctors to diagnose and treat patients based on their unique genetic profiles.

Male	Female
BB - Bald	BB - Normal
Bb - Bald	Bb - Normal
bb - Normal	bb - Bald



Multiple Choice Questions (MCQs)

1. **Traits controlled by alleles present on sex chromosomes are called:**
(A) Polygenic traits. (B) Linked traits. (C) Multiple allelic traits. (D) Sex-linked traits.
2. **Most sex-linked traits are actually:**
(A) Y-linked. (B) X-linked. (C) Autosomal. (D) Polygenic.
3. **The Y chromosome usually carries:**
(A) Almost no functional genes. (B) Many functional genes.
(C) Only dominant genes. (D) Only recessive genes.
4. **Traits controlled by alleles present on both X and Y chromosomes are called:**
(A) Incomplete dominant traits. (B) Pseudo-autosomal (X–Y-linked) traits.
(C) Polygenic traits. (D) Epistatic traits.
5. **Thomas Hunt Morgan discovered sex linkage while studying:**
(A) Human blood groups. (B) Pea plants.
(C) Drosophila. (D) Grasshoppers.
6. **The mutant male Drosophila observed by Morgan had:**
(A) White eyes. (B) Yellow eyes. (C) Brown eyes. (D) Blue eyes.
7. **When a white-eyed male was crossed with a red-eyed female, the F_1 generation consisted of:**
(A) All white-eyed flies. (B) Red-eyed males only.
(C) Red-eyed females only. (D) All red-eyed males and females.
8. **In Morgan's F_2 generation, all white-eyed flies were:**
(A) Females. (B) Males.
(C) Both males and females equally. (D) Sterile.
9. **Morgan's test cross between an F_1 red-eyed female and a white-eyed male produced offspring in the ratio:**
(A) 3 : 1. (B) 9 : 3 : 3 : 1. (C) 1 : 2 : 1. (D) 1 : 1 : 1 : 1.

Key
1.(D)
2.(B)
3.(A)
4.(B)
5.(C)
6.(A)
7.(D)
8.(B)
9.(D)

10. **Morgan concluded that the gene for white eye colour is located on the:**
(A) Y chromosome. (B) X chromosome. (C) Autosome. (D) Mitochondrial DNA.
11. **Why are X-linked traits generally more common in males than females?**
(A) Two Xs. (B) No chromosomes. (C) No Y genes. (D) More autosomes.
12. **Morgan concluded that red eye colour is dominant because:**
(A) All F_1 red. (B) White females. (C) Red males. (D) White disappeared.
13. **Which observation from Morgan's experiment provided evidence that white-eyed females can exist?**
(A) Parental cross. (B) F_2 generation. (C) Test cross. (D) Y discovery.
14. **In Morgan's final cross between a white-eyed female and a red-eyed male, the offspring were:**
(A) All red. (B) All white. (C) White females. (D) Red females.
15. **Which statement best summarizes Morgan's conclusion about sex linkage?**
(A) Autosomal gene. (B) X-linked gene. (C) Sex independent. (D) Identical alleles.
16. **X-linked recessive traits are more common in:**
(A) Females. (B) Both sexes equally. (C) Males. (D) Birds only.
17. **An X-linked recessive trait appears in a female only when she has:**
(A) One recessive allele on one X chromosome.
(B) A Y chromosome.
(C) One dominant allele. (D) Two recessive alleles on both X chromosomes.
18. **In males, an X-linked recessive trait is expressed because:**
(A) They have two X chromosomes.
(B) The Y chromosome does not carry the corresponding allele.
(C) They inherit two recessive alleles. (D) The X chromosome is absent.
19. **Which of the following is an example of an X-linked recessive trait?**
(A) Vitamin D-resistant rickets. (B) Hypertrichosis.
(C) Haemophilia. (D) Webbing of toes.
20. **If a mother has an X-linked recessive trait, all of her _____ will have the trait.**
(A) Sons. (B) Daughters. (C) Grandchildren. (D) Parents.
21. **If a mother is a carrier of an X-linked recessive trait, approximately what percentage of her sons may inherit it?**
(A) 25%. (B) 50%. (C) 75%. (D) 100%.
22. **If a father has an X-linked recessive trait, all of his daughters will be:**
(A) Affected. (B) Normal without the allele. (C) Carriers. (D) Homozygous dominant.
23. **Which of the following is an example of an X-linked dominant trait?**
(A) Colour blindness. (B) Muscular dystrophy. (C) Hypertrichosis. (D) Vitamin D-resistant rickets.
24. **If a father has an X-linked dominant trait, who will inherit it?**
(A) All sons. (B) Half of the sons. (C) All daughters. (D) No offspring.
25. **Holandric genes are found only on the:**
(A) X chromosome. (B) Y chromosome. (C) Autosomes. (D) Mitochondria.
26. **Why are X-linked recessive traits less common in females than in males?**
(A) One X. (B) No X. (C) Y suppression. (D) Two recessives.
27. **Why do sons of an affected father not inherit an X-linked trait from him?**
(A) Father's Y. (B) Two Xs. (C) X to sons. (D) Same allele.
28. **Which statement correctly describes Y-linked traits?**
(A) Both sexes. (B) Father-son. (C) Mother only. (D) Autosomal genes.
29. **Why are Y-linked traits relatively rare?**
(A) Few genes. (B) Larger chromosome. (C) Many dominants. (D) Females Y.
30. **Which of the following is an example of a Y-linked trait?**
(A) Rett syndrome. (B) Colour blindness. (C) Hypertrichosis. (D) Haemophilia.
31. **Haemophilia A is caused by the abnormality of blood clotting factor:**
(A) IX. (B) VIII. (C) XI. (D) VII.
32. **Haemophilia B results from deficiency or abnormality of clotting factor:**
(A) VIII. (B) XI. (C) X. (D) IX.
33. **Haemophilia C is inherited as an:**
(A) X-linked dominant trait. (B) X-linked recessive trait.
(C) Autosomal recessive trait. (D) Y-linked trait.
34. **In people with normal (trichromatic) vision, there are _____ kinds of cone cells.**
(A) One. (B) Two. (C) Three. (D) Four.
35. **The genes for red and green opsins are located on the:**
(A) Chromosome 7. (B) Y chromosome. (C) Chromosome 21. (D) X chromosome.
36. **The gene for blue opsin is located on:**
(A) X chromosome. (B) Y chromosome. (C) Chromosome 7. (D) Chromosome 11.

10.(B)
11.(C)
12.(A)
13.(C)
14.(D)
15.(B)
16.(C)
17.(D)
18.(B)
19.(C)
20.(A)
21.(B)
22.(C)
23.(D)
24.(C)
25.(B)
26.(D)
27.(A)
28.(B)
29.(A)
30.(C)
31.(B)
32.(D)
33.(C)
34.(C)
35.(D)
36.(C)

CamScanner

37. **Dichromacy refers to the perception of:**
(A) One primary colour. (B) Two primary colours.
(C) Three primary colours. (D) Four primary colours.

38. **Blue-cone monochromacy is also known as:**
(A) Red blindness. (B) Green blindness.
(C) Red-green colour blindness. (D) Tritanopia.

39. **The most common type of muscular dystrophy:**
(A) Becker muscular dystrophy. (B) Duchenne muscular dystrophy.
(C) Limb-girdle muscular dystrophy. (D) Myotonic dystrophy.

40. **Duchenne muscular dystrophy results from the inability to produce:**
(A) Myosin. (B) Actin. (C) Dystrophin. (D) Collagen.

41. **Why are Haemophilia A and B more common in males than females?**
(A) Autosomal recessive. (B) X-linked recessive.
(C) Y-linked disorder. (D) No clotting.

42. **Which statement correctly distinguishes Haemophilia C from Haemophilia A and B?**
(A) X-linked dominant. (B) Factor VIII. (C) Factor XI. (D) Males only.

43. **Which opsin genes are responsible for the common X-linked colour blindness?**
(A) Blue only. (B) Red, green. (C) Blue, green. (D) Red, blue.

44. **About what age does Duchenne muscular dystrophy usually become evident?**
(A) At birth. (B) Around 2. (C) Around 4. (D) Around 15.

45. **Which statement about muscular dystrophy?**
(A) Surgical cure. (B) Symptom management. (C) Colour glasses. (D) Respiratory only.

46. **Traits whose genes are present in both sexes but are expressed in only one sex are called:**
(A) Sex-linked traits. (B) Sex-influenced traits. (C) Sex-limited traits. (D) Holandric traits.

47. **Sex-limited traits are expressed due to:**
(A) Mutation. (B) Anatomical or hormonal differences.
(C) Crossing over. (D) Independent assortment.

48. **In sheep, the genes for horn development are present in:**
(A) Males only. (B) Females only.
(C) Both males and females. (D) Neither males nor females.

49. **The genes for milk production are present in:**
(A) Female mammals only. (B) Male mammals only.
(C) Birds only. (D) Both male and female mammals.

50. **The genes responsible for beard growth are expressed only in:**
(A) Females. (B) Both sexes equally. (C) Males. (D) Children.

51. **Sexual dimorphism refers to:**
(A) Male mutation. (B) Phenotypic differences.
(C) Chromosome difference. (D) Crossing over.

52. **In sex-influenced traits, the difference in expression is mainly due to:**
(A) Chromosome number. (B) Mutation.
(C) Hormonal differences. (D) Crossing over.

53. **Which of the following is given as a sex-influenced trait in humans?**
(A) Baldness. (B) Milk production. (C) Beard growth. (D) Ovarian cancer.

54. **The allele for baldness is _____ in men.**
(A) Recessive. (B) Codominant. (C) Dominant. (D) Incomplete dominant.

55. **In women, the allele for baldness behaves as:**
(A) Dominant. (B) Recessive. (C) Codominant. (D) Epistatic.

56. **Why are milk-production genes considered sex-limited rather than sex-linked?**
(A) X chromosome. (B) Females only. (C) Female expression. (D) Y chromosome.

57. **A man will be bald if his genotype is:**
(A) BB only. (B) Bb only. (C) bb only. (D) BB or Bb.

58. **A woman becomes bald only when her genotype is:**
(A) BB. (B) Bb. (C) bb. (D) XY.

59. **Which statement correctly distinguishes sex-limited and sex-influenced traits?**
(A) Sex chromosomes. (B) One sex. (C) Females only. (D) Father inherited.

60. **Which advancement has led to a deeper understanding of the genetic basis of diseases and traits?**
(A) Human Genome. (B) Mendel's laws. (C) Meiosis discovery. (D) Hybridization.

37.(B) 38.(C) 39.(B) 40.(C) 41.(B) 42.(C) 43.(B) 44.(C) 45.(B) 46.(C) 47.(B) 48.(C) 49.(D) 50.(C) 51.(B) 52.(C) 53.(A) 54.(C) 55.(B) 56.(C) 57.(D) 58.(C) 59.(B) 60.(A)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(A)	• The text states that Mendel's results suggested the 3:1 ratio in the F2 generation was really a disguised 1:2:1 ratio, consisting of 1/4 pure-breeding dominant, 2/4 not pure-breeding dominant, and 1/4 pure-breeding recessive.
2.	S/Q	• Because dominant phenotypes can be produced by either homozygous (e.g., RR) or heterozygous (e.g., Rr) genotypes due to complete dominance, where the unexpressed recessive allele is hidden, making visual appearance identical.
3.	(C)	• The text notes that all F1 seeds from the dihybrid cross showed both dominant traits and were heterozygous with genotype RrYy, and that these F1 plants are called dihybrids.
4.	S/Q	• Random alignment ensures that maternal and paternal chromosomes separate independently of each other, producing over 8 million possible allele combinations in human gametes, which are further reshuffled upon fertilization.
5.	(B)	• The text defines pleiotropy as the phenomenon where one gene controls multiple characters, causing them to be linked and controlled by a single gene.
6.	S/Q	• Using the product rule, the probability of inheriting the recessive condition for phenylketonuria is 1/4 and for albinism is 1/4. Therefore, the chance of having a child with both traits is (1/4) \(1/4) = 1/16.
7.	(D)	• The text explains that in incomplete dominance, neither allele is fully dominant, so the heterozygous individual shows an intermediate phenotype between both parents (such as pink flowers from red and white parents).
8.	S/Q	• In incomplete dominance, the two alleles blend their phenotypic effects to show an intermediate phenotype, whereas in codominance, both alleles fully express themselves simultaneously without blending or masking.
9.	(A)	• The text specifies that the ABO system is controlled by the gene I (located on chromosome 9), which has multiple alleles (I^A, I^B, and i).
10.	S/Q	• According to Landsteiner's rule, a person's blood plasma contains antibodies against the antigens they do not have; therefore, an individual with blood group A (possessing antigen A) will have anti-B antibodies in their plasma.
11.	(B)	• The text states that O blood group cells have no antigen-A and antigen-B, meaning recipient antibodies will not attack them, allowing the blood to be given to A, B, AB, or O.
12.	S/Q	• Foetal Rh-positive RBCs enter the mother's circulation, stimulating her to produce anti-Rh antibodies that cross the placenta, destroy foetal red blood cells, and lead to haemolytic anaemia, jaundice, and potential organ damage.
13.	(C)	• The text states that polygenic traits show a range of differences, known as continuous variation, because many alleles contribute to the same trait in an additive way.
14.	S/Q	• Each dominant allele adds red pigment intensity while recessive alleles produce no pigment, resulting in a graded spectrum ranging from maximum pigment in AABBCC (dark red) to zero pigment in aabbcc (white), producing a 1:6:15:20:15:6:1 distribution.
15.	(D)	• The text defines epistasis as gene interaction where an allele masks or modifies the effect of alleles of other genes at different loci, where the modifying allele is epistatic and the masked one is hypostatic.
16.	S/Q	• The hh genotype fails to produce the essential precursor H substance, meaning the enzymes produced by I^A and I^B have no substrate to modify into antigen-A or antigen-B, resulting in an O phenotype.
17.	(A)	• The text states that genes present on the same chromosome are called linked genes, and because they are arranged closely together, they tend to stay together during gamete formation.

CamScanner

18.	S/Q	• Independent assortment produces a 9:3:3:1 ratio with new recombinant combinations appearing frequently, whereas linked genes produce a significant excess of parental combinations because they do not assort independently.
19.	(A)	• The text explicitly notes that during the formation of gametes in meiosis-I, homologous chromosomes go through crossing over, swapping sections of DNA to recombine linked genes.
20.	S/Q	• Homogametic females produce all eggs carrying a single type of sex chromosome (X), whereas heterogametic males produce two distinct types of sperm, carrying either an X or a Y chromosome.
21.	(B)	• The text states that the ZW-ZZ system of sex determination is common in birds, where females are ZW and males are ZZ.
22.	S/Q	• Because the white-eye allele is an X-linked recessive trait and the Y chromosome carries no functional allele to mask it, males require only one recessive copy on their single X chromosome to express the white-eyed phenotype.
23.	(C)	• The text explains that amniocentesis involves inserting a long needle into the amniotic sac to extract fluid containing foetal cells, which are cultured and checked for abnormal chromosome numbers.
24.	S/Q	• Males are hemizygous because they possess only one X chromosome; therefore, inheriting a single recessive allele guarantees the expression of the trait, whereas females must inherit two recessive alleles across both X chromosomes.
25.	(A)	• he text states that Haemophilia C is due to abnormal blood clotting factor XI and is an autosomal recessive trait, making it present in both genders equally, unlike X-linked recessive types A and B.
26.	S/Q	• Dichromacy occurs when an individual lacks the specific pigment protein (opsin) for one of the three primary cone cells; because the genes for red and green opsins reside on the X chromosome, their mutations result in X-linked color blindness.
27.	(A)	• The text states that sex-limited traits have genes present in both sexes on autosomes/chromosomes, but they are expressed in only one sex due to anatomical or hormonal differences (such as milk production or beard growth).

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. **In the monohybrid cross of Mendel, when a pure round-seeded plant was crossed with a wrinkled-seeded plant, all the F1 progeny were round-seeded, because of:**
   (a) Co-dominance. (b) Incomplete dominance.
   (c) Complete dominance. (d) Epistasis.
2. **In a cross of AaBb × AaBb, what fraction of the offspring can be expected to express one of the two dominant alleles, but not both?**
   (a) 1/16 (b) 6/16 (c) 9/1 (d) 16/16
3. **In which of these cases, two genes can experience independent assortment?**
   (a) They are located in close proximity on the same chromosome.
   (b) Crossing over between the genes does not occur.
   (c) They are located on different chromosomes or are far apart on the same chromosome.
   (d) The expression of one gene does not affect the expression of the other.
4. **The blood group AB may be given to a person who has blood group:**
   (a) A (b) O (c) B (d) AB
5. **If father has blood group B and the mother has blood group A, what blood groups their children have?**
   (a) A or B only. (b) AB only. (c) AB or O only. (d) A, B, AB or O.

6. **A gene for corn has two alleles, one for yellow kernels and one for white kernels. Cross pollination of yellow corn and white corn results in ears with approximately equal number of yellow and white kernels. Which term best describes the relationship between the two alleles?**
   (a) Crossing over. (b) Recombination. (c) Incomplete dominance. (d) Codominance.
7. **A cross between two plants with genotypes AaBb and AaBb results in an F 1 generation that is 25% AABB, 50% AaBb, and 25% aabb. Which reason most likely explains why other possible genotypes are not present?**
   (a) The genes underwent independent assortment.
   (b) The loci of the genes are close together.
   (c) The loci of the genes are on different chromosomes.
   (d) Crossing over occurred between chromosomes.
8. **In pea plants, the allele for tall stalks (T) is dominant over the allele for short stalks (t). Suppose a cross between a tall pea plant and a short pea plant produces 43 tall offspring and 47 short offspring. If one of the tall offspring is crossed with one of the short offspring, what ratio of genotypes would be most likely in their offspring?**
   (a) 1TT:2Tt:1tt (b) 3Tt:1tt (c) All Tt (d) 1Tt:1tt
9. **Allele B produces black coat colour while b produces white coat colour. Allele C produces curly fur while c produces straight fur. In a cross between two BbCc parents, predict the fraction of offspring with black coat colour and straight fur.**
   (a) 1/16 (b) 9/16 (c) 3/4 (d) 16/16
10. **What is the criterion to mark an allele as dominant?**
    (a) The frequency of the allele in population.
    (b) The expression of the allele in heterozygous genotype.
    (c) The location of the allele on chromosome.
    (d) The frequency of the crossing over of the allele.
11. **Which of these characters is controlled by a multiple allelic system?**
    (a) ABO blood group system. (b) Rh blood group system.
    (c) MNS blood group system. (d) All of these.
12. **Albinism is caused by a recessive gene. A woman with albino father marries an albino man. What will be the proportion of her progeny?**
    (a) 2 normal : 1 albino (b) All normal. (c) All albino. (d) 1 normal : 1 albino
13. **When the activity of one gene is suppressed by the activity of a non-allelic gene, it is known as;**
    (a) Incomplete dominance. (b) Epistasis. (c) Complete dominance. (d) Multiple allelic effect.
14. **Which of the following is a result of Erythroblastosis fetalis?**
    (a) Anaemia in the foetus. (b) Jaundice in the foetus.
    (c) Mental retardation in the foetus. (d) All of these.
15. **Colour blindness is more common in males because it is a/an:**
    (a) Autosomal trait. (b) X-linked dominant trait.
    (c) X-linked recessive trait. (d) Y-linked trait.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(c)	Complete dominance.	• The dominant allele (round) completely masks the recessive allele (wrinkled) in the F1 heterozygous generation.
2.	(b)	6/16	• The fraction of offspring expressing one dominant allele and one recessive trait is 3/16 + 3/16 = 6/16.
3.	(c)	They are located on different chromosomes or are far apart on the same chromosome.	• Independent assortment occurs when genes are unlinked, either by residing on separate chromosomes or via frequent crossing over due to a large distance on the same chromosome.

CamScanner

4.	(d)	AB	• A person with blood group AB can only receive blood from blood group AB safely, or as a universal recipient for red cells in specific contexts, but strictly speaking among the choices an AB individual possesses both antigens and accepts AB.
5.	(d)	A, B, AB or O	• If the father is heterozygous I^Bi and the mother is heterozygous I^Ai, all four blood groups (A, B, AB, O) are possible in their children.
6.	(d)	Codominance	• An approximately equal number of distinct yellow and white kernels on the same ear indicates that both alleles express themselves fully without blending.
7.	(b)	The loci of the genes are close together.	• The absence of expected recombinant genotypes points to complete genetic linkage where genes are very close and do not undergo independent assortment.
8.	(d)	1 Tt : 1 tt	• A tall offspring must be heterozygous (Tt) based on the test cross results (1:1 ratio), and crossing it with a short offspring (tt) yields a 1 Tt : 1 tt genotypic ratio.
9.	(b)	3/16	• The probability of black coat (B, 3/4) multiplied by straight fur (cc, 1/4) equals 3/16.
10.	(b)	The expression of the allele in heterozygous genotype.	• By definition, a dominant allele is the one that expresses its phenotypic trait even when present in a single copy in a heterozygous state.
11.	(a)	ABO blood group system.	• (According to text Option (a) is correct) At advanced level of genetics the correct option is (d) All of these.
12.	(d)	1 normal : 1 albino	• The woman must be a carrier (Aa) since her father was albino (aa), and marrying an albino man (aa) results in a 1:1 ratio of normal carriers to albino offspring.
13.	(b)	Epistasis.	• Epistasis describes a genetic interaction where one non-allelic gene masks or suppresses the phenotypic expression of another.
14.	(d)	All of these.	• Erythroblastosis fetalis leads to severe hemolytic disease, causing fetal anemia, jaundice, and potential neurological damage or mental retardation from bilirubin buildup.
15.	(c)	X-linked recessive trait.	• Males have only one X chromosome, meaning a single recessive allele for color blindness on the X chromosome will directly manifest the trait.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Name the main exceptions to the Mendel's laws of inheritance.

Ans. Main Exceptions to the Mendel's laws of Inheritance:

- **Major Exceptions:** Include incomplete dominance, co-dominance, multiple alleles, polygenic inheritance, and gene linkage.
- **Deviation:** These phenomena show inheritance patterns that deviate from standard Mendelian ratios.

Q.2 What is probability? How does probability relate to genetics?

Ans.

- **Probability:** It is the measure of the **likelihood** that a specific event will occur.
- **Genetic Relation:** It is used to predict the expected outcomes and ratios of genotypes and phenotypes in genetic crosses.

Q.3 Justify that multiple alleles provide many different phenotypes.

Ans. Multiple Alleles Provide Many Different Phenotypes:

- **Allelic Combinations:** Multiple alleles provide more than two alternative forms of a gene for a single locus within a population.

- **Phenotypic Diversity:** Different pairwise combinations of these alleles produce a wide array of distinct physical traits or phenotypes.
- **Examples:** Blood group A, B, AB, O.

Q.4 Name various human blood group systems.

Ans. Various Human Blood Group Systems:

- **Major Systems:** Include the **ABO blood group system** and the **Rh (Rhesus)** blood group system.
- **Other Systems:** Include MNS, Kell, Lutheran, Lewis, and Duffy blood group systems.

Q.5 What do you mean by multiple alleles? Name the alleles responsible for ABO blood group system.

Ans. Multiple Alleles:

- Three or more alternative forms of a gene that occupy the same locus on a chromosome are called multiple alleles.
- **ABO Alleles:** Controlled by three alleles: I^A, I^B, and i.

Q.6 What is co-dominance? Give an example.

Ans. Co-dominance Definition:

- A condition where both alleles in a heterozygous organism are fully and simultaneously expressed.
- **Example:** The AB blood group in humans, where both I^A and I^B alleles express their respective antigens equally.

Q.7 What antigens and antibodies are found in ABO blood group system?

Ans.

Antigens	Antibodies
• Type A has A antigen, Type B has B antigen, Type AB has both, and Type O has neither.	• Type A has anti-B, Type B has anti-A, Type AB has no antibodies, and Type O has both anti-A and anti-B antibodies.

Q.8 Justify why O-negative individuals are called universal donors and AB-positive individuals are called universal recipients.

Ans.

- **O-negative As Universal Donors:** O-negative red blood cells lack A, B, and Rh antigens, preventing immune rejection in any recipient. Thus this group can be donated to all groups.
- **AB-Positive As Universal Recipients:** AB-positive individuals lack antibodies against A, B, and Rh antigens in their plasma. Thus this group can receive from all blood groups A, B, AB or O.

Q.9 Why is human male referred to as heterogametic?

Ans.

- **Sex Chromosomes:** Human males possess **two different** sex chromosomes, one X and one Y (XY).
- **Gamete Production:** They produce two different types of sperm cells: 50% carrying an X chromosome and 50% carrying a Y chromosome, that's why human males are called heterogametic.

Q.10 What is gene linkage?

Ans. Gene Linkage:

- The tendency of genes located close together on the same chromosome to be inherited together during meiosis is called **gene linkage.**
- Linked genes do not assort independently unless separated by crossing over.

Q.11 How can the linked gene assort independently?

Ans. Linked Gene of Assort Independently:

(i) **Crossing Over:** Linked genes can separate and recombine through crossing over (homologous recombination) during prophase I of meiosis.

(ii) **Distance Factor:** Greater physical distance between genes increases the frequency of crossover events between them.

CamScanner

Q.12 List at least five polygenic traits in humans.

Ans. Five Polygenic Traits in Humans:
(i) Include skin color. (ii) Height. (iii) Eye color. (iv) Intelligence. (v) Weight.

Q.13 Write brief note on Y-linked inheritance in humans.

Ans. Y-linked Inheritance in Humans:
- Traits controlled by genes located exclusively on the non-homologous region of the Y chromosome are called **Holandric Traits.**
- **Transmission Pattern:** They are passed directly exclusively from father to **all sons** and never to daughters.

Q.14 Define sex linkage and give an example.

Ans. Sex Linkage:
- The phenotypic expression of an allele related to the sex or X-chromosome of the individual are called **sex linkage**
- **Example:** Red-green color blindness or hemophilia in humans, controlled by genes on the X chromosome.

Q.15 Solve the following genetic problems:

i. **A plant of genotype AABbCC is self-pollinated. Calculate the phenotypic ratio of F2 generation.**

ii. **In four-o'clock plant, the red and white flower colours show incomplete dominance. Calculate the ratios in crosses between (i) two red-flowered plants; (ii) a red-flowered and a pink-flowered plant; (iii) a pink-flowered and a white-flowered.**

iii. **A man with blood group A marries a woman who has blood group AB. What blood groups are expected among their children?**

iv. **Two white sheep produce a black offspring. What are the parents' genotypes for the colour? What is the probability that their next offspring will be black?**

v. **Albinism (lack of pigment) in man is caused by a recessive gene. If normal parents have an albino child, what is the probability that their next child will be normal for colour?**

Ans. Solution Q.15

i. **Phenotypic Ratio of AABbCC self-Pollinated:**
- **Homozygous Genes (A & C):** AA × AA and CC × CC yield 100% dominant phenotypes for traits A and C, contributing no variation (Ratio = 1).
- **Heterozygous Gene (B):** Bb × Bb acts as a monohybrid cross, yielding 3 Dominant (BB, Bb): 1 Recessive (bb) offspring's.
- **Product Rule Calculation:** Multiplying ratios across all three loci gives (1 for A) × (3:1 for B) × (1 for C) = 3:1.
- **Phenotypic Outcome:** 75% of offspring show all dominant traits (A_B_C) and 25% show dominant traits for A and C, but recessive for B (A_bbC_)

ii. **Four-o'clock Plant Incomplete Dominance Crosses: (For detail See Page No.150)**
- Two red-flowered plants (RR\RR) produce 100% red offspring.
- Red and pink (RR\RW) produce 1 red : 1 pink ratio.
- Pink and white (RW\ww) produce 1 pink : 1 white ratio.

iii. **Blood Group A Man and AB Woman Children:**
Expected blood groups are A, B, and AB (depending on whether the man is homozygous I^AI^A or heterozygous I^Ai).

Homozygous Father I^AI^A × I^AI^B Mother

	I^A	I^B
I^A	I^AI^A (Blood Group A)	I^AI^B (Blood Group AB)
I^A	I^AI^A (Blood Group A)	I^AI^B (Blood Group AB)

Heterozygous Father I^Ai × I^AI^B Mother

	I^A	I^B
I^A	I^AI^A (Blood Group A)	I^AI^B (Blood Group AB)
i	I^Ai (Blood Group A)	I^Bi (Blood Group B)

iv. **Two White Sheep Produce a Black Offspring:**
- **Parents' Genotypes:** Both parents must be heterozygous (Ww), where the dominant allele (W) produces white wool and the recessive allele (w) produces black wool.
- **Explanation:** The black offspring must be homozygous recessive (ww), having inherited one hidden recessive w allele from each white parent.
- **Probability for Next Offspring:** Crossing two heterozygous parents (Ww × Ww) yields a 3:1 phenotypic ratio, resulting in a **1/4 or 25%** chance that their next offspring will be black.
- W = White (dominant) Sheep
- w = Black (Recessive) Sheep

(White Sheep) Ww × Ww (White Sheep)

	W	w
W	WW (White Sheep)	Ww (White Sheep)
w	Ww (White Sheep)	ww (Black Sheep)

Probability for next offspring = 1/4 or 25%

v. **Normal Parents have an Albino Child:**
- Parents must be heterozygous carriers (Aa\Aa). The probability that their next child will be normal for color is 3/4 (75%).
- A = Normal (Dominant)
- a = Albino (Recessive)

Aa × Aa

	A	a
A	AA (normal)	Aa (normal)
a	Aa (normal)	aa (Albino)

Probability of next Normal child = 3/4 75%

Q.16 Differentiate between:
- Gene and allele
- Homozygous and heterozygous
- Incomplete dominance and co-dominance
- XX-XY and ZZ-ZW sex determination
- Sex-linked and sex-limited traits
- Genotype and phenotype
- Monohybrid and dihybrid cross
- Epistasis and polygenic inheritance
- XX-XY and XX-XO sex determination
- Sex-limited and sex-influenced traits

Ans. Gene and Allele:

Gene	Allele
• A gene is a DNA sequence determining a trait.	• An allele is a specific variant form of that gene.

Genotype and Phenotype:

Genotype	Phenotype
• Genotype is the genetic makeup of an organism.	• Phenotype is its observable physical or biochemical trait.

Homozygous and Heterozygous:

Homozygous	Heterozygous
• Homozygous individuals have two identical alleles for a trait.	• Heterozygous individuals have two different alleles.

Monohybrid and dihybrid cross:

Monohybrid	Dihybrid Cross
• Monohybrid are the offspring of parents that differed in one contrasting pair of trait.	• Dihybrid are the organisms which have hybrid condition in two traits.

Incomplete Dominance and co-Dominance:

Incomplete Dominance	Co-Dominance
• Incomplete dominance results in a blended intermediate phenotype.	• Co-dominance expresses both alleles fully and distinctly.

CamScanner

Epistasis and polygenic inheritance

Epistasis	Polygenic Inheritance
• A genetic interaction where one gene masks or overrides the expression of a completely different gene. • **Example:** Bombay phenotype	• A genetic pattern where multiple independent genes work together to control a single trait with a wide range of variation. • **Example:** Human height.

XX-XY and ZZ-ZW sex Determination:

XX-XY Sex Determination	ZZ-ZW Sex Determination
• In XX-XY systems, females (XX) are homogametic and males (XY) are heterogametic. • **Example:** Humans.	• ZZ-ZW sex determination is a chromosomal system where females are heterogametic (ZW) and determine the offspring's sex, while males are homogametic (ZZ).

XX-XY and XX-XO sex determination:

XX-XY Sex Determination	XX-XO Sex Determination
• In XX-XY systems, females (XX) are homogametic and males (XY) are heterogametic. • **Example:** Humans.	• In XX-XO systems, females (XX) are homogametic and males (XO) are heterogametic. • **Example:** Grasshopper.

Sex-linked and sex-limited traits:

Sex-linked	Sex-limited
• Sex-linked traits are encoded by genes located on sex chromosomes.	• Sex-limited traits are autosomal traits expressed in only one sex due to physiological differences.

Sex-limited and sex-influenced traits

Sex-limited	Sex-influenced
• A sex limited trait is limited to only one sex due to anatomical differences.	• Sex influenced trait occurs in both males and females but is more common in one sex.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Explain Mendel's experiment which led to the formulation of the law of independent assortment.

Ans. See Page No. 143 (Q.3)

Q.2 Explain incomplete dominance and exemplify it through the inheritance of flower colour in 4 O' clock plant.

Ans. See Page No. 149 (Q.10)

Q.3 Explain Erythroblastosis foetalis in the light of antigen-antibody reaction. What measures can be taken to prevent Erythroblastosis foetalis?

Ans. See Page No. 157 (Q.25)

Q.4 Describe polygenic inheritance, using an example from grain colour in wheat.

Ans. See Page No. 160 (Q.29)

Q.5 Explain epistasis with the help of an example.

Ans. See Page No. 161 (Q.30)

Q.6 Explain how gene linkage counters independent assortment and crossing-over modifies the progeny.

Ans. See Page No. 164 - 166 (Q.36, Q.38)

Q.7 Exemplify the concept of gene linkage by quoting the example of wing length and width of abdomen in Drosophila melanogaster.

Ans. See Page No. 165 (Q.37)

Q.8 Explain the XX-XY mechanism of sex determination in Drosophila and mammals.

Ans. See Page No. 168 (Q.42)

Q.9 Describe the XX-XO and ZZ-ZW sex determination systems and evaluate by studying the karyotype.

Ans. See Page No. 169 – 170 (Q.43, Q.45)

Q.10 Explain the inheritance of a sex-linked trait in Drosophila.

Ans. See Page No. 171 (Q.48)

Q.11 Describe sex-influenced and sex-limited traits with common examples from human genetics.

Ans. See Page No. 177 (Q.59)

Q.12 Write a note on the inheritance of haemophilia in humans.

Ans. See Page No. 174 (Q.56)

Q.13 Write a note on the inheritance of colour blindness in humans.

Ans. See Page No. 175 (Q.57)

Q.14 Explain Morgan's experiment to explain crossing over and gene linkage.

Ans. See Page No. 171 (Q.48)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Collect data from the class or the college to see how many individuals have *AB* blood group and construct a pie chart and histogram for the collected data.

Ans.

Blood Group	Number of Students	Percentage (%)
A	20	20
B	35	35
AB	10	10
O	35	35
Total	100	100

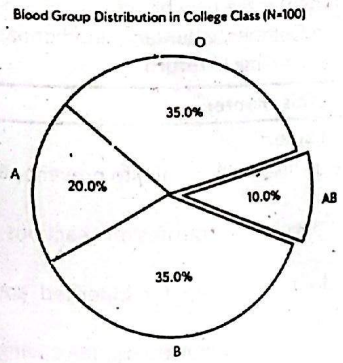
Key Observation:

- **AB Blood Group Count:** 10 individuals out of 100 (10% of the class) have the AB blood group.
- **Genotypic Reason:** AB blood group is the rarest because it requires inheriting both codominant alleles (I^A and I^B) together from parents.

Visual Representations:

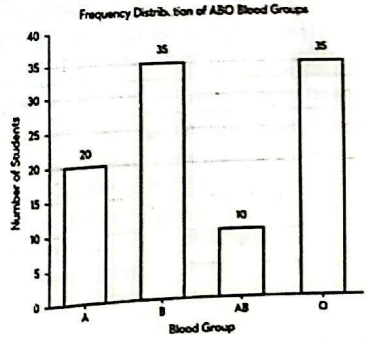
i. Pie Chart (Proportional Share)

- Shows the percentage breakdown of each blood group across the entire class population.



ii. Histogram (Frequency Distribution)

Displays the exact count of students for each blood group side-by-side.



Q.2 Use a die to calculate how many times out of 100 throws can you get sixes.

Ans.
- **Probability Per Roll:** Each throw of a fair six-sided die has a 1 in 6 (16.67%) chance of landing on a six.
- **Expected Average:** Out of 100 throws, the mathematical expected value is $100 \times 1/6 \approx 16.67$, meaning you will average 16 to 17 sixes.
- **Practical Variation:** Because each roll is independent and random, an actual test of 100 throws will typically land between 11 and 22 sixes.

Q.3 Derive an idea to get alternatives of blood transfusion. (Reference could be made to synthesized plasma and serum).

Ans.
- **Artificial Blood (HBOCs):** Engineered hemoglobin substitutes bind to oxygen in the lungs and release it directly to body tissues, performing the core job of red blood cells.
- **Synthesized Plasma & Serum Expanders:** Lab-made solutions containing proteins like recombinant albumin help maintain blood volume and osmotic pressure during severe blood loss.
- **Perfluorocarbon Chemicals:** Synthetic liquid compounds dissolve oxygen gas directly into the bloodstream without needing actual biological blood cells.
- **Stem Cell-Cultured Red Cells:** Red blood cells grown in biotechnology labs from stem cells serve as clean, pathogen-free replacements for donated red blood cells.

Q.4 Justify why a recessive blood group allele of 'i' is more frequent in population.

Ans.
- **Heterozygous Masking:** The recessive i allele remains hidden in heterozygous carriers (I^Ai and I^Bi), allowing it to be inherited silently without being eliminated by phenotypic selection.
- **Gametic Transmission:** Heterozygous parents have a 50% chance of passing the i allele to their gametes during meiosis, ensuring a high rate of allele inheritance in every generation.
- **High Carrier Pool:** Because heterozygous carriers outnumber homozygous individuals, cross-matings between carriers continuously produce and preserve the i allele in the population.
- Inheriting the i allele in either single copy (I^Ai, I^Bi) or double copy (ii) produces a fully functional, non-lethal phenotype, allowing carriers to reproduce freely.

Q.5 Justify blood donation as a service to suffering humanity.

Ans. Blood Donation As a Service to Suffering Humanity:
- **Saves Lives in Emergencies:** Blood transfusion replaces lost blood after accidents or surgeries, saving patients from dying due to sudden blood loss.
- **Helps Patients with Blood Diseases:** It gives fresh blood to people with lifelong blood conditions, like thalassemia, who cannot make enough healthy blood on their own.
- **Supports Cancer and Transplant Patients:** It keeps patients stable during strong medical treatments like chemotherapy and organ transplants when their body cannot make new blood.
- **Acts as a Gift of Kindness:** Since blood cannot be made in factories, voluntary blood donation is a pure act of human help that saves strangers without expecting anything in return.

Q.6 Suggest ways to save lives through the knowledge gained in this chapter.

Ans. Ways to Save Lives through the Knowledge Gained in this Chapter:
- **Pre-Marital Screening:** Tests carriers of recessive disorders (like thalassemia) to prevent passing severe genetic diseases to future children.
- **Safe Blood Matching:** Uses ABO and Rh genetics to prevent fatal transfusion reactions and protect newborns form Rh incompatibility diseases.
- **Pedigree Analysis:** Traces family trees to identify individuals at risk for inherited conditions like hemophilia for early medical care.
- **Early Genetic Diagnosis:** Identifies genetic defects at birth to start immediate, life-saving treatments and specialized care.

SELF-ASSESSMENT

Q.1 Encircle the correct option. Total Mark: 30

(i) The specific position of a gene on a chromosome is called its: (1 x 6 = 06)
(A) Genome. (B) Locus. (C) Chromatid. (D) Centromere.

(ii) In a cross of AaBb × AaBb, what fraction of the offspring can be expected to express one of the two dominant alleles, but not both?
(A) 1/16 (B) 6/16 (C) 9/1 (D) 16/16

(iii) Albinism is caused by a recessive gene. A woman with albino father marries an albino man. What will be the proportion of her progeny?
(A) 2 normal : 1 albino (B) All normal.
(C) All albino. (D) 1 normal : 1 albino

(vi) A dihybrid plant with genotype RrYy produces _____ different types of gametes.
(A) Two. (B) Three. (C) Four. (D) Sixteen.

(v) Which blood group has neither antigen-A nor antigen-B on red blood cells?
(A) A. (B) B. (C) AB. (D) O.

(vi) When two heterozygous black Labradors (BbEe × BbEe) are crossed, the phenotypic ratio is:
(A) 9 : 3 : 3 : 1. (B) 1 : 2 : 1. (C) 3 : 1. (D) 9 : 3 : 4.

Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) What is test cross? What is its use?
(ii) Justify that multiple alleles provide many different phenotypes.
(iii) What is gene linkage?
(iv) Differentiate between Genotype and phenotype.
(v) Differentiate between universal donors & universal recipients of ABO blood group system.
(vi) Who proposed the chromosomal theory of inheritance & state its two main points.
(vii) A pink flower four O'clock plant is crossed with a red flower plant. Find the probability of Red flower plant.
(viii) What is SRY-gene? Write its importance.

Q.3 Extensive Questions. (4 × 2 = 8)

(a) Discuss the inheritance and principle of transfusion of ABO Blood Groups.
(b) What is muscular dystrophy? Discuss effects and treatment of Duchenne muscular dystrophy as an example of muscular dystrophy.

CamScanner

ENTRANCE TEST MDCAT

1. X-linked recessive trait is: (UHS 2015)
A. Hypophosphatemia. B. Haemophilia. C. Vitamin-D resistant rickets. D. Diabetes mellitus.

2. Human skin color is a good example of: (UHS 2015)
A. Sex linked inheritance. B. x-linked inheritance.
C. polygenic inheritance. D. y-linked inheritance.

3. Number of pairs of autosomes in humans is: (UHS 2015)
A. 23 B. 21 C. 24 D. 22

4. ABO blood system is an example of: (UHS 2015)
A. Polygenes. B. Multiple alleles. C. Multiple genes. D. Multiple mutation.

5. Structures found in different species which are believed to have a common evolutionary origin are: (UHS 2016)
A. Homologus. B. Vestigeal. C. Analogous. D. Fossilized.

6. Which one of the following is X-linked trait? (UHS 2016)
A. Male pattern baldness. B. Haemophilia. C. Diabetes mellitus D. Erythroblastosis foetalis.

7. A character determined by three alleles is: (UHS 2016)
A. Human skin color. B. Human eye color. C. Human blood group. D. Human Rh factor.

8. The condition in which heterozygote has a phenotype intermediate between contrasting homozygous parents is called: (UHS 2017)
A. Dominance. B. Over dominance. C. Co-dominance. D. Incomplete dominance.

9. The interaction between different genes occupying different loci is: (UHS 2017)
A. Dominance. B. Pleiotropy. C. Co-dominance. D. Epistasis.

10. Locus stands for: (UHS 2017)
A. Position of gene on homologous chromosomes. B. Regions of chromosomes.
C. Position of an allele within a DNA molecule. D. Close regions of same chromosomes.

11. Self-fertilization of F_1 dihybrids, following independent assortment of alleles will result in: (UHS 2017)
A. 3/16 Tall, round:3/16 Dwarf, wrinkled. B. 9/16 Tall, round:1/16 Dwarf, round.
C. 9/16 Tall, wrinkled:1/16 Dwarf, round. D. 3/16 Tall, wrinkled:3/16 Dwarf, round.

12. As a result of cross-fertilization of true breeding pea plant having purple colored flowers with that of white colored flowers, the offsprings will have flowers with: (UHS 2017)
A. ¼ purple and 2/4 white. B. All white.
C. ¼ white and ½ purple. D. All purple.

13. The gene for red-green color blindness is present on: (UHS 2017)
A. Y-chromosome. B. Autosome No. 7. C. X-chromosome. D. Autosome No. 9.

14. Chance of a cross over between two loci is directly proportional to their: (UHS 2018)
A. Thickness. B. Length. C. Width. D. Distance.

15. There are _____ number of linkage groups in human: (UHS 2018)
A. 46 B. 80 C. 22 D. 23

16. _____ is the exact position of a gene on the chromosome: (UHS 2018)
A. Traits. B. Genotype. C. Centromere. D. Locus.

17. Which one of the following is a multiple allelic character? (UHS 2018)
A. Color of flower in pea plant. B. Shape of seed in pea plant.
C. Blood group of the human being. D. Length of stem in pea plant.

18. When two or more Alleles do not show complete dominance or both the Alleles are expressing independently in heterozygotic condition. Such a condition is called: (UHS 2018)
A. Complete dominance. B. Co dominance. C. Over dominance. D. Incomplete dominance.

19. A person was married to his cousin and both are heterozygous for sickle cell anaemia. Among their four kids, what will be proportion of affected homozygotes? (UHS 2019)
A. 50% B. 75% C. 25% D. 100%

20. Homozygous means: (UHS 2019)
A. Having two identical alleles of a gene. B. Alleles in an organism.
C. Having two identical genes. D. Two different alleles of a gene.

21. In genetics, the term locus refers to the _____ of the gene on the chromosome: (UHS 2019)
A. Frequency. B. Position. C. Copy. D. Inversion.

22. In which situation, Genes are not assorted independently during Meiosis in a chromosome? (UHS 2019)
A. When genes are not linked and their loci are far apart.
B. When there are two many genes on a chromosome.
C. When some genes have mutated on the chromosome.
D. When genes are linked and their loci are close to each other.

23. If a carrier haemophilic female (X^HX^h) is married to a haemophilic male (X^hY). What will be the ration of presence of haemophilia in the children? Select best answer from given condition: (UHS 2019)
$X^HX^h \times X^hY$
A. 100% all females and males will be hemophilic.
B. Carrier female 25%, hemophilic female 25%, 25% normal male and 25% hemophilic male.
C. Females and males both have 50% chances of getting hemophilia.
D. Females have 50% chances of getting hemophilia and males will be 100% hemophilic.

24. Blood group AB is an example of _____: (UHS 2019)
A. Complete dominance. B. Incomplete dominance.
C. Recessive alleles. D. Co-dominance.

25. A person was married to his cousin and both are heterozygous for sickle cell anaemia. Among their four kids, what will be proportion of affected homozygotes? (UHS 2019)
A. 50% B. 75% C. 25% D. 100%

26. Homozygous means: (UHS 2019)
A. Having two identical alleles of a gene. B. Alleles in an organism.
C. Having two identical genes. D. Two different alleles of a gene.

27. In genetics, the term locus refers to the _____ of the gene on the chromosome: (UHS 2019)
A. Frequency. B. Position. C. Copy. D. Inversion.

28. In which situation, Genes are not assorted independently during Meiosis in a chromosome? (UHS 2019)
A. When genes are not linked and their loci are far apart.
B. When there are two many genes on a chromosome.
C. When some genes have mutated on the chromosome.
D. When genes are linked and their loci are close to each other.

29. If a carrier haemophilic female (X^HX^h) is married to a haemophilic male (X^hY). What will be the ration of presence of haemophilia in the children? Select best answer from given condition: (UHS 2019)
$X^HX^h \times X^hY$
A. 100% all females and males will be hemophilic.
B. Carrier female 25%, hemophilic female 25%, 25% normal male and 25% hemophilic male.
C. Females and males both have 50% chances of getting hemophilia.
D. Females have 50% chances of getting hemophilia and males will be 100% hemophilic.

30. Blood group AB is an example of _____: (UHS 2019)
A. Complete dominance. B. Incomplete dominance.
C. Recessive alleles. D. Co-dominance.

ANSWERS KEY

1. B	2. C	3. D	4. B	5. A	6. B	7. C	8. D	9. D	10. C	11. D	12. D	13. C	14. D	15. D
16. D	17. C	18. B	19. C	20. A	21. B	22. D	23. B	24. D	25. C	26. A	27. B	28. D	29. B	30. D

FIND US ON
Facebook
LIKE OUR PAGE TODAY
@SCHOLARPUBLICATIONS.PK

SCHOLAR PUBLICATIONS

19 CHAPTER

CHROMOSOME AND DNA

Student Learning Outcomes (SLOs)

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

- Annotate the detailed structure of a chromosome.
- Narrate the experimental work of Griffith and Hershey-Chase, which proved that DNA is the hereditary material.
- Describe the three models proposed about the mechanism of DNA replication.
- Describe the events of the process of DNA replication.
- Describe DNA stability and variability as two characters of the replicating DNA molecule.
- Describe the characteristics of genetic code (universal, triplet, non-overlapping, degenerate, has no punctuation).
- Differentiate between the terms genetic code and codon.
- Explain the mechanism of transcription.
- Explain why the length of transcribed mRNA molecule (in Eukaryotes) shortens as it enters the cytoplasm for translation.
- Describe the mechanism of protein synthesis.
- State the difference between protein synthesis in prokaryotes and eukaryotes.
- Suggest possible ways in which the synthesized protein can be used within or outside a cell that synthesized it.
- State the importance of the regulation of gene expression.
- Describe the negative control of gene expression by repressor proteins.
- Describe the positive control of gene expression by activator proteins.
- Define mutation and identify various sources of mutation.
- Differentiate between natural and induced mutations and mutagens.
- Justify most mutations are harmful.
- Rationalize that mutations might be a contributing factor towards evolution.
- Describe the symptoms, causes and possible available treatments of some of the chromosomal mutations. (Down, Klinefelter and Turner syndrome).
- Describe the symptoms, causes and possible available treatments of some of the gene mutations.

CamScanner

Chromosome And DNA — Concept Map

1. CHROMOSOME STRUCTURE
- **Morphology →** Chromatids, centromere (kinetochore), NOR/satellite, telomeres, centromere types.
- **Chemical Composition & Organization →** 40% DNA, 60% histones; Nucleosome string (11nm), Chromatin fibre (30nm), Chromatids (700nm); heterochromatin vs euchromatin.
- **Genes & Alleles →** Johannsen (1909); gene as polypeptide DNA code; locus; alleles.

2. DNA AS HEREDITARY MATERIAL
- **Griffith's Experiment (1928) →** S/R strains & bacterial transformation (Avery-MacLeod-McCarty).
- **Hershey-Chase Experiments (1952) →** 35S & 32P bacteriophages proving DNA is genetic material.

3. DNA REPLICATION
- **Models →** Conservative, Semi-conservative, Dispersive.
- **Meselson-Stahl Experiment (1958) →** 15N/14N isotope centrifugation proving semi-conservative.
- **Mechanism →** Initiation (helicase, gyrase), Primer (primase), Extension (Pol III leading/lagging), Termination (Pol I, ligase), stability vs mutation.

4. GENE EXPRESSION
- **Genetic Code →** Triplet codons, 64 total, stop/start, Nirenberg/Khorana.
- **Characteristics →** Universal, triplet, degenerate, continuous, non-overlapping.

5. TRANSCRIPTION
- **Phases →** Initiation (promoters, sigma), Elongation (5' to 3'), Termination (GC hairpin).
- **Post-Transcriptional Modifications →** 5' cap, 3' poly-A tail, splicing (introns/exons).

6. TRANSLATION
- **Activation →** Aminoacyl-tRNA synthetase.
- **Phases →** Initiation, Elongation (A/P/E sites, translocation), Termination (release factor).
- **Prokaryotic vs Eukaryotic Differences →** Introns, processing, 70S vs 80S, start amino acid.

7. REGULATING GENE EXPRESSION
- **Importance & Methods →** Transcriptional control (repressors/activators), alternative splicing.

8. MUTATIONS
- **Point Mutations →** Substitutions, insertions, deletions; silent, missense (sickle cell), nonsense; disorders (PKU).
- **Chromosomal Mutations →** Rearrangements (deletions, inversions, translocations) & non-disjunction (Down, Klinefelter, Turner).

INTRODUCTION

Chapter's Intro:
- You have the basic knowledge of chromosomes and DNA.
- You know that **genes are specific** segments of DNA which carry information for the making of a protein.
- This chapter aims the **detailed study of genes.**
- We will also study the metabolic processes involved in gene working.

19.1 DETAILED STRUCTURE OF CHROMOSOME

- The structure and chemical composition of chromosomes are different in **prokaryotic** and **eukaryotic cells.**
- In this section, we will study chromosomes in **eukaryotic cells.**

Q.1 What are chromosomes, also give chemical composition of chromosome in eukaryotes? S/Q

Ans. Chromosomes:
- Chromosomes are thin, **thread-like structures.**

Composition of Chromosomes:
- They are made of **DNA** and **histone proteins.**

Q.2 Define karyotype. S/Q

Ans. Karyotype:
- The **complete set of chromosomes** on the basis of **shape & size** is called **karyotype.**
- The number and shape of chromosomes are different in each **species.**

Tidbit

Discovery + Naming of Chromosomes:
- Chromosomes were discovered by a German embryologist, Walther Flemming in 1882.
- He **discovered chromosomes** in the rapidly dividing cells of salamander larvae.
- The name **"chromosome"** was proposed by German anatomist, Waldeyer-Hartz in 1888. **"Chromosome"** literally means **coloured bodies.**

Q.3 What are homologous chromosomes? S/Q

Ans. Homologous chromosomes:
- In body cells **(somatic cells)** of diploid organisms, chromosomes occur in pairs. These pairs are called homologous chromosomes.
- Gametes (sex cells) have half the number of **chromosomes.** These chromosomes are not in pairs.

Q.4 What is Chromatin and how does chromatin form into chromosome? Exercise Q.1

Ans. Chromatin:
- When a cell is not **dividing** (interphase), its chromosomes are **not visible** as distinct structures.
- At non-dividing stage, the chromosomes **remain uncoiled** and form a fine network, called **chromatin.**

Formation of Chromosomes:
- When a cell prepares to divide, the DNA starts to coil. It wraps around **small units** of histones. These units then coil further into **highly condensed form.**
- With more coiling and condensation, the structure **becomes thicker and shorter.** Finally, it forms compact thread-like structures which are now called **chromosomes.**

Check Understanding!

1. **Who discovered chromosomes in 1882 in the rapidly dividing cells of salamander larvae?**
   (A) Waldeyer-Hartz.
   (B) Walther Flemming.
   (C) Wilhelm Johannsen.
   (D) Fredrick Griffith.

Topic: 19.1.1 Morphology of Chromosomes:

Q.5 Describe the following terms related to morphology of chromosome. Exercise Q.1
(a) Chromatids. (b) Centromere. (c) Kinetochore. (d) Secondary Constriction or NOR (Nuclear Organizer Region). (e) Satellite. (f) Telomeres.

Ans. (a) Chromatids:
- During interphase, the duplication of **chromatin** occurs. It involves the **replication of DNA** and synthesis of new **histone proteins.**

CamScanner

- After duplication, each chromosome consists of two identical strands called chromatids.
- These two strands are known as sister chromatids (Fig).

(b) Centromere:
- Chromatids are attached to each other at a constricted region called the **centromere**.
- The centromere is a specific **DNA sequence** consisting of highly repetitive nucleotides.

(c) Kinetochore:
- A **disc-shaped** protein structure, called the **kinetochore**, is attached to the **centromere**.
- Kinetochore serves as the point where chromosomes attach to the **mitotic spindle** during c division.

(d) Secondary Constriction or Nuclear Organizer Region (NOR):
- In some chromosomes, there may be another constriction (other than centromere), called **secondary constriction or Nuclear Organizer Region (NOR)**.
- NOR makes nucleoli during interphase.

(e) Satellite:
- The end of **chromosome** beside secondary constriction is **knob-like structure** called **satellite**.
- This region has highly repetitive DNA sequences.

(f) Telomeres:
- The terminal ends of chromosomes are called **telomeres**.
- They prevent the **two chromosomes** to attach with each other from their ends.

Check Understanding!
2. Analyze why histone proteins ar positively charged while DNA negatively charged, and how thi electrostatic attraction facilitates nucleosome packaging.

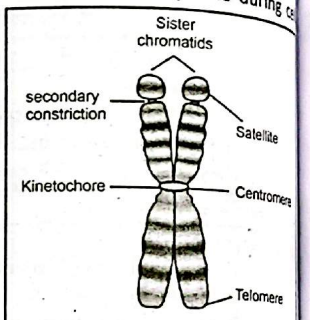


Figure: Morphology of a duplicated and condensed chromosome

Q.6 Briefly describe the 4-types of chromosomes on the basis of position of centromere. Exercise LQ

Ans. **4-Types of Chromosomes on the Basis of Position of Centromere:**
- The position of centromere is different in different chromosomes.

(i) Metacentric Chromosomes:
- The chromosomes in which **centromere is at the centre** are called metacentric chromosomes.

(ii) Sub-Metacentric Chromosomes:
- The chromosome in which **centromere** is located **slightly away** from centre are **sub-metacentric chromosomes**.

(iii) Acrocentric Chromosomes:
- In acrocentric chromosomes, centromere is **located near the end.**

(iv) Telocentric Chromosomes:
- In **telocentric** chromosomes, centromere is **located at the end.**

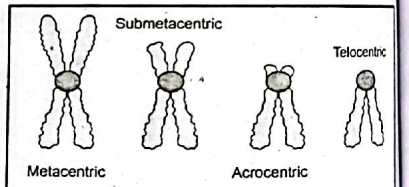


Figure: Types of chromosomes on the basis of location of centromere

Topic: Chemical Composition and Organization of Chromosome:

Q.7 What is the chemical composition of chromosome? SQ

Ans. **Chemical Composition of Chromosome:**
- A chromosome is made up of **40%** DNA and **60%** proteins (mainly histones plus some non-histone proteins and a small amount of RNA).
- Both chromatids have identical DNA molecules.

Q.8 How is DNA tightly coiled around histone proteins? SQ

Ans. **Tight Coiling of DNA around Histone Proteins:**
- DNA is a **negatively charged** due to the presence of phosphate groups.
- It has strong affinity to histone proteins, which are positively charged due to the abundance of basic amino acids such as arginine and lysine. That's why DNA is tightly coiled around histone proteins.

Q.9 What is average size & no. of nucleotides in DNA of one human chromosome? SQ

Ans. **Average Size:**
- The DNA in an average human chromosome is about 5 cm long and consists of about **140 million base-pairs.**

Q.10 Explain the levels of organization of chromosomes, considering nucleosome string, chromatin fiber, & chromatids. LQ

Ans. **Levels of Organization of Chromosomes:**
- The following are the levels of the organization of chromosomes.

(1) Nucleosome String (11nm):
- After the synthesis of DNA **(replication)**, every **~146 base-pairs of DNA** (2 nm thick) wrap twice **(~1.7 turns)** around a histone octamer **(set of 8 histone molecules** i.e., two copies each of the histones H2A, H2B, H3, and H4). This aggregation is called **nucleosomes**.
- **Linker DNA:** Nucleosomes are connected by about **80 base-pairs** long **linker DNA.**
- **Linker Histone:** The fifth type of histone i.e., **H1** called **linker histone** is present at the base of the nucleosome near the DNA entry and exit points.
- **Linker histone** helps in the winding of the chain of **nucleosomes.**
- All **nucleosomes** (without linker histone) resemble beads on a string called **nucleosome string** (11 nm thick).

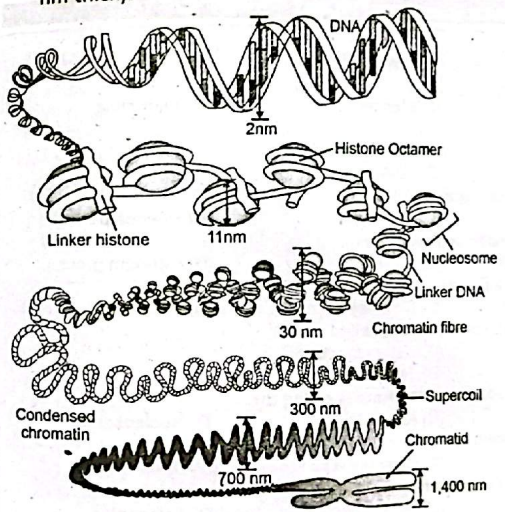


Figure: Organization of chromosome

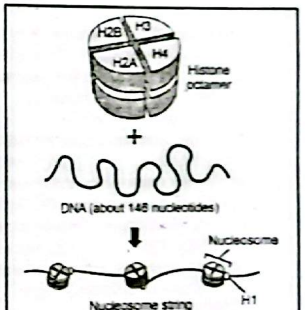


Figure: Nucleosome string

(2) Chromatin Fibre (30 nm Thick):
- In the early stages of **cell division**, the nucleosome string again coils **about its axis.**
- The tightly packed (condensed) nucleosomes make a **thicker fibre** called chromatin fibre (30 nm).

(3) Chromatids (700 nm Thick):
- **Supercoil:** The chromatin fibre folds **upon itself** to make a **supercoil** (300 nm thick).
- The supercoil further coils and condenses and takes the shape of **chromatid** (700 nm thick).

Tidbit
Heterochromatin & Euchromatin:
- There are two regions in chromatin.
(i) The inactive portions of chromatin produce dark bands and are called **heterochromatin.**
(ii) Whereas active portions of chromosomes are called **euchromatin.**

CamScanner

Topic: 19.1.3 The Concept of Genes and Alleles:

Q.11 What is gene? & who used the term gene? Also define locus & describe the term allele. Exercise LQ.2

Ans. Gene:

- A gene is "a **short segment of DNA** which encodes the sequence of amino acid of a particular polypeptide". The whole DNA molecule present in a chromosome does not contain message for sequencing amino acids (preparing proteins), it is special part of DNA, which performs this function i.e. gene.
- Rather, short segments of DNA, called genes, encode proteins.
- **Term Gene:** In 1909, a Danish botanist **Wilhelm Johannsen** introduced the term **"gene"** for the basic unit of heredity.
- **Locus:** The location where a gene is **present** on a chromosome is called its locus (plural: loci).
- **Allele:** On a homologous chromosome the **alternate forms of a gene** called alleles:
- **Alleles** are present on the same locus.
- **Example:** If a chromosome has the allele for **'eye colour'** at a particular locus, its homologous chromosome will carry the allele of same character at the **same locus.**

Check Understanding!

3. **Who introduced the term "gene" in 1909 for the basic unit of heredity?**
   (A) Francis Crick.
   (B) Walther Fleming.
   (C) Wilhelm Johannsen.
   (D) Alfred Hershey.

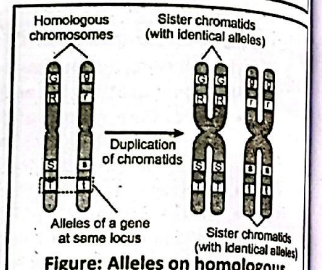


Figure: Alleles on homologous chromosomes

Multiple Choice Questions (MCQs)

		Key
1.	**Chromosomes were first discovered by:** (A) Waldeyer-Hartz. (B) Thomas Hunt Morgan. (C) Walther Flemming. (D) Walter Sutton.	1.(C)
2.	**The name "chromosome" was proposed by:** (A) Karl Correns. (B) Waldeyer-Hartz. (C) Mendel. (D) Flemming.	2.(B)
3.	**Chromosomes are mainly composed of:** (A) DNA and histone proteins. (B) RNA and lipids. (C) DNA and carbohydrates. (D) RNA and enzymes.	3.(A)
4.	**The complete set of chromosomes of an organism is called its:** (A) Genome. (B) Genotype. (C) Karyotype. (D) Phenotype.	4.(C)
5.	**In diploid organisms, chromosomes in somatic cells occur as:** (A) Single chromosomes. (B) Homologous pairs. (C) Triplets. (D) Random groups.	5.(B)
6.	**During interphase, chromosomes exist as a fine network called:** (A) Chromatid. (B) Nucleosome. (C) Chromatin fibre. (D) Chromatin.	6.(D)
7.	**The two identical strands of a duplicated chromosome are called:** (A) Homologous chromosomes. (B) Sister chromatids. (C) Chromatin fibres. (D) Telomeres.	7.(B)
8.	**The disc-shaped protein structure attached to the centromere is called the:** (A) Telomere. (B) Satellite. (C) Kinetochore. (D) Nucleosome.	8.(C)
9.	**The terminal ends of chromosomes are known as:** (A) Telomeres. (B) Satellites. (C) Centromeres. (D) Chromatids.	9.(A)
10.	**Chromosomes with the centromere located at the centre are called:** (A) Acrocentric. (B) Sub-metacentric. (C) Metacentric. (D) Telocentric.	10.(C)
11.	**What is the primary function of telomeres?** (A) Spindle attachment. (B) Nucleolus formation. (C) End protection. (D) DNA replication.	11.(C)
12.	**Why does DNA bind strongly to histone proteins?** (A) Opposite charges. (B) Both negative. (C) DNA positive. (D) Phosphate groups.	12.(A)
13.	**Approximately every 146 nucleotides of DNA wrap around:** (A) Histone dimer. (B) Histone octamer. (C) Kinetochore. (D) Centromere.	13.(B)
14.	**Which histone is known as the linker histone and helps in winding the nucleosome chain?** (A) H2A. (B) H2B. (C) H3. (D) H1.	14.(D)
15.	**Arrange the levels of chromosome organization from lower to higher condensation.** (A) Chromatid → Fibre. (B) String → Fibre → Chromatid. (C) Fibre → Chromatid. (D) Chromatid → String.	15.(B)

DNA AS THE HEREDITARY MATERIAL

Q.12 Write the facts about "gene" after which scientists tried to determine the chemical nature of gene? S/Q

Ans. Facts About Gene:

- After the confirmation of the following facts of Gene, scientists tried to determine whether genes are made of DNA, or protein or both.
- It took almost 30 years (1920s - 1950s) to solve this question.
  (i) Genes are the units of inheritance.
  (ii) Genes are located on chromosomes.
  (iii) Chromosomes are made of DNA and proteins.

Information

Q. **What characteristics must have by a molecule of genetic material?**
Ans. A molecule that serves as genetic material must have certain characteristics.
(i) It must be able to code for the sequence of amino acids in proteins.
(ii) It must be able to replicate itself prior to cell division.
(iii) It must be in the nucleus of eukaryotic cells.
(iv) It must be able to change over time to account for evolution.
Note: Only one molecule i.e., DNA fulfils all these requirements.

Topic: Griffith's Experiment:

Q.13 Discuss the Griffith's experiment. Exercise LQ.3

- In 1928, British biologist, Frederick Griffith, worked on a pathogenic bacterium ***Streptococcus pneumoniae.***
- He observed two strains of this bacterium;
  (a) "S-type": A bacterial strain had a polysaccharide coat and its colony appears "smooth".
  (b) "R-type": A bacterial strain lacked polysaccharide coat and forms a "rough" colony.
- He performed his experiment in different steps.

Check Understanding!

4. **Design a hypothetical experiment to test whether a candidate molecule can undergo stable heritable variations.**

Step-1: (Injecting S-type Bacteria)

- He infected the mice with a **virulent strain** of ***streptococcus pneumoniae*** bacteria.
- The mice **died of** blood pneumonia.

Step-2: (Injecting R-type Bacteria)

- He infected similar mice with a **mutant strain of *S. pneumoniae***. These bacteria lack polysaccharide coat. So they are not virulent.
- The mice did not become ill with pneumonia. Thus its outer coat is necessary for virulence.

Step-3: (Injecting Dead S-type Bacteria)

- Griffith wanted to know whether the polysaccharide coat itself had a toxic effect.
- He injected dead bacteria of the **virulent S. strain** into the mice.
- The mice remained **perfectly healthy.** It means itself has no toxic affect.

Step-4: (Injecting Mixture of R-type Alive + S-type Dead Bacteria)

- Now he injected mice with a mixture containing dead S bacteria of the virulent strain and live coatless R bacteria. Both of these strains are **themselves harmless.**
- Unexpectedly, the mice **developed the pneumonia and died.**
- When he observed the blood of these **dead mice,** he found many alive **S-type bacteria in the blood of dead mice.**

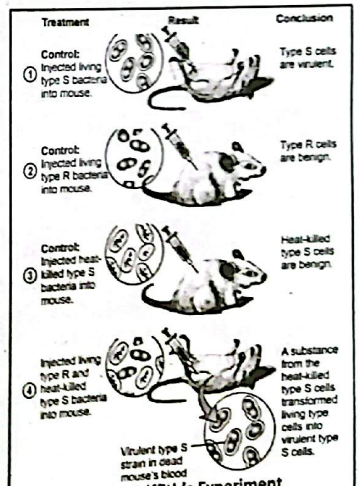


Figure: Griffith's Experiment

CamScanner

➢ **Griffith's Conclusion:**

- Griffith concluded that the information for making **polysaccharide** coat and virulence disease causing ability had passed from the heat-killed S-type bacteria to the **alive R -type.**
- So, R -type bacteria made polysaccharide coat and transformed into virulent S-type. He called this process as transformation.
- **Transformation:** The transfer of genetic material from one organism to another to change the genetic makeup of the recipient organism is called **transformation.**
- **Note:** Griffith could not find the chemical nature (DNA or protein or both) of the material that was transferred from dead **S-type** to the alive **R-type** bacteria.

➢ **Transformation:**

- Transformation is the transfer of **genetic material** from one cell to another and can alter the genetic makeup of the **recipient cell.**

Check Understanding!

5. In Frederick Griffith's 1928 experiment, what happened when a mixture of heat-killed S-type and live R-type bacteria was injected into mice?

(A) The mice remained healthy and no bacteria were found.
(B) The mice developed pneumonia and died, yielding live S-type bacteria in their blood.
(C) The mice died, but only live R-type bacteria were recovered.
(D) The mice developed an immunity to future infections.

Q. Discuss the discovery of transforming principle by Avery, Macleod & McCarty.

Ans. Discovery of Transforming Principle by Avery, Macleod & McCarty:

- In 1944, three scientists, Avery, MacLeod and McCarty discovered the transforming principle.

Step-I:

- They removed proteins from the dead **S-types bacteria** and mixed them with **alive R-type.** When they injected this mixture into mice, they developed disease and alive S-type bacteria were found in them. It means that proteins are not responsible for transforming R-type into S-type.

Step-II:

- Then, they removed all DNAs from dead S-type.
- They mixed S-type (without DNA) with alive R-type and injected into mice. They observed that no transformation had occurred this time as the mice remained healthy..
- They concluded that "DNA is the fundamental unit of the transforming principle".

Check Understanding!

7. What crucial discovery regarding the transforming principle was made by Avery, MacLeod, and McCarty in 1944?

(A) Proteins are the fundamental unit of transformation.
(B) DNA is the fundamental unit of the transforming principle.
(C) RNA acts as the primary hereditary molecule in bacteria.
(D) Carbohydrate capsules direct all bacterial mutations.

Topic: Hershey-Chase Experiments:

Q.14 Describe the Hershey-chase experiments in detail. Exercise L/Q.4

Ans. In 1952, two American biologists **Alfred Hershey** and **Martha Chase** experimented with **bacteriophages** and provided additional evidence supporting Avery's conclusion.

Background Information:

➢ **^{32}P labeled Viruses:**

- In their experiments they labeled viruses with **radio radioactive isotope ^{32}P,** which was incorporated into the newly synthesized DNA of growing phage. Now viruses have **^{32}P in their DNA.**

➢ **^{35}S Labelled Viruses:**

- In other experiments the viruses were grown on **bacteria containing ^{35}S** medium (radioactive) isotope of sulphur which is incorporated into the amino acids of newly synthesized protein coats of viruses.

➢ **Exposure of Bacteria To Labelled Viruses:**

- The **bacterial cell** agitated violently in a blender to remove the **protein coats** of the infected viruses from the surface of bacteria.
- When bacteria were tested for the presence of label it was found that bacteria had lost nearly all of ^{35}S label. However ^{32}P label was present inside the bacteria of the other group.
- It is be **because ^{35}S was** only present in protein coat **while ^{32}P was present** in DNA that had transferred to the **interior of the bacteria.**

Note: Sulphur is present in Proteins but Absent in DNA **phosphorus** is present in DNA but absent in Proteins.

➢ **Confirmation:**

- It was confirmed when viruses were released form the infected bacteria.
- The viruses released **from ^{32}P culture** were labeled (have ^{32}P) while **viruses release from ^{35}S culture** were unlabeled (Do not have ^{35}S).

Check Understanding!

6. Evaluate why sulfur-35 (^{35}S) failed to appear inside bacterial cells after infection in the Hershey-Chase experiments.

➢ **DNA the Hereditary Material:**

- It was proved that the hereditary information injected into the bacteria that specified the new generation of viruses was DNA and not protein.

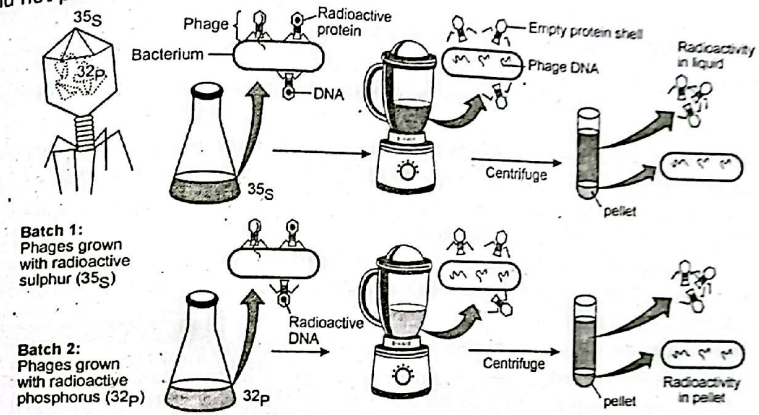


Figure: Hershey-Chase experiment

Multiple Choice Questions (MCQs)	Key
1. Frederick Griffith worked on the bacterium: (A) *Escherichia coli.* (B) *Salmonella typhi.* (C) *Streptococcus pneumoniae.* (D) *Bacillus subtilis.*	1.(C)
2. Which strain of Streptococcus pneumoniae has a polysaccharide coat? (A) R-type. (B) S-type. (C) T-type. (D) P-type.	2.(B)
3. The colony of the S-type strain appears: (A) Rough. (B) Wrinkled. (C) Smooth. (D) Dry.	3.(C)
4. Which strain of Streptococcus pneumoniae is non-virulent? (A) S-type. (B) R-type. (C) M-type. (D) N-Type	4.(D)
5. Griffith named the transfer of genetic material from one organism to another as: (A) Mutation. (B) Transformation. (C) Transcription. (D) Translation.	5.(B)
6. Hershey and Chase used _____ to confirm that DNA is the hereditary material. (A) Fruit flies. (B) Pea plants. (C) Bacteriophages. (D) Mice.	6.(C)
7. Which radioactive isotope was used to label the DNA of bacteriophages? (A) ^{32}P. (B) ^{14}C. (C) ^{35}S. (D) ^{15}N.	7.(A)
8. Which radioactive isotope was used to label the protein coat of bacteriophages? (A) ^{32}P. (B) ^{35}S. (C) ^{14}C. (D) ^{3}H.	8.(B)
9. After infection with bacteriophages containing ^{32}P-labelled DNA, radioactivity was found in: (A) The surrounding medium only. (B) The centrifuge tube only. (C) The protein coat only. (D) The bacterial cells.	9.(D)
10. Why did Griffith conclude that transformation had occurred? (A) Virulent conversion. (B) Killed bacteria. (C) Natural virulence. (D) Mouse survival.	10.(A)
11. What did Griffith fail to determine in his experiment? (A) Bacterial existence. (B) Transformation occurrence. (C) Chemical nature. (D) S-virulence.	11.(C)
12. In Hershey and Chase's experiment, why was ^{32}P used to label DNA? (A) DNA phosphate. (B) Amino acids. (C) Protein coat. (D) DNA destruction.	12.(A)
13. In the setup with ^{35}S-labelled protein, radioactivity remained in the medium because: (A) DNA rejection. (B) Protein outside. (C) Protein destruction. (D) DNA outside.	13.(B)
14. Which conclusion was drawn from Hershey and Chase's experiments? (A) Protein hereditary. (B) Lipids hereditary. (C) DNA hereditary. (D) RNA hereditary.	14.(C)

CamScanner

DNA REPLICATION

Q.15 Define DNA replication & describe three models which propose the mechanism of DNA replication. Exercise LQ.5

Ans. DNA Replication:

- A process in which the **molecule of DNA** makes its identical copy (replica) is called **DNA replication.**
- DNA is a double-helix molecule (made of two strands). So, it makes copies of both of **its strands.**

Recalling

- The DNA present in chromatids replicates so that chromatids can duplicate. It happens before a cell divides i.e., during the S-phase of interphase.

➢ **Three Models Proposed for the Mechanism of DNA Replication:**

- Three models were proposed for the **basic mechanism of DNA** replication discussed below.

(1) Conservative Model:

- According to this **model**, the double-helix of parent DNA remains intact. This **double-helix** acts a **parental molecule** and generates new double-helix under its own guidance which completely consists of new material.
- So, after replication, when two daughter DNAs are produced;
  - One daughter DNA contains both strands of **parent old DNA.**
  - One daughter DNA contains both **new strands.**

(2) Semi-Conservative Model:

- According to this model, the **double-helix** of parent DNA is broken into **two strands.**
- It means that two strands of **parent DNA** separate.
- Each of these strands acts as a template for the synthesis of a new daughter strand.
- So, after replication;
  - Both **daughter DNAs** consist of **one strand** of old parent DNA and **one new strand.**

Check Understanding!

8. **Describe how you would physically demonstrate the difference between the semi-conservative and conservative models using colored shoelaces.**

(3) Dispersive Model:

- According to this model, parent double-helix DNA is broken and **dispersed into nucleotides.**
- Then, each nucleotide combines with new nucleotides to generate the four strands of daughter DNAs.
- So, after replication:
  - Both **daughter DNAs** contain the mixtures of **old and new** nucleotides.

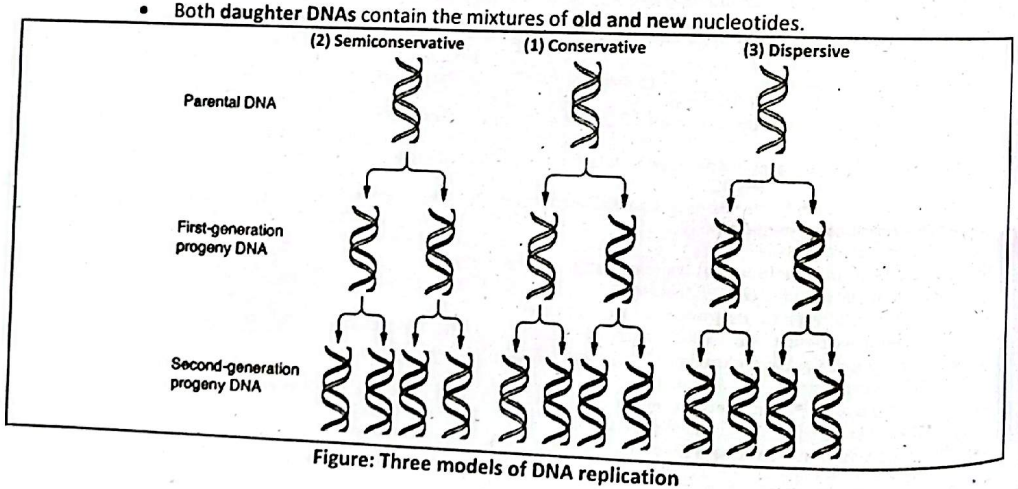


Figure: Three models of DNA replication

Topic: Meselson-Stahl Experiment:

Q.16 Who were Meselson & stahl & what they proved in his experiment? Exercise LQ.6

Ans. Meselson-Stahl Experiment:

- Matthew Meselson and Franklin Stahl were two American biologists.
- In 1958 they evaluated the **three models of DNA replication.**
- They experimentally proved that the **DNA replication** is according to semi-conservative model.

Q.17 Narrate the work of Meselson and Stahl to justify the semi-conservative replication. Exercise LQ.6

Ans. Experiment of Meselson & Stahl:

- In this experiment **they proved** that **DNA replication** is semi-conservative way.

Step-I of Their Experiment:

- For this they grew bacteria in a medium containing **heavy isotope of nitrogen** i.e., ^{15}N.
- The **next generation** of the bacteria **incorporated** ^{15}N in the **nitrogen-bases** of DNA instead of normal ^{14}N. So, after many generations, all the DNA of these bacteria was denser $^{15}N^{15}N$ than that of normal bacteria $^{14}N^{14}N$.

Check Understanding!

9. **In the Meselson-Stahl experiment, after bacteria grown in a ^{15}N medium were transferred to a ^{14}N medium for one generation, what density did their extracted DNA exhibit?**
   (A) Heavy density only.
   (B) Light density only.
   (C) Intermediate density.
   (D) Both heavy and light densities equally.

Step-II of Their Experiment:

- After that then they transferred the **new normal bacteria** with ^{15}N in DNA from the ^{15}N medium to a medium that contained ^{14}N. They thought that now these bacteria will make new DNA by using ^{14}N from the medium.
- When bacteria divided and increased in number, Meselson and Stahl collected the new DNAs at different intervals.
- They checked **heavier DNA** (with ^{15}N) and lighter DNA (with ^{14}N). For this purpose, they separated the heavier and lighter DNAs in the following steps.
  - **(i)** They dissolved the collected DNA in **aqueous solution** of **cesium chloride** and conducted the ultracentrifugation of the solution.
  - **(ii)** The **ultracentrifugation** created a gradient of cesium density (cesium with more density settled at bottom).
    - DNA strands of **different densities** were also separated during this **ultracentrifugation.**
  - **(iii)** Each **DNA strand** settled at the position where its density was exactly matching the density of the cesium there.
    - The denser DNA with ^{15}N migrated further down due to heavy ^{15}N as compared to the lighter **DNA with** ^{14}N.

Tracing radio-isotope labelled DNA in the progeny:

Q. What is pulse-chase experiment & write its two stages?

Ans. Pulse-Chase Experiment:

- An experiment in which a **radio-isotope** labelled DNA is traced in the **progeny** of an organism is called a **"pulse-chase experiment."**

The experiment has two stages:

(i) **Pulse Stage:** In "pulse" stage, the organism is exposed to the **radio-isotope** for a brief time. During this step, the organism incorporates radioisotope into its DNA.

(ii) **Chase-Stage:** In "chase" stage, the labelled DNA is observed over time by measuring the radioactivity of DNA.

➢ **Meselson-Stahl's Observations After Ultracentrifugation:**

(a) Collection of First Sample After Shifting ^{15}N-bacteria on Medium of ^{14}N:

- First sample was collected at 0 minutes i.e., before any replication.
- All sample made single sediment of heavy density. It means that all DNA was dense (with ^{15}N).

CamScanner

(b) Collection of Second Sample After Shifting ^{15}N-bacteria on Medium of ^{14}N:

- Second sample was collected at 20 minutes i.e., after the bacteria had completed first DNA replication in ^{14}N medium.
- The sample made a single sediment of intermediate density. It means that all DNA has intermediate density i.e., between ^{14}N-DNA and 15N-DNA.

Check Understanding!

10. Connect the Meselson-Stahl second-generation banding pattern (one intermediate and one light band) to the physical conservation of parental strands.

(c) Collection of 3rd sample After Shifting ^{15}N-bacteria on Medium of ^{14}N:

- Third sample was collected after 40 minutes when bacteria had completed the second replication.
- In this sample, DNA made two sediments i.e., one intermediate and one light (equal to that of ^{14}N-DNA).

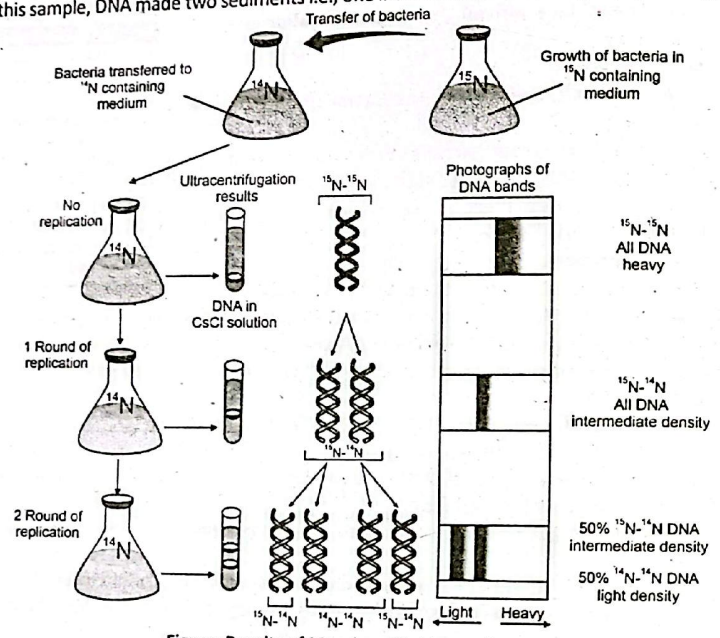


Figure: Results of Meselson-Stahl experiment

➢ **Explanation of Meselson and Stahl Experiment:**

(a) DNA collected before **any replication** after **0-minute** was heaviest because it had **both strands made of ^{15}N.**

(b) DNA collected **after first replication** was intermediate in density because each daughter DNA was a hybrid i.e., **one strand was made of ^{14}N and one of ^{15}N.**

(c) DNA collected after second replication, formed two sediments (one intermediate and one lighter) because each parent DNA contributed one heavy strand to form another hybrid DNA and one light strand to form a light DNA (containing both ^{14}N strands).

- On the basis of these results, they claimed that DNA replicates in a semiconservative manner.

Multiple Choice Questions (MCQs)

		Key
1.	**DNA replication is the process by which DNA:** (A) Breaks into nucleotides. (B) Produces proteins. (C) Makes an identical copy. (D) Forms RNA & DNA	1.(C)
2.	**According to the conservative model, after replication:** (A) Hybrid DNA. (B) Old, new. (C) Mixed nucleotides. (D) DNA destroyed.	2.(B)
3.	**In the semi-conservative model, each daughter DNA consists of:** (A) One old, one new. (B) Two parental. (C) Two new. (D) Mixed strands.	3.(A)

		Key
4.	**According to the dispersive model, the strands of daughter DNA contain:** (A) Mixed nucleotides. (B) Old only. (C) New only. (D) RNA, DNA.	4.(D)
5.	**Which model of DNA replication was proved to be correct?** (A) Conservative. (B) Dispersive. (C) Semi-conservative. (D) Random.	5.(C)
6.	**Meselson and Stahl first grew bacteria in a medium containing:** (A) ^{14}N. (B) ^{32}P. (C) ^{15}N. (D) ^{35}S.	6.(C)
7.	**To separate heavy and light DNA, Meselson and Stahl used:** (A) Electrophoresis. (B) CsCl gradient. (C) Chromatography. (D) Filtration.	7.(B)
8.	**Before any replication (0 minutes), the DNA formed:** (A) Light band. (B) Intermediate band. (C) Heavy band. (D) Two bands.	8.(C)
9.	**After the first DNA replication in the ^{14}N medium, the DNA showed:** (A) Heavy band. (B) Light band. (C) Two light. (D) Intermediate band.	9.(D)
10.	**Why did DNA collected after the first replication show an intermediate density?** (A) ^{15}N only. (B) Hybrid strands. (C) Phosphorus replaced. (D) ^{14}N only.	10.(B)
11.	**After the second replication, why were two DNA bands (intermediate and light) observed?** (A) DNA destroyed. (B) Heavy again. (C) Hybrid, light. (D) Protein mixed.	11.(C)
12.	**Which observation directly supported the semi-conservative model rather than the conservative model?** (A) Intermediate band. (B) Heavy DNA. (C) Light band. (D) Two heavy.	12.(A)
13.	**In Meselson and Stahl's experiment, cesium chloride was used because it:** (A) Replicated DNA. (B) Density gradient. (C) Destroyed proteins. (D) Labelled DNA.	13.(B)
14.	**According to the semi-conservative model, the original DNA strands serve as:** (A) Enzymes. (B) Ribosomes. (C) Histones. (D) Templates.	14.(D)

Topic: Mechanism of DNA Replication:

Q.18 Describe the events of the process of DNA replication. Exercise LQ.7

Ans. **Mechanism of DNA Replication:**

- The basic **mechanism of DNA** replication is similar in all organisms.

Steps of DNA Replication in Prokaryotes:

- The following steps refer to replication in **prokaryotes**, but eukaryotes also adopt almost the same mechanism.

(1) Opening up the DNA Double Helix:

- **Replication Origin Site (ROS):** The replication of DNA begins at one or more sites on DNA molecule where there is a specific sequence of nucleotides called a **replication origin site.**
- In **prokaryotes**, there is only **one replication** origin site.
- It in **eukaryotes**, there are many **replication origin sites** along the length of DNA.
  - **(i) Initiator Protein:** It binds to the **replication origin** site and initiates the process.
  - **(ii) Helicases Enzyme + Replication Fork:** At the origin site, the "unwinding" enzymes called **helicases** break the hydrogen bonds **between the nucleotide-pairs** (base-pairs) of two strands. The strands separate a little and make two **Y-shaped structures** called **replication forks** (collectively called a replication bubble).
  - **(iii)** Due to unwinding of the DNA helix, supercoils are produced ahead of the replication fork.
  - **(iv) Role of Gyrase Enzyme:** The enzyme gyrase (or topoisomerase) attaches ahead of the replication fork. Gyrase prevents supercoiling again.
  - **(v) Single-strand Binding Proteins (SSBPs):** These enzymes bind to single strands and prevent them from **re-joining** and **rewinding.**
  - **(vi) Two Replication Fork Formation:** The two replication forks move away from each other so that replication can occur at both forks. Both single strands act as templates for the next steps.

Check Understanding!

11. Which enzyme breaks hydrogen bonds between nucleotide base pairs to open up the DNA double helix during replication?
(A) DNA Polymerase III.
(B) Primase.
(C) Helicase.
(D) DNA Ligase.

(2) Building a Primer:

- On the exposed strands, **new DNA** cannot be formed unless some nucleotides are already arranged on template.

CamScanner

- **Role of Primase:** An enzyme **primase** attaches some RNA nucleotides in **front of each template strand** at replication origin site. This short fragment of 5 - 10 RNA nucleotides is called primer.
- After the formation of primer the DNA-Synthesis starts.

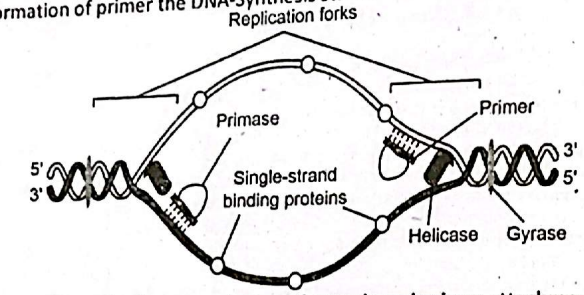


Figure: Replication - opening up of strands and primer attachment

(3) Assembling Complementary Strands (Extension):

The Main Builder: DNA Polymerase-III

- The enzyme **DNA polymerase-III** adds new nucleotides along both template strands.

Types of DNA Polymerase:

- In prokaryotes, there are three types of DNA Polymerases:
  (i) DNA polymerase-I. (ii) DNA Polymerase-II. (iii) DNA Polymerase-III.
- DNA polymerase-III is the main enzyme.

Role of DNA-Polymerase-III:

- It grabs free floating nucleotides and matches them to the exposed template strands (A with T, and C with G).

The Raw Materials For New DNA Strand:

- The units **used for synthesizing** new strands are Deoxyribonucleoside triphosphates (dATP, dCTP, dGTP, dTTP.
- These molecules have three phosphate groups. As DNA **Polymerase III** attaches a nucleotide to the strand, it breaks off two phosphates.
- This action releases energy which is used for the building process.

For Information

- DNA **polymerase-I** provides a support to **polymerase-III** by replacing the primers at the end of replication.
- **Polymerase-II** is involved in the repairing process of DNA damages during the life time of a cell.

One-Way Traffic (5′ to 3′ Direction):

- DNA **Polymerase III** can only add a **new nucleotide** to the 3′ end of an existing one. First, it adds a nucleotide at 3′ end of primer and then continues adding nucleotides in 5′ to 3′ direction.
- Because the two original DNA strands run in opposite directions, the enzyme must handle them differently.

Tidbit

Why an RNA primer, rather than DNA?

- Starting chains on **exposed templates** introduces many errors; RNA marks this initial stretch as "**temporary**".
- It makes easy to excise this error-prone later.

Building the Leading Strand During DNA-Replication:

- One unit of the enzyme attaches to the **template strand** that runs toward the **opening "fork."** Because it is moving in the same direction the **DNA is unzipping**, it can add nucleotides in one **continuous 5′ to 3′ chain.** This smoothly growing daughter strand is called the **Leading Strand.**
- **Leading Strand:** The strand in which DNA-replication moves towards **replication fork** is called **replication fork.**

Building the Lagging Strand During DNA Replication:

- The **second** unit of the enzyme works on the other template strand. However, to maintain the 5′ to 3′ direction, it must move away from the replication fork.

Tidbit

- The leading strand can be extended from one primer alone, whereas the lagging strand needs a new primer for each Okazaki fragment (named for the Japanese scientist who discovered them).

- As the DNA unzips further, the enzyme has to "**Jump back**" to a new primer to start a new segment.
- So, this **daughter** strand grows discontinuously away from the replication fork. It makes short, **separate** pieces of DNA called Okazaki fragments. Because this strand is built in "**stops and starts**" rather than one long piece, it is called the **lagging strand.**

Check Understanding!

12. **Why does the antiparallel structure of DNA force one strand to be synthesized continuously and the other discontinuously?**

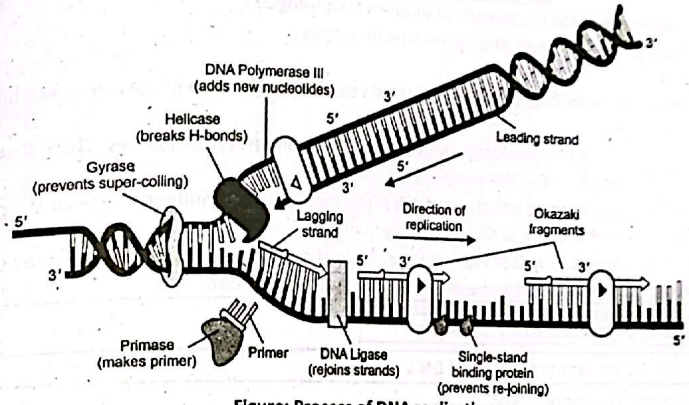


Figure: Process of DNA replication

(4) Termination of Replication:

- When the DNA-molecule is copied the process is terminated or stopped.
- **Termination Site:** The termination of replication occurs at specific sequence of nucleotides called termination site.
- **Replicon:** The **region of DNA** between the origin site and termination site is termed as a replication unit or replicon.
- During termination, **DNA polymerase-I** removes the **RNA primer** and fills in the gap with DNA nucleotides. It also fills any gaps between Okazaki fragments. The any gaps between Okazaki fragments.
- The enzyme DNA ligase joins the Okazaki fragments of the lagging strand.

For Information

- During replication, one strand of the original DNA is conserved, while the daughter strand is synthesized anew.
- It means that half of the original DNA molecule is conserved in each new generation of DNA.

Check Understanding!

13. **Short, separate pieces of DNA synthesized discontinuously on the lagging strand are called:**
(A) Promoter regions.
(B) Okazaki fragments.
(C) Telomeres.
(D) Satellite segments.

Q.19 How are DNA replication in prokaryotes & Eukaryotes different from each other? L/Q

Ans. Difference between DNA Replication in Prokaryotes and Eukaryotes:

Prokaryotes	Eukaryotes
• **Location:** In prokaryotes, replication occurs in the cytoplasm (as they do not have nucleus).	• **Location:** In eukaryotes, nucleus is the site for DNA replication.
• **Polymerases:** In prokaryotes, DNA Polymerase I, II, and III work in replication.	• **Polymerases:** In eukaryotes, there are at least 14 polymerases (such as alpha, delta, and epsilon).
• **Initiation and termination sites:** In prokaryotes, DNA has a single origin site and a single termination site.	• **Initiation and termination sites:** In eukaryotes, there are multiple origin and termination sites on each chromosome. DNA replication starts at each origin site simultaneously. Thus, each chromosome has several replicons.

CamScanner

- **Okazaki fragments:** In prokaryotes, the Okazaki fragments are longer (1000 to 2000 nucleotides).
- **Speed:** Prokaryotes replicate their small DNA very quickly. Eukaryotes have massive amounts of linear DNA.
- **Okazaki fragments:** In eukaryotes, the Okazaki fragments are short (between 100 and 200 nucleotides).
- **Speed:** To compensate for this, eukaryotes start replication at thousands of different origin sites along a single chromosome at the same time.

For Information

Q. What are the uses of DNA Replication in modern technologies?

Ans. Biotechnologists use DNA replication in new technologies.

For example:

i. In Polymerase Chain Reaction (PCR), scientists conduct replication process to make billions of copies of a specific DNA.

ii. In recombinant DNA technology, scientists cut DNA from different sources. Then, they conduct DNA replication to amplify the DNA molecules.

iii. In genome sequencing, scientists use DNA replication to make multiple copies of the genome, which are then sequenced to know the genome sequence.

iv. In diagnostic studies, scientist replicate specific sections of patient's DNA. Then, they search changes or mutations in DNA to know the presence of a genetic disorder.

Topic: Stability and Variability of DNA:

Q.20 Discuss the two important properties of DNA replication. L/Q

Ans. Stability and Variability of DNA:

- The two important **properties** of a replicating DNA are:

(1) Stability of DNA:

- It means the ability of DNA to be copied with accuracy.
- DNA **Polymerase III** (and eukaryotic polymerases) have a **"proofreading"** ability to ensure that the sequence of nucleotides is maintained.
- This consistency is vital because it maintains the specific traits of an organism. It also ensures that cells function correctly.

Check Understanding!

14. How do eukaryotic cells structurally compensate for having massive amounts of linear DNA during replication?

(2) Variability of DNA:

- While stability is the rule, **"variability"** is an exception.
- Occasionally, a permanent change in the DNA sequence occurs, known as a **mutation.**
- These mutations can be caused by errors during replication.
- Environmental factors can also cause mutations.
- Variability is the primary source of new traits. It allows populations to adapt to changing environments and is the raw material for evolution.

Multiple Choice Questions (MCQs)

		Key
1.	DNA replication begins at a specific nucleotide sequence called the: (A) Termination site. (B) Replication origin site. (C) Promoter. (D) Replicon.	1.(B)
2.	In prokaryotes, the DNA molecule usually has: (A) Two replication origin sites. (B) Three replication origin sites. (C) One replication origin site. (D) Many replication origin sites.	2.(C)
3.	The enzyme that breaks hydrogen bonds between the two DNA strands is: (A) DNA ligase. (B) Primase. (C) Helicase. (D) DNA polymerase I.	3.(C)
4.	The Y-shaped structures formed during DNA unwinding are called: (A) Replicons. (B) Replication forks. (C) Chromatids. (D) Nucleosomes.	4.(B)
5.	Which enzyme prevents supercoiling ahead of the replication fork? (A) DNA ligase. (B) Primase. (C) Gyrase (Topoisomerase). (D) Helicase.	5.(C)

		Key
6.	Single-strand binding proteins function to: (A) Join Okazaki fragments. (B) Prevent separated. (C) Synthesize RNA primers. (D) Remove RNA primers.	6.(B)
7.	The short RNA fragment synthesized before DNA synthesis begins is called the: (A) Replicon. (B) Primer. (C) Okazaki fragment. (D) Centromere.	7.(B)
8.	Which enzyme synthesizes the RNA primer? (A) DNA Polymerase III. (B) DNA Ligase. (C) Primase. (D) Helicase.	8.(C)
9.	The main enzyme responsible for DNA synthesis in prokaryotes is: (A) DNA Polymerase I. (B) DNA Polymerase II. (C) DNA Polymerase III. (D) RNA Polymerase.	9.(C)
10.	DNA Polymerase III synthesizes DNA only in the: (A) 3′ → 5′ direction. (B) 5′ → 3′ direction. (C) Both directions. (D) Random direction.	10.(B)
11.	Why is the leading strand synthesized continuously? (A) No primer. (B) Same direction. (C) No bonds. (D) DNA Ligase.	11.(B)
12.	Why is the lagging strand synthesized as Okazaki fragments? (A) 3′→5′ synthesis. (B) Repeated primers. (C) Helicase blocks. (D) No nucleotides.	12.(B)
13.	During DNA synthesis, the energy required for adding nucleotides comes from: (A) Mitochondrial ATP. (B) dNTP hydrolysis. (C) Histone proteins. (D) RNA primers.	13.(B)
14.	During termination of replication, DNA Polymerase I primarily: (A) Unwinds DNA. (B) Replaces primers. (C) Prevents supercoiling. (D) Synthesizes primers.	14.(B)
15.	Which enzyme joins the Okazaki fragments to complete the lagging strand? (A) Helicase. (B) Primase. (C) DNA Ligase. (D) DNA Polymerase III.	15.(C)
16.	In prokaryotes, DNA replication occurs in the: (A) Nucleus. (B) Cytoplasm. (C) Mitochondria. (D) Ribosome.	16.(B)
17.	In eukaryotic cells, DNA replication takes place in the: (A) Cytoplasm. (B) Chloroplast. (C) Nucleus. (D) Golgi apparatus.	17.(C)
18.	Which DNA polymerases are involved in replication in prokaryotes? (A) Alpha, Delta and Epsilon. (B) DNA Polymerase I, II and III. (C) Polymerase IV and V only. (D) RNA Polymerase only.	18.(B)
19.	Eukaryotes possess at least _____ DNA polymerases. (A) 3. (B) 5. (C) 10. (D) 14.	19.(D)
20.	In prokaryotes, DNA contains: (A) Multiple origins. (B) One origin. (C) No origin. (D) Two origins.	20.(B)
21.	Okazaki fragments in prokaryotes are approximately: (A) 100–200 nt. (B) 300–500 nt. (C) 1000–2000 nt. (D) 5000+ nt.	21.(C)
22.	Okazaki fragments in eukaryotes are approximately of _____ nucleotides: (A) 100–200 (B) 50–80 (C) 1000–2000 (D) 3000–4000	22.(A)
23.	The ability of DNA to be copied accurately is called: (A) Variability. (B) Stability. (C) Mutation. (D) Transformation.	23.(B)
24.	Permanent changes in the DNA sequence are called: (A) Replication. (B) Proofreading. (C) Mutations. (D) Transcription.	24.(C)
25.	Variability in DNA is the primary source of: (A) New traits. (B) Cell death. (C) Protein synthesis. (D) Chromosome duplication.	25.(A)
26.	Why do eukaryotes initiate DNA replication at many origin sites simultaneously? (A) Circular DNA. (B) Large genome. (C) Polymerase limitation. (D) No termination.	26.(B)
27.	Which statement correctly compares Okazaki fragments in prokaryotes and eukaryotes? (A) Same length. (B) Prokaryotes shorter. (C) Prokaryotes longer. (D) Eukaryotes only.	27.(C)
28.	Why is the proofreading ability of DNA Polymerase III important? (A) More mutations. (B) Sequence accuracy. (C) Primer synthesis. (D) Fragment joining.	28.(B)
29.	Variability in DNA is important because it: (A) Stops replication. (B) Removes mutations. (C) Drives evolution. (D) Reduces diversity.	29.(C)
30.	Which statement correctly distinguishes DNA replication in prokaryotes and eukaryotes? (A) Nucleus, cytoplasm. (B) One, multiple. (C) Polymerase III. (D) More polymerases.	30.(B)

GENE EXPRESSION

Q.21 What is gene? How does gene express itself? S/C

Ans. Gene:

- Gene is a specific sequence of nucleotides along the DNA strand which directs the synthesis of a polypeptide (protein) chain.

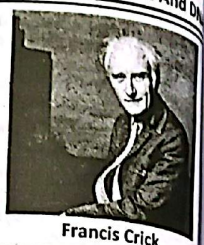
CamScanner

➢ **Expression of Gene:**

- A gene **expresses itself** by making a protein or **an enzyme** that controls the development of a specific trait.
- All organisms use the same basic mechanism of expressing genes.

DNA → RNA → Protein

- It means that the flow of genetic information is **one-way**. Once the information has gone into a protein, it never goes back.



Francis Crick

Q.22 What is central dogma & who used this term first? S/Q

Ans. Central Dogma:

- The central dogma states that information passes from the **genes** (DNA) to an RNA copy of the gene and the RNA copy directs the sequential assembly of a chain of amino acids. In simple words, the central dogma is.

DNA ⟶ RNA ⟶ Proteins

Central Dogma

- **Term used By:** English biologist, Francis Crick used the term **"Central Dogma"** for this mechanism.

Q.23 Give names & define the two steps of central dogma. S/Q

Ans. Two Steps of Central Dogma:

- The central dogma consists of two steps:
  - **(i) Transcription:** The synthesis of RNA from DNA is called transcription.
  - **(ii) Translation:** The synthesis of a protein by using the information present in RNA is called translation.

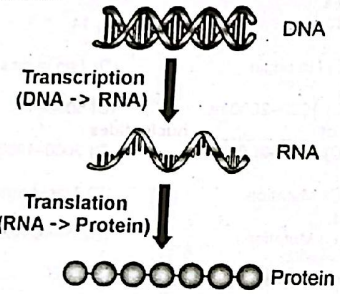


Figure: Central dogma

Check Understanding!

15. Who coined the term "Central Dogma" to describe the one-way flow of genetic information?
(A) Francis Crick.
(B) James Watson.
(C) Rosalind Franklin.
(D) Marshall Nirenberg.

Topic: Genetic Code:

Q.24 What were three essential questions came into scientists mind after the discovery of structure of DNA & idea of central dogma? S/Q

Ans. Genetic Code:

After the discovery of the **structure of DNA (in 1953)**, and the idea of **central dogma (in 1957)**, the following essential questions were came into scientists mind:

Q.1 How can DNA, a substance containing only four different nucleotides, store genetic information for making thousands of specific proteins?

Q.2 If DNA has genetic information in the form of a genetic code, what is the nature of this code?

Q.3 If genetic code is in the form of the order of nucleotides in a DNA, how does it specify the order of amino acids in a polypeptide?

- These questions started a race among biologists.

Topic: Work of Francis Crick:

Q.25 What was the idea presented by Francis Crick and his colleagues? Discuss their working in detail about codons. UQ

Ans. Work of Francis Crick:

- In 1961, Francis Crick and his colleagues presented an idea given as: **"The genetic code consists of a series of blocks of information called codons.**
- Each codon specifies one amino acid of the polypeptide to be **synthesised"**.

For Information

- The information in DNA for the synthesis of proteins is called as genetic code. The genetic code consists of a series of codons consisting of 3-nucletotide.

Working of Francis Crick & His Colleagues:

➢ They further thought that:

- If a sequence of **single nucleotides** specifies a single amino acid, only four different amino acids could be **encoded.**
- Even a sequence of **2 nucleotides** would make 16(4 × 4) codons and they would specify **16 amino acids.**

Conclusion About Codon:

➢

- They reached to a **conclusion** that **one codon** should be a sequence of **3 nucleotides**. This 3 -nucleotide sequence specifies a particular amino acid.
- The 4 nucleotides can be **arranged in 64(4 × 4 × 4)** different combinations which are more than enough to code for the **20 amino acids.**
- According to the **conclusions of Crick,** the genetic code **consists of continuous sequences of three nucleotides.** In other words, it is a **triplet code.**
- When a gene works, the codons **present** on the DNA are transcribed in the form of complementary codons of mRNA. So, the **TAC codon** on DNA would mean AUG codon on mRNA.
- In general, the term **"codon"** refers to the **codon of mRNA.**
- In some cases, the term "codon" may also be used to refer to **codons of DNA**, especially when discussing mutations in **DNA.**

Topic: Work of Marshall Nirenberg, Philip Leder and Har Gobind Khorana:

Q.26 Write a detailed note on the work of Marshal Nirenberg, Philip Leder and Har Gobind Khorana. UQ

Ans. Work of Marshall Nirenberg, Philip Leder and Har Gobind Khorana:

- In 1961, the **American biochemist,** Marshall **Nirenberg** made a **poly-U mRNA.** This mRNA consisted of uracil nucleotides only. He added this **poly-U mRNA** to the cytoplasm of bacteria.
- He observed that the bacteria produced a **polypeptide consisting** of many **phenylalanine** amino acids. He concluded that the **codon UUU specifies phenylalanine.**

Check Understanding!

16. Predict the repeating polypeptide chain translated from a synthetic mRNA containing repeating CUCUCU... codons.

Testing of Triplet Code:

➢

- **Nirenberg** and **another American** geneticist Philip **Leder** tested all **triplet 64 codons.**
- They determined the amino acids specified by **47 codons.**
- **Working of Har Gobind Khorana** (a scientist who completed his studies in Government College, Lahore).
- He determined the amino acids specified by the remaining **17 triplet codons.**
- **Stop or Non-Sense Codons:** Out of the **total 64 codons**, three codons (UGA, UAG, and UAA) are stop **codons** or **nonsense codons.** If any of these is present at the end of mRNA, it does not specify any amino acid and stops the protein synthesis.
- **Start Codon:** The codon AUG acts as **start codon.** It is present at the beginning of all genetic codes. It specifies the amino acid methionine.

For Information

➢ **Awarded Nobel Prize:**

- The 1968 Nobel Prize in **Physiology & medicine** awarded to **Nirenberg** due to his work on genetic code.
- **Har Gobind Khorana** got Nobel Prize on synthesis of **nucleic acids.**
- **Robert Holley** got Nobel Prize on discovering the **chemical structure of transfer-RNA.**

CamScanner



(Left to Right)- Marshal Nirenberg, Philip Leder, Har Gobind Khorana

Topic: Characteristics of Genetic Code:

Q.27 Discuss the characteristics of genetic codes in detail.

Ans. Characteristics of Genetic Code:

(i) Genetic Code is Universal:

- The genetic code is same in **almost all organisms.**
- **Example: AGA** specifies arginine in **bacteria, in humans** and all other organisms.
- **Importance:** Due to this characteristic, genes can be transferred among organisms.
- **Exception:** However, there are a few exceptions to this universality.
- **Example:** Genetic code in the **DNA of mitochondria** is slightly different from the genetic code in the DNA of chromosomes. It reflects the independent evolutionary history of **mitochondria.**
- Some **organisms** (e.g., ciliates) and **viruses** (e.g., bacteriophages) use different genetic codes for the same amino acids.

For Information

- The exceptions to the universality of the genetic code demonstrate that while the standard genetic code is widely used, there is still room for variation and adaptation in the genetic code.

Analyse & Interpret

- Interpret how many types of tRNA molecules are necessary for a living cell, if the genetic code is a triplet code.

(2) Genetic Code is Triplet:

- The genetic code in DNA is a **sequences** of three nucleotides (codons).
- Due to this characteristic, the amount of information present in DNA balances the information required to **specify 20 kinds of amino acids.**

(3) Degeneracy of Genetic Code:

- Degeneracy of genetic code means that multiple codons can specify the same amino acid.
- **Example:** Six different codons (UUA, UUG, CUU, CUC, CUA and CUG) code for the **same amino acid** i.e., **leucine.**
- **Importance:** This characteristic is important for **mutation tolerance** and evolutionary flexibility.

(4) A Codon Does Not Have Punctuations:

- A codon is **read** continuously.
- It means that it is without punctuation (gaps) between the three-nucleotides of a codon.

(5) Genetic Code is Non-overlapping:

- It means that each triplet codon is read independently of the adjacent codons.
- **Example:** The series of AUGAGCGCA codons cannot be read as AUG/UGA/GAG etc. These will only be read as AUG/AGC/GCA.

Check Understanding!

17. **What does the "degeneracy" of the genetic code mean?**
(A) A single codon can specify multiple different amino acids.
(B) Multiple codons can specify the same amino acid.
(C) The genetic code changes randomly across different species.
(D) Codons contain punctuation marks between them.

Table: Codons (on mRNA) and their specific amino acids (or stop functions)

FIRST NUCLEOTIDE	SECOND NUCLEOTIDE U	SECOND NUCLEOTIDE C	SECOND NUCLEOTIDE A	SECOND NUCLEOTIDE G	THIRD NUCLEOTIDE
U	UUU Phenylalanine	UCU Serine	UAU Tyrosine	UGU Cysteine	U
	UUC Phenylalanine	UCC Serine	UAC Tyrosine	UGC Cysteine	C
	UUA Leucine	UCA Serine	UAA Stop	UGA Stop	A
	UUG Leucine	UCG Serine	UAG Stop	UGG Tryptophan	G
C	CUU Leucine	CCU Proline	CAU Histidine	CGU Arginine	U
	CUC Leucine	CCC Proline	CAC Histidine	CGC Arginine	C
	CUA Leucine	CCA Proline	CAA Glutamine	CGA Arginine	A
	CUG Leucine	CCG Proline	CAG Glutamine	CGG Arginine	G
A	AUU Isoleucine	ACU Threonine	AAU Asparagine	AGU Serine	U
	AUC Isoleucine	ACC Threonine	AAC Asparagine	AGC Serine	C
	AUA Isoleucine	ACA Threonine	AAA Lysine	AGA Arginine	A
	AUG Methionine (Start)	ACG Threonine	AAG Lysine	AGG Arginine	G
G	GUU Valine	GCU Alanine	GAU Aspartate	GGU Glycine	U
	GUC Valine	GCC Alanine	GAC Aspartate	GGC Glycine	C
	GUA Valine	GCA Alanine	GAA Glutamate	GGA Glycine	A
	GUG Valine	GCG Alanine	GAG Glutamate	GGG Glycine	G

Multiple Choice Questions (MCQs)

		Key
1.	A gene expresses itself by directing the synthesis of a: (A) Lipid. (B) Carbohydrate. (C) Protein (polypeptide). (D) Vitamin.	1.(C)
2.	The term "Central Dogma" was introduced by: (A) James Watson. (B) Francis Crick. (C) Marshall Nirenberg. (D) Har Gobind Khorana.	2.(B)
3.	According to the Central Dogma, the flow of genetic information is: (A) Protein → RNA → DNA. (B) RNA → DNA → Protein. (C) DNA → RNA → Protein. (D) DNA → Protein → RNA.	3.(C)
4.	The synthesis of RNA from DNA is called: (A) Translation. (B) Replication. (C) Mutation. (D) Transcription.	4.(D)
5.	The synthesis of a protein using the information present in RNA is called: (A) Replication. (B) Translation. (C) Transcription. (D) Transformation.	5.(B)
6.	A codon consists of: (A) One nucleotide. (B) Two nucleotides. (C) Three nucleotides. (D) Four nucleotides.	6.(C)
7.	How many different codons are possible with four nucleotides arranged in triplets? (A) 16. (B) 20. (C) 32. (D) 64.	7.(D)
8.	Which codon acts as the start codon? (A) UAA. (B) UAG. (C) AUG. (D) UGA.	8.(C)
9.	The start codon AUG specifies the amino acid: (A) Methionine. (B) Phenylalanine. (C) Arginine. (D) Glycine.	9.(A)
10.	Which of the following is a stop (nonsense) codon? (A) AUG. (B) UGA. (C) UUU. (D) GUG.	10.(B)
11.	Why did Francis Crick conclude that the genetic code must be a triplet code? (A) One nucleotide. (B) Two nucleotides. (C) Sixty-four codons. (D) Three amino acids.	11.(C)
12.	If the DNA sequence contains the codon TAC, the complementary mRNA codon will be: (A) UAC. (B) AUG. (C) UAG. (D) GUA.	12.(B)
13.	Which characteristic of the genetic code allows genes to be transferred between different organisms? (A) Non-overlapping. (B) No punctuations. (C) Universal. (D) Degenerate.	13.(C)
14.	The degeneracy of the genetic code means that: (A) Many amino acids. (B) Multiple codons. (C) One codon. (D) Overlapping codons.	14.(B)
15.	According to the non-overlapping nature of the genetic code, the nucleotide sequence AUGAGCGCA is read as: (A) AUG/UGA/GAG. (B) AUGA/GCG/CA. (C) AU/GAG/CGC. (D) AUG/AGC/GCA.	15.(D)

CamScanner

TRANSCRIPTION

Exercise LQs

Q.28 Explain the mechanism of transcription.
OR Define the term transcription & explain its mechanism considering its following three phases:
(1) Initiation Phase. (2) Elongation Phase. (3) Termination Phase.

Ans. Transcription:

- **Definition:** A process of synthesis of RNA from DNA is called **transcription.**
- It is the first step of **gene expression.** During transcription, a complementary RNA is synthesised from DNA.
- **Template Strand:** The strand of DNA which is transcribed called the **template strand.** The mRNA synthesised in transcription is complementary to the **template strand of DNA.**
- **Coding Strand:** The strand of DNA that is **not transcribed** is called the coding strand because it has the same sequence as the transcribed mRNA, except T takes the place of U.

For Information
- The template strand of DNA is also known as the antisense (-) strand and coding strand as the sense (+) strand.

Check Understanding!
18. Why does transcription require only one strand of DNA to be copied as a template instead of both?

➢ **Phases of Transcription:**

- The following are the main phases of the transcription of mRNA.

(1) Initiation Phase:

- In transcription process, no **primer** is needed like DNA replication.
- An **enzyme RNA** polymerase binds at template DNA at a special nucleotides sequence. This sequence is called **promoter.** It is not itself transcribed by the enzyme.

Promoter Sites in Prokaryotes:

(a) In **prokaryotes**, a promoter **TTGACA** is present 35 nucleotides before the start point of gene. So, it also called **–35 sequence.**

(b) In **prokaryotes**, another promoter **TATAAT** is 10 nucleotides before the start point of gene. It is also called **–10 sequence.**

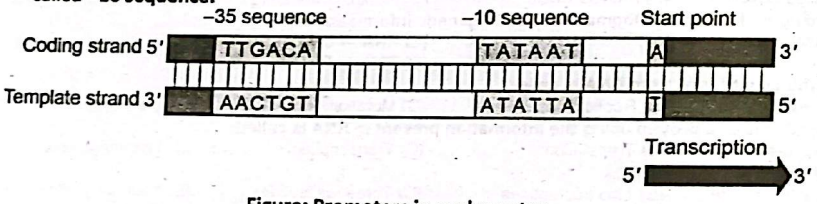


Figure: Promoters in prokaryotes

Promoter Sites in Eukaryotes:

(a) In **eukaryotes**, a promotor **TATAAA** (called **TATA box**) is **25 to 30 nucleotides** before the start point.

(b) In **eukaryotes**, a promoter **GGCCAATCT** (called **CAAT box**) is about 75 to 80 **nucleotides** before the start point.

Role & Structure of RNA Polymerase:

- The core RNA polymerase consists of five subunits:
  - i. **Two Alpha (α) subunits** - bind with regulatory proteins.
  - ii. **One Beta prime (β′) subunit** - binds with template DNA.
  - iii. **One Beta (β) subunit** - binds with RNA nucleotides.
  - iv. **An Omega (ω) subunit** - helps assemble the enzyme and maintains structural stability. In addition to the core, the Sigma (σ) factor temporarily binds to this core to form the holoenzyme. It recognizes the promoter and initiates transcription.

RNA-Polymerase in Prokaryotes & Eukaryotes
- Prokaryotes have only one RNA polymerase, which synthesises all 3 kinds of RNA.
- Eukaryotes have three different RNA polymerases:
  - (i) RNA polymerase I synthesizes rRNA in the nucleolus;
  - (ii) RNA polymerase II synthesizes mRNA;
  - (iii) RNA polymerase III synthesizes tRNA.

- When RNA polymerase attaches to promoter, its σ subunit is removed. The other subunits (core enzyme) catalyse the process.
- They unwind the DNA helix. They breakdown nucleotide-pairs (base-pairs).
- It results in the formation of a **bubblelike structure**, the **transcription bubble.** The assemblage of RNA chain occurs in this bubble.

Check Understanding!
19. Which subunit of RNA polymerase is primarily responsible for recognizing the promoter site and initiating transcription?
(A) Alpha (alpha) subunit
(B) Beta (beta) subunit
(C) Beta-prime (beta') subunit
(D) Sigma (sigma) subunit

(2) Elongation Phase:

- Phase in which **RNA-molecules** starts to synthesize & its length increases.
- Inside the transcription bubble, RNA **polymerase** begins making a chain of complementary ribonucleotides in front of template DNA strand. It is done in 5′ to 3′ direction.
- It usually starts with **A or G ribonucleotide.** Here, the nucleotides available for attachment are in the form of ribonucleoside triphosphates (rNTP).
- When an rNTP is added, its **two phosphates** detach with the release of energy, and ribonucleotide is attached to the chain.
- The first **12 bases of new mRNA** strand make a temporary helix with template DNA strand. Due to it, the position of the 3′ end of the mRNA remains stable.
- So, it can receive an incoming ribonucleotide.
- The **RNA-DNA** helix rotates each time a nucleotide is added. So, the 3′ end of RNA stays at the catalytic site of RNA polymerase. The transcription bubble moves down the DNA.
- The **growing mRNA** strand protrudes from the bubble. After the transcription bubble passes, the transcribed DNA is re-wound.

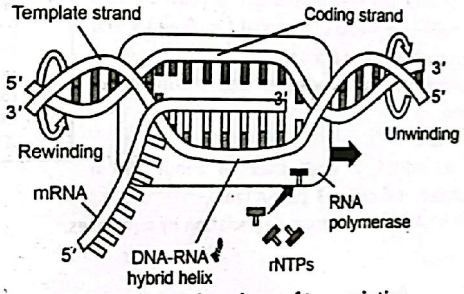


Figure: Elongation phase of transcription

(3) Termination Phase:

- A phase in which RNA synthesis is stopped is called **termination phase.**
- At the end of a gene, there is a "terminator sequence" –a GC-rich **region** followed by a run of A-T pairs.

Synthesis of GC Hair-Pin & U-ribonucleotides:

- When these **nucleotide-pairs** are transcribed into mRNA, hydrogen bonds are formed within the strand of mRNA. This intra-strand nucleotide-pairing (base-pairing) creates a loop called **GC hairpin** with a tail of four or more **U ribonucleotides.** The GC hairpin causes the RNA polymerase to pause.

Check Understanding!
20. How does internal complementary base-pairing within a single RNA strand act as a mechanical brake during transcription termination?

Weakest Pairing:

- The pairing of four **U of mRNA** of with A of DNA is the **weakest.**
- It cannot hold the RNA-DNA hybrid strands together during the long pause.
- So, the RNA strand dissociates from DNA stand within the **transcription** bubble, and **transcription stops.**

CamScanner

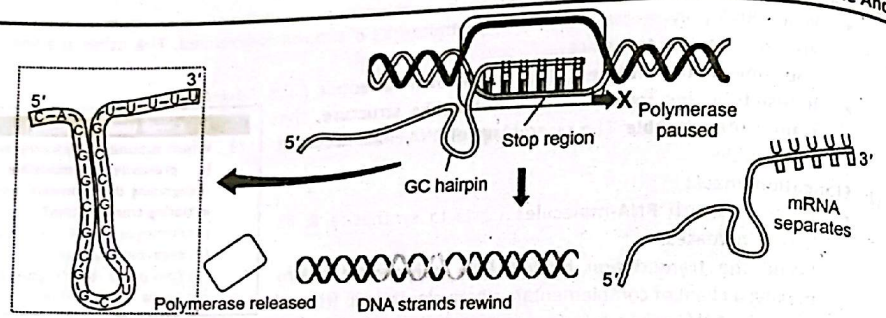


Figure: Termination phase of transcription

Topic: Post-Transcriptional Modification:

Q.29 Discuss the post-transcriptional modification. Exercise Q.13

Ans. Post-Transcriptional Modifications: (Only in Eukaryotes)

- As the **prokaryotes** have **no nucleus** and transcription happens in cytoplasm, their new mRNA does not need to travel anywhere to start translation.
- On the other hand, in eukaryotic **cells** the new mRNA has to travel from nucleus to cytoplasm. For this journey, the new mRNA undergoes the following modifications.

(1) Addition of 5′ Cap:

- The first nucleotide (at the 5′ end of mRNA) is A or G. At the terminal 5′ end of A or G a methylated GTP is attached. This bond is formed between 5′ end of terminal A or G and 5′ end of GTP. This structure is called a 5′ cap.
- It protects the mRNA from nucleases and phosphatases during its journey.

(2) Addition of 3′ Poly-A tail:

- At the 3′ end of mRNA, a small chain of about 250 A nucleotides is added. It is called 3′ poly-A tail.
- It protects the mRNA transcript from degradation by nucleases.

Check Understanding!

21. **What is the process by which introns are removed from immature eukaryotic mRNA and remaining exons are joined together called?**
(A) Replication. (B) Translocation.
(C) Translation. (D) Splicing.

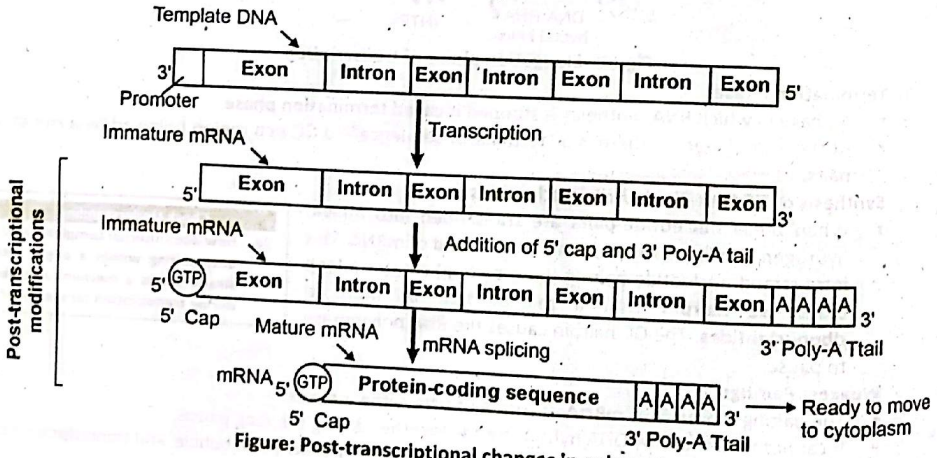


Figure: Post-transcriptional changes in eukaryotes

(3) Splicing:

- The process of **removal of unwanted regions** of mRNA, which do not code for protein is called splicing.
- The new mRNA is **immature** because it contains **introns.**
- Intron's the regions of DNA or mRNA that do not code for **proteins.**
- Exons the regions of DNA or mRNA which are "expressed" or translated into a protein.
- mRNA splicing is the process by which **introns** are removed from the immature mRNA.
- After it, the remaining exons are joined. So, the mature RNA is short and consists of coding segments (gene) only.

Check Understanding!

22. **How does alternative splicing expand proteomic diversity from a limited genome in eukaryotes?**

TRANSLATION

Q.30 Define the process of translation. S/Q

Ans. Translation:

- **Definition:** The process of synthesis of **proteins** with the help of RNA is called **translation.**
- In translation or **protein synthesis,** the information present in an mRNA transcript is used to direct the sequence of amino acids to produce a **polypeptide.**

Q.31 Describe the pre-translational modification. S/Q

Ans. Pre-translational Modification:

Activation of Amino Acids:

- Before **protein synthesis,** the assemblage units for **proteins** are prepared.
- Specific tRNAs attach with specific amino acids and make **aminoacyl-tRNAs (aa-tRNA).**

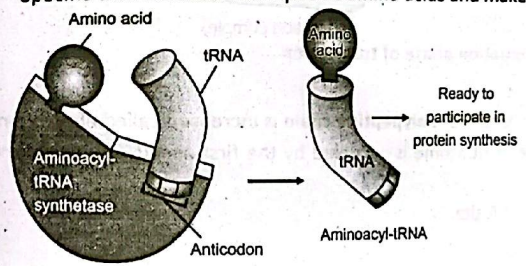


Figure: Activation of amino acids

Check Understanding!

23. **During translation elongation, which enzyme forms a peptide bond between the amino acid at the P site and the amino acid at the A site?**
(A) RNA Polymerase.
(B) Peptidyl transferase.
(C) DNA Ligase.
(D) Aminase.

- The **enzyme aminoacyl-tRNA synthetase** carries out this reaction. There are 20 kinds of this enzyme.
- Each **kind binds** to a specific amino acid. It also recognizes and binds to the tRNA with anticodons for that amino acid. The aa-tRNA delivers the amino acid to the ribosome for incorporation into the polypeptide chain.

Q.32 Explain the process of translation with the help of three phases named as, initiation, elongation and termination. Exercise Q.9

Ans. Phases of Translation:

(1) Initiation Phase: (Synthesis of Initiation Complex)

- In this phase, an **initiation complex** is formed in the following steps:

(i) The aminoacyl-tRNA (aa-tRNA) carrying the **first amino acid** binds to the smaller ribosomal subunit. An enzyme called **initiation factor** controls this binding. In prokaryotes, the **first amino acid** is modified methionine i.e., **N–formyl-methionine.** While in eukaryotes, it is **non-modified methionine.**

CamScanner

(ii) Another initiation factor attaches the 5′ end of mRNA with smaller ribosomal subunit. It positions the anticodon of aa-tRNA over the first codon (AUG) of mRNA.

(iii) The larger ribosomal subunit is also placed upon smaller subunit.

Components of Initiation Complex:

- The **initiation complex** formed in this way consists of:
  (a) Both ribosomal subunits. (b) First aa-tRNA.
  (c) mRNA. (d) The enzyme (Initiation Factor).
- The site of ribosome where first aa-tRNA is placed consists of 3-sites:
  (a) A Peptidyl Site (P Site): Where peptide bonds will form between amino acids.
  (b) An Aminoacyl Site (A Site): Where next aa-tRNA will bind.
  (c) An Exit Site (E Site): Where empty tRNAs will exit the ribosome.
- With respect to mRNA, the three **sites are oriented** in 5′ to 3′ as E-P-A, because ribosomes move toward the 3′ end of mRNA.

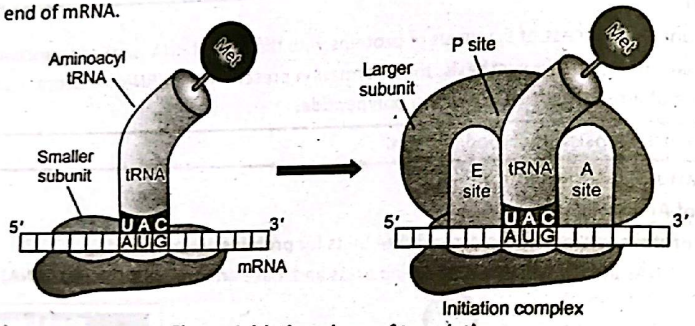


Figure: Initiation phase of translation

(2) Elongation Phase:

- The phase of translation in which the length of **polypeptide chain is increased** called **elongation** phase.
- In the initiation complex, the **P -site** of ribosome is occupied by the first aa-tRNA (with its anticodon matching the mRNA codon).
- The **next codon** of mRNA is exposed at A site.

Steps Involve in Elongation Phase:

- Elongation happens in the following steps;
  (i) After the First **aa-tRNA** the next aa-tRNA with matching anticodon and matching amino acid binds to **A site** with the help of an enzyme, the **elongation factor.**
  (ii) Another enzyme **peptidyl transferase** removes methionine from first aa-tRNA present on P site and attaches it by a peptide bond to the amino acid of the second aa-tRNA present at A site.
  (iii) The ribosome moves three nucleotides along the mRNA in 5′- 3′ direction. This movement is called **translocation.**
  (iv) As a result of the previous step, the aa-tRNA carrying the chain of two amino acids is shifted from A site to P site. The new codon of mRNA is also exposed at A site. Moreover, the empty tRNA comes to E site to leave the ribosome. These steps are repeated again and again until the stop codon is reached at A site.
  (v) These steps are **repeated again and again** until the stop codon is reached at A site.

Check Understanding!

24. Trace the pathway of a tRNA molecule from its activation to its final departure from the ribosome.

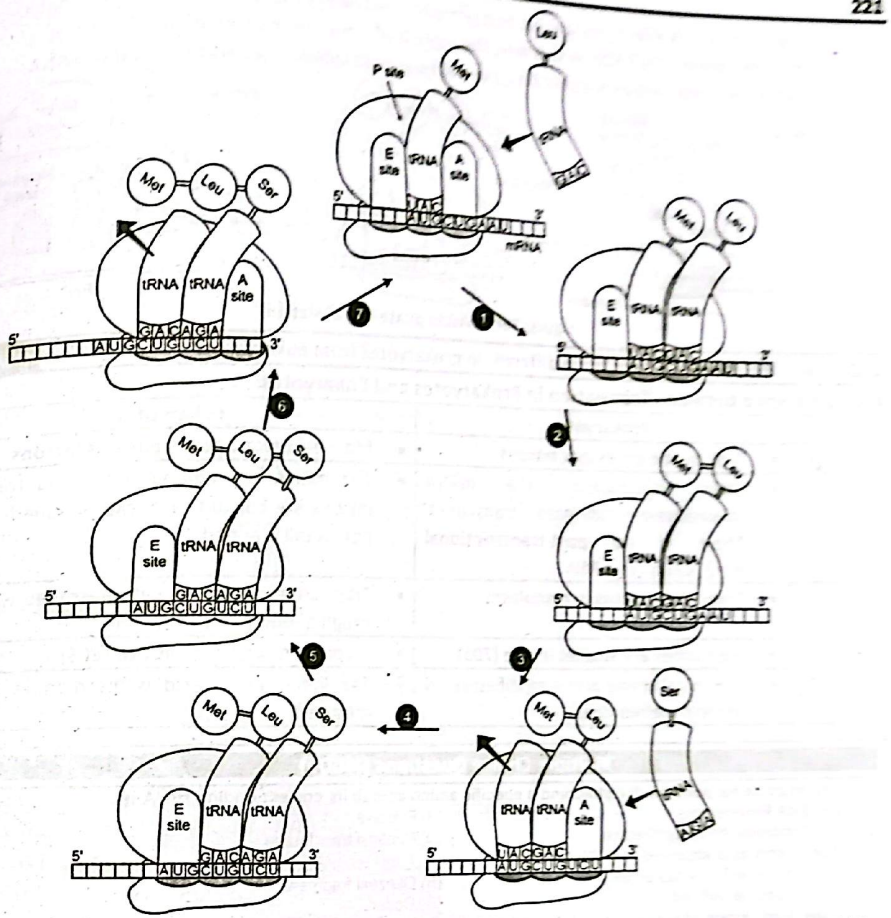


Figure: Elongation phase of translation (1- second aminoacyl-tRNA binds to A site; 2- first amino acid is removed from first tRNA and attached to the amino acid of the second aminoacyltRNA; 3-ribosome moves three nucleotides in 5′- 3′ direction; 4 - third aminoacyl-tRNA binds to A site; 5-chain of first two amino acids is removed from the tRNA at P-site and attached to the amino acid of the third aminoacyl-tRNA; 6- ribosome again moves three nucleotides and next codon of mRNA is exposed at A site; 7- the process is repeated for all codons)

(3) Termination Phase:

- When the required length of the **polypeptide chain** is completed the translation process is stoped this phase is called **termination phase.**

Mechanism of Termination Phase:

- When a **stop codon** is exposed at **A site,** no **aminoacyl-tRNA** comes to A-site (because there is no anticodon of the stop codons).

Check Understanding!

25. Which of the following is a structural difference between prokaryotic and eukaryotic translation?
(A) Prokaryotes use 80S ribosomes, while eukaryotes use 70S ribosomes.
(B) Prokaryotic translation occurs on rough ER, while eukaryotic translation occurs strictly in free cytoplasm.
(C) Prokaryotes possess introns, whereas eukaryotic genes lack them.
(D) Prokaryotes utilize smaller 70S ribosomes, whereas eukaryotes utilize larger 80S ribosomes.

CamScanner

- Stop codon at A site is recognized by a protein called release factor. It releases the polypeptide from the tRNA present at P site. In this way, the process of translation is terminated.
- The tRNA is also released from ribosome and ribosomal subunits separate from the mRNA.

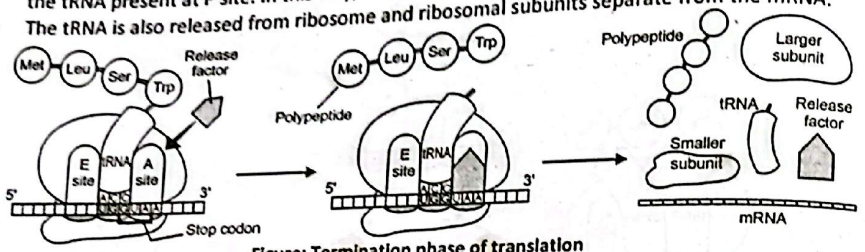


Figure: Termination phase of translation

Q.33 How is the process of translation different in prokaryotes from eukaryotes? Exercise L/Q.10

Ans. Difference between Translation in Prokaryotes and Eukaryotes:

	Prokaryotes	Eukaryotes
(i)	• Prokaryotic genes lack introns.	• Most eukaryotic genes possess introns.
(ii)	• After transcription, the mRNA immediately undergoes translation. There is no post-transcriptional modification in mRNA.	• The mRNA is modified before its translation: introns are cut out; a 5′ cap is added; and a 3′ poly-A tail is added.
(iii)	• Translation occurs in cytoplasm.	• Translation occurs in cytoplasm as well as in rough endoplasmic reticulum.
(iv)	• Ribosomes are smaller in size (70S).	• Ribosomes are larger in size (80S).
(v)	• The initial amino acid is modified i.e., N -formyl methionine.	• The initial amino acid is methionine. It is not modified.

Multiple Choice Questions (MCQs)

1. The enzyme responsible for attaching a specific amino acid to its corresponding tRNA is:
(A) DNA Polymerase. (B) Primase. (C) Aminoacyl-tRNA synthetase. (D) Peptidyl transferase.
2. The amino acid attached to a tRNA forms:
(A) Aminoacyl-tRNA (aa-tRNA). (B) Okazaki fragment. (C) Ribosomal subunit. (D) Codon.
3. How many kinds of aminoacyl-tRNA synthetase enzymes are?
(A) 10. (B) 20. (C) 40. (D) 64.
4. In prokaryotes, the first amino acid used during translation is:
(A) Methionine. (B) Glycine. (D) Phenylalanine. (C) N-formyl methionine.
5. During initiation, the start codon (AUG) is recognized by the anticodon of the first aa-tRNA with the help of:
(A) Elongation factor. (B) Release factor. (C) Initiation factor. (D) DNA Ligase.
6. Which ribosomal site receives the incoming aminoacyl-tRNA?
(A) E site. (B) P site. (C) A site. (D) T site.
7. The enzyme that forms peptide bonds between amino acids is:
(A) Primase. (B) Peptidyl transferase. (C) DNA Polymerase III. (D) Aminoacyl-tRNA synthetase.
8. The movement of the ribosome by three nucleotides along the mRNA is called:
(A) Replication. (B) Translation. (C) Translocation. (D) Transformation.
9. During translation, ribosomes move along mRNA in the:
(A) 3′ → 5′ direction. (B) 5′ → 5′ direction. (C) Circular direction. (D) 5′ → 3′ direction.
10. Which protein recognizes the stop codon during termination?
(A) Initiation factor. (B) Elongation factor. (C) Release factor. (D) Helicase.
11. Why does no aminoacyl-tRNA bind to the A site when a stop codon is reached?
(A) No anticodon. (B) Ribosome stops. (C) mRNA destroyed. (D) No amino acids.

Key
1.(C)
2.(A)
3.(B)
4.(D)
5.(C)
6.(C)
7.(B)
8.(C)
9.(D)
10.(C)
11.(A)

12. What is the primary role of aminoacyl-tRNA during translation?
(A) Synthesizes mRNA. (B) Delivers amino acid. (C) Unwinds DNA. (D) Joins subunits.
13. Which statement correctly compares translation in prokaryotes and eukaryotes?
(A) Both 80S. (B) 70S, 80S. (C) 80S, 70S. (D) No ribosomes.
14. Which post-transcriptional modification occurs in eukaryotic mRNA before translation?
(A) Add introns. (B) Remove exons. (C) Cap, tail, splicing. (D) Uracil replacement.
15. Which statement about translation in prokaryotes is correct?
(A) Nucleus only. (B) fMet, immediate. (C) 5′ cap. (D) 80S ribosomes.

Key
12.(B)
13.(B)
14.(C)
15.(B)

REGULATING GENE EXPRESSION

Q.34 What is the regulation of gene expression discuss the importance of regulation of gene expression? Exercise L/Q.11

Ans. Regulating Gene Expression:

- **Definition:** Turning the genes ON and OFF and the timing of their expression are controlled by regulator proteins and the process is called regulation of gene expression.
- All of the genes in an organism are not expressed simultaneously. Instead, different genes are expressed at different times.
- Similarly, all types of cells contain the same genome but all genes are not turned ON in all cells.
- Instead, specific genes are turned ON in each cell type.

Check Understanding!
26. How does transcriptional control account for functional cellular differentiation between cells with identical genomes?

Importance of Regulation of Gene Expression:

(i) Enables Cells To Respond Environmental Condition:
- Regulation of gene expression enables the cells to respond to environmental conditions and to prepare protein when needed.

(ii) Basis of Cellular Differentiation + Morphogenesis:
- In multicellular organisms, gene regulation is the basis for cellular differentiation and morphogenesis. It leads to the creation of different cell types.
- In different cell types, the genome is the same but different genes are expressed according to the type.

Topic: Methods of Regulation of Gene Expression:

Q.35 Name the four levels of regulation of gene expression. S/Q

Ans. 4-Levels of Regulation of Gene Expression:

- Regulation of gene expressions occurs at several levels out of which 4-most important are given below:
  - **(i) Transcription Level:** At which the rate of transcription is regulated.
  - **(ii) Post-transcriptional Level:** At which the modification of mRNA is controlled.
  - **(iii) Translation Level:** At which the rate of translation is regulated.
  - **(iv) Post-Translational Level:** At which the modification of protein (its folding, stability etc.) is regulated.

Q.36 Discuss the methods of regulation of gene expression. Exercise L/Q.12

Ans. Methods of Regulation of Gene Expression:

- The important methods of regulation of gene expression include:

(1) Regulation at Transcriptional Level:

- The genes have special regulatory sequences. Specific regulatory proteins bind to these sequence.
- These proteins can take two types of actions:

(a) Negative Gene Regulation:
- Some regulatory proteins, called repressors bind to some pieces of DNA, called operators, present near the promoter.
- Here, the repressors (proteins) block RNA polymerase and stop or reduce transcription.

Check Understanding!
27. What process allows regulatory proteins to remove different combinations of exons and introns from a single immature mRNA, yielding multiple polypeptides?
(A) Point mutation. (B) Alternative splicing. (C) Non-disjunction. (D) DNA ligation.

CamScanner

(b) Positive Gene Regulation:

- Some regulatory proteins, called **activators** (or inducers) bind to the **operators (piece of DNA).**
- Here, the activators start transcription or **increase** its speed by helping in the binding of RNA polymerase to the promoter.

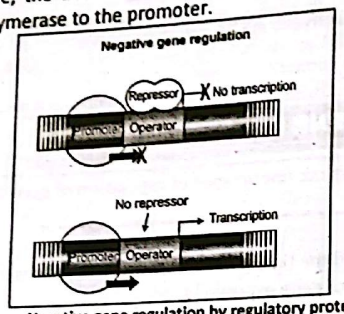


Figure: Negative gene regulation by regulatory protein

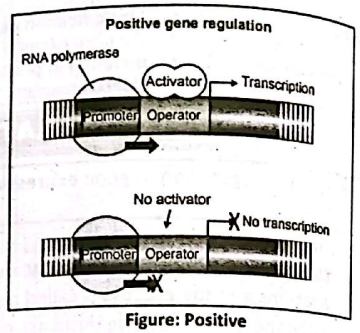


Figure: Positive

(2) Regulation During Splicing: (Post Transcriptional Level)

- In eukaryotes, **mRNA is modified** before its export to cytoplasm.
- Genes can also be **regulated (tuned ON or OFF)** during mRNA splicing **(removal of introns and joining the exons).**
- Specific regulatory proteins in specific cell types control **splicing.**
- These proteins remove the pieces of mRNA **(introns or exons)** in different ways.
- So, mRNAs of different lengths are **produced.**
- It results in the **production** of more than one polypeptide from a single gene.

Tidbit

- Liver cells express specific genes which make the enzyme alcohol dehydrogenase. This enzyme breaks alcohol down into a non-toxic molecules.
- The neurons of brain also have these genes but they keep these genes unexpressed or **"turned OFF".**

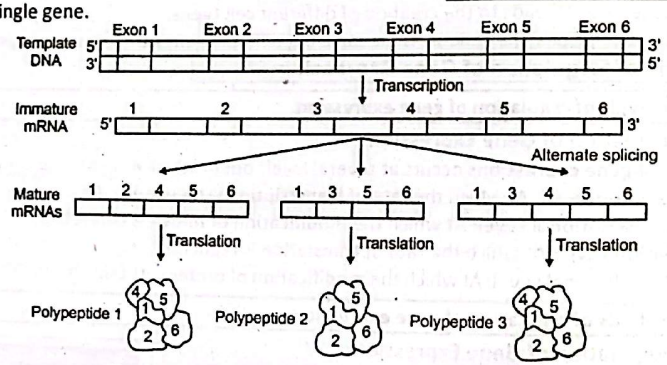


Figure: Alternate splicing and different gene products

MUTATIONS

Q.37 Define mutation, name its types on the base of range. S/Q

Ans. Mutation:

- A change in the content of **genetic message** is called mutation.

➢ **Types of Mutation: (On the Basis of Range)**

(a) Small Mutations: A change in a single or a few nucleotides.

(b) Large Mutations: A change in a **large segment** or **whole chromosome.**

Q.38 Define & explain the effects of the following types of mutation: (i) Natural Mutations. (ii) Induced Mutations. L/Q

Ans. Types of Mutation:

(i) Natural Mutations:

- The mutations which occur **spontaneously** as a result of sequencing errors or DNA damage during **replication.**
- **Effects:** These mutations are a part of the process of evolution and can result in **beneficial, neutral,** or **harmful** effects on organism.

(ii) Induced Mutations:

- The mutation which are **caused by external factors** such as exposure to mutagen substances or radiation are called induced mutations.
- Induced mutations can also result from **exposure to chemicals** in the environment, including certain pesticides and industrial pollutants, or from medical treatments such as chemotherapy.
- **Effects:** Induced mutations can have **serious health** effects on an organism.

Mutations - Contributors in Evolution

- The ultimate sources of all genetic variation are mutation are recombination.
- These processes create new DNA sequence (allele) and combination of alleles.
- The new alleles form new traits which may be advantageous, harmful or neutral.
- Natural selection acts upon the variations created by new traits and the allelic frequencies of advantageous traits increase.
- It leads of evolution in the long run.

For Information

Q. Define the terms (i) Mutagens (ii) Mutant.

Ans. (i) **Mutagen:** The agents that cause mutations are called mutagens.

(ii) **Mutant:** The organism or cell in which mutation occurs is called mutant.

Q.39 Name the types of mutations on the basis of size of mutations. S/Q

Ans. Types of Mutations on the Basis of Size of Mutations:

- On the basis of the size of mutations, we can classify them in **two main types.**

(i) Point Mutations. **(ii) Chromosomal Mutations.**

Topic: Point Mutations:

Q.40 What is point mutation, discuss examples & sources of point mutation. Exercise L/Q.14

Ans. Point Mutations: (Small Mutations)

- The **mutations** involving the change in **only one or a few nucleotides,** are called point mutations.

➢ **Examples of Point Mutations:**

- The following are the common examples:

(i) Substitutions:

- These mutations involve **exchange of a single nucleotide** for another.
- **Example:** During replication, A may be substituted with G or C is substituted with T.

(ii) Insertions:

- It is the **addition** of one or more extra nucleotides into the DNA.
- These mutations usually occur due to errors during replication.

(iii) Deletions:

- The removal of **one or more nucleotides** from the DNA are called **deletions.**

For Information

Gene mutation:

- It is a general term for any change within the chemical structure of a single gene. It is a change at the **"molecular level"** (the nucleotide sequence) rather than at the "chromosomal level" (large chunks of DNA).
- **Point mutation are the most common gene mutation.**

Normal DNA	• TAT CAT CCT AAG GTA
• Protein	• Tyr-His-Pro-Lys-Val
• Substitution	• TAT CAT CGT AAG GTA
• Protein	• Tyr-His-Arg-Lys-Val
• Insertion	• TAT CAT CGC TAA GGT A
• Protein	• Tyr-His-Arg-Stop
• Deletion	• TAT CTC CTA AGG TA
• Protein	• Tyr-Leu-Leu-Arg-···

Figure: Point mutations

➢ **Sources of Point Mutations:**

(i) Physical Damage to DNA:

(a) Ionizing Radiations:

- High-energy forms of radiations, such as **X rays** and **gamma rays,** are highly mutagenic.

CamScanner

- Such radiations change atoms into free radicals which may break phosphodiester bonds of DNA strand and cause changes in DNA.

(b) Ultraviolet Radiations:

- DNA strongly absorbs UV radiation.
- When two adjacent pyrimidine nucleotides (C and T) absorb UV radiations, a double covalent bond forms between them.
- It can result in complete **replication blockage.**

(ii) Mutagen Chemicals:

- Many point mutations are caused by **mutagen chemicals.**

(a) Resemblance of Mutagen Chemical with Nucleotides:

- Some of these chemicals resemble nucleotides and are incorporated into DNA. Such DNA cannot be properly transcribed.

(b) Mutagen Chemical Remove Amino Group:

- Some chemicals remove the **amino** group from adenine or cytosine, causing them to **mis-pair.**

(c) Mutagen Chemicals add Hydrocarbons:

- Some **chemicals** add hydrocarbon groups to nucleotides, also causing them to mis-pair.

- Such mutagen chemicals are commonly used in **laboratories,** and sometimes released into the environment (e.g., **mustard gas**).

Check Understanding!

28. Compare how UV radiation and ionizing radiation induce point mutations at a molecular level.

Topic: Spontaneous Point Mutations:

Q.41 What are spontaneous point mutations? SQ

Ans. Spontaneous Point Mutations:

- The mutations or change in nucleotides without **any cause** i.e. automatic mutations are called **spontaneous point mutations.**
- Many **point mutations** occur spontaneously. Sometimes nucleotides spontaneously shift to alternative positions.
- During replication, DNA polymerase pairs a different nucleotide with the shifted nucleotide.
- Sometimes, the nucleotide sequences misalign when homologous chromosomes pair. It causes a **portion** of one strand to loop out.
- The cell cuts out the loop and it results in a deletion of several hundred nucleotides from one of the chromosomes which results in mutations.

Q.42 Describe the five type of minor-mutations in human. LQ

Ans. 5-Types of Minor Mutations in Humans:

(i) Single Nucleotide Polymorphisms (SNPs):

- These mutations involve a **single nucleotide.**
- These are very common and can be harmless or have a subtle effects.
- **Example:** A single base change in a gene can make a **person** unable to **digest milk** (lactose).

(ii) Insertions and Deletions:

- These mutations **add or remove** one or more nucleotides.
- **Example:** The common cause of **Cystic Fibrosis** is a deletion of just three nucleotides in a gene.
- This deletion causes a specific amino acid to be left out, resulting in a protein that doesn't fold correctly, leading to lung and digestive issues.

(iii) Silent Mutations:

- The mutations which do not change the amino acid sequence of protein.

Check Understanding!

29. A mutation changing a DNA codon from GGC to GGU without altering the resulting amino acid is called a:
(A) Missense mutation.
(B) Nonsense mutation.
(C) Silent mutation.
(D) Frameshift deletion.

- **Example:** A DNA code changes from **GGC to GGU.** Because of the "degeneracy" of the genetic code, both of these codes translate to the same amino acid: Glycine.

(iv) Missense Mutations:

- The mutations which change only one amino acid, which can affect protein function.
- **Example:** A single nucleotide change **(A to T)** in the gene for haemoglobin causes one amino acid (Glutamic acid) to be replaced by another (Valine).
- This single "wrong" amino acid causes red blood cells to lose their round shape and causes sickle cell anaemia.

(v) Nonsense Mutations:

- The mutations which **create a premature stop codon** in the protein sequence. It results in shortened and non-functional proteins.
- **Example:** In Duchenne **Muscular Dystrophy,** a nonsense mutation creates a premature stop signal in the middle of the gene. The resulting protein is **too short and cannot function,** leading to progressive muscle weakness.

Q.43 Why are Most Mutations Harmful? SQ

Ans. Harms of Mutations:

- Most mutations **disrupt the normal** functioning of genes and prove harmful.
- **Example:**

(i) Sickle Cell Anaemia:

- A mutation that changes a **single amino acid** in the haemoglobin protein can lead to sickle cell anaemia, a debilitating (loss of strength) and potentially life-threatening disease.

Check Understanding!

30. How does substituting a single amino acid in sickle cell hemoglobin alter red blood cell morphology?

(ii) Cancer:

- Mutations can also **disrupt gene regulation** and can alter developmental processes and contribute to the development of various diseases, such as cancer.

(iii) Phenylketonuria:

- Some **mutations** can create non-functional or **unstable proteins** that can be harmful to the organism e.g., phenylketonuria.

Topic: Genetic Disorders Caused by Point Mutations:

Q.44 How are disorders due to point mutations inherited & give two examples? SQ

Ans. Genetic Disorders Caused by Point Mutations:

- The disorders that result from a **change in the DNA sequence** can be inherited in an autosomal dominant, autosomal **recessive,** or **X-linked manner.**
- The following are **two important genetic** disorders caused by single-gene mutations.
  (1) Sickle Cell Anaemia. **(2) Phenylketonuria.**

Topic: (1) Sickle Cell Anaemia:

Q.45 Discuss the causes, effects, symptom, & treatment of sickle cell anaemia. Exercise LQ.17

Ans. Causes of Sickle Cell Anaemia:

- Sickle cell Anaemia is caused due to a **recessive** gene of **abnormal β chain** of haemoglobin. This gene is present on **chromosome 11.**
- The recessive gene has a point mutation in which the **DNA nucleotide T is substituted by A.**
- So, the **codon CTC** of glutamic acid is converted to **CAC,** which is for **valine.** If a child receives both recessive (mutant) alleles, he produces **abnormal β chains** (with glutamic acid replaced by valine).

Effects of Sickle Cell Anaemia:

- The abnormal haemoglobin carries lesser than normal oxygen.
- Due to this abnormal haemoglobin, RBCs also become sickle shaped.

CamScanner

➢ **Symptoms of Sickle Cell Anaemia:**
- Major symptoms of sickle cell anaemia include **pain, fatigue, shortness of breath, jaundice,** and an **increased risk of infections.**

➢ **Treatment & Cure of Sickle Cell Anaemia:**
- The treatments for sickle cell anaemia include **pain management** with non-steroidal **anti-inflammatory drugs (NSAIDs)** and opioids etc.
- Blood transfusions can help to increase the number of **healthy RBCs.**
- **Long Term Cure:** Bone marrow transplants can provide a long-term cure.

Prevention of Complications:
- Regular monitoring and **preventative** measures such as **vaccinations** and antibiotics can help to prevent complications.

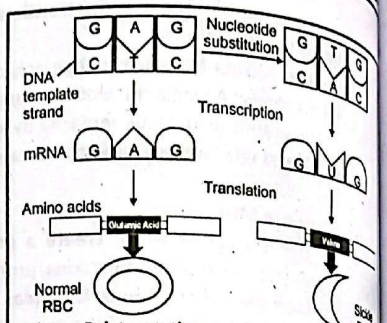


Figure: Point mutation, causing sickle cell anaemia

Topic: (2) Phenylketonuria:

Q.46 What is phenylketonuria, discuss its causes, effect, symptoms, prevention, and treatments. Exercise LQ

Ans. Phenylketonuria (PKU):d
- It is a genetic metabolic disorder.

➢ **Causes of Phenylketonuria:**
- A normal gene present on **chromosome 12** produces an enzyme of liver called **phenylalanine hydroxylase (PAH).**
- This enzyme coverts amino acid phenylalanine into tyrosine.
- Point mutation (e.g., substitution or deletion of a nucleotide) makes the allele recessive.
- If a child inherits both recessive alleles, **PAH enzyme** is not **produced** properly and its activity is reduced.
- As a result, **phenylalanine** can build up to **toxic levels** in the blood and other tissues. This condition is called **phenylketonuria (PKU).**

➢ **Symptoms of Phenylketonuria:**
- Major symptoms include **intellectual disability, seizures, behavioural problems, mental disorder, microcephaly (smaller head size),** and **musty odour in breath, skin,** and **urine.**
- Excessive phenylalanine can also cause **brain damage.**

➢ **Preventive Measures for Phenylketonuria:**
- Individuals with PKU have to avoid foods that are high in **phenylalanine** (e.g., **meat, dairy products, eggs,** and **some grains**).
- The blood phenylalanine levels are monitored regularly to adjust the diet.

➢ **Treatments of Phenylketonuria:**
- Some medications contain **synthetic enzymes.** These are used to lower blood phenylalanine levels.
- Patients are also given nutritional **supplements** to ensure they are getting enough **vitamins** and **minerals** that may be lacking in the low-phenylalanine diet.

Topic: Possible ways to Treat Genetic Diseases:

Q.47 Give brief description of possible ways to treat genetic disease. LQ

Ans. Possible ways to Treat Genetic Diseases:

(i) Gene Therapy:
- It involves correcting or replacing the mutated gene with a functional gene.

(ii) Cell Therapy:
- For example, in type 1 diabetes, the pancreatic beta cells that produce insulin do not function.

- Cell therapy involves replacing these cells with healthy ones through transplantation.

(iii) Pharmacogenomics:
- This involves tailoring drug treatments to an individual's genetic makeup.
- By analysing a patient's DNA, doctors can identify the best drug for them.

(iv) Genetic Counselling:
- For individuals with a family history of genetic diseases, genetic counselling can provide valuable information and support.
- This includes genetic testing, education on the disease, and guidance on family planning and reproductive options.

Topic: Chromosomal Mutations:

Q.48 What are chromosomal mutations, give names of their two types? S/Q

Ans. Chromosomal Mutations:
- **Definition:** The large-scale **mutations** which involve changes in the **position of genes,** or changes in the structure or number of chromosomes are called as **chromosomal mutations.**
- These mutations are usually **spontaneous.**

➢ **Types of Chromosomal Mutations:**
- The following are the main types of chromosomal mutations.
  (1) Changes in Chromosome Structure.
  (2) Changes in Chromosome Number (Chromosomal Aberrations).

Q.49 Discuss the two types of chromosomal mutations which cause changes in structure of chromosomes. LQ

Ans. Types of Chromosomal Mutations:

(1) Chromosomal Changes which Changes in Chromosome Structure:

(i) Chromosomal Rearrangements:
- Chromosomes can **undergo** physical alterations (changes). Such changes may involve **deletions, duplications, inversions,** and **translocations.**
- **Causes:** Usually, these changes are caused by a breakage in the DNA double helices at two different locations.
  (a) Translocations: In which a segment of **one chromosome** becomes part of another chromosome.
  (b) Inversions: In which the orientation of a **portion** of a chromosome is reversed.

Check Understanding!
31. Mobile genetic elements that can move around the genome and cause insertional inactivation of genes are called:
(A) Histones.
(B) Transposons (jumping genes).
(C) Okazaki fragments.
(D) Promoters.

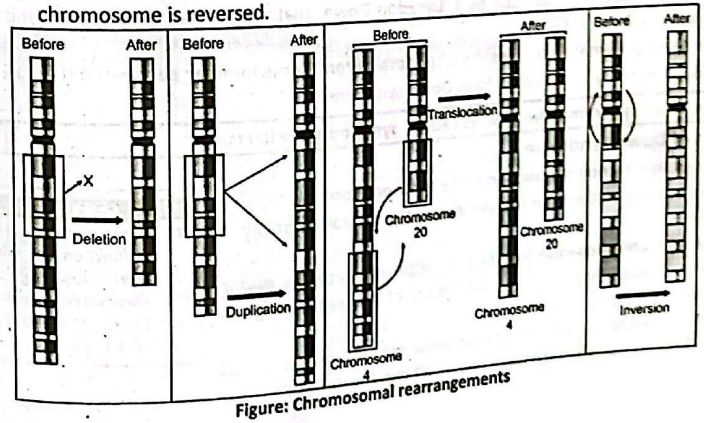


Figure: Chromosomal rearrangements

(ii) Insertional Inactivation:

- Many small segments of chromosomes can move from one location to another in the genome.
- **Transposons:** The mobile bits of DNA are called **transposons or jumping genes.**
- **Transposons** select their new locations at random.
- Some transposons are able to be **inserted into genes** and inactivate the genes. This form of mutation is common in nature.
- Many **human gene** disorders are the result of **transposition.**
- **Example:** A human transposon gets inserted into clotting **factor IX** gene on **X chromosome.** It places a stop codon in the middle of the gene. It results in **X-linked haemophilia.**

Tidbit

- There is a much greater chance of nondisjunction to accumulate over time in eggs than in sperm.
- The reason is that all of the future eggs have developed to the point of prophase I by the time a female is born. It means that when she has children her eggs are as old as she is.
- In contrast, men produce new sperm daily. Therefore, the age of mother is more critical than that of father.

(2) Changes in Chromosome Number (Chromosomal Aberrations):

- The failure of sister chromatids separate properly in meiosis, leading to the gain or loss of a chromosome in a gamete condition, called **non-disjunction.**
- **Effects:** It can result in individuals with **severe abnormalities** if the affected gamete forms a zygote.
- Nondisjunction can happen in **autosomes** or in sex chromosomes.

Q.50 Define non-disjunctions, what are its effects & give a few examples.

Ans. Non-Disjunctions:

- The failure of separation of **chromosome** pairs—either homologous chromosomes during **meiosis-I** or **sister chromatids** during **meiosis-II** results in abnormal chromosome numbers in daughter cells is called non-disjunction.
- The following are the major abnormalities that arise due to **non-disjunction.**
  (1) Down Syndrome.
  (2) Klinefelter Syndrome.
  (3) Turner Syndrome.

Check Understanding!

32. Why do human autosomal monosomies fail to complete embryonic development while certain sex chromosome aberrations survive?

Topic: (1) Down Syndrome:

Q.51 Who first time describe Down Syndrome? Exercise L/Q.5

Ans. Down Syndrome:

- It was first described in **1866 by J. Langdon Down;** that's why it is called Down syndrome (formerly "Down's syndrome").
- It is developmental defect, results when **total chromosome number becomes 47(2n+1).**
- About 1 in every 750 children have Down syndrome.

Q.52 What is Down syndrome, describe its causes, symptoms, & effects. Exercise L/Q.5

Ans. Causes of Down Syndrome:

- It is caused by **non-disjunction** in the **autosome pair 21.**
- This non-disjunction can happen during the **formation** of egg in women.
- The **21st chromosomal** pair fails to segregate properly during meiosis and results in the formation of an egg having 24 chromosomes.
- The fertilization of such egg by a **normal sperm** produces a child (male or female) with **trisomy** having **47 chromosomes.**

Check Understanding!

33. Down syndrome is caused by non-disjunction in which autosome pair, resulting in a total chromosome count of 47?
(A) Pair 13 (B) Pair 18
(C) Pair 21 (D) Pair 22.

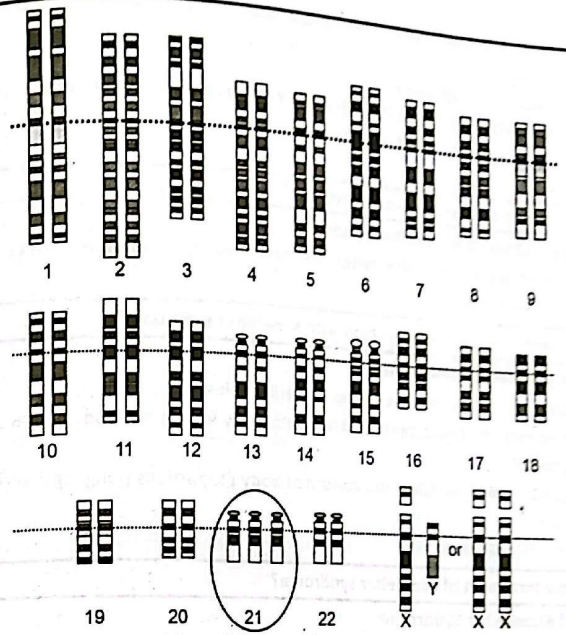


Figure: Karyotype of Down syndrome

Symptoms of Down Syndrome:

- Its symptoms include **mental** impairment, **stunted growth,** increased **skin on back and neck, flat facial features, small head, short neck** and **limbs, upward slanting eyes, small ears, poor muscles, a protruding tongue,** and **heart defects.**

Effects of Down Syndrome: (Both in Males & Females)

- **Males** with Down syndrome are usually **sterile.**
- **Females** have lower rates of **fertility relative** to normal females.

Q.53 How can down syndrome be managed? Exercise L/Q.15

Ans. Management of Down Syndrome's Child:

- Proper management of affected children can improve the quality of life of people with Down syndrome including:
  (i) Screening for common problems and medical treatment where indicated.
  (ii) A good family environment and special education and proper care.

Tidbit

- If an **XX** egg fuses with an X sperm, the female child will have **47 chromosomes** with XXX sex chromosomes. This Trisomy in X is known as triple **X** syndrome.
- Such females show symptoms of learning disabilities, tall stature, and wide-spaced eyes.
- They are **fertile** and puberty starts at normal age.

Topic: (2) Klinefelter Syndrome (XXY): [Phenotype – Male]

Q.54 How is Klinefelter syndrome caused? Exercise L/Q.15

Ans. Klinefelter Syndrome:

- If **non-disjunction** of **X chromosome** occurs during meiosis in mother, the egg may have **both X chromosomes** (XX) or may have no **sex chromosome** (designated as O).

Concept Clarity

Non-Disjunction:

- Process of failure of separation of chromosomes during meiosis.

(i) Due to Non-disjunction in Egg:

- If an egg due to non-disjunction with **XX chromosomes** is fertilized by a **normal sperm** with Y the offspring will have **trisomy (XXY)** in sex chromosomes and the **total number of chromosomes** will be 41 (2n + 1 or 44 + XXY).

CamScanner

- Such non-disjunction may also occur in father during gamete formation.

(ii) Due to Non-disjunction of Sperm:

- It can result with a sperm having **both X and Y chromosomes** i.e., XY. If such sperm fertilizes a norma egg (X) it may result in **XXY chromosomes** in child. This condition (XXY) is known as Klinefelte syndrome.

Q.55 Who described the Klinefelter syndrome first time? SExercise L/Q.

Ans. First Time Description of Klinefelter Syndrome:

- An **American physician Harry Klinefelter**, first described this syndrome in **1942 that's** why it is name as Klinefelter syndrome.

Q.56 What are the symptoms of affected person with Klinefelter syndrome? Exercise L/Q.

Ans. Symptoms of Klinefelter Syndrome:

- **Sterile Males:** The affected children grow to **sterile males.**
- **Male with Female like Characteristics:** Male with many female like body characteristics **less body hair & breast growth.**
- Such males have **small testicles**, and **abnormal body** proportions (long legs, short trunk, and shoulde equal to hip size).
- Their voices may not be as deep.

Q.57 What is possible treatment of Klinefelter syndrome? Exercise L/Q.1

Ans. Treatment of Klinefelter Syndrome:

- The treatments include:

(i) Giving Testosterone: To compensate testosterone deficiency at onset of puberty.
(ii) Surgical removal of breast.
(iii) Behavioural Therapy: It is given to help in language disorders, difficulties at school, and socialization.

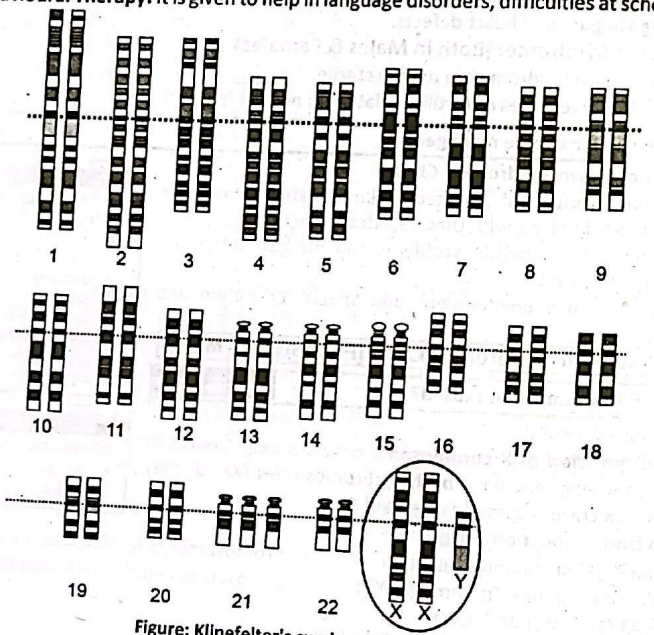


Figure: Klinefelter's syndrome karyotype

Topic: (3) Turner Syndrome: (XO + 44 = 45) [Phenotype - Female]

Q.58 Describe the symptoms, causes, and treatments of turner syndrome. Exercise L/Q.16

Ans. Turner Syndrome: (XO Condition Phenotype = Female)

- If an egg with **no X chromosome** (O) fuses with a **normal Y sperm**, the resulting **OY zygote fails to develop** further because humans cannot survive without the **genes on X chromosome.**

Causes of Turner Syndrome:

- If an **egg with no** (zero) X chromosome fuses with a **normal X sperm** (or a O sperm fuses with a normal X egg), the zygote develops into female baby with 45 chromosomes (XO or 2 n -1 or 44 + XO).

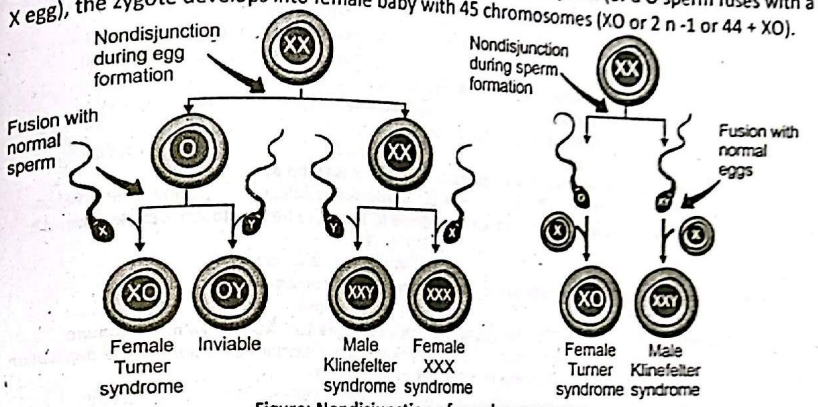


Figure: Nondisjunction of sex chromosomes

- The XO chromosomal condition is called **monosomy** in sex chromosomes.
- **Name As Turner Syndrome:** The affected female is sterile and the **condition is called Turner syndrome** (American endocrinologist **Dr. Henry Turner** first described it in 1938).

Symptoms of Turner Syndrome:

- **Body Structures:** The major symptoms include **short stature, webbed neck, immature sex** organs and infertility, and small chin and jaw. Sometimes, they face spatial or mathematical learning difficulties.
- **Health Problem:** Turner syndrome may also lead to **health problems** e.g., **liver and kidney** issues, obesity, diabetes, and hypertension.

Check Understanding!

34. Explain the chromosomal basis of Turner syndrome and how modern hormone therapies assist affected individuals.

Frequency of Occurrence:

- Turner syndrome occurs roughly once in every **2,500 female births.**

Treatment of Turner Syndrome:

- Growth hormone treatment can **improve growth.**
- The affected female can have **adult height**, if growth hormone treatment is started early in childhood.
- Estrogen **replacement therapy (ERT)** is used for the development of secondary sexual characteristics.

Tidbit

- If a zygote receives one **less autosome**, it cannot complete development.
- Most of the zygotes with an **extra autosome** also do not survive. However, the chromosome pairs **13, 15, 18, 21,** and 2 can have three chromosomes and the individual can survive for a time.
- The presence of an **extra chromosome** in pairs 13, 15, or 18 causes severe developmental defects, and infants with such a genetic makeup die within a few months.
- In contrast, individuals who have an extra copy of chromosome **21 or 22,** usually survive to **adulthood.** In such individuals, the maturation of the skeletal system is delayed, so they generally are short and have poor muscles. Their mental development is also affected.

CamScanner

Multiple Choice Questions (MCQs)

1. A change in the content of the genetic message is called:
(A) Translation. (B) Mutation. (C) Replication. (D) Transcription.
2. Mutations that occur spontaneously due to sequencing errors or DNA damage during replication are called:
(A) Induced mutations. (B) Chromosomal mutations. (C) Natural mutations. (D) Artificial mutations.
3. Mutations caused by chemicals, radiation, or other external factors are known as:
(A) Induced mutations. (B) Natural mutations. (C) Neutral mutations. (D) Silent mutations.
4. Mutations involving a change in only one or a few nucleotides are called:
(A) Chromosomal mutations. (B) Point mutations.
(C) Genome mutations. (D) Polyploid mutations.
5. Which type of point mutation involves the exchange of one nucleotide for another?
(A) Insertion. (B) Deletion. (C) Duplication. (D) Substitution.
6. Addition of one or more nucleotides into DNA is called:
(A) Deletion. (B) Substitution. (C) Insertion. (D) Inversion.
7. Removal of one or more nucleotides from DNA is called:
(A) Deletion. (B) Insertion. (C) Substitution. (D) Replication.
8. High-energy radiations such as X-rays and gamma rays are classified as:
(A) Mutagen chemicals. (B) Ionizing radiation. (C) Ultraviolet radiation. (D) Infrared radiation.
9. Which radiation can cause adjacent pyrimidine nucleotides (C and T) to form a double covalent bond?
(A) Gamma rays. (B) X-rays.
(C) Ultraviolet (UV) radiation. (D) Microwave radiation.
10. Sickle cell anaemia is caused by a recessive gene present on chromosome:
(A) 11. (B) 12. (C) X chromosome. (D) 21.
11. In sickle cell anaemia, the codon CTC (for glutamic acid) changes to CAC (for valine) because:
(A) Nucleotide deletion. (B) T→A substitution. (C) Nucleotide insertion. (D) Chromosome duplication.
12. Why does phenylketonuria (PKU) develop in affected individuals?
(A) Excess tyrosine. (B) Excess haemoglobin. (C) Enzyme deficiency. (D) Valine substitution.
13. Which of the following is mentioned as a dietary precaution for individuals with PKU?
(A) More meat. (B) Avoid phenylalanine. (C) More glucose. (D) Fruits only.
14. Non-disjunction occurs when:
(A) Polymerase error. (B) Chromatid separation. (C) Translation failure. (D) Replication stops.
15. Which statement correctly distinguishes natural mutations from induced mutations?
(A) Radiation only. (B) Spontaneous induced.
(C) Spontaneous, external. (D) Chromosome loss.
16. Chromosomal mutations mainly involve changes in the:
(A) Single nucleotide only. (B) Position of genes.
(C) RNA sequence only. (D) Protein structure only.
17. Which of the following is a chromosomal rearrangement?
(A) Substitution. (B) Insertion. (C) Translocation. (D) Replication.
18. In a chromosomal translocation:
(A) A segment of one chromosome. (B) A chromosome is duplicated.
(C) A chromosome is completely lost. (D) A chromosome forms a loop.
19. In a chromosomal inversion:
(A) A chromosome is deleted. (B) Chromosome segment is reversed.
(C) Two chromosomes fuse together. (D) An extra chromosome is formed.
20. Mobile DNA segments that move from one location to another are called:
(A) Introns. (B) Codons. (C) Transposons (jumping genes). (D) Exons.
21. Insertion of a transposon into a gene may:
(A) Activate the gene permanently. (B) Inactivate the gene.
(C) Duplicate the chromosome. (D) Increase chromosome number.
22. Failure of sister chromatids to separate properly during meiosis is called:
(A) Crossing over. (B) Replication. (C) Non-disjunction. (D) Translation.
23. Down syndrome is caused by non-disjunction of:
(A) Chromosome 11. (B) Chromosome 12. (C) Chromosome 22. (D) Chromosome 21.
24. Individuals with Down syndrome possess a total of:
(A) 45 chromosomes. (B) 46 chromosomes. (C) 47 chromosomes. (D) 48 chromosomes.
25. Klinefelter syndrome is represented by the chromosome constitution:
(A) XXY. (B) XO. (C) XXX. (D) XYY.
26. Why is the age of the mother considered more critical than the father's regarding non-disjunction?
(A) No sperm. (B) Ageing eggs. (C) More chromosomes. (D) Faster replication.

Key
1.(B)
2.(C)
3.(A)
4.(B)
5.(D)
6.(C)
7.(A)
8.(B)
9.(C)
10.(A)
11.(B)
12.(C)
13.(B)
14.(B)
15.(C)
16.(B)
17.(C)
18.(A)
19.(B)
20.(C)
21.(B)
22.(C)
23.(D)
24.(C)
25.(A)
26.(B)

27. Which condition results when an XX egg is fertilized by a normal sperm?
(A) Turner syndrome. (B) Down syndrome. (C) Klinefelter syndrome. (D) Triple X.
28. Which statement correctly describes Turner syndrome?
(A) XXY trisomy. (B) XO monosomy. (C) Trisomy 21. (D) Chromosome inversion.
29. A person with Klinefelter syndrome is most likely to:
(A) Sterile male. (B) Fertile female. (C) Trisomy 21. (D) Normal chromosomes.

Key
27.(C)
28.(B)
29.(A)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(B)	• Walther Flemming discovered chromosomes in 1882 using salamander cells, whereas Waldeyer-Hartz only coined the name "chromosome" in 1888.
2.	S/Q	• DNA carries a negative charge from its phosphate backbone, while histones are rich in basic amino acids giving them a net positive charge. This opposite electrostatic attraction allows DNA to wrap tightly around the histone core without covalent bonding.
3.	(C)	• Danish botanist Wilhelm Johannsen officially coined the term "gene" in 1909 to designate the fundamental physical unit of heredity.
4.	S/Q	• Expose purified samples of the candidate molecule to controlled mutagens in vitro to induce structural alterations, then introduce them into recipient cells. Track subsequent generations to see if the modified traits stably pass down without degradation.
5.	(B)	• A transforming principle passed from the dead virulent S-type bacteria into live R-type bacteria, converting them into lethal live pathogens.
6.	S/Q	• Sulfur-35 selectively labels proteins but cannot bind to DNA. Because it remained entirely in the culture medium outside the cells, it proved that viral protein coats stay outside during infection and do not direct replication.
7.	(B)	• By systematically removing components from heat-killed extracts, they proved transformation stopped only when DNA was extracted, confirming DNA as genetic material.
8.	S/Q	• For the conservative model, keep an original double helix zipped together and build a completely separate new helix next to it. For the semi-conservative model, unzip the original helix strands and pair each old strand with a newly synthesized strand to form two hybrids.
9.	(C)	• After one generation in ^{14}N, every daughter molecule consists of one heavy ^{15}N strand and one light ^{14}N strand, forming an intermediate hybrid band.
10.	S/Q	• The appearance of two distinct bands proves original parental strands remain intact rather than fragmenting. If the dispersive model were correct, centrifugation would yield only a single homogeneous band instead of two discrete layers.
11.	(C)	• Helicase is specifically designated as the unwinding enzyme that breaks hydrogen bonds to separate complementary strands at the replication fork.
12.	S/Q	• DNA polymerase III can only add nucleotides in the 5' to 3' direction. Because templates run antiparallel, one template opens continuously toward the fork (leading strand), while the other opens away, forcing discontinuous backward fragments (lagging strand).
13.	(B)	• Okazaki fragments are named after their discoverer as the short segments built discontinuously away from the fork on the lagging strand.
14.	S/Q	• Unlike prokaryotes with a single origin site, eukaryotes initiate DNA replication simultaneously at thousands of different origin sites (replicons) along each chromosome to complete copying efficiently.
15.	(A)	• Francis Crick coined the term "Central Dogma" to illustrate the strict, unidirectional flow of genetic instructions from DNA to RNA to protein.
16.	S/Q	• Alternating codons CUC (leucine) and UCU (serine) translate into a repeating dipeptide chain of Leucine-Serine-Leucine-Serine (Leu-Ser-Leu-Ser).
17.	(B)	• Degeneracy describes the redundant characteristic where several distinct triplet codons encode the exact same amino acid.

CamScanner

18.	S/Q	• Copying both strands would produce complementary sense and antisense RNAs that bind together into double-stranded RNA, preventing ribosomes from translating the genetic message into proteins.
19.	(D)	• The sigma subunit acts as the specific recognition factor that binds to promoter sequences to correctly position RNA polymerase before dissociating.
20.	S/Q	• Transcribing a GC-rich stop region causes RNA to fold into a strong hairpin loop via internal hydrogen bonding, creating physical friction that pauses RNA polymerase and triggers dissociation.
21.	(D)	• Splicing is the post-transcriptional editing process that precisely excises non-coding introns and ligates coding exons together.
22.	S/Q	• Alternative splicing allows different combinations of exons to be joined together from a single gene transcript, enabling one gene to code for multiple distinct protein isoforms.
23.	(B)	• Peptidyl transferase is the ribosomal catalyst responsible for forging the peptide bond linking the growing chain to the incoming amino acid.
24.	S/Q	• Aminoacyl-tRNA synthetase attaches a specific amino acid to the tRNA. It enters the ribosomal A site, transfers its amino acid via peptide bonding, shifts to the P and E sites during translocation, and exits uncharged.
25.	(D)	• Prokaryotic and eukaryotic translation systems structurally diverge by utilizing smaller 70S ribosomes versus larger 80S ribosomes, respectively.
26.	S/Q	• Regulatory proteins selectively turn specific gene sets "ON" in certain cell types while keeping them permanently "OFF" in others, producing distinct functional proteomes despite identical DNA.
27.	(B)	• Alternative splicing selectively retains or removes varied exons to produce multiple distinct mature mRNA transcripts from one gene.
28.	S/Q	• Ionizing radiation generates free radicals that break DNA backbone phosphodiester bonds, whereas UV radiation causes adjacent pyrimidine bases to form covalent cross-linked dimers. Both disrupt replication.
29.	(C)	• Code degeneracy allows multiple codons to specify the same amino acid, so changing a single base without changing the amino acid is silent.
30.	S/Q	• Replacing hydrophilic glutamic acid with hydrophobic valine creates sticky patches. Under low oxygen, these molecules polymerize into rigid fibers that distort the cell into a sickle shape.
31.	(B)	• Transposons are mobile DNA sequences capable of relocating within genomes, frequently disrupting gene function when inserting into coding regions.
32.	S/Q	• Autosomes carry vital housekeeping genes required across all tissues, making gene dosage deficiencies lethal. Conversely, sex chromosome aberrations survive due to X-inactivation and the Y chromosome carrying few essential structural genes.
33.	(C)	• Down syndrome (trisomy 21) is specifically caused by the failure of the 21st autosomal pair to segregate properly during meiosis.
34.	S/Q	• Turner syndrome results from an XO genotype (45 total chromosomes) due to non-disjunction. Growth hormone therapy helps patients achieve normal adult height, while estrogen replacement safely induces secondary sexual characteristics.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. **Which of the following looks like beads on a string?**
(a) Chromosomes. (b) Chromatin. (c) Nucleosomes. (d) Heterochromatin.
2. **The most convincing proof that DNA is the genetic material was provided by:**
(a) Mendel. (b) Morgan. (c) Hershey & Chase. (d) Meselson and Stahl.

3. **Degeneracy of genetic code means that:**
(a) A codon consists of 3 nucleotides.
(b) Multiple codons can specify the same amino acid.
(c) Same codon can specify multiple amino acids.
(d) Each codon is read independently of the adjacent codons.
4. **How many codons are needed to specify five amino acids?**
(a) 3 (b) 5 (c) 15 (d) 30
5. **Which of the following is NOT involved in the initiation of replication?**
(a) DNA ligase. (b) DNA gyrase
(c) single-stranded binding protein. (d) Primase
6. **Why DNA polymerase synthesises the leading and lagging strands of DNA in different manners?**
(a) The origins of replication occur only at the 5′ end.
(b) DNA ligase works only in the 3′ to 5′ direction.
(c) DNA polymerase can only work on one strand at a time.
(d) DNA polymerase can join new nucleotides only to the 3′ end of strand.
7. **Synthesis of a new DNA strand usually begins with:**
(a) RNA primer. (b) DNA primer. (c) DNA ligase. (d) Okazaki fragment.
8. **The elongation of the leading strand during DNA synthesis:**
(a) Progresses away from the replication fork. (b) Occurs in the 3′ - 5′ direction.
(c) Produces Okazaki fragments. (d) Depends on the action of polymerase.
9. **Which of the following enzymes remove supercoiling in replicating DNA ahead of the replication fork?**
(a) DNA polymerases. (b) Helicases. (c) Primases. (d) Topoisomerases.
10. **Which enzyme joins the bits of DNA?**
(a) DNA polymerase. (b) DNA ligase (c) Endonuclease. (d) Primase.
11. **Which of these subunits of RNA polymerase is required to initiate transcription?**
(a) Alpha (α) (b) Sigma (σ) (c) Omega (ω) (d) Beta (β)
12. **When and where does the splicing of mRNA occur?**
(a) Before transcription in nucleus. (b) After transcription in nucleus.
(c) After transcription in cytoplasm. (d)After mRNA attachment with ribosome.
13. **What happens in mRNA splicing?**
(a) Introns and exons are removed from the gene.
(b) Introns and exons are joined together.
(c) Exons are removed and introns are joined together.
(d) Introns are removed and exons are joined together.
14. **Which of these happens first during protein synthesis?**
(a) Peptide bond formation. (b) Binding of aminoacyl t-RNA with ribosome
(c) Translocation. (d) Binding of release factor with ribosome.
15. **The synthesis of protein chains is initiated with the amino acid:**
(a) Arginine. (b) Methionine. (c) Serine. (d) Valine.
16. **The main function of tRNA is to:**
(a) Bind the mRNA with the smaller ribosomal subunit.
(b) Form a portion of ribosomes.
(c) Bind the complementary RNA and DNA strands together.
(d) Bring amino acids from the cytoplasm to the ribosomes?
17. **Ultraviolet radiation can cause mutations by:**
(a) Making double covalent bonds between adjacent pyrimidine bases.
(b) Breaking phosphodiester bonds in DNA strands.
(c) Adding nucleotides in NA.
(d) Substituting nucleotides in DNA.

CamScanner

18. **Phenylketonuria is a genetic disorder with a defect in the metabolism of:**
(a) Vitamin. (b) Glucose. (c) Amino acid. (d) Lipid.

19. **The condition sickle cell anaemia is due to:**
(a) Deletion type point mutation. (b) Substitution type point mutation.
(c) Insertion type point mutation. (d) Chromosomal rearrangement.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(c)	Nucleosomes.	• DNA wrapped around histone octamers creates repeating structural units that visually resemble beads on a string.
2.	(c)	Hershey & Chase.	• Their radioisotope labeling experiments provided the definitive proof that DNA is the genetic material of phages.
3.	(b)	Multiple codons can specify the same amino acid.	• Degeneracy refers to the genetic code property where multiple triplet codons code for the same single amino acid.
4.	(b)	5	• Since each individual amino acid is encoded by one triplet codon, specifying five amino acids requires five codons.
5.	(a)	DNA ligase.	• DNA ligase is used to seal nicks during later stages of DNA replication rather than initiating it.
6.	(d)	DNA polymerase can join new nucleotides only to the 3′ end of strand.	• Antiparallel strands and unidirectional synthesis force continuous leading strand and discontinuous lagging strand mechanisms.
7.	(a)	RNA primer.	• DNA polymerases cannot start a chain from scratch and require a short RNA primer to provide a free 3'-OH group.
8.	(d)	Depends on the action of polymerase.	• The continuous elongation of the leading strand is driven steadily by the continuous action of DNA polymerase.
9.	(d)	Topoisomerases.	• Topoisomerases relieve torsional strain and supercoiling ahead of the moving replication fork.
10.	(b)	DNA ligase.	• DNA ligase joins DNA fragments together by catalyzing the formation of phosphodiester bonds.
11.	(b)	Sigma (σ).	• The sigma factor is the specific subunit of RNA polymerase necessary for recognizing promoters and initiating transcription.
12.	(b)	After transcription in nucleus.	• Pre-mRNA transcripts undergo splicing modifications inside the nucleus following transcription.
13.	(d)	Introns are removed and exons are joined together.	• Splicing processes the primary transcript by cutting out non-coding introns and ligating coding exons together.
14.	(b)	Binding of aminoacyl t-RNA with ribosome.	• Translation initiation begins when the initial aminoacyl-tRNA binds to the ribosomal complex.
15.	(b)	Methionine.	• The initiation codon AUG codes for methionine, which starts almost all protein chains.
16.	(d)	bring amino acids from the cytoplasm to the ribosomes?	• Transfer RNA functions as an adaptor that delivers specific cytoplasmic amino acids to the ribosome based on mRNA codons.
17.	(a)	Making double covalent bonds between adjacent pyrimidine basesr.	• UV light induces mutations by creating covalent linkages like thymine dimers between adjacent pyrimidines.
18.	(c)	Amino acid.	• Phenylketonuria is caused by an enzymatic defect that disrupts the normal metabolic breakdown of the amino acid phenylalanine.
19.	(b)	Substitution type point mutation.	• Sickle cell anemia is caused by a single base substitution mutation in the hemoglobin gene.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 What are the four types of chromosomes on the basis of position of centromere?

Ans. **Four Types of Chromosomes on the Basis of Position of Centromere:**
(i) **Metacentric:** Chromosomes where the centromere is located in the middle, creating two equal arms.
(ii) **Submetacentric:** Chromosomes with the centromere slightly off-center, resulting in one slightly shorter arm and one longer arm.
(iii) **Acrocentric:** Chromosomes where the centromere is located very close to one end, producing one extremely short arm.
(iv) **Telocentric:** Chromosomes featuring the centromere positioned directly at the very tip or terminal end.

Q.2 What is chromatin fibre? How is it formed during condensation of chromatin?

Ans. **Chromatin Fibre:**
- It is a **30 nm** thick structural fiber composed of DNA and histone proteins that packages genetic material within the nucleus.
- **Condensation Process:** It forms when **"beads-on-a-string"** nucleosomes coil and fold into a more compact or zigzag structure with the help of histones proteins.

Q.3 Briefly describe the concept of gene and gene locus.

Ans.
- **Gene:** The basic physical and **functional** unit of heredity made up of DNA that codes for a specific functional product (protein or RNA).
- **Gene Locus:** The specific, fixed physical position or location of a gene on a chromosome.

Q.4 State the functions of DNA polymerase I, II and III.

Ans.
- **Function of DNA Polymerase I:** Removes RNA primers, replaces them with DNA nucleotides, and participates in DNA correction.
- **Function of DNA Polymerase II:** Primarily involved in the **DNA repair** process and restarting stalled replication forks.
- **Function of DNA Polymerase III:** The primary enzyme responsible for **synthesizing the bulk** of new DNA strands by adding nucleotides during replication.

Q.5 State the central dogma of gene expression.

Ans. **Central Dogma:**
- **Core Concept:** It describes the **unidirectional** flow of **genetic information** within a biological system.
- **Information Pathway:** Genetic information flows sequentially from DNA to mRNA via transcription, and then from mRNA to proteins via translation.

DNA ⟶ RNA ⟶ Proteins

Q.6 What do you mean by "degeneracy of genetic code"?

Ans. **Degeneracy of Genetic Code:**
- **Multiple Codons:** It means that a single amino acid can be specified by more than one distinct triplet codon.
- This degeneracy is largely due to flexibility at the third base position of the tRNA anticodon pairing.

Q.7 Enlist some commonly occurring minor mutations in human.

Ans. **Commonly Occurring Minor Mutations in Human:**
- **Common Examples:** Include point mutations like **sickle-cell anemia, color blindness, alkaptonuria,** and **phenylketonuria (PKU).**

Q.8 Differentiate between:
- **Histone and nucleosome**
- **Conservative and semi-conservative model of DNA replication**
- **DNA helicase and DNA gyrase**
- **Leading strand and lagging strand of DNA**
- **Heterochromatin and euchromatin**
- **DNA polymerase I and II**
- **Translation and transcription**

CamScanner

- Genetic code and codon
- Gene and allele
- Start codon and stop codon
- Repressor and activator proteins
- Down syndrome and Klinefelter syndrome
- Codon and anticodon
- Intron and exon
- Non-sense codon and sense codon
- Point mutation and chromosomal mutation
- Klinefelter syndrome and Tuner syndrome

Ans. Histone and Nucleosome:

Histone	Nucleosome
• Histones are positively charged proteins that package DNA.	• A nucleosome is the structural unit consisting of DNA wrapped around a core of eight histone proteins.

Heterochromatin and Euchromatin:

Heterochromatin	Euchromatin
• Heterochromatin is permanently tightly packed, transcriptionally inactive DNA.	• Euchromatin is loosely packed, genetically active DNA & only packed during cell division.

Conservative and Semi-conservative Model of DNA Replication:

Conservative	Semi-conservative
• The conservative model preserves the original parental double helix while creating an entirely new daughter molecule.	• The semi-conservative model splits the parental strands so each new molecule has one old and one new strand.

DNA Helicase and DNA Gyrase:

DNA Helicase	DNA Gyrase
• DNA helicase unwinds and unzips the double helix at the replication fork.	• DNA gyrase relieves the torsional strain and supercoiling ahead of the replication fork.

DNA polymerase-I and II:

DNA polymerase-I	DNA polymerase-II
• DNA polymerase-I removes primers and fills gaps with DNA during DNA replication process.	• DNA polymerase-II mainly functions in DNA repair mechanisms.

Leading Strand and Lagging Strand of DNA:

Leading Strand of DNA	Lagging Strand of DNA
• The leading strand is synthesized continuously in the direction of the replication fork.	• The lagging strand is synthesized discontinuously in short segments (Okazaki fragments) away from the fork.

Translation and Transcription:

Translation	Transcription
• Transcription is the synthesis of mRNA from a DNA template.	• Translation is the synthesis of a polypeptide chain from the mRNA code

Genetic code and Codon:

Genetic code	Codon
• The genetic code is the complete set of rules mapping nucleotide triplets to amino acids.	• A codon is a specific sequence of three adjacent nucleotides on mRNA.

Codon and Anticodon:

Codon	Anticodon
• A codon is a triplet sequence on mRNA that codes for an amino acid.	• An anticodon is the complementary triplet sequence on tRNA that matches the codon.

Gene and Allele:

Gene	Allele
• A gene is a functional unit of heredity governing a specific trait.	• An allele is an alternative variant form of that gene.

Intron and Exon:

Intron	Exon
• Introns are non-coding intervening sequences spliced out of pre-mRNA.	• Exons are coding sequences retained and expressed in mature mRNA.

Start Codon and stop Codon:

Start Codon	Stop Codon
• A start codon (AUG) initiates the translation process.	• Stop codons (UAA, UAG, UGA) terminate translation process.

Non-sense Codon and Sense Codon:

Non-sense Codon	Sense Codon
• Sense codons code for specific amino acids.	• Nonsense codons (stop codons) do not code for any amino acid and terminate protein synthesis.

Repressor and Activator Proteins:

Repressor	Activator Proteins
• Repressor proteins bind to operators (piece of DNA) or silencers to block gene transcription.	• Activator proteins bind to enhancers to promote transcription.

Point Mutation and Chromosomal Mutation:

Point Mutation	Chromosomal Mutation
• Point mutations involve a change in a single base pair or a few nucleotides.	• Chromosomal mutations involve large-scale structural changes or altered chromosome numbers.

Down Syndrome and Klinefelter Syndrome:

Down Syndrome	Klinefelter Syndrome
• Down syndrome is caused by an extra copy of chromosome 21 (trisomy 21).	• Klinefelter syndrome is caused by an extra X chromosome in males (XXY).

Klinefelter Syndrome and Tuner Syndrome:

Klinefelter Syndrome	Tuner Syndrome
• Klinefelter syndrome features an XXY genotype resulting in male phenotype.	• Turner syndrome features a single XO genotype resulting in female monosomy.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Annotate the detailed structure of a chromosome.

Ans. See Page No. 197 – 198 (Q.4 ⟶ Q.6)

Q.2 Explain the concept of alleles as the alternative forms of a gene.

Ans. See Page No. 200 (Q.11)

Q.3 Narrate the experimental work of Griffith that proved that DNA is the hereditary material.

Ans. See Page No. 201 (Q.13)

Q.4 Narrate the experimental work of Hershey and Chase that proved that DNA is the hereditary material.

Ans. See Page No. 203 (Q.14)

CamScanner

Q.5 Describe the three models proposed about the mechanism of DNA replication.

Ans. See Page No. 204 (Q.15)

Q.6 Narrate the work of Meselson and Stahl to justify the semi-conservative replication.

Ans. See Page No. 205 (Q.16 ⟶ Q.17)

Q.7 Describe the events of the process of DNA replication.

Ans. See Page No. 207 (Q.18)

Q.8 Explain the mechanism of transcription.

Ans. See Page No. 216 (Q.28)

Q.9 Describe the mechanism of protein synthesis.

Ans. See Page No. 219 (Q.32)

Q.10 Describe the difference between protein synthesis in prokaryotes and eukaryotes.

Ans. See Page No. 222 (Q.33)

Q.11 Describe the importance of the regulation of gene expression.

Ans. See Page No. 223 (Q.34)

Q.12 Describe the negative and positive control of gene expression.

Ans. See Page No. 223 (Q.36)

Q.13 Explain the post-transcriptional modification of mRNA.

Ans. See Page No. 218 (Q.29)

Q.14 Write a note on point mutations and their sources.

Ans. See Page No. 225 (Q.40)

Q.15 Describe the symptoms, causes and treatments Down syndrome and Klinefelter syndrome.

Ans. See Page No. 230 – 232 (Q.51 ⟶ Q.57)

Q.16 Describe the symptoms, causes and treatments Turner syndrome.

Ans. See Page No. 233 (Q.58)

Q.17 Describe the symptoms, causes and treatments of Sickle cell anaemia and phenylketonuria.

Ans. See Page No. 227 – 227 (Q.45 ⟶ Q.46)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 DNA is tightly wrapped around histone proteins. How can replication enzymes read the code if it is buried inside a coil?

Ans. DNA is tightly wound around histone octamers to form nucleosomes, which coil further into chromatin fibers.

- For replication enzymes (like DNA polymerase and helicase) to read and duplicate the code, specialized protein machinery dynamically remodels that tightly coiled chromatin:

Chromatin Remodeling Complexes:

- ATP-dependent remodeling complexes slide, or restructure nucleosomes to temporarily expose specific segments of the double helix.

Histone Modification:

- Enzymes such as histone acetyltransferases (HATs) attach acetyl groups to positively charged histone tails, neutralizing their charge and loosening their tight electrostatic grip on negatively charged DNA.

Enzymatic Uncoiling:

- Once local regions are exposed and relaxed, initiator proteins and helicases can easily unwind the strands for replication forks to progress.

Q.2 Our genetic code uses three-letter "words" to create 20 amino acids. Could a complex human exist if the code used only two-letter words?

Ans. **If Genetic Codes Contain Two Letters:**

- If the genetic code utilized **two-letter words** (duplets) instead of three-letter triplets (codons) using the same four nucleotide bases (A, T/U, C, G), the mathematical permutation limit would be $4^2 = 16$ unique combinations.

Inability to Support Complex Life:

- Because living organisms require at **least 20 standard** amino acids to construct functional proteins and complex enzymatic machinery, a 16-word vocabulary is insufficient to code for all necessary 20 amino acids.

Q.3 DNA Polymerase III is a highly efficient proof-reader that fixes its own mistakes. What happens to a cell if the gene for the "proof-reader" enzyme itself gets a mutation?

Ans.

- The 3′ to 5′ exonuclease **proofreading** activity of DNA Polymerase-III is essential for maintaining genomic integrity. If the gene coding for this proofreading domain mutates and loses function then:

Hypermutation and Genomic Instability:

- Replication errors accumulate unchecked at a rate up to 1,000 times higher than normal, leading to a severe mutator phenotype.

Loss of Cellular Viability:

- The overwhelming accumulation of deleterious point mutations across vital protein-coding genes typically results in rapid cell death (apoptosis) or malignant transformation (cancer).

Q.4 Why the length of transcribed mRNA molecule (in eukaryotes) shortens as it enters the cytoplasm for translation?

Ans.

- Primary transcript mRNA (pre-mRNA) undergoes extensive processing within the nucleus before entering the cytoplasm, which significantly shortens its physical length:
- **RNA Splicing:** Spliceosomes enzymes excise **non-coding** intervening sequences (introns) and ligate the protein-coding sequences (exons) together, removing a massive portion of the initial transcript length.

Q.5 How many types of tRNA molecules are necessary for a living cell, if the genetic code is a triplet code?

Ans.

- A triplet code based on **4 nucleotides** yields $4^3 = 64$ possible codon combinations. However, the exact number of functional tRNA types needed is a fewer than 64:
- **Stop Codons:** Three codons (UAA, UAG, UGA) act as termination signals and do not code for amino acids, meaning no standard tRNA molecules are assigned to them. This leaves **61 sense codons.**
- **Wobble Hypothesis:** Due to the flexibility ("wobble") in the base-pairing interactions at the third position of the codon-anticodon interface, a single **tRNA molecule** can recognize more than one synonymous codon. Consequently, typical cells require **roughly 30 to 45 distinct tRNA types** to successfully translate all sense codons.

Q.6 After isotopic labelling of the starting DNA with ^{15}N, Meselson and Stahl continue their experiment to at least two rounds of replication instead of stopping the experiment after only one round of replication. Justify their decision to continue to at least two replications.

Ans.

- Meselson and Stahl tracked the replication of ^{15}N-labeled DNA in a ^{14}N medium.
- Stopping after only one round of replication would have **yielded hybrid ($^{15}N^{14}N$)** DNA molecules, which supported both the semi-conservative and dispersive models of DNA replication.
- **Differentiating Replication Models:** A second round of replication (Generation-II) was strictly necessary to produce a distinct split between hybrid DNA and light ($^{14}N^{14}N$) DNA.
- **Disproving Alternatives:** The appearance of **both intermediate-density and light-density bands** in exact ratios during the **second generation conclusively ruled out the dispersive model** (which would have continued yielding a single uniform density) and definitively confirmed the **semi-conservative model.**

CamScanner

SELF-ASSESSMENT

Q.1 Encircle the correct option. Total Marks: (1 x 6 = 6)

(i) **The name "chromosome" was proposed by:**
(A) Karl Correns. (B) Waldeyer-Hartz. (C) Mendel. (D) Flemming.

(ii) **The most convincing proof that DNA is the genetic material was provided by:**
(A) Mendel. (B) Morgan. (C) Hershey & Chase. (D) Meselson and Stahl.

(iii) **When and where does the splicing of mRNA occur?**
(A) Before transcription in nucleus. (B) After transcription in nucleus.
(C) After transcription in cytoplasm. (D)After mRNA attachment with ribosome.

(iv) **Which radioactive isotope was used to label the protein coat of bacteriophages?**
(A) ^{32}P. (B) ^{35}S. (C) ^{14}C. (D) ^{3}H.

(v) **After the first DNA replication in the ^{14}N medium, the DNA showed:**
(A) Heavy band. (B) Light band. (C) Two light. (D) Intermediate band.

(vi) **The term "Central Dogma" was introduced by:**
(A) James Watson. (B) Francis Crick. (C) Marshall Nirenberg. (D) Har Gobind Khorana.

Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) Briefly describe the 4-types of chromosomes on the basis of position of centromere.
(ii) What is chromatin fibre? How is it formed during condensation of chromatin?
(iii) Write the facts about "gene" after which scientists tried to determine the chemical nature of gene?
(iv) Differentiate between DNA helicase and DNA gyrase.
(v) What is gene? How does gene express itself?
(vi) Name the four levels of regulation of gene expression.
(vii) Differentiate between Gene and Allele.
(viii) What are spontaneous point mutations

Q.3 Extensive Questions. (4 x 2 = 8)

(a) Explain the concept of alleles as the alternative forms of a gene
(b) Describe the symptoms, causes and treatments Down syndrome and Klinefelter syndrome.

ENTRANCE TEST MDCAT

1. **The disease in which an individual has extra sex chromosome (44+XXY) is known as:** (UHS 2019)
A. Down's syndrome. B. Klinefelter's syndrome. C. Turnor's syndrome. D. Jacob's syndrome.
2. **During maternal meiosis, non-disjunction of autosomal chromosomal pair results in the formation of an egg having 24 chromosomes in:** (UHS 2019)
A. Klinefelter's syndrome. B. Turner' syndrome. C. Down's syndrome. D. Jacob's syndrome.
3. **Typical symptoms like enlarged breasts and small testes in males are attributed to:** (UHS 2015)
A. Down's syndrome. B. Klinefelter's syndrome. C. Turner' syndrome. D. Phenylketonurie.
4. **Turner's syndrome is characterized by having:** (UHS 2015)
A. Trisomy 21. B. Trisomy 18. C. 44+XXY. D. 44+XO.
5. **Infertility, short height, webbed neck and low hairline at back are symptoms of _____ syndrome:** (UHS 2016)
A. Down's. B. Edward's. C. Turner's. D. Patau's.
6. **Down's syndrome is characterized by _____ at chromosome 21:** (UHS 2016)
A. Monosomy. B. Polysomy. C. Trisomy. D. Disomy.
7. **Which one of the following is an example of autosomal non-disjunction?** (UHS 2016)
A. Turner's syndrome. B. Down's syndrome. C. Jacob's syndrome. D. Metafemales.

ANSWERS KEY

1. B	2. C	3. B	4. D	5. C	6. C	7. B

20 CHAPTER

BIOTECHNOLOGY

Student Learning Outcomes (SLOs)

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

- Introduce genetic engineering.
- Outline the function of restriction enzymes.
- Describe plasmids as vectors and explain how recombinant plasmids can be formed.
- Explain polymerase chain reaction (PCR).
- Define genetically modified organism.
- Explain the formation of human insulin protein in bacteria.

CamScanner

Biotechnology — Concept Map

1. GENETIC ENGINEERING

- Altering organism DNA via Recombinant DNA Technology and PCR to solve medical, agricultural, and industrial challenges.

2. RECOMBINANT DNA TECHNOLOGY

- **Tools →** Gene of interest (synthesis, reverse transcription, restriction), Restriction endonucleases (molecular scissors/palindromic sites), Vectors (plasmids, phages, BACs/YACs), DNA ligase (molecular glue), Expression system (bacteria).

Steps →

1. **Formation** (cleavage & ligation),
2. **Cloning** (bacterial uptake),
3. **Screening** (antibiotic resistance, blue-white lacZ' screening, radioactive probes).

3. POLYMERASE CHAIN REACTION (PCR)

- **Overview →** In vitro DNA amplification developed by Kary Mullis (1983).

Steps & Uses →

- Denaturation (98°C), Annealing (60°C), Extension (Taq polymerase at 72°C); used in diagnostics, forensics, and ancient DNA analysis.

4. GENETICALLY MODIFIED ORGANISMS (GMOS)

- **Transgenic Bacteria →** Pharmaceuticals (insulin, vaccines), food enzymes, and pollution bioremediation.
- **Transgenic Animals →** Pharming (milk/silk), enhanced fish, gene therapy, and disease models (mice).
- **Transgenic Plants →** Bt insect resistance, herbicide tolerance, and Golden Rice (iron/beta-carotene).

5. FORMATION OF HUMAN INSULIN IN BACTERIA

Steps →

- Synthesize Chain A & B DNA, insert into separate plasmids, transform E. coli cultures, ferment in bioreactors, extract, and chemically join via di-sulfide bonds.

INTRODUCTION

Q.1 What do you know about word biotechnology & define it as scientific term? S/Q

Ans. Biotechnology:

- The word "**Biotechnology**" means "**Technology based on biology**".
- In **scientific terms**, it is defined as: ***"The use of organisms, biological processes, or systems to make products that improve human lives and environment".***

For Information

Q. What is traditional & modern biotechnology?

Ans.

Traditional Biotechnology	Modern Biotechnology
• Traditional biotechnology has been used for thousands of years in the form of fermentation to create food products like bread, cheese, and beer.	• Modern biotechnology emerged in the 20th century, after the discovery of the structure of DNA and advanced molecular techniques

Q.2 What is the main focus or purpose of biotechnology? S/Q

Ans. Main Focus of Biotechnology:

- Its main focus is to solve **complex challenges** in **medicine, agriculture,** and **industry.**
- Biotechnology is a **vast field** but this chapter would deal with the most **important component** of biotechnology i.e., **genetic engineering.**

GENETIC ENGINEERING

- Biotechnology is a broad "**umbrella**" term.
- However, the true "**engine**" of modern biotechnology is "**Genetic Engineering**".

Q.3 What is genetic engineering, give two basic techniques used by scientists in genetic engineering? S/Q

Ans. Genetic Engineering:

- The **alteration** of an **organism's DNA** to change its **characters** (traits) or capabilities is called genetic engineering.
- It involves **inserting, deleting,** or **modifying genes,** and sometimes **transferring** genes between different species.
- In genetic engineering, scientists rely on two **basic technologies:**
  - **(i) Recombinant DNA Technology:** Physically cutting a piece of DNA from one organism and "**pasting**" it into the DNA of another.
  - **(ii) Polymerase Chain Reaction (PCR):** Rapidly amplifying a tiny segment of DNA into a large quantity.

Check Understanding!

Q.1 What is defined as the true "engine" of modern biotechnology?
(A) Genetic engineering
(B) Traditional fermentation
(C) Organic synthesis
(D) Cellular respiration

Multiple Choice Questions (MCQs)				Key
1. Biotechnology mainly relies on which modern technology?	(A) Hybridization.	(B) Genetic engineering.	(C) Tissue culture.	(D) Selective breeding.	1.(B)
2. Genetic engineering is the alteration of an organism's _____.	(A) Proteins.	(B) Lipids.	(C) Ribosomes.	(D) DNA.	2.(D)
3. Recombinant DNA technology mainly involves:	(A) DNA cutting.	(B) Protein digestion.	(C) RNA translation.	(D) Cell division.	3.(A)
4. Recombinant DNA introduced into a host is called:	(A) Genomic DNA.	(B) Recombinant DNA.	(C) Satellite DNA.	(D) Mitochondrial DNA.	4.(B)
5. The gene selected for manipulation is called:	(A) Marker gene.	(B) Reporter gene.	(C) Operator gene.	(D) Gene interest.	5.(D)
6. Which enzyme synthesizes DNA from mRNA?	(A) DNA ligase.	(B) Reverse transcriptase.	(C) Helicase.	(D) Primase	6.(B)
7. Restriction endonucleases are also called:	(A) Molecular scissors.	(B) Molecular glue.	(C) DNA clamps.	(D) Gene carriers.	7.(A)
8. Which enzyme joins DNA fragments?	(A) DNA polymerase.	(B) DNA ligase.	(C) Helicase.	(D) Topoisomerase	8.(B)

CamScanner

9. The most common vector is:
(A) Plasmid. (B) Ribosome. (C) Chromosome. (D) Lysosome.

10. Bacterial cells are ideal expression systems because of:
(A) Long lifespan. (B) Short generation. (C) Large genome. (D) Complex genetics.

11. Why are restriction endonucleases called molecular scissors?
(A) DNA joining. (B) RNA synthesis. (C) DNA cutting. (D) Protein digestion.

12. Why are sticky ends important in recombinant DNA technology?
(A) DNA replication. (B) Protein formation. (C) Gene mutation. (D) Easy joining.

13. Why can DNA fragments cut by the same restriction enzyme be joined together?
(A) Same proteins. (B) Complementary ends. (C) Same chromosomes. (D) Same vectors.

14. Why are plasmids commonly used as vectors?
(A) Gene transfer. (B) Protein carriers. (C) ATP storage. (D) Lipid transport.

15. Why are bacterial cells preferred as expression systems?
(A) Slow growth. (B) Rapid growth. (C) Large nucleus. (D) Complex genome.

9.(A) 10.(B) 11.(C) 12.(D) 13.(B) 14.(A) 15.(B)

RECOMBINANT DNA TECHNOLOGY

Q.4 What is recombinant DNA technology? S/Q

Ans. Recombinant DNA Technology:

- The process of **cutting, splicing,** and **combining DNA** molecules from different sources into a single hybrid molecule is called recombinant DNA technology.
- It also involves the introduction of **recombinant DNA (rDNA)** into a host.
- **Example:** Bacteria to produce **new genetic** combinations or specific proteins.

Topic: Tools Used in Recombinant DNA Technology:

Q.5 Enlist the 5-basic tools used in recombinant DNA technology. S/Q

Ans. 5-Basic Tools Used in Recombinant DNA Technology:

(1) Gene of Interest. (2) Restriction Endonucleases. (3) Vectors or Carrier.
(4) DNA Ligase. (5) Expression System.

Topic: (1) Gene of Interest:

Q.6 What is gene of interest & how can we get gene of interest? S/Q

Ans. Gene of Interest:

- The gene which is to be **manipulated** or under study is called gene of interest.

➢ **Ways to Get Gene of Interest:**

- The gene of interest can be obtained by **one** of the following three ways:
  i. **Direct synthesis** of the gene of interest in the lab by using different enzymes (e.g., polymerases and ligases).
  ii. **Synthesis by doing reverse transcription** of its mRNA by using reverse transcriptase enzymes.
  iii. **Cleavage from chromosome** by using enzymes restriction endonucleases.

Topic: (2) Restriction Endonucleases: (Molecular Scissors)

Q.7 Write a detailed note on restriction enzymes. Exercise L/Q.2

Ans. Restriction Endonucleases:

- The naturally occurring enzymes in bacteria, which **cut specific sequences** of nucleotides in DNA are called **restriction endonucleases.**

➢ **Characteristics of Restriction Endonucleases:**

- These enzymes are also called **molecular scissors.**
- There are many kinds of restriction endonuclease.
- **Restriction Site:** Each kind recognizes a specific **nucleotide sequence** in a DNA, this sequence of nucleotides is called restriction site or recognition region.

For Information

- Restriction endonucleases are valuable due to the fact that any two DNA fragments produced by the same restriction endonuclease can be joined together.

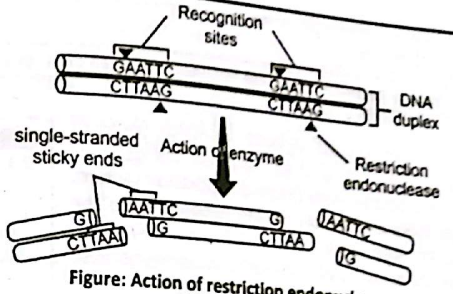


Figure: Action of restriction endonuclease

➢ **Working of Restriction Endonuclease Enzymes:**

- **Palindromic Sequence:** A sequence of 4 – 8 nucleotides which are symmetrical but reverse in order e.g. GAATTC & CTTAAG.
- The enzyme binds to the DNA at **restriction sequence,** and cuts the DNA at a particular place within this site.
- The restriction sites have **palindromic sequences** of four to **eight nucleotides.** This means the nucleotides at **one end** of the restriction site are **complementary** to those at the **other end.**
- So, the **two strands of the DNA** have the **same nucleotide** sequence running in opposite directions at the restriction site. Restriction endonuclease binds to and cleaves both strands.
- After cleavage, both **DNA fragments** have **single-stranded ends** (a few nucleotides long) that are sticky i.e., complementary to each other.

Check Understanding!

Q.2 Why must restriction sites feature palindromic sequences of four to eight nucleotides in order to create restriction fragments?

Topic: (3) Vectors: (Carriers)

Q.8 What are vectors or carriers, give examples with their uses? L/Q

Ans. Vectors:

- The Special molecules which are **used** for the **introduction** of gene of interest into host cells are called molecular **vectors or carriers.**
- The gene of interest is attached to the **vector** and the vectors becomes a **recombinant DNA (rDNA).**
- The rDNA is introduced into the host cells.

➢ **Different Examples Use As Vectors or Carriers:**

- **Most Common Example:** The plasmids of bacteria are the **most commonly** used vectors.
- Other examples of vectors:
  i. **Bacteriophages** (e.g., phage lambda, bacteriophage P1)
  ii. **Cosmids** (plasmids that contain a small region of bacteriophage DNA called the cos sequence)
  iii. **Bacterial artificial chromosomes** BACs
  iv. **Yeast artificial chromosomes** YACs.
  v. **P1 artificial chromosomes** (have features of both P1 vectors and Bacterial Artificial Chromosomes)
  vi. **Animal viruses** (e.g., human cold virus) also serve as vectors to carry genes of interest into monkey and human cells.

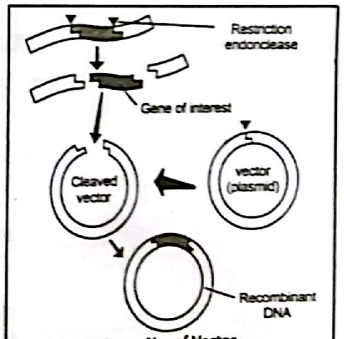


Figure: Use of Vector

Topic: (4) DNA Ligase:

Q.9 What is molecular glue? S/Q

Ans. DNA Ligase As Molecular Glue:

- The enzyme which joins **two DNA fragments** is called **DNA ligase,** thus ligase is called **molecular glue.**
- Ligase forms the **phosphodiester** linkage between two adjacent nucleotides.

CamScanner

Topic: (5) Expression System:

Q.10 What is expression system in recombinant DNA technology? Also give its example.

Ans. Expression System:

- A suitable organism that can act as host for rDNA (gene of interest attached with vector) and can express the gene of interest & produce required product is called **expression system.**
- The selection of **suitable expression** system depends upon the type of vector used to make rDNA.
- **Example:** Bacterial cells act as an ideal expression system because of their short generation time and simple genetic system.

Check Understanding!

Q.3 Why do bacterial cells act as an ideal expression system?
(A) Short generation time.
(B) Complex chromosomes.
(C) Slow metabolic rate.
(D) Large nuclear size.

Topic: Steps of Recombinant DNA Technology:

Q.11 Write the names of major steps involve in recombinant DNA technology.

Ans. Major Steps Involve in Recombinant DNA Technology:
(1) Formation of Recombinant Vector (Plasmid). (2) Cloning of Recombinant Vector,
(3) Screening of Clone Library.

Q.12 Name & explain the steps involve in recombinant DNA technology. Exercise L/Q.1, L/Q.

Ans. Steps Involve in Recombinant DNA Technology:

- To get recombinant DNA, the scientists work through the following steps.

(1) Formation of Recombinant Vector (Plasmid):

i. DNA Cleavage:

- The source DNA of the organisms is cleaved by using a restriction endonuclease and the gene of interest is isolated.
- The DNA of vector (e.g., plasmid or viral DNA) is also cleaved by using the same endonuclease. So, compatible sticky ends are produced at the gene of interest and the cleaved vector.

Check Understanding!

Q.4 What two specific components are incubated together with DNA ligase during the production of a recombinant DNA vector?

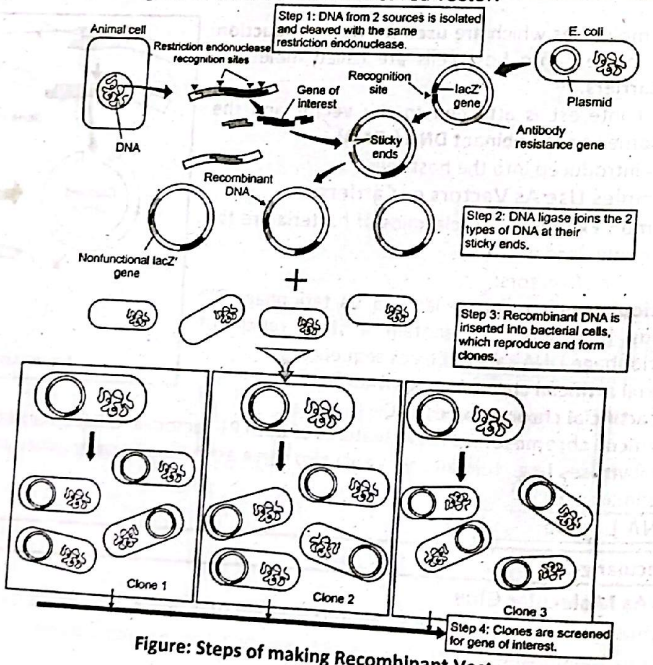


Figure: Steps of making Recombinant Vectors

ii. Production of Recombinant DNA (Vector):

- The gene of interest is inserted into the cleaved vector. For this purpose, the cleaved vector and the gene of interest are incubated together in the presence of DNA ligase. This enzyme connects them by forming phosphodiester linkages.
- So, the vector turns into recombinant vector (i.e., vector having the gene of interest).

(2) Cloning of Recombinant Vector:

- The **recombinant DNA (vector)** and the expression system (usually bacteria) are incubated in the same medium.
- The **bacterial cells** take up recombinant DNA.
- All the incubated bacteria make **bacterial clones** which also contain the identical copies i.e., clones of the gene of interest.

(3) Screening of Clone Library:

- Once the **vectors** have been inserted into **host cells**, scientists identify which bacteria actually took up the recombinant plasmid. This is done through:

3-i. Selecting for the Vector (Antibiotic Resistance):

- The plasmid contains an antibiotic **resistance gene.**
- The bacteria are grown on a **medium containing** that antibiotic (e.g., ampicillin).
- Only cells that took up a plasmid will survive and grow.

3-ii. Selecting for the Gene of Interest (Blue-White Screening):

- To distinguish between a **"plain"** plasmid and a **"recombinant plasmid"**, the **lacZ'** gene of the plasmid is used.
- The lacZ' gene produces an enzyme which metabolizes a specific sugar and **turns it blue**

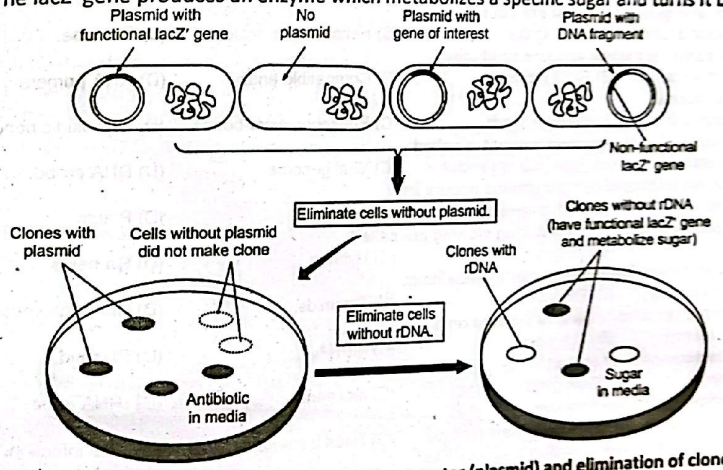


Figure: Screening of clones (Elimination of clones without vector (plasmid) and elimination of clones with vector (plasmid) but without recombinant DNA)

Identification Weather the Plasmid is Recombinant or Not:

- If the plasmid is **not recombinant**, the **lacZ'** gene remains functional and turns the **bacterial colony blue.**
- If gene of interest was successfully inserted, it "breaks" the **lacZ' gene.**
- Therefore, the desired recombinant clones will remain white.

Check Understanding!

Q.5 What color do desired recombinant clones remain during blue-white screening?
(A) Blue. (B) White.
(C) Yellow. (D) Red.

3-iii. Identifying the Specific Gene (DNA Hybridization):

- To confirm the **presence of gene of interest,** a radioactive probe is used. It is a DNA strand complementary to gene of interest.

CamScanner

- The probe sticks (hybridizes) only to the colonies containing the gene of interest.
- **Auto-radiography** (photographic film) is used to locate these specific colonies on the master plate.
- The main steps of this technique are mentioned in the following diagram.

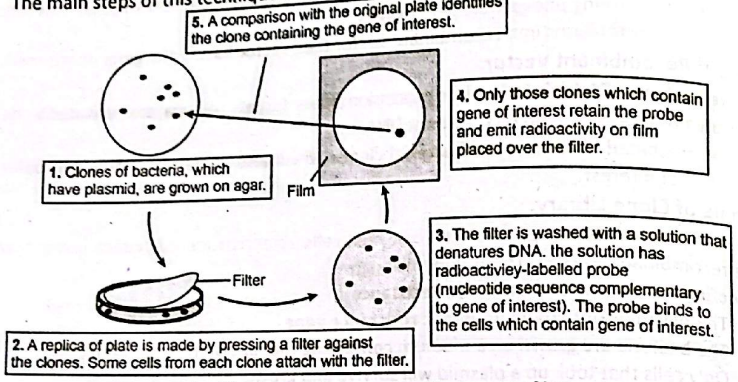


Figure: Identification of the clones that have gene of interest

Multiple Choice Questions (MCQs)

		Key
1.	**The first step in recombinant DNA technology is:** (A) Clone screening. (B) DNA cleavage. (C) Gene expression. (D) PCR amplification.	1.(B)
2.	**The vector and gene of interest are cut using:** (A) Restriction enzyme. (B) DNA ligase. (C) Helicase. (D) Primase.	2.(A)
3.	**Using the same restriction enzyme produces:** (A) Random ends. (B) Blunt proteins. (C) Compatible ends. (D) RNA primers.	3.(C)
4.	**DNA ligase forms:** (A) Hydrogen bonds. (B) Peptide bonds. (C) Phosphodiester bonds. (D) Glycosidic bonds.	4.(C)
5.	**A vector containing the gene of interest is called:** (A) Empty plasmid. (B) Recombinant vector. (C) Viral genome. (D) DNA probe.	5.(B)
6.	**Cloning of recombinant vectors usually occurs in:** (A) Bacteria. (B) Animal cells. (C) Fungi. (D) Plants.	6.(A)
7.	**Identical bacterial cells formed during cloning are called:** (A) Mutants. (B) Clones. (C) Hybrids. (D) Gametes.	7.(B)
8.	**Antibiotic selection identifies bacteria containing:** (A) RNA molecules. (B) Ribosomes. (C) Plasmids. (D) Chromosomes.	8.(C)
9.	**The antibiotic resistance gene is present on the:** (A) Chromosome. (B) Ribosome. (C) mRNA. (D) Plasmid.	9.(D)
10.	**Blue-white screening uses the:** (A) lacZ gene. (B) trp gene. (C) lacI gene. (D) rRNA gene.	10.(A)
11.	**White bacterial colonies indicate:** (A) Empty plasmid. (B) Recombinant plasmid. (C) Dead bacteria. (D) Viral infection.	11.(B)
12.	**DNA hybridization uses a:** (A) DNA probe. (B) Histone protein. (C) Ribosome. (D) Centromere.	12.(A)
13.	**Why are the vector and gene cut with the same restriction enzyme?** (A) Faster cloning. (B) Matching ends. (C) Protein synthesis. (D) DNA replication.	13.(B)
14.	**Why do only some bacteria survive on antibiotic medium?** (A) Faster growth. (B) More nutrients. (C) Plasmid uptake. (D) Larger cells.	14.(C)
15.	**Why do recombinant colonies appear white in blue-white screening because?** (A) lacZ disrupted. (B) No plasmid. (C) DNA degraded. (D) No antibiotic.	15.(A)
16.	**Why is DNA hybridization performed after blue-white screening?** (A) Protein detection. (B) Gene confirmation. (C) Cell division. (D) Plasmid removal.	16.(B)
17.	**A radioactive probe used in DNA hybridization to _____?** (A) Cut DNA. (B) Join fragments. (C) Detect gene. (D) Kill bacteria.	17.(C)
18.	**What is the main purpose of clone screening?** (A) Protein digestion. (B) Desired clones. (C) DNA replication. (D) Cell growth.	18.(B)

POLYMERASE CHAIN REACTION (PCR)

Q.13 Define PCR, & why is this name given to this technique & who developed this technique? S/Q

Ans. Polymerase Chain Reactions (PCR):
- A technique in which, **multiple identical copies** of the gene of interest are made is called PCR.
- It is simply an artificial DNA replication.

Named As Polymerase Chain Reaction (PCR):
- The enzyme **DNA polymerase** is used to copy which polymerizes a given piece of DNA again and again, so that multiple copies are produced. That's why the technique is known as **polymerase chain reaction (PCR).**

Technique Developed By:
- Kary Mullis developed PCR in 1983. He won the Nobel Prize in Chemistry in 1993.

Topic: Steps of PCR:

Q.14 Name the 4-steps involve in PCR. S/Q

Ans. Steps involve in PCR:
(1) Denaturation of Primer & DNA. **(2) Annealing of Primer.**
(3) Extension of Primer. **(4) Repeating the cycle.**

Check Understanding!
Q.6 What specific roles do primers and Taq polymerase play during the steps of PCR?

Q.15 Write a note on polymerase chain reaction.
OR Describe in detail the 4-steps involve in PCR. Exercise L/Q.3 L/Q

Ans. 4-Main Steps of PCR:

Step 1: Denaturation:
- **Mixing:** First, an **excessive** amount of primer (a sequence of 20 to 30 nucleotides) is mixed with the DNA fragment (gene of interest).
- **Heating:** The mixture of primers and DNA is heated to about 98°C. At this temperature, the double-stranded DNA breaks into single strands.
- Each single **stranded DNA** can act as the **template** for the in vitro DNA synthesis.

Step 2: Annealing of Primer:
- The solution is **allowed to cool** to about 60°C.
- As it cools, the forward and the backward primers anneal or hybridize to the single-stranded DNA at its complementary regions.
- So, the rest of the fragment remains single-stranded.

Step 3: Extension of Primer:
- A very heat-stable DNA polymerase, called **Taq polymerase** is added.
- All four types of nucleotides are also added.
- The **Taq polymerase** adds new nucleotides to the **3′ end** of primer. In this way, it copies the rest of the fragment just like the **replication of DNA.**

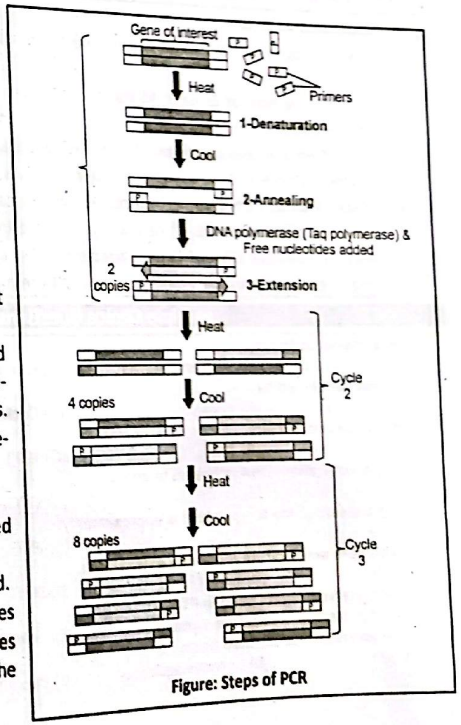


Figure: Steps of PCR

- In this way, a complimentary copy of the entire single-stranded DNA has been added to the primer.
- Because both DNA strands are replicated, there are now two copies of the original DNA fragment.

➢ **Step 4: Repeating the Cycle:**

- Steps 1 to 3 are repeated and the two copies become four.
- It is not necessary to add any more polymerase, as the heating does not harm this enzyme.
- Each cycle is completed in one or two minutes and it doubles the number of DNA molecules.
- After 20 cycles, a single fragment of DNA produces more than one million copies.

Q.16 Define genomic library? S/Q

Ans. Genomic Library:

- Genomic library is the collection of the total DNA (Genes) from a single organism. Genomic libraries are commonly used for sequencing the DNA.
- PCR is also used to build genomic library.

Q.17 What is Taq polymerase & how is it obtained? S/Q

Ans. Taq Polymerase:

- The Taq polymerase is a temperature-tolerant enzyme isolated from *Thermus aquaticus*, a bacterium found in hot water springs. This enzyme is stable and active at near-boiling temperatures.
- The optimum temperature for carrying out the extension of primer is 72°C. This step is completed in just one minute.

Check Understanding!

Q.7 From which specific organism is Taq polymerase isolated?
(A) Aspergillus fungus.
(B) Escherichia coli.
(C) Bacillus thuringiensis.
(D) Thermus aquaticus.

Q.18 What are the uses & applications of PCR? U/Q

Ans. Applications of PCR:

i. **Use in Diagnostic Techniques:** It is an efficient diagnostic technique used for detecting genotypes of infectious agents.
ii. **Use in Detection of Genetic Mutation:** It is used to detect genetic mutations responsible for certain genetic diseases and cancers.
iii. **Use in Criminal Investigations:** In criminal investigations, "DNA fingerprints" are prepared from the cells in a tiny sample of dried blood or at the base of a single human hair.
iv. **Helps to Detect Embryonic Defects:** Physicians can detect genetic defects in very early embryos by collecting a few sloughed-off cells and amplifying their DNA.
v. **Helps to Examine DNA of Extinct Species:** PCR is also used to examine the DNA of extinct species, as long as even a minuscule amount of their DNA remains intact.

Multiple Choice Questions (MCQs)

		Key
1.	PCR is mainly used for: (A) Protein synthesis. (B) DNA amplification. (C) Cell division. (D) Gene deletion.	1.(B)
2.	PCR was developed by: (A) Kary Mullis. (B) Watson. (C) Crick. (D) Meselson.	2.(A)
3.	PCR was developed in: (A) 1973. (B) 1983. (C) 1993. (D) 2003.	3.(B)
4.	During denaturation, DNA is heated to about: (A) 60°C. (B) 72°C. (C) 98°C. (D) 37°C.	4.(C)
5.	During annealing, the temperature is approximately: (A) 98°C. (B) 72°C. (C) 25°C. (D) 60°C.	5.(D)
6.	The optimum temperature for primer extension is: (A) 98°C. (B) 72°C. (C) 60°C. (D) 37°C.	6.(B)
7.	The heat-stable enzyme used in PCR is: (A) Taq polymerase. (B) DNA ligase. (C) Helicase. (D) Primase.	7.(A)
8.	Taq polymerase was isolated from: (A) E. coli. (B) Thermus aquaticus. (C) Bacillus subtilis. (D) Yeast.	8.(B)

					Key
9.	After 20 PCR cycles, one DNA fragment produces: (A) 100 copies.	(B) 1000 copies.	(C) Million copies.	(D) 20 copies.	9.(C)
10.	PCR is used in criminal investigations for: (A) Blood grouping.	(B) DNA fingerprinting.	(C) Gene therapy.	(D) Vaccination.	10.(B)
11.	PCR helps detect: (A) Vitamin deficiency.	(B) Blood pressure.	(C) Hormones.	(D) Genetic mutations.	11.(D)
12.	Why is Taq polymerase used instead of ordinary DNA polymerase? (A) Faster enzyme.	(B) Heat stable.	(C) More accurate.	(D) RNA synthesis.	12.(B)
13.	Why are primers required in PCR? (A) Start synthesis.	(B) Cut DNA.	(C) Join DNA.	(D) Unwind DNA.	13.(A)
14.	Why does PCR produce exponential DNA amplification? (A) One copy.	(B) Doubling cycles.	(C) Protein synthesis.	(D) RNA replication.	14.(B)
15.	Why is denaturation necessary before annealing? (A) Separate strands.	(B) Join primers.	(C) Destroy DNA.	(D) Activate ligase.	15.(A)
16.	Why is PCR valuable in forensic science? (A) Large organs.	(B) Protein analysis.	(C) Tiny samples.	(D) Cell culture.	16.(C)
17.	Why can PCR detect genetic defects in early embryos? (A) DNA amplification.	(B) Protein digestion.	(C) Chromosome fusion.	(D) RNA translation.	17.(A)

GENETICALLY MODIFIED ORGANISM (GMO)

Q.19 Define the term GMO & give some examples of GMOs. U/Q

Ans. GMO:

- A plant, animal or microbe in which the genome has been changed is called genetically modified organism.
- Transgenic organisms are a specific subset of GMOs that have received DNA from a different, unrelated species.
- **Examples of GMO:** Approximately 90% of canola, cotton, corn, soybean, and sugar beets grown in the world are transgenic.

Topic: Methods of Gene Transfer:

Q.20 What is the method used to transfer a gene if you want to produce a whole multicellular GMO? S/Q

Ans. Methods of Gene Transfer:

- The gene (DNA) is transferred into the target cell through cell membrane or cell wall without destroying the cell.
- To produce a whole multicellular GMO, the gene is transferred into a gamete or gamete-producing tissue. Such gametes are then fused to produce GMOs.

Q.21 Discuss some of the common techniques used to transfer gene of interest into target cell. U/Q

Ans. Common Techniques Used to Transfer Gene of Interest into Target Cell:

- The following are common techniques used to transfer the gene of interest into a target cell.

Check Understanding!

Q.8 How do electroporation and biolistic transformation differ in their physical methods for transferring a gene into a target cell?

(a) **Electroporation:**
  - In this technique pores are created in the cell wall or cell membrane of target cell.
  - The pores allow gene intake. Once the electrical current is discharged, the pores are closed.

(b) **Microinjection:**
  - A technique in which a fine needle, or injection, is used to directly inject the gene into the target cell nucleus.

(c) **Biolistic Transformation:**
  - In this method the gene of interest coated with heavy metal ions is inserted into the target cell by mechanical force e.g., gene gun.

(d) **Protoplast Mediated Technique:**
  - In this technique the cell wall and cell membrane are removed from the target cell. This protoplast is mixed with the medium containing the gene of interest.

CamScanner

(e) Chemical Methods:
- A technique in which the **naked DNA** is fused with a chemical agent.
- The chemical and DNA complex enters into the cell cytoplasm through diffusion or endocytosis.

(f) Virus Mediated Gene Transfer:
- A technique in which **Adenovirus, Adeno-associated virus, HIV, lentivirus** and other retroviruses are used for gene transfer.

Topic: GMO (Transgenic) Bacteria:

Q.22 What are transgenic bacteria, discuss the importance of transgenic bacteria in different industries? LIQ

Ans. GMO or Transgenic Bacteria:
- The bacteria which have **foreign gene** are called transgenic bacteria.
- Genes from a wide range of organisms can be added to a plasmid and inserted **into bacteria.**
- Transgenic bacteria can **synthesize** large amounts of the proteins encoded by the inserted foreign genes.

➢ **Importance of Transgenic Bacteria in Different Industries**
- Different forms of transgenic bacteria are being used to;

(i) Pharmaceutical Industry:
- Transgenic bacteria produce pharmaceutical products as given below:

(a) Insulin: To treat diabetes
(b) Clotting Factors: To treat haemophilia.
(c) Hepatitis B Vaccine: Against hepatitis B.
(d) Covid-19 Vaccine: Against Corona.
(e) Human Growth Hormone: To treat dwarfism.
(f) Interferon: To treat some cancers.
(g) Erythropoletin: To treat anaemia.
(h) Tissue Plasminogen Activator: Which dissolves blood clots.

(ii) Food Industry:
- Transgenic bacteria are also used to produce many food products:

(a) Alpha-amylase: Which converts starch to simple sugars.
(b) Chymosin: Which clots milk protein for cheese making.
(c) Pectin-esterase: Which improves fruit juice clarity.

(iii) Enzymes Production:
- Transgenic bacteria are also used to produce **enzymes** which degrade toxins to convert pollutants into a less toxic form.

(iv) Remove Pollution:
- Leach copper from ore, clean up mercury pollution and detect arsenic in drinking water.

Topic: GMO (Transgenic) Animals:

Q.23 Define the term transgenic animal & give the importance of transgenic animals for human. LIQ

Ans. Transgenic Bacteria:
- An animal which carries a **foreign gene** to produce the desired protein is called **transgenic animals.**
- Transgenic animals serve **various purposes** e.g., producing drugs, enhancing yields, increasing resistance to disease etc.

➢ **Importance of Transgenic Animals for Human:**

(i) Transgenic Dairy Cows:
- Transgenic dairy cows have genes from human beings to **produce milk** that is the same as **human breast milk.**

(ii) Transgenic Goats:
- Transgenic goats produce **milk** with strong spiderweb-like **silk proteins.**

(iii) Production of Lysozyme Enzyme:
- Transgenic goats also produce human enzyme **lysozyme** in their milk to fight **diarrhoea** causing bacteria in humans.

Tidbit

Q. Why most of the research related to genes transfer are focused on body or somatic cells not on sex cells?

➢ **Ans.** In theory, foreign genes may be inserted either in germline or in somatic cells of humans.
- If genes are inserted in germline cells, it results in inheritable changes.
- But, most research has focused on somatic cells because of risks and ethical issues associated with germline transformation.

Check Understanding!

Q.9 What substance do transgenic goats produce in their milk to help fight diarrhea-causing bacteria in humans?
(A) Interferon. (B) Insulin
(C) Lysozyme. (D) Hemoglobin

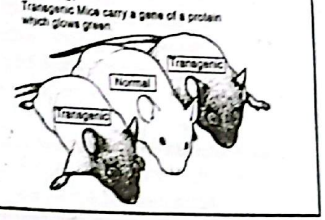
(iv) Transgenic Fish:
- Transgenic fish show **better growth,** reduced food intake, **increased cold tolerance,** and disease **resistance.**

(v) Use in Gene Therapy:
- In gene therapy, genetically modified viruses are used to deliver genes to humans to cure various inheritable diseases such as abnormal development of **T and B cells** and inherited blindness.

(vi) Production of Anticoagulant:
- The first human biological drug produced from a **transgenic** goat was an **anticoagulant** to reduce the probability of blood clots during surgery or childbirth.

(vii) Malarial Resistant Mosquitoes:
- Malaria-resistant mosquitoes have been developed in the laboratory by inserting a gene that **reduces the development of Plasmodium** in them.

Tidbit
- Since the mid-1980s, transgenic mice are a key model for investigating diseases.
- Mice are the **model** for this purpose because there is complete analysis of its genome sequence and its genome is very much similar to humans.



Topic: Transgenic Plants:

Q.24 Define the term totipotent. SIQ

Ans. Totipotent:
- Many plant cells are totipotent, it is the ability of a **single cell** to form a **complete new plant.**
- Biologists grow a new plant from a **transgenic cell** of plant.

Q.25 What are transgenic plants, give examples & importance of transgenic plants for human? LIQ

Ans. Transgenic Plants:
- The plants which have **foreign genes** are called transgenic plants.

➢ **Examples & Importance/Purpose of Transgenic Plants:**
- The main purposes of producing transgenic plants are;

(i) Plants with Harmful Insects Killer Genes:
- Genes of ***Bacillus thuringiensis*** (a soil bacterium) have been inserted in many plants (e.g., cotton, rice, maize, potato, tomato, brinjal, cauliflower, cabbage etc.).
- These genes make **proteins** that kill **insect pests** but do not **harm other useful insects.**

For Information
- Each year, **deficiency of iron** affects 1.4 billion women and deficiency of **vitamin A** kills 670,000 children and causes 500,000 cases of irreversible childhood blindness.

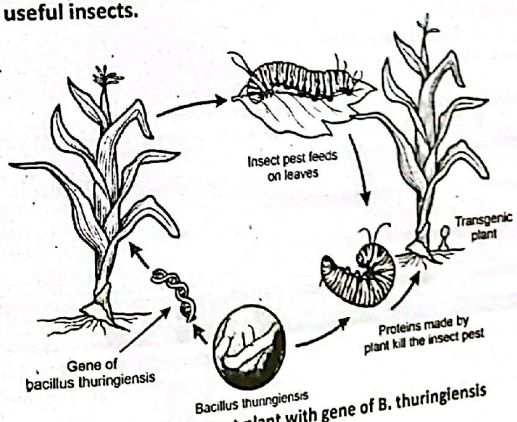


Figure: Insect-resistant plant with gene of B. thuringiensis

CamScanner

(ii) Herbicidal Resistant Crops:
- Many crops have been modified to be resistant against **glyphosate** (an herbicide).

(iii) Production of Golden Transgenic Rice:
- In developing countries, biologists have made GMO (transgenic) **rice (golden rice)** in which they have inserted genes to increase **iron content.**
- These genes were taken from **beans, Aspergillus fungus,** and **wild rice.**
- Similarly, the genes for making beta-carotene (a precursor of vitamin A) were taken from daffodil and inserted in **rice.**
- **Importance of Golden Rice:** The transgenic rice is **grown** and consumed in areas with a shortage of dietary iron and vitamin A.

Check Understanding!
Q.10 What specific sources were used to obtain the genes inserted into golden rice to increase iron content and synthesize beta-carotene?

(iv) Production of Pharmaceuticals:
- GMO plants and plant cells are used for the production of **biopharmaceuticals** e.g., cytokines, hormones, antibodies, enzymes and vaccines etc.

Multiple Choice Questions (MCQs)

		Key
1.	A genetically modified organism (GMO) has a changed: (A) Protein. (B) Genome. (C) Ribosome. (D) Cell wall.	1.(B)
2.	A transgenic organism contains DNA from: (A) Same species. (B) Same parent. (C) Identical cells. (D) Different species.	2.(D)
3.	Electroporation transfers genes by creating: (A) DNA breaks. (B) Cell pores. (C) Protein channels. (D) Vacuoles.	3.(B)
4.	Which technique directly injects DNA into the nucleus? (A) Electroporation. (B) Gene gun. (C) Microinjection. (D) Endocytosis.	4.(C)
5.	Biolistic transformation is commonly known as: (A) Gene gun. (B) DNA probe. (C) PCR method. (D) Cell fusion.	5.(A)
6.	Which technique removes the cell wall before gene transfer? (A) Microinjection. (B) Protoplast method. (C) Electroporation. (D) Hybridization.	6.(B)
7.	Which virus is mentioned as a gene-transfer vector? (A) Influenza virus. (B) Poliovirus. (C) Adenovirus. (D) Rabies virus.	7.(C)
8.	Transgenic bacteria are widely used to produce: (A) Insulin. (B) Cellulose. (C) Chlorophyll. (D) Starch.	8.(A)
9.	Human growth hormone treats: (A) Diabetes. (B) Dwarfism. (C) Anaemia. (D) Cancer.	9.(B)
10.	Transgenic goats produce milk containing: (A) Spider silk. (B) Collagen. (C) Keratin. (D) Elastin.	10.(A)
11.	Golden rice is enriched with: (A) Calcium, iodine. (B) Protein, fat. (C) Iron, beta-carotene. (D) Zinc, sodium.	11.(C)
12.	Bt genes were obtained from: (A) Rhizobium. (B) Bacillus thuringiensis. (C) E. coli. (D) Aspergillus.	12.(B)
13.	Why are bacterial plasmids commonly used in genetic engineering? (A) Protein storage. (B) ATP production. (C) Cell division. (D) Gene carriers.	13.(D)
14.	Why is microinjection considered a precise gene-transfer method? (A) Direct injection. (B) Chemical diffusion. (C) Electrical pores. (D) Virus infection.	14.(A)
15.	Why are Bt crops resistant to insect pests? (A) Extra chlorophyll. (B) More nutrients. (C) Thicker leaves. (D) Toxic proteins.	15.(D)
16.	Why is golden rice important in developing countries? (A) Vitamin supply. (B) More protein. (C) Higher starch. (D) Better flavour.	16.(A)
17.	Why are genetically modified viruses used in gene therapy? (A) Protein digestion. (B) DNA cutting. (C) Gene delivery. (D) Cell fusion.	17.(C)

FORMATION OF HUMAN INSULIN IN BACTERIA

- The production of **human insulin** was the first major **triumph (success)** of genetic engineers.
- By using bacteria, scientists produce **vast quantities** of insulin that is identical to the insulin hormone naturally made in the pancreas.

- The process of creating synthetic human insulin involves producing the two polypeptide chains separately and then **joining them chemically.**

Q.26 How is human insulin produced from transgenic bacteria describe its steps briefly with the help of diagram? U/A

Ans. Steps of Human Insulin Production From Transgenic Bacteria:

(i) Preparation of the Two Genes:
- Since insulin **consists of two distinct chains,** scientists synthesise two different DNA sequences for this purpose:
  (a) One for **Chain A.** (b) One for **Chain B.**

Check Understanding!
Q.11 What is used in the laboratory to link Chain A and Chain B together into a functional human insulin molecule?
(A) Disulfide bonds.
(B) Peptide bonds.
(C) Hydrogen bonds.
(D) Glycosidic bonds.

(ii) Construction of Recombinant Plasmids:
- For the synthesis of **two chains** two sets of **plasmids** are obtained.
- **The DNA for Chain A** is inserted into **one set of plasmids,** and the DNA for Chain B is inserted into another.
- In both cases, the insulin gene is often attached next to a bacterial gene **(like lacZ)** to help the bacteria "recognize" and express the foreign DNA.

(iii) Transformation of Host Cells:
- The both recombinant plasmids are introduced into two **separate cultures** of *Escherichia coli* **bacteria.**

(a) Culture-1: It acts as a factory for **Chain A.** **(b) Culture-2:** It acts as a factory for **Chain B.**

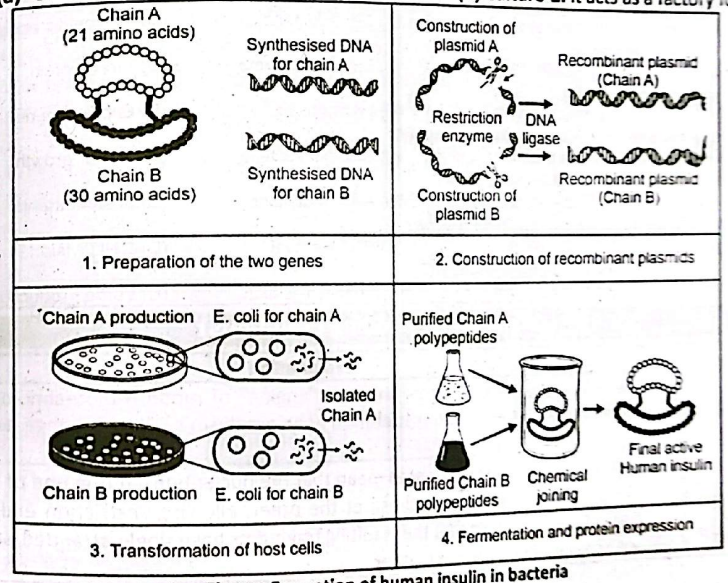


Figure: Formation of human insulin in bacteria

(iv) Fermentation and Protein Expression:
- The bacteria are grown in large industrial **bioreactors.**
- As the bacteria multiply and perform their **normal metabolic functions,** they simultaneously "read" the human DNA and **produce large quantities** of the individual insulin chains.

(v) Extraction and Chemical Joining:
- Once the chains are **synthesized,** the bacteria are harvested and the insulin chains are extracted and purified.

CamScanner

- In a laboratory setting, Chain A and Chain B are mixed together.
- They are linked by creating di-sulfide bonds (sulfur-to-sulfur bridges) between specific amino acids.
- This final step creates the functional, three-dimensional human insulin molecule, identical to that produced by a healthy human pancreas.

Multiple Choice Questions (MCQs)

1. The first major success of genetic engineering was producing:
(A) Growth hormone. (B) Human insulin. (C) Interferon. (D) Lysozyme.
2. Human insulin is naturally produced in the:
(A) Pancreas. (B) Liver. (C) Kidney. (D) Spleen.
3. Human insulin consists of:
(A) One chain. (B) Two chains. (C) Three chains. (D) Four chains.
4. Scientists prepare how many insulin genes?
(A) One gene. (B) Three genes. (C) Two genes. (D) Four genes.
5. The insulin gene is commonly attached beside the bacterial:
(A) trp gene. (B) lacZ gene. (C) rRNA gene. (D) recA gene.
6. The host bacterium used for insulin production is:
(A) Bacillus subtilis. (B) Thermus aquaticus. (C) Rhizobium. (B) Escherichia coli.
7. Chain A and Chain B are produced in:
(A) One culture. (B) Separate cultures. (C) Plant cells. (D) Animal cells.
8. Bacteria are grown in large:
(A) Bioreactors. (B) Petri dishes. (C) Test tubes. (D) Flasks.
9. After synthesis, insulin chains are first:
(A) Destroyed. (B) Extracted. (C) Replicated. (D) Mutated.
10. Chain A and Chain B are linked by:
(A) Peptide bonds. (B) Hydrogen bonds. (C) Disulfide bonds. (D) Glycosidic bonds.
11. The final insulin molecule is:
(A) Artificial protein. (B) Human identical. (C) Bacterial enzyme. (D) Viral protein.
12. The lacZ gene helps bacteria:
(A) Destroy DNA. (B) Replicate plasmids. (C) Form spores. (D) Express gene.
13. Why are Chain A and Chain B produced separately?
(A) Two polypeptides. (B) One plasmid. (C) Different bacteria. (D) Faster growth.
14. Why are two separate bacterial cultures used?
(A) More oxygen. (B) Separate chains. (C) Avoid mutations. (D) Less nutrients.
15. Why is the lacZ gene linked with the insulin gene?
(A) Gene expression. (B) DNA cutting. (C) RNA removal. (D) Cell division.
16. Why are bioreactors used in insulin production?
(A) DNA storage. (B) Gene transfer. (C) Protein digestion. (D) Large production.

MCQs
1.(B)
2.(A)
3.(B)
4.(C)
5.(B)
6.(D)
7.(B)
8.(A)
9.(B)
10.(C)
11.(B)
12.(D)
13.(A)
14.(B)
15.(A)
16.(D)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(A)	• The text explicitly states that the true "engine" of modern biotechnology is "Genetic engineering," defined as the alteration of an organism's DNA to change its characters or capabilities.
2.	S/Q	• Because palindromic sequences mean that the nucleotides at one end of the restriction site are complementary to those at the other, allowing restriction endonucleases to cleave both strands so that the resulting fragments have single-stranded, sticky ends that are complementary to each other.
3.	(A)	• The text explicitly states that bacterial cells act as an ideal expression system because of their short generation time and simple genetic system.
4.	S/Q	• The gene of interest (isolated by cleaving source DNA with a restriction endonuclease) and the cleaved vector (such as plasmid or viral DNA cleaved by the same endonuclease) are incubated together in the presence of DNA ligase.
5.	(B)	• The text states that if the gene of interest was successfully inserted, it "breaks" the lacZ gene, meaning the desired recombinant clones will remain white instead of turning blue.
6.	S/Q	• Primers (sequences of 20 to 30 nucleotides) are mixed with the DNA and anneal to complementary regions at about 60°C, after which the heat-stable Taq polymerase adds new nucleotides to the 3' end of the primer to copy the rest of the fragment.
7.	(D)	• The text notes in the information box that Taq polymerase is a temperature-tolerant enzyme isolated from Thermus aquaticus, a bacterium found in hot springs.
8.	S/Q	• In electroporation, electrical current creates pores in the cell wall or cell membrane to allow gene intake, whereas in biolistic transformation, the gene of interest coated with heavy metal ions is inserted into the target cell by mechanical force using a gene gun.
9.	(C)	• The text explicitly lists transgenic goats producing the human enzyme lysozyme in their milk to fight diarrhea-causing bacteria in humans.
10.	S/Q	• The genes to increase iron content were taken from beans, Aspergillus fungus, and wild rice, while the genes for making beta-carotene were taken from daffodil.
11.	(A)	• The text states that in the final extraction and chemical joining step, Chain A and Chain B are mixed together and linked by creating disulfide bonds (sulfur-to-sulfur bridges) between specific amino acids.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. Identify the FALSE statement.
(a) Restriction enzyme is used for the production of RFLPs.
(b) DNA ligase enzyme is used to cut DNA, creating the sticky ends.
(c) Reverse transcriptase enzyme is used for making cDNA from mRNA.
(d) Electrophoresis means the separation of DNA fragments.
2. Which bacterium is used in the production of insulin by genetic engineering?
(a) Saccharomyces. (b) Rhizobium. (c) Escherichia. (d) Mycobacterium.
3. Which technique is used for cloning of gene/DNA?
(a) RFLP analysis. (b) Polymerase Chain Reaction (PCR).
(c) Electroporation. (d) Gel electrophoresis.
4. Which method is used for obtaining the gene of interest?
(a) Artificial gene synthesis. (b) Reverse transcription.
(c) Cleavage from chromosome. (d) All of these.
5. When a gene of interest is attached to the vector, the new molecule is called:
(a) Recombinant DNA. (b) Restriction length fragment.
(c) Complimentary DNA. (d) Genomic library.
6. What is the use of plasmid in genetic engineering?
(a) To carry DNA to a cell. (b) To cut DNA.
(c) To join pieces of DNA. (d) To replicate DNA.
7. Which of these can serve as ideal expression system for gene cloning?
(a) Bacteriophages. (b) Bacterial cells. (c) Plant cells. (d) Animal cells.
8. In PCR, optimum temperature for carrying out the extension of primer is;
(a) 98°C. (b) 72°C. (c) 60°C. (d) 37°C.
9. Which enzyme is used for the extension of primer in PCR?
(a) DNA polymerase. (b) Transcriptase.
(c) DNA ligase. (d) Restriction endonuclease.
10. What is true for a Genetically Modified Organism:
(a) Genes have been introduced. (b) Genes have been enhanced.
(c) Genes have been deleted. (d) All of these.

CamScanner

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(b)	DNA ligase enzyme is used to cut DNA, creating the sticky ends.	• DNA ligase is used to join or seal DNA fragments, whereas restriction enzymes are the ones that cut DNA.
2.	(c)	Escherichiar.	• Escherichia coli is the most widely used host bacterium for recombinant DNA-based production of human insulin.
3.	(b)	Polymerase Chain Reaction (PCR).	• PCR is a standard molecular technique used to amplify and clone specific gene segments rapidly.
4.	(d)	All of these.	• A gene of interest can be obtained through artificial synthesis, reverse transcription of mRNA, or direct cleavage from genomic chromosomes.
5.	(a)	Recombinant DNA.	• When a target gene is inserted into a vector molecule, the resulting hybrid DNA is known as recombinant DNA.
6.	(a)	To carry DNA to a cell.	• Plasmids act as vectors to transport foreign genetic material into a host cell.
7.	(b)	Bacterial cells.	• Bacterial cells, particularly E. coli, serve as ideal and efficient expression systems for cloning due to their rapid growth and ease of manipulation.
8.	(b)	72° C.	• Taq polymerase operates at its optimal catalytic activity for DNA strand extension at approximately 72 degrees Celsius.
9.	(a)	DNA polymerase.	• Thermostable DNA polymerase (like Taq polymerase) is responsible for extending primers during the PCR cycle.
10.	(d)	All of these.	• Genetically Modified Organisms can be created by introducing foreign genes, enhancing existing genes, or deleting specific genetic sequences.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 What is the role of restriction endonucleases and DNA ligases in gene cloning?

Ans. (a) **Role of Restriction Endonucleases:** It act as molecular scissors to cut target DNA molecules at specific recognition sequences, creating compatible sticky or blunt ends.

(a) **Role of DNA Ligases:** It act as molecular glue to permanently seal and join the sugar-phosphate backbones of the foreign DNA insert and the vector.

Q.2 What is the role of vectors in recombinant DNA technology?

Ans. **Role of Vectors in Recombinant DNA Technology:**

(i) **Gene Carriers:** Vectors serve as vehicles to carry foreign DNA fragments into a host cell for cloning or expression.

(ii) **Replication and Selection:** They ensure independent replication of the inserted gene inside the host and often carry selectable markers like antibiotic resistance genes.

Q.3 Describe how the gene of interest is selected and isolated during recombinant DNA technology.

Ans. **Selection & Isolation of Gene of Interest during Recombinant DNA Technology:**

- **Identification:** The desired gene is located within the source genome using specific probes or genomic libraries.
- **Isolation:** The gene is cut out and separated using restriction enzymes.
- Synthesized artificially via PCR or cDNA techniques.

Q.4 State the steps for the integration of gene of interest into the vector.

Ans. **Steps for the Integration of Gene of Interest into the Vector:**

- **Cleavage:** Both the plasmid vector and the **gene of interest** are cut with the same restriction endonuclease to produce matching ends.
- **Ligation:** The cut gene is mixed with the cleaved vector in the presence of DNA ligase to form a stable recombinant DNA molecule.

Q.5 State the role of GMO in making biotechnology products.

Ans. **Role of GMO in making Biotechnology Products:**

- **Protein Factories:** Genetically Modified Organisms are engineered to express foreign genes for mass production of therapeutic proteins like insulin and human growth hormone.
- **Metabolic Enhancement:** They are used to synthesize industrial enzymes, vaccines, and agricultural products efficiently.

Q.6 Differentiate between; Endonuclease and ligase, PCR and recombinant DNA technology.

Ans. **Endonuclease and Ligase:**

Endonuclease	Ligase
• Endonucleases cleave phosphodiester bonds within DNA strands at specific sites.	• Ligases catalyze the formation of phosphodiester bonds to join DNA fragments together.

PCR and Recombinant DNA Technology:

PCR	Recombinant DNA Technology
• PCR is an in vitro technique used to rapidly amplify specific DNA sequences.	• Recombinant DNA Technology involves inserting foreign DNA into a vector and host system for expression or cloning.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Describe the components and steps of recombinant DNA technology.

Ans. See Page NO. 250 (Q.12)

Q.2 Write a detailed note on restriction enzymes.

Ans. See Page NO. 248 (Q.7)

Q.3 Write a note on polymerase chain reaction.

Ans. See Page NO. 253 (Q.15)

Q.4 Describe the methods for the introduction of human DNA into bacteria.

Ans. See Page NO. 250 (Q.12)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Find and describe the accomplishments of the renowned genetic engineers working in private and public institutions in your province or city.

Ans. • At the **Centre of Excellence in Molecular Biology** (CEMB) in Lahore, researchers have successfully engineered insect-resistant transgenic Bt cotton and rice varieties, developed recombinant biopharmaceuticals, and discovered novel genetic loci linked to human hereditary deafness and vision impairment.

Q.2 Analyse and interpret the DNA of a child by comparing it with that of two individuals in a case of disputed parenthood.

Ans. • DNA profiling compares short **tandem repeats** (STR markers) between a child and putative parents.
• Since a child inherits half their genetic markers from the mother and half from the father, any mismatch across multiple loci conclusively excludes biological parenthood.

Q.3 What may be the application of polymerase chain reaction?

Ans. **Application of Polymerase Chain Reaction:**

- Polymerase Chain Reaction (PCR) is widely applied in forensic DNA fingerprinting for criminal investigations, detecting viral pathogens (such as Hepatitis B and C), diagnosing hereditary genetic disorders, and amplifying target genes for recombinant cloning and sequencing.

CamScanner

Q.4 The human genome project is regarded as the most ambitious project ever undertaken by man. Justify.

Ans. Human Genome Project:

- The Human Genome Project mapped and sequenced all three billion nucleotide base pairs of human DNA.
- It helps in providing a foundational reference blueprint that revolutionized personalized medicine, gene discovery, and our understanding of complex genetic diseases.

Q.5 Investigate careers that require an understanding of biotechnology and genetic engineering.

Ans. Careers in Biotechnology and Genetic Engineering:

- Key professions utilizing these fields include biomedical researchers, genetic counselors, clinical laboratory technologists, bioprocess engineers, bioinformatics specialists, and regulatory affairs officers in agricultural or pharmaceutical biotech firms.

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. (1 x 6 = 06)

(i) Recombinant DNA technology mainly involves:
(A) DNA cutting. (B) Protein digestion. (C) RNA translation. (D) Cell division.

(ii) Which technique is used for cloning of gene/DNA?
(A) RFLP analysis. (B) Polymerase Chain Reaction (PCR).
(C) Electroporation. (D) Gel electrophoresis.

(iii) A vector containing the gene of interest is called:
(A) Empty plasmid. (B) Recombinant vector. (C) Viral genome. (D) DNA probe.

(iv) In PCR, optimum temperature for carrying out the extension of primer is:
(A) 98°C. (B) 72°C. (C) 60°C. (D) 37°C.

(v) PCR was developed in:
(A) 1973. (B) 1983. (C) 1993. (D) 2003.

(vi) Human insulin consists of:
(A) One chain. (B) Two chains. (C) Three chains. (D) Four chains.

Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) Enlist the 5-basic tools used in recombinant DNA technology.
(ii) What is molecular glue?
(iii) What is the role of vectors in recombinant DNA technology?
(iv) Differentiate between; Endonuclease and ligase, PCR and recombinant DNA technology.
(v) Define PCR, & why is this name given to this technique & who developed this technique?
(vi) Name the 4-steps involve in PCR.
(vii) Define genomic library?
(viii) Define the term totipotent.

Q.3 Extensive Questions. (4 x 2 = 8)

(a) Write a detailed note on restriction enzymes.
(b) Define the term transgenic animal & give the importance of transgenic animals for human.

ENTRANCE TEST MDCAT

1. **The DNA formed by the reverse transcription is called:** (UHS 2015)
A. rDNA B. Cdna C. dDNA D. DNA

2. **Bacterial cells take up recombinant plasmids when they are treated with:** (UHS 2015)
A. $CaCl_2$ B. KCl C. NaCl D. NaOH

3. **Which one of the following is made up of radioactively labeled nucleotides?** (UHS 2015)
A. Phage DNA B. Recombinant DNA C. Genomic library D. Gene probe

4. **A technique in transgenic animals in which desired gene is inserted into the eggs of animal is called:** (UHS 2015)
A. Embryonic stem cell mediated transfer B. Retro-virus mediated gene transfer
C. Microinjection D. None of these

5. **The modified plasmid or phage DNA is called:** (UHS 2016)
A. Clone DNA B. cDNA C. Recombinant DNA D. rDNA

6. **Restriction endonucleases cleave the _____ of duplex DNA.** (UHS 2016)
A. Nitrogenous base B. Phosphodiester bond C. Pentose sugar D. Hydrogen bond

7. **The enzyme which is responsible for the formation of bond between two double stranded DNA fragments is:** (UHS 2016)
A. Endonuclease B. Ligase C. Lipase D. Helicase

8. **_____ acts as an ideal expression system in recombinant DNA technology.** (UHS 2016)
A. Retrovirus B. Algae C. Rotavirus D. Bacteria

9. **_____ enzyme is very stable and active even at very high temperature.** (UHS 2016)
A. RNA polymerase B. Helicase C. DNA polymerase II D. Taq polymerase

10. **Restriction enzyme EcoR1 cuts DNA to produce:** (UHS 2017)
A. Blunt ends B. Sticky ends C. Non-palindromic ends D. Split ends

11. **Restriction endonuclease are produced by:** (UHS 2017)
A. Fungi B. Bacteria C. Algae D. Viruses

12. **DNA fragments of different lengths can be separated by a process of:** (UHS 2017)
A. Western blotting B. Autoradiography C. Northern blotting D. Gel electrophoresis

13. **_____ is the first heat stable component used in PCR:** (UHS 2017)
A. *Taq* isomerase B. *Taq* polymerase C. *Taq* helicase D. *Taq* SSBP

14. **Patients of cystic fibrosis (CF) produce thick mucus due to faulty:** (UHS 2017)
A. Trans-membrane carrier B. Na^+ ions C. Cl^- D. Mucus membrane

15. **Chemical nature of primer used in PCR process is _____:**
A. RNA B. Carbohydrate C. Protein D. DNA

16. **DNA made by joining pieces from two or more different sources:** (UHS 2018)
A. Probes B. Mutated DNA C. Restriction endonuclease D. Recombinant DNA

17. **By PCR we means:** (UHS 2018)
A. Polymerase chronic reaction B. Polymerase copy reaction
C. Polymerase chain reaction D. Polymerase cross reaction

18. **Deficiency of enzyme _____ causes combined immunodeficiency syndrome:** (UHS 2018)
A. Adenosine transcriptase B. Adenosine polymerase
C. Adenosine transaminase D. Adenosine deaminase

19. **DNA polymerase enzyme for PCR is isolated from bacteria *Thermus aquaticus* because:** (UHS 2019)
A. It can withstand high denaturation temperature B. It can work at high speed
C. It can withstand low denaturation temperature D. It can be used again and again

20. **Which enzyme is administered to the patients of Severe Combined Immunodeficiency Disease (SCID)?** (UHS 2019)
A. Pancreatic Enzyme B. β-galactosidase
C. Adenosine Deaminase (ADA. D. β-lactamase

CamScanner

21. **Transgenic mice have been used to produce:** (UHS 2019)
A. Protein rich milk B. Protein rich meat C. A growth hormone D. Extra hair

22. **If sequence in DNA is CCTAGAG, then what would be the sequence in messenger RNA after transcription?** (UHS 2019)
A. GGGAUCUC B. GGGGTCTC C. GGGATCTC D. GGAAUCUC

23. **Complementary DNA molecule is:** (UHS 2019)
A. An artificial DNA B. DNA and mRNA
C. Single stranded DNA D. A small segment of chromosomal DNA

24. **DNA polymerase enzyme for PCR is isolated from bacteria *Thermus aquaticus* because:** (UHS 2019)
A. It can withstand high denaturation temperature C. It can work at high speed
B. It can withstand low denaturation temperature D. It can be used again and again

25. **Which enzyme is administered to the patients of Severe Combined Immunodeficiency Disease (SCID)?** (UHS 2019)
A. Pancreatic Enzyme B. β-galactosidase
C. Adenosine Deaminase (ADA). D. β-lactamase

26. **If sequence in DNA is CCTAGAG, then what would be the sequence in messenger RNA after transcription?** (UHS 2019)
A. GGGAUCUC B. GGGGTCTC C. GGGATCTC D. GGAAUCUC

27. **Complementary DNA molecule is:** (UHS 2019)
A. An artificial DNA B. DNA and mRNA
C. Single stranded DNA D. A small segment of chromosomal DNA

ANSWERS KEY

1. B	2. A	3. D	4. C	5. C	6. B	7. B	8. D	9. D	10. B	11. B	12. D
13. B	14. A	15. D	16. D	17. C	18. D	19. A	20. C	21. C	22. A	23. B	24. A
25. C	26. A	27. B									

21 CHAPTER

IMMUNITY

Student Learning Outcomes (SLOs)

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

- List the structural features of human skin that make it an impenetrable barrier against invasion by microbes (1st line of defense).
- Explain how oil and sweat glands within the epidermis inhibit the growth and also kill microorganisms. (1st line of defense)
- Recognize the role of the acids of the digestive tract in killing bacteria present in food.
- State the role of the ciliated epithelium of the nasal cavity and the mucus of the bronchi and bronchioles in trapping airborne microorganisms.
- Describe the role of macrophages and neutrophils in killing bacteria.
- Explain how Natural Killer (NK) cells kill cells infected by microbes and cancer cells.
- State the way proteins of the complement system kill bacteria and that interferons inhibit viruses from infecting cells.
- State the events of the inflammatory response as a generalized, nonspecific defense.
- Outline the release of pyrogens by microbes and their effect on the hypothalamus to boost the body's temperature.
- List the ways that fever affects microbes.
- Define the specific immune system as providing specific defense and acting as the most powerful means of resisting infection.
- Identify monocytes, T- cells, and B-cells as components of the immune system.
- State inborn and acquired immunity as the two basic types of immunity.
- Differentiate between active and passive immunity as the two types of acquired immunity.
- Describe the role of T-cells in cell-mediated immunity.
- Describe the role of B-cells in antibody-mediated immunity.
- Discuss the role of T-cells and B-cells in transplant rejections.
- Evaluate the discovery of monoclonal antibodies and justify how this accomplishment revolutionized many aspects of biological research.
- Identify the process of vaccination as a means to develop active acquired immunity.
- Draw the structural model of an antibody molecule.
- Explain the role of memory cells in long- term immunity.
- Define allergies and correlate the symptoms of allergies with the release of histamines.
- Describe the autoimmune diseases with examples.

CamScanner

Immunity — Concept Map

1. FIRST LINE OF DEFENCE (Non-Specific / Innate)

- **Skin →** Epidermis (stratum corneum with keratin); sebaceous/sweat glands (pH 3-5, lysozyme).
- **Digestive & Respiratory Tracts →** Saliva/stomach acid/intestinal enzymes; nasal ciliated cells, bronchial mucus, cilia escalator.

2. SECOND LINE OF DEFENCE (Non-Specific / Innate)

- **Germ-Killer Cells →** Macrophages (monocyte-derived, phagocytosis, lysozyme), Neutrophils (phagocytosis, antimicrobial chemicals, DNA traps), Natural Killer/Cytotoxic T cells (perforins cause lysis; target infected/cancer cells via self-protein recognition).
- **Protective Proteins →** Complement system (liver proteins, MAC pore formation), Interferons (cytokines alerting virus-infected cells).
- **Inflammatory Response →** Histamines/prostaglandins cause vasodilation, permeability, redness, heat, swelling, and phagocyte migration.
- **Temperature Response →** Pyrogens act on hypothalamus to induce fever (pyrexia); inhibits pathogens, enhances phagocytosis.

3. THIRD LINE OF DEFENCE (Specific / Acquired Immunity)

- **Components →** Monocytes/macrophages, T cells (thymus-matured: helper, cytotoxic, inducer, suppressor), B cells (bone-marrow-matured to plasma/memory cells).

Cell-Mediated & Antibody-Mediated Immunity

- **Cell-Mediated →** T cells protect against viruses/cancer; 6 steps (Proliferation, Activation, Induction, Attack, Suppression, Memory).
- **Antibody-Mediated (Humoral) →** B cells / plasma cells secrete antibodies; attack via Complement, Macrophages, Killer cells; suppressed by suppressor T cells; memory B cells.
- **Antibody Structure →** Y-shaped, 2 heavy + 2 light chains (disulfide bridges), constant & variable regions, determinant binding.
- **Monoclonal Antibodies →** Hybridomas (plasma cells + myelomas; Kohler & Milstein 1984) for purification and therapies.

Disorders of Immune System

- **Allergies →** E-antibodies & mast cell histamines (anaphylactic shock); treatment: antihistamines, desensitization (G-antibodies).
- **Autoimmune Diseases →** Attacks self-tissues (Myasthenia gravis, SLE, Rheumatoid arthritis, Type I diabetes).
- **Transplant Rejection →** Mismatched self-proteins trigger T/B cell attack; prevented via matching, immunosuppressants, monoclonal antibodies, or stem cells.

INTRODUCTION

Q.1 What are the most common causes of human diseases and how does our body protect us from them? S/Q

Ans. Most Common Causes of Human Diseases:

- Most human diseases are caused from Microbial infections - invasions of the body by:
  - (i) Viruses.
  - (ii) Pathogenic Bacteria.
  - (iii) Fungi.
  - (iv) Protists.

Protection Against Diseases:

- To defend against infections and against cancers, vertebrates possess a defence system called the **immune system.**
- It continually checks the bloodstream for the presence of any foreign cells and molecules.

Tidbit

- Our body is **defended** from infection the same way that a city is defended against foreign invasion.
- There are walls to make invaders entry difficult, **roaming policemen** check strangers, security guards challenge anyone wandering and call policeman if a proper ID is not presented. Our body also has **different lines of defence.**

Q.2 Why are AIDS like diseases so dangerous? S/Q

Ans. When the immune system detects an infection, it attacks and destroys the invading microbes but disease like AIDs destroy **immune system.** That is why, the diseases that weaken the immune system, such as AIDS, are very dangerous.

Check Understanding!

Q.1 Why are diseases like AIDS very dangerous to the human body?

(A) They weaken the immune system.
(B) They increase blood pressure rapidly.
(C) They stop the digestion of food.
(D) They destroy red blood cells directly.

Q.3 Give brief description of three line of defence of human body through a flow sheet. S/Q

Ans. Three Line of Defence of Human Body:

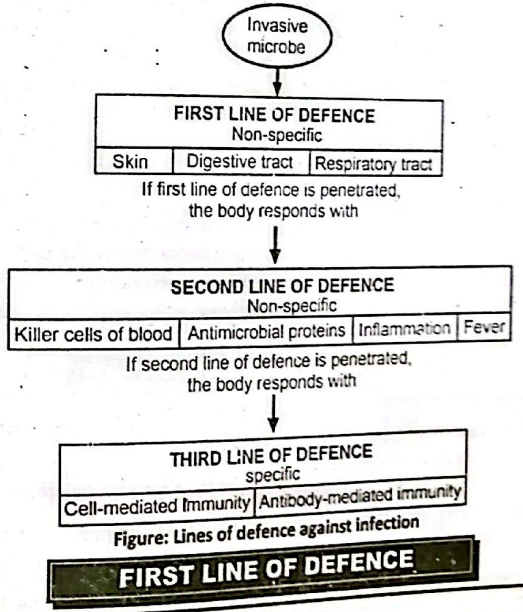


Figure: Lines of defence against infection

FIRST LINE OF DEFENCE

Q.4 What are the components of first line of defence? S/Q

Ans. Components of First Line of Defense:

- The first line of defence against infections consists of:
  - (i) Skin.
  - (ii) Digestive tract.
  - (iii) Respiratory tract.

CamScanner

Topic: Defence Provided by Skin: (As Component of First Line of Defence)

Q.5 Discuss the skin as first line of defence, also draw diagram & label three major parts of skin. L/Q

Ans. Skin As First Line of Defence:

- Skin is the **outermost** layer of our body.
- It provides the **first defence** against invasion of microbes.
- The epidermis of skin is **10 to 30 cells** thick.
- **Stratum Corneum:** The outer layer of epidermis is called **stratum corneum.** Its cells are continuously shed, because they are continuously damaged.
- **New cells** of stratum corneum are formed in the **deep epidermis** from where they **migrate upward and replace** the worn-out cells.
- These **cells form** keratin protein which makes the skin tough and **impenetrable for microbes.**

Check Understanding!
Q.2 How does the outer layer of the skin (stratum corneum) and its chemical secretions protect the body from microbes?

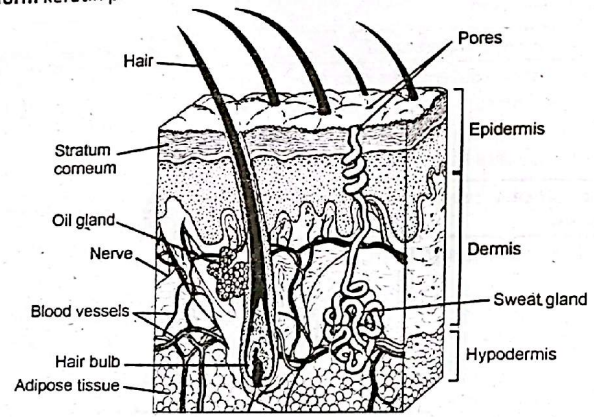


Figure: Layers of skin

➢ **Role of Skin Through Secretions:**

- Skin further **reinforces** the defence by **secreting chemicals.**
- **Oil + Sweat Glands:** The oil and sweat glands present in **skin lower the pH** at the skin's surface to 4 – 6. This is enough acid level that inhibits the **growth of many microbes.**
- **Sweat Glands:** Sweat also contain the enzyme **lysozyme,** which attacks and digests the cell walls of many **bacteria.**

For Information

Q.6 Skin is largest organ of vertebrate justify it & give importance of skin. S/Q

Ans. Largest Organ of Vertebrate:

- Skin is the largest organ of the vertebrate body.
- In an adult human, 15% of the total weight is skin.
- One square centimetre of human skin contains **200 nerve endings,** 10 hairs and muscles, **100 sweat glands,** 15 oil glands, **3 blood vessels,** 12 heat receptors, 2 cold receptors, and **25 pressure receptors.**

Topic: Defence Provided by Digestive and Respiratory Tracts: (As First-line of Defence)

Q.7 How do digestive tract & respiratory tract act as first line of defence? L/Q

Ans. Digestive Tract & Respiratory Tract as First Line of Defence:

(i) Protection from Bacteria Present in Food:

- Many bacteria are **present** in the **food** that humans eat.

(a) Killed By Saliva: Most of these are killed by saliva in the oral cavity, which also contains **lysozyme.**

(b) Killed by Strong Acids In Stomach + Enzymes: The strong digestive acids present in the stomach and the protein-digesting enzymes in the intestine also kill bacteria.

(ii) Protection Against Microbes Present In Air:

- Many microbes are present in the air that we **breathe.**
  - **(a) Traped By Nasal Epithelium:** Ciliated epithelial cells in the nasal cavity trap many bacteria before they can enter the air passageway.
  - **(b) Traped By Sticky Mucous:** The cells lining the **smaller** bronchi and bronchioles secrete a layer of **sticky mucus** that traps microbes before they can reach the warm, **moist lungs.**
- Cilia on the cells lining these passages continually **sweep** the mucus upward, where it can be swallowed.

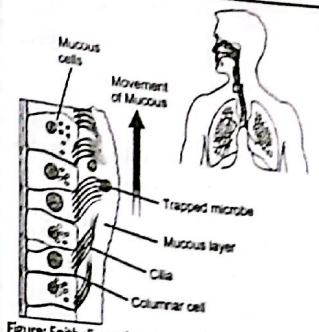


Figure: Epithelium of trachea, with trapped microbes

Check Understanding!
Q.3 What is the function of the sticky mucus secreted by cells in the bronchi and bronchioles?
(A) To digest proteins in the lungs.
(B) To trap microbes before they reach the lungs.
(C) To lower the temperature of the air
(D) To produce lysozyme enzymes in alveoli.

Multiple Choice Questions (MCQs)

		Key
1.	**What is the specific name given to the outer layer of the skin's epidermis?** (A) Stratum corneum. (B) Stratum basale. (C) Dermal layer. (D) Subcutaneous fat.	1.(A)
2.	**According to the text, what structural property does the protein keratin impart to the skin?** (A) Flexible and soft. (B) Tough and impenetrable. (C) Water-soluble and thin. (D) Elastic and porous.	2.(B)
3.	**If a skin secretion has a pH of 4, what biological effect does this level produce according to the text?** (A) Enhances bacterial growth. (B) Activates white cells. (C) Neutralizes all toxins. (D) Inhibits microbial growth.	3.(D)
4.	**How do sweat and saliva functionally collaborate in the first line of defence based on text details?** (A) Both secrete antibodies. (B) Both contain lysozyme. (C) Both produce keratin. (D) Both regulate temperature.	4.(B)
5.	**Based on respiratory tract mechanisms, how are trapped microbes from bronchi cleared from the body?** (A) Swept upwardly. (B) Filtered via kidneys. (C) Expelled through skin. (D) Dissolved by bile.	5.(A)
6.	**Assess why the stomach's environment is categorized under the first line of defence:** (A) Contains ciliated cells. (B) Secretes interferon proteins. (C) Has strong acids. (D) Produces self-proteins.	6.(C)
7.	**The first line of defence against infections consists of skin, the digestive tract, and which other tract?** (A) Urinary tract. (B) Respiratory tract. (C) Reproductive tract. (D) Circulatory tract.	7.(B)

SECOND LINE OF DEFENCE

Q.8 Why is second line of defence needed even though the first line of defence exists? S/Q

Ans. Need of Second Line of Defence:

- Although first line of **defence** of the body is **very effective.** However, it may **occasionally** be overcome by **invaders.** When such invaders **reach deep tissues,** a second line of defence comes into play.
- Along with the first line of defence, the second line is also categorized as a **non-specific defence.**

Q.9 Name the most important components of second line of defence. S/Q

Ans. Most Important Components of Second Line of Defence:

- Human body uses a **lot of non-specific** cellular and **chemical devices** in its second line of defence.
- The **four most important** of these are:
  (i) The Germ-Killer Cells of Blood. (ii) Antimicrobial Proteins.
  (iii) The Inflammatory Response. (iv) The Temperature Response (Fever).

CamScanner

Topic: Germ-Killer Cells of Blood: (Part of Second Line of Defence)

Q.10 What are germ killer cells of blood? Write three basic types of germ killer cells. SQP

Ans. Germ Killer Cells of Blood:

- As second line of defence the most important non-specific defence is provided by the germ-killer cells of the blood.
- They attack and kill the microbes.
- These cells patrol the bloodstream and wait for invaders.

➢ **Types of Germ Killer Cells:**

- **There are three basic kinds:**
  (i) Macrophages. (ii) Neutrophils. (iii) Natural killer cells.

Q.11 Discuss the role of macrophages, neutrophils, & natural killer cells as second line of defence. Exercise Q.1

Ans. Role of Types of Germ Killer Cells in Second Line of Defence:

(1) Role of Macrophages As Second Line of Defence:

- Macrophages develop from **monocytes** (a type of white blood cells).
- **Ingest + Kill Bacteria:** A macrophage **ingests a bacterium**, by **endocytosis**, and kills it mainly by its **lysozyme enzymes**.
- Some macrophages are fixed within some organs e.g., lungs, liver, spleen, and brain.
- **Patrolling in Body:** Most macrophages patrol in the blood, lymph and interstitial fluid where they find foreign invaders & kill them.

(2) Role of Neutrophils As Second Line of Defence:

- Neutrophils are a **type of white blood** cells.
- They use three methods for killing pathogens.
  - **(a) Phagocytosis:** The first method is phagocytosis.
  - **(b) Release Chemical on Pathogen:** In second method, they release soluble anti-microbial chemicals on pathogens.
  - **(c) Release DNA Network:** In the third method, they **generate** and release network of DNA fibres. These fibres bind with pathogenic bacteria and **kill them.**

(3) Role of Natural Killer Cells As Second Line of Defence:

- These are a type of **lymphocytes.**
- They do not kill **invading microbes**, rather they **detect** and **attack** the body cells that have been infected with viruses.
- **Perforins:** The special proteins released by natural killer cells are called **perforins.**

Check Understanding!

Q.4 What are the three different methods that neutrophils use to kill pathogens?

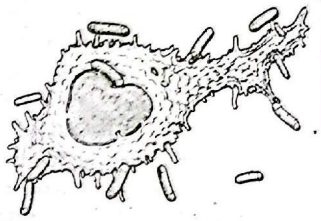


Figure: A macrophage attacking microbes

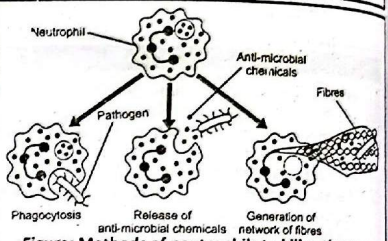


Figure: Methods of neutrophils to kill pathogens

Check Understanding!

Q.5 Why do patrolling germ-killer cells avoid attacking normal body cells?

(A) Normal body cells move too fast to catch.
(B) Normal body cells contain surface self-proteins.
(C) Normal body cells release protective interferons.
(D) Normal body cells secrete active complement proteins.

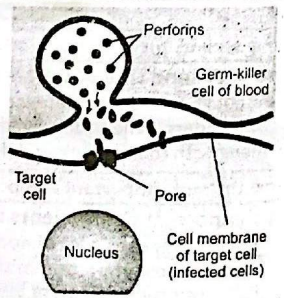


Figure: Natural killer cell attacking an infected cell

- **Perforin Proteins:** The protein's insert into the membrane of the target cell. It results in the formation of a pore in the membrane of target cell.
- The pores allow water to rush into the target cell, which then **swells and bursts.**
- **Detect Cancer Cells:** They are also able to detect cancer cells, which they kill before the cancer cells have **a chance to develop into a tumour.**

For Information

The body's patrolling immune cells use different methods to differentiate between healthy body cells and harmful germs.
- Natural killer cells check body cells for a protective surface protein called a self-protein.
- If a virus or cancer damages the self-protein of a cell, the natural killer cells attack and destroy such a cell.
- However, phagocytes like macrophages and neutrophils do not just look for missing self-proteins.
- They seek out and attack cells that display foreign proteins.

Topic: Protective Proteins: (As Second Line of Defence)

Q.12 Name two main types of protective proteins, which participate in the non-specific defence of the body. SQP

Ans. Two Main Types of Protective Protein:

- Two main groups of proteins participate in the non-specific defence of the body.
  (1) Complement System Proteins. (2) Interferons.

Q.13 Explain the role of two types of protective proteins in non-specific defence of body (second line of defence). Exercise Q.2

Ans. Role of Two Types of Protective Proteins in Non-specific Defence of Body:

(1) Role of Complement System Proteins in Non-specific Defence of Body:

- Special proteins produced in the liver make the **complement system** of proteins. This system consists of more than a **dozen different proteins** that circulate in the blood in an inactive state.
- When they **encounter** a microbe, they become active in a sequence.
- **The first** protein activates the **second and so on.**
- The final five proteins form a **membrane-attack complex (MAC)** into the plasma membrane of microbe. This complex punctures the plasma membrane of microbe. So, fluids and salts move inside microbe resulting in its swelling and **bursting.**

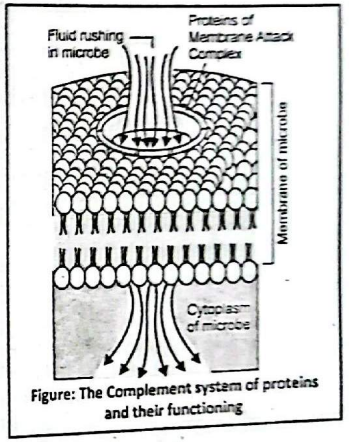


Figure: The Complement system of proteins and their functioning

(2) Role of Interferons in Non-specific Defence of Body:

- Interferons are another class of **protective proteins** that play a key role in body's defence.

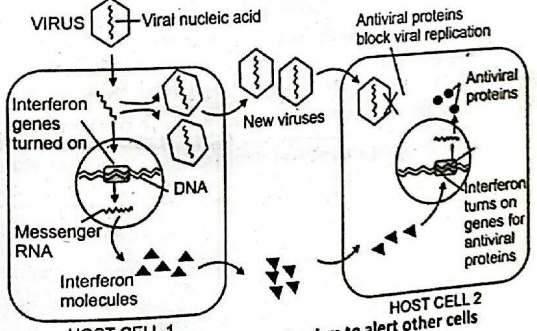


Figure: The interferon mechanism to alert other cells

- They are released by virus-infected cells. They cause nearby cells to enhance their anti-viral defen
- Interferons belong to the large class of proteins known as **cytokines.**
- These proteins work for communication between cells to trigger the protective defences of i immune system.
- Interferons also activate other immune cells, such as **natural killer cells** and **macrophages.**

Topic: Inflammatory Response: (As Second Line of Defence)

Q.14 Inflammation is one of the most generalized non-specific defences. How? Exercise Q.

Ans. Inflammation As Most Generalized Non-Specific Response to Infections:

- The condition of **redness, swelling** and **warmth** at the spot is called **inflammation.**
- Inflammation is one of the **most generalized** non-specific responses to infections.

➢ ***Release of Histamines & Prostaglandins:***

- Infected or injured cells release chemical signals such as **histamines** and **prostaglandins.** These **chemicals** cause local expansion of **blood vessels.**
- In this way, the capillary blood flow is increased at the site of injury or infection. The capillaries also become more permeable.

For Information

- The pus associated with some infections is a mixture of dead or dying neutrophils, broken down tissue cells, and dead pathogens.
- In some cases (for example, arthritis) inflammation occurs in the absence of infection or injury.
- This is an example of misdirected immune response.

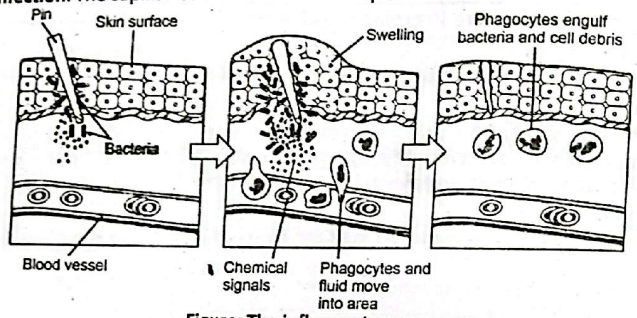


Figure: The inflammatory response

- The results in **redness, swelling** and **warmth** at the spot. This condition is called **inflammation.**
- **Heat Inhibits Microbial Growth + Promotes Healing:** The heat makes the site unfavourable for **microbial growth.** It also **promotes** healing and raises mobility of white blood cells.
- More **phagocytes** (macrophages and neutrophils) **migrate** from the blood to the inflamed tissue, where they engulf microbes.
- **Monocytes** arrive and **release chemicals** to kill the **microbes** and then **macrophages** clean up dea microbes, cells, and debris.
- Thus, the inflammatory response is often strong enough to stop the spread of microbes.

Check Understanding!

Q.6 What happens to blood vessels and c11110apillaries when infected or injured cells release histamines and prostaglandins?

Topic: Temperature Response (Fever): (As Second Line of Defence)

Q.15 What are pyrogens and how do pyrogens increase body temperature also discuss the role of high body temperature in defence mechanism? LC

Ans. Temperature Response: (Fever)

Pyrogens:

- When macrophages attack the invading microbes, they release chemicals called **pyrogens.**
- The pyrogens pass through the **bloodstream** to the brain and reach the hypothalamus.
- **Hypothalamus** is the **body's thermostat.** Here, the pyrogens stimulate the hypothalamus to boost the **body's core temperature** above the normal value of 37°C(98.6°F).

- It results in the rise in body temperature. The higher-than-normal temperature is known as **fever (pyrexia).**

Role of Temperature in Defence Mechanism:

- High Temperature or Fever acts as a defence mechanism against microbes.
- It hinders the ability of bacteria and viruses to reproduce.
- Some microbes (e.g., ***Streptococcus pneumoniae, Influenza***) are temperature-sensitive and are killed at high fever.
- Fever also enhances the speed of the actions of neutrophils and macrophages.
- During fever, the body releases more cytokines (interferons).

For Information

- In general, temperatures greater than 103°F(39.4°C) are considered dangerous, and those greater than 105°F (40.5° C) are often fatal.

Check Understanding!

Q.7 Which part of the body acts as the thermostat and is stimulated by pyrogens during a fever?

(A) The thymus gland behind the heart.
(B) The bone marrow producing white blood cells.
(C) The hypothalamus located in the brain.
(D) The lymph nodes filtering interstitial fluid.

Multiple Choice Questions (MCQs)

		Key
1.	**From which precursor white blood cells do macrophages directly develop?** (A) Monocytes. (B) Platelets. (C) Basophils. (D) Neutrophils.	1.(A)
2.	**Which unique method is utilized exclusively by neutrophils to bind and kill pathogenic bacteria?** (A) Releasing perforin proteins. (B) Generating DNA fibre networks. (C) Secreting viral interferons. (D) Producing complement complexes.	2.(B)
3.	**When a viral-infected body cell is targeted by a natural killer cell, what specific molecule is inserted into its membrane?** (A) Histamine. (B) Pyrogen. (C) Perforins. (D) Fibrinogen.	3.(C)
4.	**Why do patrolling germ-killer cells of the blood avoid attacking normal body cells?** (A) Presence of self-proteins. (B) Absence of cell walls. (C) High internal temperature. (D) Thick keratin layer.	4.(A)
5.	**In which organ are the inactive complement system proteins primarily produced?** (A) Kidneys. (B) Liver. (C) Spleen. (D) Thymus.	5.(B)
6.	**What structural entity is formed by the final five complement proteins on a microbe's plasma membrane?** (A) Lipid bilayer pore. (B) Nuclear envelope. (C) Membrane-attack complex. (D) Ribosomal subunit.	6.(C)
7.	**If a cell is infected by a virus, what specific protective proteins does it release to alert neighboring cells?** (A) Albumins. (B) Interferons. (C) Globulins. (D) Keratins.	7.(B)
8.	**How do interferons functionally classify within cellular communication networks?** (A) Steroid hormones. (B) Digestive enzymes. (C) Bile pigments. (D) Cytokines.	8.(D)
9.	**Which chemical signals are released by infected or injured cells to cause local blood vessel expansion?** (A) Histamines and prostaglandins. (B) Pyrogens and interferons. (C) Pepsin and trypsin. (D) Insulin and glucagon.	9.(A)
10.	**What physiological purpose does the localized heat of an inflammation serve at the injury site?** (A) Slows white cells. (B) Unfavorable for microbes. (C) Freezes pathogens instantly. (D) Destroys self-proteins.	10.(B)
11.	**The pus associated with some infections is specifically a mixture of broken tissue cells, dead pathogens, and what else?** (A) Live platelets. (B) Dead neutrophils. (C) Red corpuscles. (D) Nerve fibres.	11.(B)
12.	**What specific chemical messengers do attacking macrophages release to reach the brain's thermostat?** (A) Pyrogens. (B) Histamines. (C) Perforins. (D) Heparin.	12.(A)
13.	**Which specific part of the brain acts as the body's thermostat during a temperature response?** (A) Cerebellum. (B) Hypothalamus. (C) Medulla. (D) Thalamus.	13.(B)
14.	**A higher-than-normal core body temperature is clinically termed as what?** (A) Hypothermia. (B) Frostbite. (C) Anaphylaxis. (D) Pyrexia.	14.(D)
15.	**How does an elevated body temperature (fever) directly assist the immune defense?** (A) Stops cell division. (B) Hinders microbial reproduction. (C) Eliminates self-proteins. (D) Neutralizes antibodies.	15.(B)
16.	**The second line of defence uses non-specific cellular and chemical devices. How many primary ones are highlighted in the text?** (A) Two devices. (B) Three devices. (C) Four devices. (D) Five devices.	16.(C)

CamScanner

17. Assess why the second line of defence is categorized alongside the first line as non-specific:
(A) Targets specific germs. (B) Does not target specifics.
(C) Requires prior exposure. (D) Involves B cells only. 17.(B)

18. Which of the following is explicitly listed as a temperature-sensitive bacterium killed at high fever?
(A) E. coli. (B) Rhizobium meliloti.
(C) Lactobacillus acidophilus. (D) Streptococcus pneumoniae. 18.(D)

19. Natural killer cells are alternatively identified as which type of lymphocytes?
(A) B-lymphocytes. (B) Cytotoxic T-cells. (C) Helper T-cells. (D) Suppressor T-cells. 19.(B)

THIRD LINE OF DEFENCE

Q.16 How is third line of defence activated? S/Q

Ans. Activation of Third Line of Defence:

- Sometimes, **microbes overcome** the first and second lines of defence. Then third line of defence is activated so microbe face a third line of defence.

Q.17 How is third line of defence provided to body & how does it work? S/Q

Ans. The **third line of defence** is provided by the **immune system.**

- Immune system is the **specific defence**, which means that it targets specific germs and acts especially against them.
- The third line of **defence** (immune system) can remember previous invaders and responds quickly if they enter the body again.

Q.18 What is immunity describe its types & role in defence of body? Exercise Q.Q.1

Ans. Immunity:

- The ability of body to resist and **fight against infections** caused by harmful or foreign invaders.

➢ **Types of Immunity:**

(1) Inborn or Innate Immunity:

- A non-specific **defence** (first and second line of defence) or immunity which is present at birth is called **inborn** or **innate immunity.**

(2) Acquired Immunity:

- The specific defence which is **acquired** during growth and it is called **acquired immunity.**

➢ **Types of Acquired Immunity:**

- The acquired immunity is further of **two types: (a) Active Immunity. (b) Passive Immunity.**

(a) Active Immunity:

- A type of acquired immunity in which body itself prepares antibodies against the antigens of **microbes** is called active immunity. Active immunity slowly progresses but has long term effects.

Types of Active Immunity:

- Active immunity may be natural or artificial.

(i) Natural Active Immunity: A type of immunity in which body prepares antibodies naturally when exposed to antigens. It is the most **effective form of immunity.**

(ii) Artificial Active Immunity: A type of immunity which is achieved by **administering weakened antigens** in the body (vaccination). In this case, the **weak antigens** stimulate the **body to prepare** antibodies against the real **antigens.**

(b) Passive Immunity:

- A type of acquired immunity in which the individual is given directly antibodies to combat specific microbes is called passive immunity.
- Passive immunity is short-lived, but it has quick effects.

Q.19 Show the types of Immunity in the form of flow sheet. S/Q

Ans. Types of Immunity:

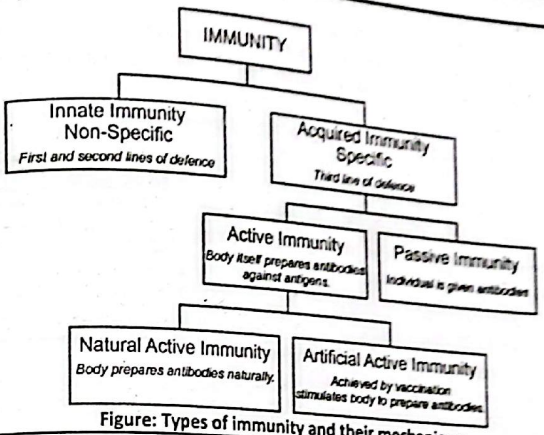


Figure: Types of immunity and their mechanisms

Topic: Components of the Immune System

Q.20 How does immune system work & give names of main kinds of white blood cells involve in immune system? S/Q

Ans. Working of Immune System:

- The immune system is not **localized** to **one place** in the body. Rather, it is composed of a lot of **individual cells** that rush to the infection site to combat invading microbes.
- These cells are the **white blood cells** which arise in the bone marrow and circulate in **blood** and **lymph.**
- They are also found in lymph nodes, spleen, liver, thymus, and bone marrow.

➢ **Main Types of White Blood Cells:**

- There are three main kinds of **white blood cells:**
  (1) Monocytes. (2) T-cells. (3) B-cells.
- T and B-cells are collectively called **lymphocytes.**

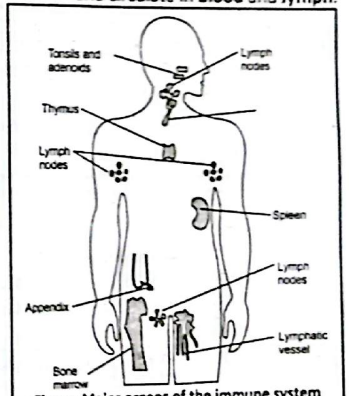


Figure: Major organs of the immune system

Q.21 How are monocytes, T-cells, and B-cells the components of the immune system? Exercise Q.Q.4

Ans.

(1) Monocytes As Component of Immune System:

- They are a type of **WBCs** and produced in **bone marrow.**
- They circulate in blood and also enter the interstitial fluid, where they mature into macrophages.

Action of Macrophages:

- **Destroy Microbes:** The macrophages phagocytose and destroy the **microbes.**
- **Produce Protein:** They also produce proteins that activate the **helper T-cells.**
- **Mature into Other Kinds of Phagocytes:** Monocytes also mature into other kinds of phagocytes, which remain in **liver, spleen, lymph nodes,** and other tissues.
- **Clear Cellular Debris:** They also help to clear cellular debris and assist in repairing tissue damage.

Check Understanding!

Q.8 Where do T cells migrate to mature after developing in the bone marrow, and what do they learn to identify?

CamScanner

(2) T-Cells As Component of Immune System:

- Like other white blood cells, T-cells also develop from the **stem cells** in the bone marrow.
- **They Migrate to the Thymus:** A small grey gland located just above the heart. There, they mature and develop the ability to identify **foreign molecules** (antigens) present on the invading microbes.
- **Tens of millions of different T-cells are made.** Each T-cell is **specialized** in recognizing one particular antigen.
- No invader can escape being recognized by at least a **few T-cells.**

Main Kinds of T-Cells:

- There are four main kinds of T-cells.
  - **(i) Helper T-cells:** Which coordinate the overall immune response by releasing chemical signals that activate other WBCs.
  - **(ii) Cytotoxic T-cells:** Which directly bind and destroy virus-infected or cancerous cells.
  - **(iii) Regulatory (Suppressor) T-cells:** They shut down the immune response once an infection is cleared.
  - **(iv) Memory T-cells:** They remain in the body long-tem to launch a rapid defence if the same pathogen returns.

Check Understanding!

Q.9 What is the role of suppressor T cells in cell-mediated immunity after 1 to 2 weeks?

(A) Shut down the cytotoxic T cell response.
(B) Proliferate helper T cells using growth factors.
(C) Attract macrophages to the site of infection.
(D) Puncture membranes of host target cells.

(3) B-Cells As Component of Immune System:

- The B-cells also develop in **bone marrow** but unlike T-cells, they do not travel to the thymus for maturity.
- They **complete their maturation** in the bone marrow.
- From there they are released to circulate in the bloodstream and lymph.
- Individual B-cells, like T-cells, are specialized to recognize particular antigens.
- When a B-cell encounters an antigen, it begins to divide into many new cells called **plasma cells.**
- Each plasma cell produces an **antibody** that sticks to the antigen, marking it for destruction.

Topic: Cell-Mediated and Antibody-Mediated Immunity:

- We have learned that when **microbes** attack body, macrophages provide the immediate response by engulfing them.
- This response cannot eliminate many microbes, but it gives time for the immune system **(third line of defence)** to respond.

Q.22 How are cell-mediated and antibody mediated immunity initiated? SQP

Ans. Initiation of Cell Mediated & Antibody Immunity:

- When a **macrophage engulfs** a microbe, it also produces special proteins for the **helper T-cells.**
- When the helper T-cells recognize these proteins through their receptors, they are activated.
- The **activated helper T-cells** initiate two parallel **immune responses** i.e., **cell-mediated immunity,** and **antibody-mediated immunity.**

Topic: (1) Cell-Mediated Immunity:

Q.23 Describe the roles of T-cells in cell-mediated immunity. Exercise LQ1

Ans. Role of T-Cells in Cell-Mediated Immunity:

Cell-Mediated Immunity:

- A type of immunity in which ***cytotoxic T-cells recognize*** & destroy infected body cells is called **cell-mediated immunity.**
- The **cell-mediated** immunity, carried out by **T-cells,** protects the body from virus **infections** and **cancer,** killing abnormal or virus-infected cells.

Check Understanding!

Q.10 How do helper T cells help B cells start producing plasma cells during antibody-mediated immunity?

Mechanism & Role of T-cells in Cell Mediated Immunity:

- In **cell-mediated** immunity, **cytotoxic T-cells** recognize and destroy infected body cells.
- Their mechanism of killing is the same as that of natural killer cells i.e., they puncture the membranes of the host **target cells** (infected cells or abnormal cancer cells).
- Important events in cell **mediated immunity** are as follows.

(i) Activation:

- The proteins produced by a macrophage bind to a resting Helper T-cell. This interaction activates the helper T-cell, which immediately secretes soluble factors. The factors attract more macrophages towards the infected cell to help destroy the invading pathogen.

(ii) Proliferation:

- Simultaneously, the soluble factors drive the proliferation of T-cells. The cells divide rapidly to form a large clone of all types of T cells.

(iii) Attack:

- Specialized cytotoxic T-cells attack the infected cell. Their surface receptors lock onto the target cell, allowing them to puncture its outer membrane and cause the infected cell to burst.

(iv) Suppression:

- When the: infection is cleared, Suppressor T-cells (also called Regulatory T cells) block the response. Because they multiply more slowly than the cytotoxic T cells, they do not interfere with the initial attack, but safely shut down the immune response after one to two weeks.

(v) Memory:

- After suppression, a population of T-cells persists, probably for the life of the individual.
- These **helper and cytotoxic T-cells** are now called memory cells. And they provide a rapid response to any later encounter with the microbe again.

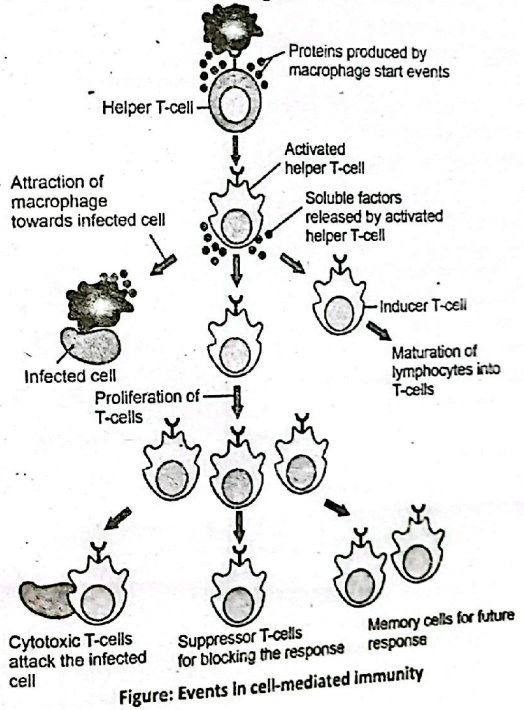


Figure: Events in cell-mediated immunity

Topic: (2) Antibody-Mediated Immunity:

Q.24 Describe the role of B-cells in antibody-mediated immunity. Exercise Q.

Ans. Role of B-Cells in Antibody Mediated Immunity:

- When helper **T-cell is stimulated**, it does not activate the cell-mediated immunity only. Rather, it also activates a second, stronger defence, called antibody-mediated or humoral immunity.
- The key players in this **immunity are the B-cells.**
- **B-cells** do not attack the **antigens directly**. Rather, they mark them for destruction.
- They also inactivate the **toxic molecules.**

➢ **Mechanism of Antibody Mediated Immunity Via B-cells:**

- Important events in antibody-mediated immunity are as follows.

(i) **Proliferation:**
- Each **B-cell** binds to the antigens through the B-receptor proteins on its surface.
- Helper T-cells recognize such **antigen-bound B-cells** and bind with them.
- **Plasma Cell Formation:** The helper T-cells release proteins that stimulate the B-cell to proliferate.
- As a result, a large number of cells called **plasma cells** are produced from **each B-cell.**

(ii) **Differentiation and Secretion:**
- Most plasma cells stop **reproducing** and start producing more **B-receptor proteins.**
- The **B receptor proteins** are secreted and now called as antibodies.
- The plasma cells secrete a great number of antibodies in only a few days.

➢ **Mechanism of Antibodies to Destroy Antigens:**

- Antibodies do not destroy an antigen directly. Rather, they mark it for destruction by one of three mechanisms.

(a) **Activation of Complement System:**
- Some antibodies, when attached to an **antigen**, activate the proteins of the complement system.
- These proteins **penetrate** the membrane of the antibody-coated antigen and make holes in it.
- Water is drawn into the antigen cell, causing it to **swell and burst.**

(b) **Recognition of Antigen by Macrophages:**
- Some antibodies, when attached to an antigen, are recognized by a macrophage, which ingests and breaks it.

(c) **Recognition of Antibody Coated Antigens by Killer cells:**
- Killer cells are similar to **natural killer cells**, except that these possess receptors that **recognize antibody-coated antigens.**

- Antibodies constitute about 20% by weight of the total protein in blood plasma.

Check Understanding!

Q.11. Which of the following is used by antibodies to mark antigens for destruction?
(A) Strong digestive acids in the stomach.
(B) Complement system proteins to make holes.
(C) Keratin protein layers in the epidermis.
(D) Soluble anti-microbial chemical secretions.

Q. What is Vaccine?

Ans. Vaccine:
- A vaccine stimulates the antibody production and formation of memory cells.
- Vaccines are made **from killed or weakened pathogens, as well as from toxoids, subunit components, and mRNA genetic code.**

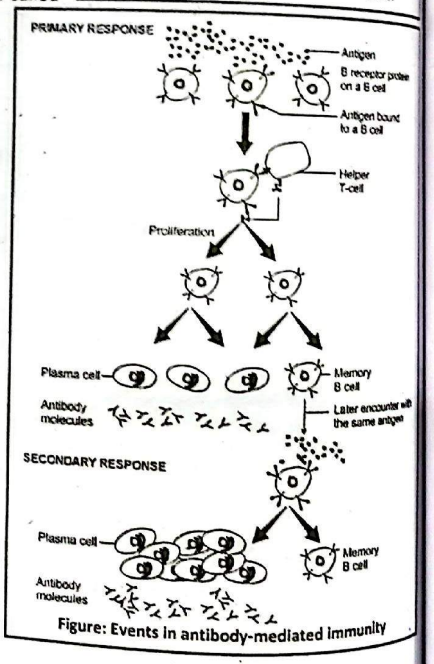


Figure: Events in antibody-mediated immunity

- When a killer cell encounters an antibody-coated antigen, it binds and kills the cell.

(d) **Suppression:**
- After several weeks, the suppressor T-cells shut down the antibody response.

(e) **Memory:**
- Some members of the clone of plasma cells do not produce antibodies. Instead, they persist as memory B-cells.
- These cells provide a rapid secondary response to any later encounter with the same antigen.

Immune System and Gene Therapy
- **Malignant melanoma** is a lethal skin cancer. A special type of WBC called tumourinfiltrating lymphocyte (TIL) normally attacks a **cancerous tumour.** But, is not strong enough to control the tumour.
- Genetic engineers are trying to insert a gene into TIL.
- The gene will enable TIL to make a protein called **tumour necrosis factor (TNF).** This protein kills **tumour cells.**
- When genetically engineered TIL will be returned to patient's blood, they will enter a tumour and produce TNF to kill it.

Topic: Structure of Antibody:

Q.25 What is antibody? Describe its structure with reference to its 4-chains. L/Q

Ans. Antibody:
- A Y-shaped protein which destroy the antigens is called **antibody.**

➢ **Four Chains of Antibody:**
- Antibody is composed of **four polypeptide chains:**
  - **(a) Two identical** long **heavy chains.**
  - **(b) Two short** light **chains.**
- The four chains are held together by disulfide bridges.

Constant Region:
- Each chain has a **constant region** (similar in all the antibodies of the same class).

Variable Region:
- A variable region differs among antibodies.
- The variable regions **on one heavy and one light** chain of each arm of **Y form a specific binding site.**

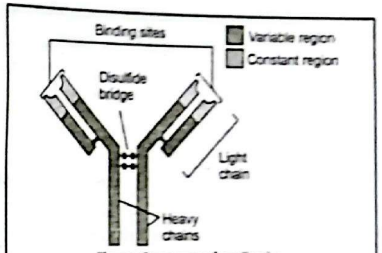


Figure: Structure of antibody

Q.26 What is the base of specificity of antibody? S/Q

Ans. Base of Specificity of Antibody:
- Different antibodies have different variable regions.
- Due to difference in **variable regions** antibodies are specific i.e., cause the destruction of **specific antigen** that stimulated their production.

Check Understanding!

Q.12 How are the four polypeptide chains of a Y-shaped antibody held together?

Topic: Monoclonal Antibodies:

Q.27 Define determinant of antibody. S/Q

Ans. Determinant of Antibody:
- A small portion of antigen molecule fits into an antibody's binding site. This portion is called determinant.

Q.28 Differentiate between monoclonal antibodies & Polyclonal antibodies. S/Q

Ans. Monoclonal Antibodies & Polyclonal Antibodies:

Monoclonal Antibodies	Polyclonal Antibodies
• The antibodies which can attach with **only one** determinant are called **monoclonal antibodies.**	• The antibodies **which fit into a different** portions of antigen surface is called **polyclonal antibody.**

Q.29 Why Cesar Milstein & George Kohler awarded Nobel Prize? S/Q

Ans. In 1984, César Milstein (Argentine biochemist) and Georges Köhler (German biologist) were awarded Nobel Prize for discovering how to produce a monoclonal antibody.

Q.30 Discuss the experiment of Cesar Milstein & George Kohler for the production of Monoclonal Antibodies. LQ

Ans. Experiment of Cesar Milstein & George Kohler for the Production of Monoclonal Antibodies:

- In their experiment, **César Milstein & Georges Köhler** mixed **plasma cells** (that produce antibodies) with cancer cells, called **myelomas.**
- They found some **new cells** growing and dividing in **the culture.** These cells, called **hybridomas,** used the genes of the plasma cell to make antibodies and used myeloma genes to grow and **divide.**
- The hybridoma cells continued to **produce** the antibody in which the **plasma cells** had specialized.
- They obtained rapidly growing cell hybridoma cells which were **producing monoclonal antibodies.**

Check Understanding!

Q.13 What two types of cells are mixed together to create hybridoma cells that produce monoclonal antibodies?

(A) T cells and helper cells.
(B) Neutrophils and macrophages.
(C) Plasma cells and myelomas.
(D) Monocytes and lymphocytes.

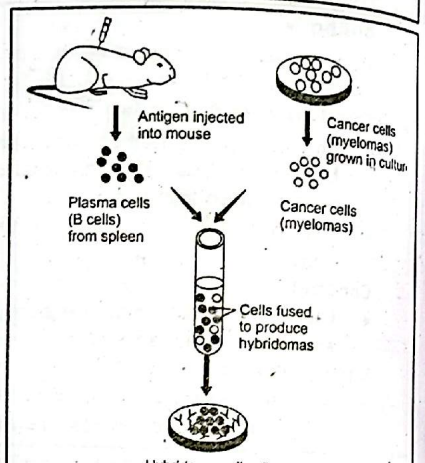


Figure: Monoclonal antibodies

➢ **Importance of Monoclonal Antibodies:**

- Monoclonal antibodies have proved **very important,** because they can be used to purify **specific molecules** from complex mixtures.
- Interferon was purified in this way.
- In **medicine, monoclonal antibodies** are used as **vehicles** for delivering specific therapies.
- There is a **research underway** for antigens that occur only on cancer cells, against which **radioactive monoclonal antibodies** could be targeted to selectively kill cancer cells.

Topic: Disorders of Immune System:

Q.31 What are disorders of immune system & Give their 3-examples. LQ

Ans. Disorders of Immune System:

- **Definition:** A condition where the body's defense system malfunctions, causing it to either **over-react** to harmless **substance,** mistakenly attack its own **healthy, tissues,** or fail to protect the body against infections is called disorder of **immune system.**
- **Examples:** (1) Allergies. (2) Autoimmune Diseases. (3) Transplant Rejection.

Topic: (1) Allergies: (Disorder of Immune System)

Q.32 Define allergies. Correlate the symptoms of allergies with the release of histamines. Exercise LQ.8

Ans. Allergies: (Disorder of Immune System)

- A strong or over-reaction of Immune system to harmless substance is called **allergy.**
- Allergies result from the **hypersensitivity of immune system** to weak antigens that do not cause an immune response in most people.
- **Allergens:** The substances that cause allergies are called allergens.
- **Examples:** Dust, molds, pollen, cat dander, certain foods, and some medicines (such as penicillin).

Check Understanding!

Q.14. What type of antibodies do sensitive individuals produce after exposure to an allergen, and which cells do these antibodies bind to?

➢ **Mechanism of Relationship of allergies with Histamine Production:**

- When we expose to an allergen, **some people** make **E-antibodies (Immunoglobulin E - IgE).**

- These antibodies bind to mas cells (usually found in connective tissues surrounding blood vessels).
- These mast cells release **histamines,** which start the inflammatory response.

Effects of Histamine Production:

- Histamine causes dilation of **blood vessels,** leakage of fluid, and other responses like sneezing, runny nose, itching etc.
- In some **individuals** the histamines can causes **life-threatening anaphylactic shock,** in which swelling makes breathing difficult.

Treatment of Allergies:

(i) Use of Antihistamine Drugs: A treatment of common allergies includes **antihistamine** drugs that block histamines.

(ii) Desensitization: Many allergies are also treated by injecting the extracts of the antigens in patients. This treatment is called **desensitization.** This method produces **G-antibodies (Immunoglobulin G - IgG)** in the blood.

- When an allergen enters, it is readily killed by **G-antibodies** before facing **E-antibodies.**

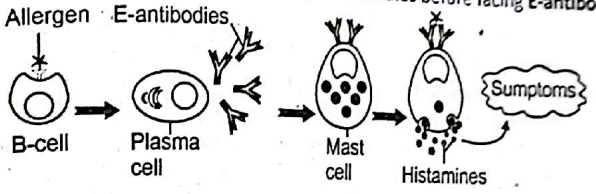


Figure: Events of allergic response

Topic: (2) Autoimmune Diseases: (Disoder of Immune System)

Q.33 What are autoimmune diseases discuss 4-examples of autoimmune diseases briefly? LQ

Ans. Autoimmune Diseases:

- The diseases which result when the **immune system** cannot **distinguish** the body-cells and foreign materials. The immune system produces autoantibodies which attack and destroy the cells and tissues of the body is called **autoimmune disease.**
- Most of the medicines for such diseases suppress the body's immunity. Some autoimmune diseases are:

➢ **Examples of Autoimmune Diseases:**

- The following are some autoimmune diseases.

(i) Myasthenia Gravis (MG): The patient produces autoantibodies which bind with acetylcholine receptors on skeletal muscle cells. As a result, the muscles do not respond to acetylcholine. The nerve impulse cannot communicate with the muscle.

(ii) Systemic Lupus Erythematosus (SLE): The patient's autoantibodies cause tissue damage in the skin, joints, kidneys, blood cells, heart, and lungs.

(iii) Rheumatoid Arthritis: The patient forms autoantibodies against the cartilaginous tissue of joints, which damage them.

(iv) Type-1 diabetes (Juvenile diabetes): The cytotoxic T-cells (with autoantibodies as markers) destroy the insulin-producing β-cells of the pancreas.

Most medicines for treating autoimmune diseases suppress immunity in general.

Topic: (3) Transplant Rejection: (Disoder of Immune System)

Q.34 How are T-cells and B-cells related to transplant rejections? Exercise LQ.9

Ans. Role of T-Cells & B-cells in Transplant Rejection:

- Normally the **T and B-cells** of immune system attack and kill only the **foreign molecules** and cells. It is due to the presence of **self-proteins** on cell surfaces of each person.
- A **particular** set of **self-proteins** is like the molecular **"fingerprints"** recognized by own **T and B-cells.**

CamScanner

➢ **Mechanism of Transplant Rejection in Relation to T & B-Cells:**

- **Difference in Self Proteins:** When a person receives an organ transplant, there are chances that the self-proteins present on the donated organ do not match the self-proteins of the recipient.
- As a result, recipient's T-cells may attack the cells of the transplanted organ and B-cells produce antibodies against its proteins. This problem is called as transplant rejection.

- Identical twins have a 100% self-proteins match.
- The best matches are going to occur within a family. The preference order for transplants is identical twin > sibling > parent > unrelated donor.
- Chances of an unrelated donor matching the recipient are 1 in 100,000-200,000.

➢ **Minimizing the Rejection:**

- To minimize rejection, doctors look for a donor whose self-proteins are matching the recipient's self-proteins, as closely as possible.
- They also use drugs to suppress the recipient's immune system against the transplanted organs. But these drugs also reduce the ability to fight infections.

Check Understanding!

Q.15. Why do identical twins present the lowest risk of organ transplant rejection?
(A) They have a 100% self-proteins match.
(B) They lack any T and B lymphocytes.
(C) They share identical blood vessel lengths.
(D) They produce no antibody-secreting cells.

➢ **Prevention of Transplant Rejection:**

- There are two approaches to prevent transplant rejection.
  - (i) In one approach, monoclonal antibodies are used to destroy the T-cells that attack the transplant.
  - (ii) In another approach, stem cells are used to make a new immune system that recognizes the transplant as self.

Multiple Choice Questions (MCQs)

		Key
1.	The specific defence acquired during growth is formally called what? (A) Innate immunity. (B) Inborn immunity. (C) Acquired immunity. (D) Passive immunity.	1.(C)
2.	In which type of immunity does the body independently prepare its own antibodies against antigens? (A) Passive immunity. (B) Active immunity. (C) Artificial passive. (D) Short-lived immunity.	2.(B)
3.	How is artificial active immunity primarily achieved in medical practice? (A) Blood transfusion. (B) Antibiotic ingestion. (C) Surgery. (D) Vaccination.	3.(D)
4.	Where do T cells specifically migrate from bone marrow to complete their maturation? (A) Spleen. (B) Thymus. (C) Liver. (D) Tonsils.	4.(B)
5.	Which T cell sub-type is responsible for initiating the overall immune response? (A) Helper T cells. (B) Cytotoxic T cells. (C) Inducer T cells. (D) Suppressor T cells.	5.(A)
6.	What is the specific function of suppressor T cells in the immune cycle? (A) Initiate responses. (B) Terminate responses. (C) Mature lymphocytes. (D) Phagocytose microbes.	6.(B)
7.	Unlike T cells, where do B cells complete their primary maturation process? (A) Thymus gland. (B) Lymph nodes. (C) Blood plasma. (D) Bone marrow.	7.(D)
8.	When a B cell encounters an antigen, what specialized cells does it proliferate into? (A) Platelets. (B) Plasma cells. (C) Erythrocytes. (D) Stem cells.	8.(A)
9.	What specific proteins are secreted in large numbers by plasma cells during antibody-mediated immunity? (A) Hormones. (B) Antibodies. (C) Enzymes. (D) Bile salts.	9.(B)
10.	Cell-mediated immunity is primarily carried out by which group of cells? (A) B cells. (B) Mast cells. (C) T cells. (D) Basophils.	10.(C)
11.	What soluble growth factor is produced by activated helper T cells to stimulate T cell proliferation? (A) Insulin. (B) T cell growth factor. (C) Erythropoietin. (D) Pepsinogen.	11.(B)
12.	What happens to helper and cytotoxic T cells after suppression concludes, enabling rapid secondary responses? (A) They all die. (B) Migrate to liver. (C) Transform into B cells. (D) Persist as memory cells.	12.(D)
13.	Antibody-mediated immunity is alternatively referred to by what other descriptive name? (A) Cellular immunity. (B) Humoral immunity. (C) Innate immunity. (D) Passive immunity.	13.(B)
14.	Approximately what percentage of total blood plasma protein weight do antibodies constitute? (A) 5 percent. (B) 10 percent. (C) 20 percent. (D) 50 percent.	14.(C)
15.	What is the fundamental overall shape of a standard functional antibody molecule? (A) O-shaped. (B) Y-shaped. (C) S-shaped. (D) Linear.	15.(B)

		Key
16.	How many total polypeptide chains comprise a single antibody protein molecule? (A) Two chains. (B) Three chains. (C) Four chains. (D) Six chains.	16.(C)
17.	Which specific chemical bonds hold the polypeptide chains of an antibody together? (A) Hydrogen bonds. (B) Disulfide bridges. (C) Peptide bonds. (D) Ionic bonds.	17.(B)
18.	Which regions of the antibody polypeptide chains vary to create specific antigen binding sites? (A) Variable regions. (B) Constant regions. (C) Lipid cores. (D) Heavy stems.	18.(A)
19.	What specific small portion of an antigen molecule fits precisely into an antibody's binding site? (A) Receptor. (B) Determinant. (C) Histone. (D) Promoter.	19.(B)
20.	What are the hybrid cell lines created by fusing plasma cells with cancer myelomas called? (A) Erythrocytes. (B) Leukocytes. (C) Hybridomas. (D) Sarcomas.	20.(C)
21.	Hypersensitivity of the immune system to weak, harmless antigens results in which condition? (A) Autoimmunity. (B) Allergies. (C) Immunodeficiency. (D) Cancer.	22.(B)
22.	What are environmental substances that trigger allergic reactions commonly called? (A) Nutrients. (B) Toxoids. (C) Hormones. (D) Allergens.	22.(D)
23.	Upon initial allergen exposure, susceptible individuals predominantly produce which specific class of antibodies? (A) A-antibodies. (B) E-antibodies. (C) G-antibodies. (D) M-antibodies.	23.(B)
24.	In connective tissues, E-antibodies bind primarily to which specialized cells that release histamines? (A) Mast cells. (B) Muscle cells. (C) Nerve cells. (D) Bone cells.	24.(A)
25.	What severe, life-threatening systemic reaction can be caused by widespread histamine release during an allergy? (A) Renal failure. (B) Cardiac arrest. (C) Anaphylactic shock. (D) Type I diabetes.	25.(C)
26.	Which pharmaceutical drugs are commonly administered to block histamines for temporary allergy relief? (A) Antihistamines. (B) Antibiotics. (C) Analgesics. (D) Antivirals.	26.(A)
27.	Desensitization treatments for allergies stimulate the production of which protective antibody class in the blood? (A) E-antibodies. (B) G-antibodies. (C) M-antibodies. (D) D-antibodies.	27.(B)
28.	Autoimmune diseases occur when the immune system fails to distinguish foreign materials from what? (A) Body-cells. (B) Dead debris. (C) Pathogenic fungi. (D) Viral capsids.	28.(A)
29.	Myasthenia gravis is an autoimmune disorder causing muscle weakness by attacking receptors for which neurotransmitter? (A) Dopamine. (B) Acetylcholine. (C) Serotonin. (D) Adrenaline.	29.(B)
30.	Systemic Lupus Erythematosis involves the formation of antibodies against the body's own connective tissues and what else? (A) Major organs. (B) Hair follicles. (C) Nail beds. (D) Tooth enamel.	30.(A)
31.	Rheumatoid arthritis is an autoimmune condition that specifically damages which joint component? (A) Bone marrow. (B) Cartilaginous tissue. (C) Synovial fluid. (D) Ligament fibers.	31.(B)
32.	Type I diabetes is an autoimmune disease characterized by antibody destruction of insulin-producing cells located where? (A) Liver. (B) Stomach. (C) Pancreas. (D) Thyroid.	32.(C)
33.	What unique molecular cell-surface markers allow the immune system to recognize normal body cells? (A) Self-proteins. (B) Foreign antigens. (C) Histones. (D) Keratin fibers.	33.(A)
34.	When a transplanted organ suffers an immune attack due to mismatched surface markers, what is it called? (A) Autoimmunity. (B) Transplant rejection. (C) Anaphylaxis. (D) Hypersensitivity.	34.(B)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(A)	• The text states that diseases like AIDS are very dangerous because they weaken the immune system, preventing it from attacking and destroying invading microbes.
2.	S/Q	• The stratum corneum continuously sheds dead cells and forms keratin protein, making the skin tough and impenetrable. Additionally, oil and sweat glands lower the skin's surface pH to 3-5 to stop microbial growth, and sweat contains lysozyme to digest bacterial cell walls.
3.	(B)	• The text explains that cells lining the smaller bronchi and bronchioles secrete a layer of sticky mucous that traps microbes before they can reach the warm, moist lungs.
4.	S/Q	• Neutrophils use phagocytosis, release soluble anti-microbial chemicals on pathogens, and generate and release a network of DNA fibers that bind with and kill pathogenic bacteria.

CamScanner

5.	(B)	• The text notes that all normal body cells contain a surface protein marker called a self-protein, and germ-killer cells do not attack cells that have these proteins.
6.	S/Q	• These chemicals cause local expansion of blood vessels, increase capillary blood flow at the site of infection or injury, and make capillaries more permeable, resulting in redness, swelling, and warmth (inflammation).
7.	(C)	• The text identifies the hypothalamus as the body's thermostat that is stimulated by pyrogens passing through the bloodstream to boost core temperature above normal.
8.	S/Q	• T cells migrate to the thymus (a small grey gland above the heart) to mature and develop the ability to identify foreign molecules (antigens) present on invading microbes.
9.	(A)	• The text states that after 1 to 2 weeks, the number of suppressor T cells rises to the point where they are able to shut down the cytotoxic T cell response.
10.	S/Q	• Helper T cells recognize antigen-bound B cells, bind with them, and release proteins that stimulate the B cell to proliferate into a large number of plasma cells.
11.	(B)	• The text lists complement system activation (making holes causing swelling/bursting), macrophage ingestion, and killer cell binding as the three mechanisms by which antibodies mark antigens for destruction.
12.	S/Q	• They are held together by disulfide bridges, consisting of two identical long (heavy) chains and two short (light) chains.
13.	(C)	• The text states that plasma cells (that produce antibodies) are mixed with cancer cells called myelomas to create hybridoma cells.
14.	S/Q	• Sensitive individuals produce E-antibodies, which bind to mast cells (usually found in connective tissues surrounding blood vessels) to release histamines.
15.	(A)	• The text explicitly states that identical twins have a 100% self-proteins match, which prevents the recipient's immune system from rejecting the organ.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQS

1. **Which of these are known for stimulating an immune response?**
   (a) Pathogens. (b) Antigens. (c) Antibodies. (d) Histamines.
2. **Which of the following is a part of the innate immune system?**
   (a) T lymphocytes. (b) B lymphocytes. (c) Skin and mucous membranes. (d) Antibodies.
3. **Which of these is not involved in body's non-specific defence?**
   (a) Natural killer cells. (b) Inflammatory response. (c) Antibodies. (d) Complement system.
4. **Skin offers an impenetrable barrier to microbes. It is categorized as;**
   (a) Non-specific defence. (b) Specific defence. (c) Acquired immunity. (d) Passive Immunity.
5. **What is the difference between B-cells and T-cells?**
   (a) B-cells make antibodies, and T-cells destroy infected cells.
   (b) B-cells and T-cells do the same work.
   (c) B-cells attack germs directly, and T-cells make antibodies.
   (d) B-cells control cell-mediated immunity, and T-cells control humoral immunity.
6. **How do the neutrophils kill microbes?**
   (a) By engulfing and digesting them. (b) By producing antibodies.
   (c) By releasing hormones. (d) By carrying oxygen to cells.
7. **Which group of chemicals is involved in inflammatory response?**
   (a) Antibodies. (b) Histamines and prostaglandins.
   (c) Prostaglandins and pyrogens. (d) Antibodies and pyrogens.
8. **Which type of white blood cell is responsible for producing antibodies?**
   (a) Neutrophils. (b) B lymphocytes (B-cells). (c) Macrophages. (d) Natural killer cells.
9. **What types of drug are not prescribed to a recipient of organ-transplantation?**
   (a) Drugs that suppress immunity. (b) Drugs that strengthen immunity.
   (c) Anti-inflammatory drugs. (d) Anti-histamine drugs.
10. **Cell-mediated immunity works best against:**
    (a) Viruses infected cells and toxic molecules. (b) Viruses and toxic molecules.
    (c) Virus infected cells and cancer cells. (d) Toxic molecules and cancer cells.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(b)	Antigens.	• Antigens are foreign molecules or structures that are specifically recognized by the immune system and capable of triggering an immune response.
2.	(c)	Skin and mucous membranes.	• The skin and mucous membranes form the body's primary physical and chemical barriers, which are components of the innate immune system.
3.	(c)	Antibodies.	• Antibodies are specialized proteins produced by the adaptive immune system for specific targeted defense, not non-specific defense.
4.	(a)	Non-specific defence.	• The skin provides a generalized, immediate mechanical barrier against a wide variety of pathogens regardless of their specific identity.
5.	(a)	B cells make antibodies, and T cells destroy infected cells.	• B cells are responsible for humoral immunity through antibody production, whereas T cells mediate cellular immunity to destroy infected cells.
6.	(a)	By engulfing and digesting them.	• Neutrophils are phagocytic white blood cells that engulf microbes and break them down using intracellular enzymes.
7.	(b)	Histamines and prostaglandins.	• Histamines and prostaglandins are key chemical mediators released during inflammation to increase blood flow and vascular permeability.
8.	(b)	B lymphocytes (B cells).	• B lymphocytes differentiate into plasma cells, which synthesize and secrete large volumes of specific antibodies.
9.	(b)	Drugs that strengthen immunity.	• Organ transplant recipients are given immunosuppressive drugs to prevent rejection rather than treatments that strengthen immune activity.
10.	(c)	Virus infected cells and cancer cells.	• Cell-mediated immunity relies on T cells to target and destroy host cells altered by viral infections or malignancy.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Define the roles of the different types of T-cells.

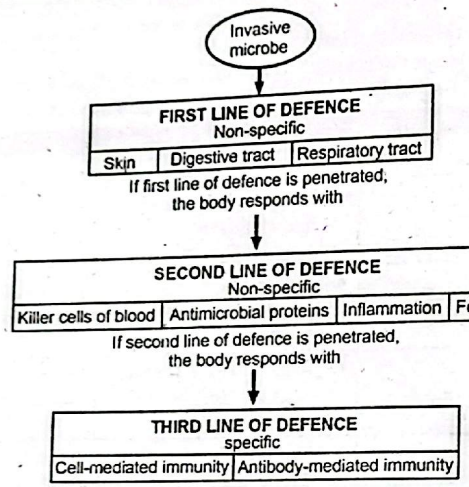
Ans. Roles of the Different Types of T-cells:

- There are four main kinds of T-cells.
  - **(i) Helper T-cells:** Which initiate the immune response.
  - **(ii) Cytotoxic T-cells:** Which break the cells that have been infected by microbes.
  - **(iii) Inducer T-cells:** Which supervise the development of T-cells in the thymus.
  - **(iv) Suppressor T-cells:** Which terminate the immune response.

CamScanner

Q.2 Skin is an important component of our defence system. Comment.

Ans.



Q.3 State how the digestive and respiratory tracts play a role in body's defence.

Ans.
- **Respiratory Defense:** Mucus traps airborne pathogens, and cilia sweep them upward out of the airways.
- **Digestive Defense:** Stomach acid, digestive enzymes, and gut-resident flora destroy ingested pathogens.

Q.4 How the natural killer cells play role in body's defence?

Ans. Role of Natural Killer Cells in Body's Defence:
- These are a type of **T-lymphocytes** and are also called **cytotoxic T-cells.**
- They do not kill **invading microbes**, rather they **detect** and **attack** the body cells that have been infected with viruses.
- **Perforins:** The special proteins released by natural killer cells are called **perforins.**
- **Perforin Proteins:** The protein's insert into the **membrane** of the target cell. It results in the **formation** of a pore in the membrane of target cell.
- The pores allow water to rush into the **target cell**, which then **swells and bursts.**
- **Detect Cancer Cells:** They are also able to detect cancer cells, which they kill before the cancer cells have **a chance to develop into a tumour.**

Q.5 Define pyrogens and state their effect of hypothalamus.

Ans.
- **Pyrogens:** Pyrogens are fever-producing substances released by white blood cells or invading pathogens.
- **Hypothalamus Effect:** They reset the body's thermal set point in the hypothalamus, triggering mechanisms to raise core body temperature.

Q.6 What do you mean by autoimmune diseases?

Ans. Autoimmune Diseases:
- A condition where the immune system fails to recognize self-antigens and attacks healthy body tissues.
- **Examples:** Result in chronic inflammation and tissue damage, such as in rheumatoid arthritis or type 1 diabetes.

Q.1 Differentiate between;
- Antigen and antibody.
- Macrophages and neutrophils.
- Innate and acquired immunity.
- Natural active immunity and artificial active immunity.
- Cell-mediated and Antibody-mediated immunity.
- B-cells and T-cells.
- Complement system proteins and interferons
- Active and passive immunity.

Ans. Antigen and Antibody:

Antigen	Antibody
• Antigens are foreign molecules that trigger an immune response.	• Antibodies are specialized proteins produced by B cells to neutralize specific antigens.

B cells and T cells:

B cells	T cells
• B cells mature in the bone marrow and mediate antibody-mediated immunity.	• T cells mature in the thymus and mediate cell-mediated immunity.

Macrophages and Neutrophils:

Macrophages	Neutrophils
• Macrophages are long-lived phagocytes that also present antigens.	• Neutrophils are short-lived, highly abundant phagocytes that arrive first at infection sites

Complement System Proteins and Interferons:

Complement System Pro	Interferons
• Complement proteins form membrane attack complexes to lyse pathogens.	• Interferons are signaling proteins that protect uninfected cells from viral replication.

Innate and Acquired Immunity:

Innate Immunity	Acquired Immunity
• Innate immunity is non-specific and present from birth.	• Acquired immunity is pathogen-specific and develops after exposure.

Active and Passive Immunity:

Active Immunity	Passive Immunity
• Active immunity is produced by the host's own immune system following antigen exposure.	• Passive immunity involves receiving pre-formed antibodies from an external source

Natural Active Immunity and Artificial Active Immunity:

Natural Active Immunity	Artificial Active Immunity
• Natural active immunity develops after a natural infection.	• Artificial active immunity is acquired through vaccination.

Cell-mediated and Antibody-mediated Immunity:

Cell-mediated Immunity	Antibody-mediated Immunity
• Cell-mediated immunity involves T cells destroying infected body cells directly.	• Antibody-mediated immunity involves B cells and circulating antibodies targeting extracellular pathogens.

CamScanner

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Describe the role of macrophages and neutrophils in killing bacteria.

Ans. See Page No. 272 (Q.11)

Q.2 Explain how the proteins of the complement system kill bacteria and how the interferons inhibit the ability of viruses to infect-cells.

Ans. See Page No. 273 (Q.13)

Q.3 Inflammation is one of the most generalized nonspecific defences. How?

Ans. See Page No. 274 (Q.14)

Q.4 How are monocytes, T-cells and B-cells the components of the immune system?

Ans. See Page No. 277 (Q.21)

Q.5 Differentiate the two types of acquired immunity (active and passive immunity).

Ans. See Page No. 276 (Q.18)

Q.6 Describe the roles T-cells in cell-mediated immunity.

Ans. See Page No. 278 (Q.23)

Q.7 Describe the role of B-cells in antibody-mediated immunity.

Ans. See Page No. 280 (Q.24)

Q.8 Define allergies. Correlate the symptoms of allergies with the release of histamines.

Ans. See Page No. 282 (Q.32)

Q.9 How are T-cells and B-cells related to transplant rejections?

Ans. See Page No. 283 (Q.34)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Rationalize the inflammatory response in arthritis as an example of a misdirected immune response.

Ans. **Arthritis as an Example of a Misdirected Immune Response:**

- In arthritis, the immune system mistakenly targets healthy **joint tissues**, viewing them as foreign invaders.
- This misdirected immune response releases inflammatory cytokines that cause painful joint swelling, cartilage degradation, and progressive tissue destruction.

Q.2 Justify why the physicians prescribe antipyretic drugs, when fever is a nonspecific defence against microbial infections.

Ans. **Antipyretic Drug:**

- A drug which is used to lower the body temperature called **antipyretic drug.**
- Although fever acts as a **natural defense** by inhibiting pathogen replication and enhancing white blood cell efficiency, but excessive temperatures are dangerous.
- Physicians prescribe antipyretics to prevent cellular damage, **extreme metabolic strain,** and neurological complications while keeping patient discomfort manageable.

Q.3 Justify why physicians prescribe antihistamine therapy to the patients of runny nose or skin rashes.

Ans. **Prescription of antihistamine therapy to the patients of runny nose or skin rashes**

- During allergic reactions, immune cells release histamines that bind to cellular receptors, causing blood vessels to dilate and leak fluid.
- Antihistamines block these receptors, preventing vasodilation and capillary leakage to quickly stop symptoms like a runny nose, watery eyes, and skin rashes.

Describe the discovery of monoclonal antibodies and justify how this accomplishment revolutionized many aspects of biological research.

Discovery of Monoclonal Antibodies:

- Monoclonal antibodies were developed by **Georges Köhler** and **César Milstein** through hybridoma technology, which fuses B-cells with immortal myeloma cells to produce specific antibodies indefinitely.
- This breakthrough revolutionized science by providing identical antibodies tailored to a single antigen, vastly improving **targeted cancer therapies, diagnostic assays,** and **biomedical research.**

SELF-ASSESSMENT

Total Mark: 30

1 Encircle the correct option. (1 x 6 = 06)

What is the specific name given to the outer layer of the skin's epidermis?
(A) Stratum corneum. (B) Stratum basale. (C) Dermal layer. (D) Subcutaneous fat.

Which of the following is a part of the innate immune system?
(A) T lymphocytes. (B) B lymphocytes. (C) Skin and mucous membranes. (D) Antibodies.

In which organ are the inactive complement system proteins primarily produced?
(A) Kidneys. (B) Liver. (C) Spleen. (D) Thymus.

Which T cell sub-type is responsible for initiating the overall immune response?
(A) Helper T cells. (B) Cytotoxic T cells. (C) Inducer T cells. (D) Suppressor T cells.

Rheumatoid arthritis is an autoimmune condition that specifically damages which joint component?
(A) Bone marrow. (B) Cartilaginous tissue. (C) Synovial fluid. (D) Ligament fibers.

Which type of white blood cell is responsible for producing antibodies?
(A) Neutrophils. (B) B lymphocytes (B-cells). (C) Macrophages. (D) Natural killer cells.

2 Write short answers of the following questions. (2 x 8 = 16)

i. Name the most important components of second line of defence.
ii. Define the roles of the different types of T-cells.
iii. How is third line of defence activated?
iv. Differentiate between Innate and acquired immunity.
v. How does immune system work & give names of main kinds of white blood cells involve in immune system?
vi. Define determinant of antibody.
vii. Why Cesar Milstein & George Kohler awarded Nobel Prize?
viii. Differentiate between Cell-mediated and Antibody-mediated immunity.

3 Extensive Questions. (4 x 2 = 8)

i. How are monocytes, T-cells and B-cells the components of the immune system?
ii. Discuss the experiment of Cesar Milstein & George Kohler for the production of Monoclonal Antibodies.

CamScanner

ENTRANCE TEST MDCAT

1. In _____ response, B-cells produce plasma cells that synthesize antibodies and release in blood plasma and tissue fluid. (UHS 2016)
   A. Cell mediated. B. Humoral. C. Hormonal. D. Phototactic.
2. B-cells release antibodies in blood plasma, tissue fluid and lymph. This kind of immune response is called: (UHS 2016)
   A. Cell mediated response. B. Active response.
   C. Humoral response. D. Compound response.
3. The type of immunity in which antibodies are passed from one individual to another is called: (UHS 2016)
   A. Passive immunity. B. Natural active immunity. C. Artificial active immunity. D. Humoral immunity.
4. To combat the active infections of tetanus, rabies and snakes the method of immunization is used. (UHS 2016)
   A. Active. B. Active artificial. C. Humoral. D. Passive.
5. In antibody molecule, two heavy and two light chains are bonded by: (UHS 2016)
   A. Disulphide bond. B. Hydrogen bond. C. Monosulphide bond. D. Ionic bond.
6. Variable amino acid sequences in antibody molecule are found in: (UHS 2016)
   A. Both light chains only. B. One heavy and one light chain.
   C. Both heavy chains only. D. Both heavy and light chains.
7. The antibody molecule consists of _____ polypeptide chains. (UHS 2017)
   A. Eight. B. Six. C. Four. D. Two.
8. _____ cells survive for few days and they secrete huge number of antibodies in blood, tissue fluid or lymph: (UHS 2017)
   A. Memory cells. B. T lymphocytes. C. B lymphocytes. D. Plasma cells.
9. The immediate protection by inflection of snake bite can be obtained by: (UHS 2017)
   A. Active immunity. B. Passive immunity. C. Natural active immunity. D. Vaccination.
10. Cell mediated immune response is given by: (UHS 2018)
    A. T lymphocytes. B. Neutrophils. C. B lymphocytes. D. Macrophages.
11. Antivenom given after a snake bite venom is an example of: (UHS 2018)
    A. Natural passive immunity. B. Natural active immunity.
    C. Artificial active immunity. D. Artificial passive immunity.

ANSWERS KEY

1. B	2. C	3. A	4. D	5. A	6. D	7. C	8. D	9. B	10. A	11. D

CHAPTER 22

BIOSTATISTICS

Student Learning Outcomes (SLOs)

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

- Define biostatistics and its use.
- Define mean, median, mode, standard deviation, range and percentile.
- Calculate mean, median, mode, standard deviation, range and percentile from a given set of data.
- Sketch a bar chart from a given set of data.
- Sketch error bars based off of range or standard deviation for a given set of data on a bar chart.
- Evaluate the appropriate type of figure or chart for a given set of data and/or experiment (bar chart, pie chart, x -axis data figure etc.).
- Make the appropriate chart with proper title, labelled axis, legend, axis units.
- Design an appropriate experiment with a control group and dependent, independent and control variables.

CamScanner

Biostatistics — Concept Map

1. BIOSTATISTICS

- **Definition →** Application of statistical methods to biological, medical, and health data for population insights using sample data.
- **Components →** Study design & planning, Data collection (primary/secondary), Data management & processing, Data analysis (descriptive/inferential), Interpretation of results, Presentation & communication.
- **Applications →** Clinical trials, epidemiology, genetics/genomics, public health policy, environmental health, bioinformatics, quality control, population programs, epidemic control, barrier identification, risk assessment/demography.

2. KEY STATISTICAL MEASURES

- **Mean →** Average value (ungrouped & grouped data via midpoints and frequencies).
- **Median →** Middle value position (odd/even dataset rules).
- **Mode →** Most frequent value (grouped data formula using modal class boundaries and frequencies).
- **Standard Deviation →** Spread of data around the mean.
- **Range →** Difference between maximum and minimum values.
- **Percentile →** Value below which a given percentage falls; rank calculated via with interpolation.

3. CHARTS & VISUALIZATIONS

- **Bar Chart →** Categorical comparison using rectangular bars (X-axis categories, Y-axis values/frequencies, legends).
- **Pie Chart →** Circular graph divided into proportional sectors summing to 100% **X-Axis Data Figures →** Independent variable baseline against dependent variables (e.g., temperature vs. enzyme activity).
- **Error Bars →** Visualizing data variability/uncertainty (Range error bars vs. Standard deviation.

4. EXPERIMENTAL DESIGN

- **Variables →** Independent (manipulated), Dependent (measured), Control/Constants (kept constant).
- **Groups →** Control group (no treatment baseline) vs. Experimental group (receives treatment).
- **Steps →** State question, formulate hypothesis, identify variables, set up groups, plan procedure, analyze results, and draw conclusions.

Q.1 Define biostatistics, write its importance and code an example. LQ

Ans. **Biostatistics:**

- A scientific discipline that **applies statistical methods and techniques specifically** to biological, medical and health-related data is called **biostatistics.**

Importance of Biostatistics:

(i) **To Draw Meaningful Results:** Biostatistics involves the collection, presentation, analysis, and interpretation of data to draw **meaningful conclusions.**

(ii) **To Make Decisions About Populations:** Biostatistical Analysis allows researchers and health professionals to make **informed decisions** about **populations** using sample data, rather than testing entire populations which may be impractical or costly.

- **Example:** By studying a representative subset of workers in a population, biostatistics helps estimate the prevalence of a health condition among all **workers.**

Check Understanding!

Q.1 Which component of biostatistics specifically involves formulating research questions and structuring studies to ensure unbiased results?
(A) Study design.
(B) Data management.
(C) Result interpretation.
(D) Data communication.

Topic: Components of Biostatistics:

Q.2 Only write the names of key components of biostatistics, which completely cover the several critical areas? SQ

Ans. **Key Components of Biostatistics:**

- There are **six (06)** key components of biostatistics which **cover most** of the critical areas.

(i) Study Design and Experimental Planning. (ii) Data Collection.
(iii) Data Management and Processing. (iv) Data Analysis.
(v) Interpretation of Results. (vi) Presentation and Communication.

Q.3 Describe the 6-key components of biostatistics which comprehensively cover the several critical areas of study like biological, medical & heath. LQ

Ans. **6-Key Components of Statistics:**

- The key **components** of biostatistics **comprehensively** encompass (cover) several critical areas that collectively **enable** the proper **collection, analysis, interpretation,** and **application** of biological or health-related data.

(1) **Study Design and Experimental Planning:**

- This component involves **formulating** the research question, **determining objectives,** and structuring experiments or observational studies to test **hypothesis.**
- It **includes** selecting the population, defining variables, randomization, controlling confounding factors, and calculating adequate sample size.
- Proper study design **ensures** validity, reliability, and unbiased results.

(2) **Data Collection:**

- Collecting accurate and relevant data is fundamental component of biostatistics.
- Data collection can be done through various methods:
  - (a) **Primary Data Collection:** Collection of data directly from **experiments, surveys, interviews,** observations, and **clinical trials.**
  - (b) **Secondary Data Collection:** The using of existing data from published research, medical records, government reports, and databases is considered as secondary data collection.

(3) **Data Management and Processing:**

- The organization of the **collected** data systematically and ensuring accuracy before analysis is called data **analysis.**
- It also includes cleaning, coding, and storage, maintaining confidentiality and integrity of the data.

CamScanner

c) **Data Analysis:**
- The application of statistical **techniques** to summarize, describe, and draw inferences from data called data analysis.
  - **(a) Descriptive Statistics:** It describe **characteristics** of the data (mean, median, mode, standard deviation etc.
  - **(b) Inferential Statistics:** It includes hypothesis testing, regression analysis, and modelling, allow conclusions about populations from sample data.

d) **Interpretation of Results:**
- The translation of statistical findings into **meaningful** biological or health conclusions is known as interpretation of results.
- Consideration of **context**, limitations, and assumptions of the analysis is important for interpretation of results of data.

e) **Presentation and Communication**
- Effectively communicating results using visualizations like **charts, graphs** and clear language tailored to scientific, medical, and public audiences.
- Transparency in reporting methods and findings is essential for reproducibility and trust.

Multiple Choice Questions (MCQs)				Key
1 **Biostatistics mainly applies statistics to:** (A) Engineering. (B) Biology.	(C) Astronomy.	(D) Economics.		1.(B)
2 **Biostatistics mainly deals with:** (A) Data analysis. (B) Cell division.	(C) Photosynthesis.	(D) Respiration.		2.(A)
3 **Testing a sample helps estimate the:** (A) Mutation rate. (B) Population.	(C) Cell size.	(D) DNA length.		3.(B)
4 **Formulating research objectives is part of:** (A) Data analysis. (B) Data storage.	(C) Presentation.	(D) Study design.		4.(D)
5 **Directly collected information is called:** (A) Secondary data. (B) Primary data.	(C) Processed data.	(D) Random data.		5.(B)
6 **Medical records are an example of:** (A) Primary data. (B) Raw data.	(C) Secondary data.	(D) Field data.		6.(C)
7 **Removing errors from data is called:** (A) Data cleaning. (B) Coding.	(C) Sampling.	(D) Graphing.		7.(A)
8 **Mean, median, and mode are:** (A) Inferential statistics. (B) Descriptive statistics.	(C) Experimental methods.	(D) Variables.		8.(B)
9 **Hypothesis testing is part of:** (A) Descriptive statistics. (B) Data coding.	(C) Inferential statistics.	(D) Data storage.		9.(C)
10 **Graphs and charts are mainly used for:** (A) Data collection. (B) Data presentation.	(C) DNA analysis.	(D) Cell culture.		10.(B)
11 **Transparency mainly improves:** (A) Digestion. (B) Respiration.	(C) Mutation.	(D) Reproducibility.		11.(D)
12 **Why is a good study design important?** (A) Reduce bias. (B) Increase errors.	(C) Store data.	(D) Grow samples.		12.(A)
13 **Why is sample data commonly used instead of entire populations?** (A) More mutations. (B) Less accuracy.	(C) More practical.	(D) More variables.		13.(C)
14 **Why is data cleaning necessary before analysis?** (A) Increase size. (B) Change results.	(C) Reduce samples.	(D) Improve accuracy.		14.(D)
15 **Why are inferential statistics important?** (A) Cell counting. (B) DNA sequencing.	(C) Population conclusions.	(D) Protein synthesis.		15.(C)
16 **Why are charts and graphs widely used?** (A) Clear presentation. (B) Store samples.	(C) Reduce variables.	(D) Collect data.		16.(A)

Topic: Applications of Biostatistics:

Q.4 **Write the applications of biostatistics as discus in the text book.** U/A

Applications of Biostatistics:

(1) Clinical trials and medical research. **(2)** Epidemiology.

(3) Genetics and genomics. **(4)** Public health policy.
(5) Environmental health. **(6)** Bioinformatics.
(7) Healthcare quality control. **(8)** Health programs and population interventions.
(9) Controlling epidemics. **(10)** Identifying barriers to care.
(11) Health risk assessment and demography.

Q.5 **Discuss any four application of biostatistics also write their importance.** U/A

Ans. **Four Application of Biostatistics with Importance:**

(1) **Clinical Trials and Medical Research:**
- Biostatistics **plays** a crucial role in **clinical trials** and **medical research** by providing the framework for designing studies and analyzing data to ensure valid and reliable outcomes.

Importance:
- Through **statistical methods**, biostatisticians evaluate the safety and effectiveness of new drugs, treatments, and medical devices.
- This process enables healthcare professionals to make evidence-based decisions that improve patient care and advance medical knowledge.

(2) **Epidemiology:**
- In epidemiology, **biostatistics** is used to investigate the distribution and determinants of diseases within populations.

Importance:
- It helps public health experts understand how diseases spread, identify risk factors, and evaluate the impact of preventive measures.
- By modelling disease trends and assessing intervention outcomes, biostatistics supports efforts to control epidemics and improve community health.

(3) **Genetics and Genomics:**
- The field of **genetics** and **genomics** relies heavily on biostatistics to analyze complex genetic data.

Check Understanding!
Q.2 How is biostatistics applied in the field of genetics and genomics for personalized medicine?

Importance:
- It includes uncovering relationships between genes and diseases, understanding inheritance patterns, and **exploring** genetic variations.
- Biostatistical methods are essential in **personalized** medicine, where treatments are tailored to an individual's genetic profile to enhance **effectiveness** and reduce adverse effects.

(4) **Public Health Policy:**
- Biostatistics is instrumental in **shaping public health policy** by analyzing population **health data** and evaluating health programs.

Importance:
- Public health policy identifies vulnerable groups and **health disparities**, providing policymakers with evidence to design and implement interventions that promote **equity** and improve overall health outcomes on a large scale.

Q.6 **Describe the following applications of biostatistics with their Importance:** U/A
(1) Environmental Health. **(2) Bioinformatics.**
(3) Healthcare Quality Control. **(4) Health Programs & Population Interventions.**

Ans. **Applications of Biostatistics with Importance:**

(1) **Environmental Health:**
- Environmental health benefits from biostatistics through the assessment of how environmental factors like pollution and **toxins** affect human health.

Importance:
- Statistical analysis **helps identify** harmful exposures and guides regulations and preventive strategies to protect communities from environmental hazards.

CamScanner

(2) Bioinformatics:
- In bioinformatics, biostatistics supports the analysis of vast biological datasets from genomics and proteomics.

Importance:
- By developing algorithms and models, biostatisticians enable the interpretation of complex data essential for drug discovery, disease diagnosis, and the development of personalized therapies.

(3) Healthcare Quality Control:
- Healthcare quality control also relies on biostatistics to monitor and improve healthcare services.

Importance:
- By applying statistical tools, healthcare providers can evaluate diagnostic test accuracies, track patient outcomes, and ensure consistency in medical procedures, ultimately enhancing the quality of patient care.

(4) Health Programs and Population Interventions:
- Biostatistics evaluates the effectiveness of health programs and population-based interventions.

Importance:
- It helps public health officials understand the impact of immunization campaigns, health education efforts, and training programs for healthcare workers.
- This evaluation is vital for optimizing resource allocation and maximizing the benefits of public health initiatives.

Q.7 Explain that controlling epidemic, identifying barriers to risk & health risk assessment & demography are important applications of biostatistics. L/Q

Ans. Applications of Biostatistics with Importance:

(1) Controlling Epidemics:
- During epidemics, biostatistics is critical in tracking the spread of disease, estimating mortality rates, and identifying at-risk populations.

Importance:
- This real-time statistical analysis informs decision-making and helps implement targeted strategies to contain outbreaks and mitigate their effects.

(2) Identifying Barriers to Care:
- Biostatistics also uncovers barriers to healthcare access by analyzing survey data and health service usage patterns.

Importance:
- This insight helps healthcare providers and policymakers develop strategies to improve access and reduce health disparities, making healthcare systems more efficient and equitable.

(3) Health Risk Assessment and Demography:
- Finally, biostatistics plays an essential role in health risk assessment and demography by analyzing trends in births, deaths, disease prevalence, and other vital statistics.

Importance:
- These analysis provide crucial information for government agencies and health organizations to plan services, allocate resources, and address public health challenges effectively.
- Together, these multifaceted uses illustrate the indispensable nature of biostatistics in improving health outcomes worldwide.

Multiple Choice Questions (MCQs)				Key
1. Clinical trials mainly evaluate: (A) Weather.	(B) Treatments.	(C) Soil fertility.	(D) Population size,	1.(B)
2. Biostatistics helps determine the: (A) Plant height.	(B) Earthquakes.	(C) Drug safety.	(D) Rainfall.	2.(C)
3. Epidemiology mainly studies: (A) Rocks.	(B) Diseases.	(C) Stars.	(D) Fossils.	3.(B)
4. Genetics mainly studies: (A) Climate.	(B) Oceans.	(C) Fossils.	(D) Genes.	4.(D)
5. Personalized medicine depends on: (A) Blood group.	(B) Genetic profile.	(C) Body weight.	(D) Age only.	5.(B)
6. Public health policy uses: (A) Planet data.	(B) Weather data.	(C) Population data.	(D) Ocean data.	6.(C)
7. Environmental health studies: (A) Pollution effects.	(B) Moon phases.	(C) Volcanoes.	(D) Earthquakes.	7.(A)
8. Healthcare quality control monitors: (A) Crop yield.	(B) Patient outcomes.	(C) Rainfall.	(D) Fuel usage.	8.(B)
9. Immunization campaigns are evaluated through: (A) Biostatistics.	(B) Astronomy.	(C) Physics.	(D) Geology.	9.(A)
10. During epidemics, biostatistics estimates: (A) Crop prices.	(B) River depth.	(C) Wind speed.	(D) Mortality rates.	10.(D)
11. Health service usage helps identify: (A) Care barriers.	(B) DNA mutations.	(C) Fossils.	(D) Minerals.	11.(A)
12. Demography mainly analyzes: (A) Rock layers.	(B) Vital statistics.	(C) Weather data.	(D) Soil types.	12.(B)
13. Births and deaths are examples of: (A) Chemical reactions.	(B) Enzyme actions.	(C) Vital statistics.	(D) DNA sequences.	13.(C)
14. Why is biostatistics important in clinical trials? (A) Evidence decisions.	(B) Plant breeding.	(C) Weather prediction.	(D) Rock analysis.	14.(A)
15. Why is disease modelling useful? (A) Grow crops.	(B) Build roads.	(C) Mine minerals.	(D) Control outbreaks.	15.(D)
16. Why is personalized medicine more effective? (A) Higher dosage.	(B) Genetic matching.	(C) More vitamins.	(D) Less exercise.	16.(B)
17. Why do policymakers use biostatistics? (A) Health planning.	(B) Space travel.	(C) Bridge design.	(D) Forest mapping.	17.(A)
18. Why is environmental risk assessment necessary? (A) Increase pollution.	(B) Reduce rainfall.	(C) Improve mining.	(D) Protect communities.	18.(D)

KEY STATISTICAL MEASURES AND THEIR CALCULATION

Q.8 What is the importance of statistical measure? S/Q

Ans. Importance of Statistical Measures:
(i) In the field of statistics, understanding and calculating key measures is essential for summarizing and interpreting data.
(ii) These measures provide valuable insights into the central tendency, variability, and distribution of data, helping to identify patterns and make informed decisions.

Q.9 Name & define the key statistical measures. S/Q
OR Define the following terms: S/Q
(i) Mean, (ii) Median. (iii) Mode. (iv) Standard Deviation. (v) Range. (vi) Percentile.

Ans. Name & Definition of the Key Statistical Measures:
(i) **Mean:** It represents the average value of the data.
(ii) **Median:** It indicates the middle point of the data set.
(iii) **Mode:** It highlights the most frequent value of dataset.
(iv) **Percentiles:** It breaks the data into specific intervals for a deeper analysis.
(v) **Standard Deviation:** Dispersion of a set of values from its mean.
(vi) **Range:** The difference between the highest & lowest number in a data set.

Topic: Mean:

Q.10 Explain the concept of mean & discuss the steps to calculate the mean for ungrouped data & grouped data. Exercise L/Q.1

Ans. Mean:
- The mean, also known as the average.
- It is a measure of central tendency that gives an idea of the central value in a dataset.

CamScanner

- From a biological perspective, it can be used to summarize large datasets, providing a central value that represents typical characteristics, such as average size or growth rate.

➢ **Formula:**

(a) For ungrouped data

$$\text{Mean} = \frac{x}{n}$$

Where,
x = sum of all the values.
n = number of values in the dataset.
For grouped data

$$\text{Mean} = \frac{\sum_{i=1}^{n} f_i x_i}{\sum_{i=1}^{n} f_i}$$

Where:
x_i = Midpoint of the i th class interval.
f_i = frequency of the i th class.
f_i = sum of all the frequencies.

(i) Steps to Calculate the Mean (For Ungrouped Data):

- A biologist measured the **average weight** of a specific species of bird in a park.
- He recorded the **weights (g)** of five birds from the same species.
- The bird's weights are 400 g, 420 g, 470 g, 390 g and 460 g.

Step 1: Add all the weights together (X); X = 400 + 420 + 470 + 390 + 460 = 2140 g
Step 2: Count the total number of birds (n); n = 5 birds
Step 3: Divide the sum of bird's weights by the number of birds:

$$\text{Mean} = \frac{x}{n} = \frac{2140}{5} = 428\text{g}$$

Thus average weight of a specific species of birds is **428 g.**

(ii) Steps to Calculate the Mean (For Grouped Data):

- A biologist **studied the growth of a certain** plant species under different soil conditions.
- The plant **heights (cm)** are grouped into class intervals based on measurements from different plots of land with varying soil types.

Step 1: Organize the data set into class intervals.
Step 2: Calculate the midpoint of each class interval.
Step 3: Multiply each midpoint by its corresponding frequency.
Step 4: Sum the products of midpoints and frequencies.
Step 5: Divide the result of the step 4 by the total frequency.

Check Understanding!
Q.3 What does the sum of the products of class midpoints and frequencies ($f_i x_i$) divided by total frequency represent in grouped data?
(A) Median. (B) Mean.
(C) Mode. (D) Range.

➢ **Table: Mean plant height (cm) calculation using grouped data across soil types.**

Soil Type	Class Interval (Height in cm)	Frequency (f_i)	Midpoint (x_i = lower limit + upper limit / 2)	f_i, x_i
• Sandy Soil	0-9	5	4.5	22.5
• Loamy Soil	10-19	8	14.5	116
• Clayey Soil	20-29	7	24.5	171.5
• Peaty Soil	30-39	4	34.5	138
		$\Sigma f_i = 24$		$\Sigma f_i x_i = 448$

$$\text{Mean} = \frac{\sum f_i x_i}{\sum f_i} = \frac{448}{24} = 18.67\text{cm}$$

- Thus average growth of a certain plant species under different soil conditions is 18.67 cm.

Topic: Median:

Q.11 Define & explain the median, discuss the steps to calculate the value, also discuss the steps to calculate media for odd number of values & even number of values with the help of examples. Exercise Q.1

Ans. Median:

- A **measure** of central tendency that represents the middle value in a dataset when the data is arranged in order is called **median.**

➢ **Description of Median:**

- If the number of values in data set is **odd**, the median is the **middle values.**
- If the number of values in data set is **even**, the median is the **average of the two middle numbers.**
- From a biological perspective, it provides a better representation of the central tendency in cases like population size, disease prevalence, or body measurements, where data might not be normally distributed.

➢ **Formula:**

- There is no single formula to calculate the median but there are steps to calculate it.

➢ **Steps to calculate the Median:**

- **Step 1:** Arrange the **dataset** in **ascending** or **descending** order.
- **Step 2:** Count the total number of values in the dataset.

(a) If the number of values in the **dataset is odd:**

Median = The value at the position $\left(\frac{n+1}{2}\right)^{th}$.

(b) If the number of values in the dataset is **even.**

Median = The average of values at the positions $\left(\frac{n}{2}\right)^{th}$ and $\left(\frac{n+2}{2}\right)^{th}$.

Check Understanding!
Q.4 How is the median calculated when the total number of values in a dataset is even?

(i) Calculation of Median of Odd Number of Data Set:

Example 1 (Odd number of values)

- A biologist studied the **average height (cm)** of five plants in a garden.
- The heights of the plants are **50 cm, 65 cm, 60 cm, 75 cm, and 80 cm.**
- **Step 1:** 50cm, 60 cm, 65 cm, 75 and 89 cm.
- **Step 2:** n = 5 plants
- **Step 3:** n = 5 is odd, the median is the value at the position $\left(\frac{5+1}{2}\right) = \left(\frac{6}{2}\right) = 3$. So, the median is 65 cm.

(ii) Calculation of Median of Even Number of Data Set:

Example 2 (Even number of values)

- A biologist studied the **average weight (kg)** of six different animals in a zoo.
- The weights of the animals are **300 kg, 400 kg, 330, 315 kg, 450 kg and 500 kg.**
- **Step 1:** Arrange the values in ascending number i.e., 300 kg, 400 kg, 330, 315 kg, 450 kg and 500 kg.
- **Step 2:** n = 6 animals
- **Step 3:** n = 6 is even, so the median is the average of value at the position $\left(\frac{6}{2}\right) = 3$ and $\left(\frac{6+2}{2}\right) = \left(\frac{8}{2}\right) = 4$

3^{rd} value = 330 kg 4^{th} value = 400 kg

- Thus median = $\frac{(330+400)}{2} = 365\text{kg}$

CamScanner

Topic: Mode:

Q.12 Define & describe the mode, give its formula & discuss the steps to calculate the mode for grouped data & for ungrouped data with examples. Exercise LQ.1

Ans. Mode:

- The mode is the **value or values** that appear most frequently in a dataset.
- From a biological **perspective**, it can be used to understand the most common characteristics or traits in a biological sample, such as the most frequent number of flowers on a plant, the most common size of seeds in a population, or the most frequently occurring weight in a sample of animals.

➢ **Formula to Calculate Mode:**

(a) There is **no specific formula** to calculate mode in **ungrouped data.** The mode is simply the value or values that appear **more frequently** in a data set.

(b) For **grouped data** the **mode** can be calculated by using the **given formula:**

Where:

$$\text{Mode} = l + \frac{(fm - f_1)}{(fm - f_1) + (fm - f_2)} \times h$$

l = lower boundary of the modal class.
fm = frequency of the modal class.
F_1 = frequency of the class before the modal class.
f_2 = frequency of the class after the modal class.
h = class width (the difference between upper and lower limits of any class interval).

(i) Steps to Calculate the Mode for Ungrouped Data with Example:

- A biologist studied the **height (cm) of ten plants in a garden.**
- The heights of plants are 50 cm, 60 cm, 50 cm, 55 cm, 50 cm, 65 cm, 60 cm, 70 cm, 55 cm and 50 cm.
- **Step 1:** Arrange the data in ascending order (Higher to Lower Number).
  50 cm, 50 cm, 50 cm, 50 cm, 55 cm, 55 cm, 60 cm, 60 cm, 65 cm, 70 cm.
- **Step 2:** Count the frequency of each value.
  (Frequency: How often a specific number appears in a data set).
  50 cm appears 4 times. 55 cm appears 2 times. 60 cm appears 2 times.
  65 cm appears 1 time. 70 cm appears 1 time.
- **Step 3:** Identify the mode (Most frequent No.).
- The number 50 appears the most frequently i.e. 4 times. Therefore, the mode for this dataset is 50 cm.

(ii) Steps to Calculate the Mode for Grouped Data with Example:

- Consider that we are studying the weight (kg) distribution of animals in a zoo.

Class	Class Interval Weight (kg)	Frequency
I	10 – 20	5
II	20 – 30	12
III	30 – 40	18
IV	40 – 50	10
V	50 – 60	3

- **Step 1:** Identify the modal class.
  The class interval (30 - 40) **Class III** is the modal class with the **highest frequency (18).**
- **Step 2:** Put the values in the formula to calculate mode for **grouped data.**
  l = 30 (lower boundary of the modal class)
  Fm = 18 (frequency of the modal class)
  f_1 = 12 (frequency of the class **before** the **modal class**)
  f_2 = 10 (frequency of the class **after** the **modal class**)
  h = 10 (class width)

$$\text{Mode} = l + \frac{(fm - f_1)}{(fm - f_1) + (fm - f_2)} \times h$$

$$= 30 + \frac{(18 - 12)}{(18 - 12) + (18 - 10)} \times 10$$

$$= 30 + \frac{6}{6+8} \times 10 = 30 + \frac{6}{14} \times 10$$

$$= 34.29 \text{ kg}$$

- Thus mode of the givens dataset is 34.29 kg.

Topic: Standard Deviation (SD):

Q.13 What is standard deviation & how does it give information about a data set? Exercise LQ.2

Ans. Standard Deviation (SD):

- **A measure of how much the numbers in a group or data set differ from the average.**

Or A measure of how **dispersed** the data is in relation to the mean is called **standard deviation.**

(i) Low SD: Low, or small, **standard deviation** indicates data are **clustered tightly** around the mean.

(ii) High SD: High, or large, **standard deviation** indicates data are **more spread out.**

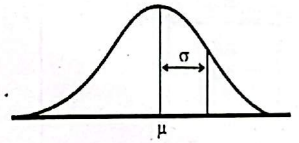
(iii) SD Close to Zero: A standard deviation close to zero indicates that **data points** are very **close to the mean,** whereas a larger standard deviation indicates data points are spread further away from the mean.

Check Understanding!

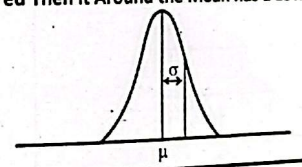
Q.5 What does a low or small standard deviation indicate about a dataset?
(A) Widely spread.
(B) Maximum mean.
(C) Tightly clustered.
(D) Zero median.

Q.14 How is different types of curve determine that standard deviation (SD) of data set higher & lower? S/Q

Ans. (i) When Curve is More Spread Out Then it has High Standard Deviation of Data Set:



(ii) When Curve is More Clustered Then it Around the Mean has a Lower Standard Deviation of Data Set:



Q.15 What is the use of standard deviation (SD) in biology? S/Q

Ans. Use of SD in Biology:

- In biology, standard deviation is commonly used to:
- Assess the **variability** in measurements, such as the **growth rates of plants and the concentration of enzymes** in a sample, or any other **biological data.**

Q.16 What is the formula to calculate the standard deviation (SD) also discuss the steps to calculate SD with an example. Exercise LQ.2

Ans. Formula to Calculate the Standard Deviation (SD):

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}$$

CamScanner

Where:

σ = standard deviation

x_i = each individual data point in the set

μ = mean

N = total number of data points.

➢ **Steps Involve to Calculate Standard Deviation with Example:**

- **Examples:** A biologist studied the heights of **9 different plants** of the same species. The heights of the plants are 56 cm, 65c m, 74 cm, 75 cm, 76 cm, 77 cm, 80 cm, 81 cm and 91 cm.
- **Step 1:** Find the mean.
- **Step 2:** Subtract the mean from each **data point** to find the deviation of each point.
- **Step 3:** Square the result of each **deviation** which eliminates negative values and emphasizes larger deviations.
- **Step 4:** Find the average of the squared deviations.
- **Step 5:** Take the square root of the result from **step 4**. This is the standard deviation.

Table: Calculation of standard deviation for plant heights

Height in (cm) x_i	Mean μ	Subtract mean from each data point ($x_i - \mu$)	Square the result of each deviation $(x_i - \mu)^2$	Sum of squared deviations $\Sigma(x_i - \mu)^2$	Variance (Average of the squared deviations) $\Sigma\ (x_i - \mu)^2/N$	Standard deviation $\sigma = \sqrt{\frac{\Sigma(x_i - \mu)^2}{N}}$
56	75	56 – 75 = –19	361	784	87.11	9.33
65		65 – 75 = –10	100			
74		74 – 75 = –1	1			
75		75 – 75 = 0	0			
76		76 – 75 = 1	1			
77		77 – 75 = 2	4			
80		80 – 75 = 5	25			
81		81 – 75 = 6	36			
91		91 – 75 = 16	256			

Topic: Range:

Q.17 Define range & what does it represent in data set? Exercise LIQ.1

Ans. Range:

- The difference between the **lowest & highest** values in a **set of data** is called range.
- A **measure** of the spread or **dispersion** of a set of data. It is the simplest form of variability and is used to understand the extent of variation in the dataset.
- **Range Represents:** The **range represents** the difference **between the maximum and minimum** values in a dataset.

Range: Highest value – Lowest value

Q.18 Differentiate between larger range & the smaller range in a data set. S/Q

Ans.

Larger Range	Smaller Range
• A larger **range suggests** a greater spread of data, meaning the **data points** are more **dispersed** from each other.	• A smaller range indicates that the **data points** are closely **clustered** around a central value.

Q.19 Give the formula to calculate range & explain the steps for calculating range with the help of an example. L/Q

Ans. Formula For Calculation of Range:

$$\text{Range} = X_{max} - X_{min}$$

Where:

X_{max} = maximum value in the data set.

X_{min} = minimum value in the data set.

➢ **Steps to Calculate the Range with Example:**

- Consider a dataset representing the ages of a group of people: 25, 20, 22, 30, 42, 45, 50.
- **Step 1:** Arrange the data in **ascending order** (From Lower to higher values). 20, 22, 25, 30, 42, 45, 50
- **Step 2:** Identify the highest value in the dataset i.e. 50
- **Step 3:** Identify the **smallest value** in the dataset i.e. 20
- **Step 4:** Subtract the **minimum value** from the **maximum value** to calculate the range.

$$\text{Range} = X_{max} - X_{min}$$

$$\text{Range} = 50 - 20 = 30$$

Topic: Percentile:

Q.20 Define & describe percentile, give uses of percentile also write the formula to calculate percentile & discuss the steps to calculate percentile with the help of an example. Exercise LIQ.2

Ans. Percentile:

- A **measure** that indicates the value in a **dataset** below which a given percentage of observations in a group of data falls is called **percentile.**
- For instance, the **25th percentile**, also known as the **first quartile** (Q1), is the **value below** which 25% of the data points lie.
- Similarly, the **50th percentile**, or the median, is the value below which 50% of the data points lie, and the 75th percentile, or the third quartile (Q3), is the value below which 75% of the data points lie.
- Percentiles are **particularly useful** in biostatistics as they help in understanding the distribution of biological data which is skewed (Biased/unfair) or normally distributed.

➢ **Formula to Calculate Percentile:**

$$R = \frac{P}{100}(n+1)$$

Where

R = rank

P = desired percentile

n = number of observations in the data set

- If R is an **integer**, the value at the R^{th} **position** in the ordered dataset is the percentile.
- If R is not an **integer** (e.g., 4.4), interpolation between the two nearest ranks is used to estimate the percentile value.
- **Example:** If it lies between 4^{th} and 5^{th} data points, percentile value = value at 4^{th} + 0.4 × (value at 5^{th} – value at 4^{th})

➢ **Steps to Calculate Percentile with Example:**

- Suppose we have the **following dataset** representing the heights (cm) of 10 **individuals:** 160, 162, 168, 165, 170, 175, 172, 178, 180, 182.

CamScanner

- To calculate the 40th percentile:
- **Step 1:** Arrange the data in ascending order (Lower to Higher number).
  160, 162, 168, 165, 170, 175, 172, 178, 180, 182.
- **Step 2:** Determine the total number of observations.
  $n = 10$
- **Step 3:** Calculate the rank.
  $R = P/100 \times (n + 1)$
  $R = 40/100 \times (10 + 1) = 4.4$
- **Step 4:** Locate the rank in the dataset and interpolate if necessary.
  The rank is 4.4, which is not an integer. This means that the 40th percentile lies between 4th (168) and 5th (170) data points.
  Interpolate between the 4th and 5th values:
  Percentile value = value at 4th + 0.4 × (value at 5th – value at 4th)
  Percentile value = 168 + 0.4 × (170 – 168) = 168 + 0.4 × 2 = 168 + 0.8 = 168.8
- **Step 5:** Interpret the result.
  The 40th percentile value is 168.8. This means that 40% of the observations fall below or equal to 168.8 in this data set.

For Information
- Variance is the average of the squared deviations of observations from their mean and is equal to the square of the standard deviation.

Check Understanding!
Q.6 What does the 40th percentile signify in a biological dataset?

CHART

Q.21 Define the term chart with reference to statistics also name its two types. S/Q

Ans. Chart:
- A graphical **representation of data** used to present information in a simple, clear and easy to understand form.
- **Types of chart:** (1) Bar Chart. (2) Pie chart.

For Information
- **Histograms are used for continuous/grouped data, while bar charts are used for categorical data.**

Topic: Bar Chart:

Q.22 What is Bar chart, write its uses, key characteristics & explain the steps to create a bar chart with the help of an example. Exercise L/Q.4, L/Q.5

Ans. Bar Chart:
- A bar chart (or bar graph) is a **graphical representation** used to **display categorical** data with rectangular **bars**, where the length or height of each bar is proportional to the value it represents.

Check Understanding!
Q.7 In a standard bar chart representing categorical data, what does the y-axis typically display?
(A) Categories. (B) Percentages.
(C) Frequencies. (D) Angles.

➢ **Use of Bar Chart:**
- Bar charts are used to **compare** quantities across **distinct** categories or groups.
- In biology, **bar charts** are valuable for showing data like the **counts of different species**, experimental groups, or measurement results from biological samples.

➢ **Key Characteristics of Bar Chart:**
- The key characteristics of a bar chart are:
  i) Categories are represented by the x-**axis** (horizontal axis).
  ii) Values or frequencies are represented by the **y -axis** (vertical axis).
  iii) Bars can be oriented **vertically** or **horizontally.**

➢ **Steps to Create a Bar Chart with Example:**
- A team of research students conducted an **insect diversity** study in a local forest and counted the number of individuals for **five common insect** species over a month.

Table: Relative abundance of the insect species

Sr. No.	Insect species	Number of Individuals counted	Percentage (%)
1.	• Ladybug	45	16
2.	• Ant	120	41
3.	• Butterfly	30	10
4.	• Bee	75	26
5.	• Dragonfly	20	7

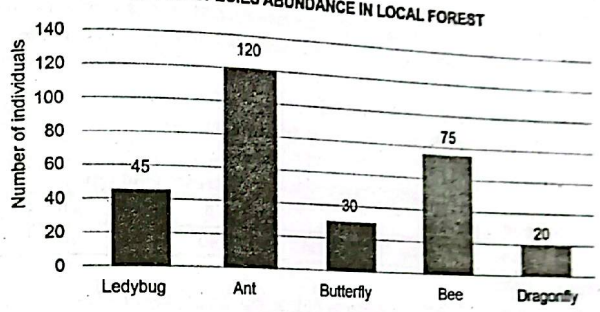


Figure: species in a local forest

- **Legend:** A **legend** is a key or guide on a chart, graph, or map that explains the meaning of symbols, colours, patterns, or labels used in the visual.
- It helps the viewer understand what different elements represent, making the data or information easier to interpret and analyse.
- **Example:** In a bar chart with different colours for each category, the legend identifies what each colour corresponds to.

- **Step 1: Purpose and Data:**
  - **Purpose:** To visually compare the abundance of five different insect species.
  - **Categorical variable:** Insect species (ladybug, ant, butterfly, bee, dragonfly).
  - **Numerical variable:** Number of individuals counted.
- **Step 2: Determine the Axis:**
  - **X-axis (Categorical):** Insect species.
  - **Y-axis (Numerical):** Number of individuals counted.
- **Step 3: Scale the Numerical Axis:**
  - Greatest value is 120 (Ants).
  - Scale the **y-axis from 0 to 130 or 140.**
  - An increment of 10 or 20 is used for good readability. Let's choose 0 to 140 with increment of 20.
- **Step 4: Draw the Bars (Along Y-Axis):**
  - Draw a bar for ladybug up to 45 on the y -axis.
  - Draw a bar for ant up to 120 on the y -axis.
  - Draw a bar for butterfly up to 30 on the y -axis.
  - Draw a bar for bee up to 75 on the y -axis.
  - Draw a bar for dragonfly up to 20 on the y-axis.
  - Ensure bars are of equal width and evenly spaced.
- **Step 5: Add Labels and Title:**
  - **Chart title:** Insect species abundance in local forest.
  - **X-axis label:** Insect species.
  - **Y-axis label:** Number of individuals.

CamScanner

Topic: Pie Chart:

Q.23 What is pie chart, give its uses & describe the steps to create pie chart with example. Exercise L/Q.4, L/Q.5

Ans. Pie Chart:

- A pie chart is a **circular statistical** graph divided into sectors (slices), each representing a proportion of the whole dataset.
- The entire circle corresponds to 100% (or 360°), and each sector's angle is proportional to its category's share in the dataset.

➢ **Uses of Pie Chart:**

- Pie charts are ideal for visualizing categorical data as portions of a whole, making it intuitive to compare different group's **contributions** in biology, such as types of cells, species distributions, or survey responses.

➢ **Steps to create a pie chart with example:**

- A biology class surveys 100 students to find their blood types.
- The results are as follows:

Table: Survey results of student blood types

Blood Type	A	B	AB	O
Number of students (frequency)	30	20	10	40

➢ **Step 1: Organize Data:**

- Arrange the categorical data in a table, noting the frequency or total for each category as shown in table.....

➢ **Step 2: Add up all frequency values to get the total sum:**

- Total number of students = 30 + 20 + 10 + 40 = 100

Table: Frequency distribution of blood types and sector angle

Sum of frequency	Blood Type	No. of Student	Sector angle = Sum of values
30	A	30	$\frac{30}{100} \times 360° = 108°$
20 + 30 = 50	B	20	$\frac{20}{100} \times 360° = 72°$
10 + 50 = 60	AB	10	$\frac{10}{100} \times 360° = 36°$
40 + 60 = 100	O	40	$\frac{40}{100} \times 360° = 144°$
	Total	n =100	

➢ **Step 3: Calculate the sector angles (Sector angle = Category value/ total value X 360°)**

A = 30/100 × 360° = 180°
B = 20/100 × 360° = 72°
AB = 10/100 × 360° = 36°
O = 40/100 × 360° = 144°

➢ **Step 4: Draw the Pie Chart:**

- Draw a circle by using a protractor, draw each sector angle in sequence (clock wise or counter clockwise) using the calculated angles in step 3.
- Start with a reference line (radius).
- Use different colours/shades to differentiate each category.

➢ **Step 5: Label and Title:**

- Clearly label each sector and provide a legend if needed. Add a descriptive title to the chart.

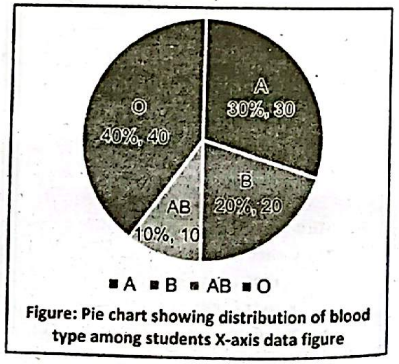


Figure: Pie chart showing distribution of blood type among students X-axis data figure

X-Axis:

- The *x*-axis refers to the **horizontal** line on a **Cartesian coordinate system** or **data figure** such as a graph, chart, or plot. It is most commonly used to represent the **independent variable.**
- The *x*-axis provides the **baseline against** which other variables (typically shown on the *y*-axis) are measured.
- It is always drawn **horizontally,** running left to right, and often starts at the origin (0,0), extending in the positive direction, though it can also include negative values when needed.
- In biological studies, the *x*-axis is often used to represent variables like time intervals, different species, or experimental conditions.
- It provides a **baseline** for comparison and helps visualize trends or relationships between **variables in biological data.**

Q.24 Discuss the steps to create an x-axis data figure with the help of example & draw x-axis data figure. L/Q

Ans. Steps to Create an x-Axis Data Figure with Example:

- Suppose we are measuring the activity of enzyme. The activity is measured at, 10°C, 20°C, 30°C, 40°C and 50°C.

➢ **Step 1: Identify variables:**

- **Independent variable (x-axis):** Temperature, measured in degrees Celsius (°C).
- **Dependent variable (y-axis):** Rate of enzyme activity.

➢ **Step 2: Determine Scale and Range:**

- Decide the minimum and maximum values, and the intervals or categories for the x-axis.
- Temperatures at which enzyme activity is measured i.e. 10°C, 20°C, 30°C, 40°C and 50°C.

➢ **Step 3: Label the axis**

- X -axis is labeled as Temperature (°C) and Y -axis is labeled as Enzyme Activity (µmol/min).

➢ **Step 4: Plot the Data Points:**

- For each measurement, find its position on the *x*-axis and plot it against the corresponding y-axis value (the dependent variable).
- **We measured these pairs:** (10°C, 2µmol/min), (20°C, 4µmol/min), (30°C, 7µmol/min), (40°C, 5µmol/min), (50°C, 3µmol/min).

➢ **Step 5: Adjust Formatting:**

- Make sure tick marks are evenly placed for this data.
- Temperature values are evenly spaced along the *x*-axis since the interval between points is similar.
- Connect the data points with a line to show the trend.

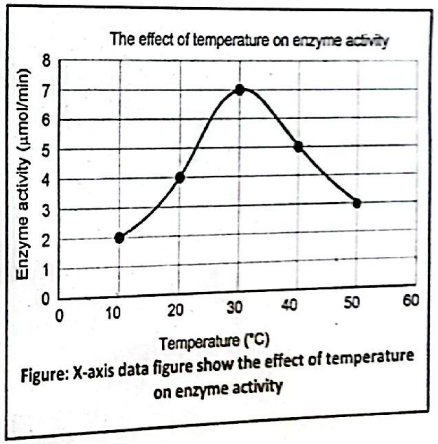


Figure: X-axis data figure show the effect of temperature on enzyme activity

Topic: Error Bars:

Q.25 What are error bars, describe its two types. Exercise L/Q.3, L/Q.5

Ans. Error Bars:

- Error bars are **graphical elements** placed on **bar charts** (and other types of plots) to visually represent the variability or uncertainty in data.
- **Uses of Error Bars:** They help to visualize how much the individual data points **typically deviate** from the central tendency (e.g., mean) represented by the bar.

CamScanner

➢ **Types of Error Bars:**

- The two most common ways to sketch errors bars for a bar chart are:

(1) Range Error Bars:

- Range error bars use the smallest (minimum) and greatest (maximum) data points in a set for each bar.
- The bar extends from the minimum to the maximum value, illustrating the full spread of the data.

(2) Standard Deviation (SD) Error Bars:

- Standard deviation error bars show the average distance of each data point from the mean.
- On a bar chart, each bar represents a group mean.
- Standard deviation error bars extend above and below the mean value of a data-set by one or more standard deviations (± SD).

Check Understanding!
Q.8 How do Standard Deviation (SD) error bars differ from range error bars on a bar chart?

Q.26 Discuss the steps to sketch error bars on a bar chart. Exercise Q.3

Ans. Steps to Sketch Error Bars on a Bar Chart:

- The researchers are measuring the average plant height (cm) in three different light conditions.
- They grow bean plants in three groups:
  (i) **Group A:** Low light. (ii) **Group B:** Medium light. (iii) **Group C:** High light.
- After four weeks they measure the heights of the plants.

	Group A	Group B	Group C
• Plant 1	10	14	18
• Plant 2	11	16	20
• Plant 3	9	15	19

➢ **Step 1: Calculate the mean of each group:**

- Group A Mean of = (10 + 11 + 9)/3 = 10 cm
- Group B Mean of = (14 + 16 + 15)/3 = 15 cm
- Group C Mean of = (18 + 20 + 19)/3 = 19 cm
- The bars on the bar chart are drawn at heights 10, 15, and 19 for Groups A, B, and C, respectively.

➢ **Step 2: Calculate the spread:**

- **A) For SD Error Bars:**
  - **Group A:** SD ≈ 0.82 (Data: 10, 11, 9)
  - **Group B:** SD ≈ 0.82 (Data: 14, 16, 15)
  - **Group C:** SD ≈ 0.82 (Data: 18, 20, 19)
- **B) For Range Error bars:**
  - **Group A:** min = 9, max = 11
  - **Group B:** min = 14, max = 16
  - **Group C:** min = 18, max = 20

➢ **Step 3: Draw the error bars:**

- **SD Error Bars:** Start at the mean (top of each bar), extend up and down by 0.82 cm (Mean ±0.82 SD).
  Group A: from 9.18 (10 – 0.82) to 10.82 (10+ 0.82)
  Group B: from 14.18 (15 – 0.82) to 15.82 (15+ 0.82)
  Group C: from 18.18 (19 – 0.82) to 19.82 (19+ 0.82)
- **Range Error Bars:** Extend from the minimum to maximum value for each group. Add a horizontal cap at each end of the vertical error bar for clarity.

Table: Statistical summary of plant measurements

Group	Plant 1	Plant 2	Plant 3	Mean	Range (max–min)	Minimum	Maximum	Standard deviation error (±SD)
• A	10	11	9	10	2	9	11	0.82
• B	14	16	15	15	2	14	16	0.82
• C	18	20	19	19	2.	18	20	0.82

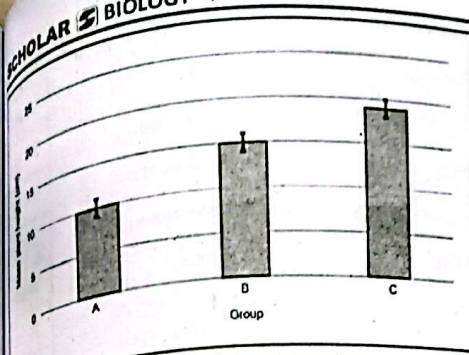


Figure (a): Graph showing average plant height in different light conditions with SD error bars

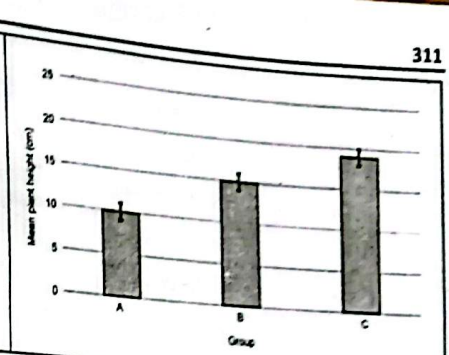


Figure (b): Graph showing average plant height in different light conditions with Range error bars

Multiple Choice Questions (MCQs)

					Key
1.	Mean is also called:	(A) Median.	(B) Average.	(C) Mode.	(D) Range.	1.(B)
2.	Mean is a measure of:	(A) Dispersion.	(B) Position.	(C) Frequency.	(D) Central tendency.	2.(D)
3.	Mean for grouped data uses:	(A) Σfi.	(B) Σfixi/Σfi.	(C) Xmax – Xmin.	(D) P(n+1).	3.(B)
4.	In the mean formula, n represents:	(A) Frequencies.	(B) Midpoints.	(C) Observations.	(D) Classes.	4.(C)
5.	Why is the mean useful in biology?	(A) Average traits.	(B) Count cells.	(C) Classify species.	(D) Label samples.	5.(A)
6.	Median is the:	(A) Highest value.	(B) Middle value.	(C) Frequent value.	(D) Average value.	6.(B)
7.	Before finding the median, data must be:	(A) Squared.	(B) Divided.	(C) Grouped.	(D) Arranged.	7.(D)
8.	Even observations require:	(A) First value.	(B) Two middle values.	(C) Last value.	(D) Highest value.	8.(B)
9.	Median is useful for:	(A) Skewed data.	(B) Equal classes.	(C) DNA analysis.	(D) Cell counting.	9.(A)
10.	Why is the median preferred for skewed data?	(A) More frequent.	(B) Larger value.	(C) Less affected.	(D) Easy counting.	10.(C)
11.	Mode is the:	(A) Average value.	(B) Frequent value.	(C) Middle value.	(D) Largest value.	11.(B)
12	Highest-frequency class is:	(A) Median class.	(B) Mean class.	(C) Range class.	(D) Modal class.	12.(D)
13.	Mode identifies the:	(A) Common value.	(B) Smallest value.	(C) Middle value.	(D) Total value.	13.(A)
14.	Ungrouped mode requires:	(A) Formula only.	(B) Frequency count.	(C) Graph only.	(D) Division.	14.(B)
15.	Why is mode useful in biology?	(A) Common traits.	(B) DNA copying.	(C) Blood flow.	(D) Cell division.	15.(A)
16.	Standard deviation measures:	(A) Frequency.	(B) Position.	(C) Average.	(D) Dispersion.	16.(D)
17.	Small standard deviation means:	(A) Wide spread.	(B) Close values.	(C) Random values.	(D) Large range.	17.(B)
18.	Standard deviation near zero means:	(A) High variation.	(B) Random data.	(C) Near mean.	(D) Large classes.	18.(C)
19.	Standard deviation uses:	(A) Square root.	(B) Cube root.	(C) Multiplication.	(D) Division only.	19.(A)
20.	Why is standard deviation important?	(A) Count samples.	(B) Find median.	(C) Measure variability.	(D) Rank values.	20.(C)
21.	Range equals:	(A) Mean – Mode.	(B) Max – Min.	(C) Median – Mean.	(D) Mode – Median.	21.(B)

CamScanner

22.	Range measures:	(A) Position.	(B) Frequency.	(C) Average.	(D) Variability.	22.(D)
23.	Large range indicates:	(A) Low spread.	(B) High spread.	(C) Equal values.	(D) Same mean.	23.(B)
24.	Small range indicates:	(A) Clustered data.	(B) High variation.	(C) Many classes.	(D) Random data.	24.(A)
25.	Why is range called the simplest measure of variability?	(A) Many formulas.	(B) Uses graphs.	(C) Uses frequency.	(D) Two values.	25.(D)
26.	Percentile shows:	(A) Frequency.	(B) Position.	(C) Mean.	(D) Range.	26.(B)
27.	The 25th percentile is:	(A) Q1.	(B) Q2.	(C) Q3.	(D) Q4.	27.(A)
28.	The 50th percentile is:	(A) Mean.	(B) Median.	(C) Mode.	(D) Range.	28.(B)
29.	The 75th percentile is:	(A) Q1.	(B) Q2.	(C) Q4.	(D) Q3.	29.(D)
30.	Why are percentiles useful?	(A) Data position.	(B) Data cleaning.	(C) DNA analysis.	(D) Cell counting.	30.(A)

22.4 EXPERIMENTAL DESIGN

Q.27 What do you know about experimental design, explain it & discuss the types of variables i.e. control group & experimental group in experimental design. LO

Ans. Experimental Design:

- The planning in which scientists want to **test an idea**, & plan an **experiment carefully** is called **experimental design.**
- Scientists decide subjects or participants and control the conditions so results are fair.

Check Understanding!

9. In an experimental design, what is the role of a control group?
(A) Treatment group.
(B) Variable modifier.
(C) Baseline comparison.
(D) Constant eliminator.

➢ **Types of Variables in Experimental Design:**

- They change one thing:
  (i) Independent Variable: The thing which changes
  (ii) Dependent Variable: See how it affects another thing.
- **Use of Variable:** This help them **find out if their hypothesis** is right or wrong by looking at how different variables are connected.
- To do this effectively, scientists identify different **types of variables.**
  (i) Independent Variable: The factor that the experimenter changes or manipulates to observe its effect is called **independent variable.**
  (ii) Dependent Variable: What is measured or observed; it changes in response to the independent variable is called **dependent variable.**
  (iii) Control Variables or Constants: All the other factors that must be kept the same throughout the experiment to ensure a fair test are called **control variables.**

➢ **Groups in Experimental Design:**

(i) Control Group:

- A **control group** is a group in the experiment that **does not receive** the treatment or change in the independent variable.
- It serves as a **baseline** to compare the results of the experimental group, helping to show whether the independent variable actually causes any effect.

(ii) Experimental Group:

- An **experimental group** is a group that is exposed to the **specific treatment,** condition, or environmental change being tested in an experiment.
- Their responses are **measured** and **compared** to a control group to assess the effect of that treatment on biological processes or characteristics.

Q.28 Narrate the steps involve for experimental design. LO

Ans. Steps Involve For Experimental Design:

(i) Formation of Question:
- State the question of your experiment first. This clearly defines what you want to find out.

(ii) Hypothesis Formation:
- Formulate a hypothesis based on your research e.g., what you think will happen, based on existing knowledge.

(iii) Variable Identification:
- Clearly identify variables to understand what you will change (independent variable), measure (dependent variable) and keep constant (control variable).

(iv) Setting the Groups:
- Set up groups e.g., control group (does not receive the treatment or change in independent variable) and experimental group (receives the treatment or change).

(v) Procedure:
- Plan the procedure and outline detailed steps on how experiments will be conducted e.g., how subjects are selected and assigned to groups, how each group treated, the duration and frequency of measurement and how data will be collected.

(vi) Methodology:
- Use **appropriate methods** (such as averaging, graphing or statistical tests) to compare outcomes between groups and assess whether there is a significant effect

(vii) Conclusion:
- Draw conclusions in **relation to the original hypothesis** and research question. Accept or reject hypothesis on the basis of results.

Topic: Experiment to Study the Effect of High-fat Diet on Weight gain in Albino Mice:

Q.29 Set an experimental design to study the effect of high fat diet on weight gain in albino mice. LO

Ans. Experiment to Study the Effect of High-fat Diet on Weight Gain in Albino Mice:

1.	**Question:**	• Does a high-fat diet cause greater weight gain in mice compared to normal diet?
2.	**Hypothesis:**	• Mice given a **high-fat diet** will gain **more weight** than those on a normal diet.
3.	**Identify variables:**	**(i) Independent variable:** Type of diet. **(ii) Dependent variable:** Weight gain. **(iii) Control variables:** Mouse age, strain, sex, cage, environment (light, temperature) and feeding schedule etc.
4.	**Set up groups:**	**(i) Control group:** Mice on normal diet. **(ii) Experimental group:** Mice on a high-fat diet.
5.	**Procedure & methodology outline:**	**(i)** Select albino mice that are matched by age, strain, and sex. **(ii)** Randomly assign albino mice to control and experimental groups. **(iii)** House all albino mice under identical conditions (same cages, light, temperature, humidity). **(iv)** Administer the assigned diet to each group for a set period (e.g., 8 weeks). **(v)** Measure and record each albino mice weight weekly.
6.	**Analyse results:**	• Use statistical tests or graphs to compare the average weight gain between groups at the end of the experiment.

CamScanner

7.	Draw conclusions:	• The experiment will determine whether a **high-fat diet** leads to greater weight gain in mice compared to a normal diet. **(i) When Hypothesis (Step-2) is Supported:** • If the **high-fat diet** group shows a statistically **significant increase** in average **weight gain**, the hypothesis will be supported, suggesting that diet type influences weight gain. **(ii) When Hypothesis (Step-2) is not Supported:** • If there is **no significant difference** between groups, or if the normal diet group gains more weight, the hypothesis will be rejected, indicating that factors other than diet type may play a greater role in influencing weight gain under the given experimental conditions.

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(A)	• Study design and experimental planning involve formulating objectives, selecting populations, and controlling confounding factors to ensure unbiased results.
2.	S/Q	• It analyzes complex genetic data to uncover gene-disease relationships and inheritance patterns, enabling treatments to be tailored to individual genetic profiles.
3.	(B)	• The formula for the mean of grouped data is the sum of $f_i x_i$ divided by the sum of frequencies (f_i).
4.	S/Q	• The median is calculated by finding the average of the two middle values after arranging the dataset in order.
5.	(C)	• A low standard deviation indicates that data points are clustered closely around the mean value.
6.	S/Q	• It represents the value below or equal to which 40% of the observations in the dataset fall.
7.	(C)	• Bar charts represent categories on the x-axis and values or frequencies on the y-axis.
8.	S/Q	• SD error bars extend above and below the mean by one or more standard deviations to show data variability, while range error bars extend from the minimum to the maximum data points.
9.	(C)	• A control group does not receive the treatment, serving as a baseline to evaluate whether the independent variable causes an effect.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQS

1. **Which of the following is a primary data collection method?**
   (a) Government reports. (b) Published articles.
   (c) Experiment and surveys. (d) Online databases.
2. **What does mode represent in a dataset?**
   (a) The average of values. (b) The value occurring most frequently.
   (c) The difference between two values. (d) None of these.
3. **Which statistical measure is also called the 50th percentile?**
   (a) Mean. (b) Median. (c) Mode. (d) Range.
4. **If the maximum value in a dataset is 50 and the minimum value is 20, what is the range?**
   (a) 30 (b) 25 (c) 20 (d) 115
5. **What does it mean if the 40th percentile value is 148 cm?**
   (a) 40% of values are above 148 cm. (b) 40% of values are below or equal to 148 cm.
   (c) All the values are equal to 148 cm (d) 60% of values are above 148 cm.

6. **In a pie chart, what does the full circle represent?**
   (a) 180° (b) 280° (c) 380° (d) 360°
7. **What do error bars represents in a chart?**
   (a) Average. (b) Variability or uncertainty in data.
   (c) Both of these. (d) None of these.
8. **In an experiment, what does the dependent variable represent?**
   (a) The factor kept constant. (b) The factor being changed.
   (c) The factor ignored. (d) All of these.
9. **What is the main purpose of including a control group in an experiment?**
   (a) To test the dependent variable. (b) To provide a baseline for comparison
   (c) To collect random data. (d) All of these.
10. **Which group in an experiment receives the treatment?**
    (a) Control group. (b) Dependent group. (c) Experimental group. (d) Independent group.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(c)	Experiment and surveys.	• Primary data collection involves gathering first-hand information directly from original sources through methods like experiments and surveys by researcher.
2.	(b)	The value occurring most frequently.	• By definition, the mode is the statistical value or observation that appears most often in a dataset.
3.	(b)	Median.	• The median divides a dataset into two equal halves, which corresponds precisely to the 50th percentile.
4.	(a)	30	• The range is calculated as the difference between the maximum and minimum values (50 - 20 = 30).
5.	(b)	40% of values are below or equal to 148cm.	• A percentile indicates the percentage of observations falling at or below a given value.
6.	(d)	360°	• A complete pie chart represents a full circle, which equals 360 degrees.
7.	(b)	Variability or uncertainty in data.	• Error bars are graphical representations used to show the variability, standard deviation, or uncertainty associated with measured data points.
8.			• None of the options are correct. Option (b) is least in correct choice.
9.	(b)	To provide a baseline for comparison.	• A control group is kept unmanipulated to serve as a baseline for comparison against the experimental group.
10.	(c)	Experimental group.	• The experimental group is the specific subset in an experiment that is exposed to the test treatment or independent variable.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Explain why biostatistics is important in medical research?

Ans. Importance of Biostatistics in Medical Research:
- **Data Analysis:** It helps in organizing, summarizing, and analyzing complex medical and health-related data.
- **Evidence-Based Decisions:** It enables researchers to draw valid conclusions, test hypotheses, and make reliable clinical decisions.

Q.2 Describe the difference between descriptive and inferential statistics?

Ans.
- **Descriptive Statistics:** They summarize and describe the main features of a dataset using measures like mean, median, and mode.
- **Inferential Statistics:** They use sample data to make predictions, generalizations, or inferences about a larger population.

CamScanner

Q.3 How are independent and dependent variables related in experimental design?

Ans.
- **Independent Variable:** This is the factor manipulated or controlled by the researcher to test its effects.
- **Dependent Variable:** This is the measured outcome or response that changes in direct reaction to the independent variable.

Q.4 The height of six children are 100, 115, 118, 120, 122 and 125. What is the median height of the children?

Ans. Median:
- **Ordered Data:** The given heights in order are 110, 115, 118, 120, 122, and 125.
- **Calculation:** Since there is an even number of values, the median is the average of the two middle numbers (118 + 120/ 2), median height of the children 119.

Q.5 What does a legend in a chart present?

Ans. Legend in a Chart:
- **Symbol Identification:** A chart legend explains the meaning of **colors, patterns,** or **symbols** used to represent different data series.
- **Data Clarity:** It helps readers correctly interpret and distinguish various components within the graphical display.

Q.6 What are error bars?

Ans. Error Bars:
- **Variability Representation:** Error bars are graphical representations of the variability of data, showing the uncertainty or error of a reported measurement.
- **Statistical Spread:** They typically display standard deviation, standard error, or confidence intervals around a plotted point or mean.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Explain the concepts of mean, median, and mode as measures of central tendency. Illustrate with examples when each measure would be most appropriate.

Ans. See Page No. 299 – 302 (Q.10 ⟶ Q.12)

Q.2 Describe standard deviation, range, and percentiles as measures of variability. Compare their advantages and limitations in interpreting biological data?

Ans. See Page No. 303 – 305 (Q.13, Q.16, Q.17, Q.20)

Q.3 What are error bars? Explain their types (range error bars, standard deviation error bars) and significance in experimental biology. Illustrate your answer with a hypothetical dataset?

Ans. See Page No. 309 – 310 (Q.25 ⟶ Q.26)

Q.4 Compare and construct bar charts and pie charts. Which situations favour one over the other? Support your answer with real-world biological or health data examples.

Ans. See Page No. 306 – 308 (Q.22 ⟶ Q.23)

Q.5 Discuss different types of data presentation tools in biostatistics (bar chart, pie chart and error bars). For each, explain an appropriate biological example where it would be the best choice.

Ans. See Page No. 306 – 310 (Q.22, Q.23, Q.25)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 A pharmaceutical company claims their drug improves recovery time from flu. Propose an experimental design using biostatistics principles, and explain how you would ensure validity and reliability of results?

Ans.
- **Design:** Implement a Randomized Controlled Trial (RCT) dividing participants into a treatment group receiving the new drug and a control group receiving a placebo, using double-blind blinding.
- **Validity & Reliability:** Ensure validity through random assignment and strict inclusion/exclusion criteria to eliminate confounders; secure reliability by standardizing symptom-scoring metrics and using proper sample size calculations for statistical power.

Q.2 Evaluate the usefulness of range versus standard deviation in representing variability. Which one would you trust more in medical research and why?

Ans.
- **Usefulness:** The range only measures the difference between extreme values, making it highly sensitive to outliers, whereas the standard deviation measures the dispersion of all data points around the mean.
- **Medical Trust:** Standard deviation is trusted much more in medical research because it provides a statistically robust and reliable reflection of variability, ignoring anomalous individual extremes.

Q.3 During an epidemic, mortality rate estimates vary depending on whether the mean, median, or percentile is used. Discuss how policymakers might misinterpret such statistics and how biostatistics can prevent this.

Ans.
- **Misinterpretation:** Policymakers may misinterpret mortality data if they rely on the mean, which can be heavily skewed by extreme outbreak clusters or outlier demographics, leading to misallocated medical resources.
- **Biostatistical Prevention:** Biostatisticians prevent this by utilizing medians or percentiles for skewed epidemiological data, presenting comprehensive distribution curves, and providing transparent confidence intervals for informed decision-making.

Q.7 What is the relationship between percentiles and quartiles?

Ans. Relationship Between Percentiles and Quartiles:
- Quartiles and percentiles both measure relative standing by dividing a dataset into equal portions.
- Percentiles split data into 100 parts (each 1%), whereas quartiles divide it into 4 parts (each 25%).
- Therefore, quartiles are specific benchmark percentiles: Q1 equals the 25th percentile, Q2 (the median) equals the 50th percentile, and Q3 equals the 75th percentile.

CamScanner

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. (1 x 6 = 06)

(i) **Biostatistics mainly deals with:**
(A) Data analysis. (B) Cell division. (C) Photosynthesis. (D) Respiration.

(ii) **Which statistical measure is also called the 50th percentile?**
(A) Mean. (B) Median. (C) Mode. (D) Range.

(iii) **Demography mainly analyzes:**
(A) Rock layers. (B) Vital statistics. (C) Weather data. (D) Soil types.

(iv) **Mean is a measure of:**
(A) Dispersion. (B) Position. (C) Frequency. (D) Central tendency.

(v) **Which group in an experiment receives the treatment?**
(A) Control group. (B) Dependent group. (C) Experimental group. (D) Independent group.

(vi) **The 50th percentile is:**
(A) Mean. (B) Median. (C) Mode. (D) Range.

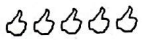
Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) Only write the names of key components of biostatistics, which completely cover the several critical areas?
(ii) Describe the difference between descriptive and inferential statistics?
(iii) What is standard deviation & how does it give information about a data set?
(iv) What is the importance of statistical measure?
(v) Define range & what does it represent in data set?
(vi) Define the term chart with reference to statistics also name its two types.
(vii) What are error bars?
(viii) Define range & what does it represent in data set?

Q.3 Extensive Questions. (4 x 2 = 8)

(a) Describe the 6-key components of biostatistics which comprehensively cover the several critical areas of study like biological, medical & heath.

(b) Discuss different types of data presentation tools in biostatistics (bar chart, pie chart and error bars). For each, explain an appropriate biological example where it would be the best choice.



CHAPTER 23

PHARMACOLOGY

Student Learning Outcomes (SLOs)

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

- Explain the drug discovery and development process.
- Define 4 classes of antibiotics (Penicillins, Tetracyclines, Fluoroquinolones and Sulfonamides) and describe their mode of action.
- Define antivirals and antiretrovirals.
- Describe advantages of monoclonal antibodies as compared to other drug classes.

CamScanner

Pharmacology — Concept Map

1. DRUG DISCOVERY & DEVELOPMENT

- **(a) Discovery Stages →** Target Identification, Target Validation, Lead Compound Identification, Lead Optimization.
- **(b) Development Stages →** Preclinical Research (in vitro/in vivo), Clinical Trials (Phase 1: 20–100 safety, Phase 2: 100–300 efficacy, Phase 3: 1,000–3,000 large-scale validation), FDA Review, Manufacturing & Marketing, Post-Marketing Surveillance.

2. CLASSES OF ANTIBIOTICS

- **(a) Penicillin →** Fungal-derived (Fleming, 1928), bactericidal, inhibits peptidoglycan cell wall cross-linking (targets Gram-positive).
- **(b) Tetracycline →** Streptomyces-derived, bacteriostatic, reversibly binds 30S ribosomal subunit to block translation.
- **(c) Fluoroquinolones →** Synthetic chloroquine derivatives (Lesher, 1962), bactericidal, inhibits Type II topoisomerases (DNA gyrase & Topoisomerase IV).
- **(d) Sulfonamides →** Synthetic sulfanilamide (Domagk, 1932), bacteriostatic competitive inhibitor of folate synthesis (PABA pathway).

3. ANTIVIRAL, ANTIRETROVIRAL & MONOCLONAL ANTIBODIES

- **(a) Antivirals & Antiretrovirals →** General antivirals block viral growth (Hep, Flu, Herpes); antiretrovirals specifically target retroviruses (HIV reverse transcriptase).
- **(b) Monoclonal Antibodies →** Lab-produced, high specificity, low toxicity, targeted therapy for cancer and autoimmune disorders.

INTRODUCTION

Q.1 Define pharmacology, which type of studies are covered in this branch. SQ

Ans. Pharmacology:

- The branch of biology that deals with the study of drugs and their effects on living organisms is called **pharmacology.**
- Pharmacology includes the study of the sources, properties, composition, therapeutic uses, and effects of drugs on the body.

Q.2 What are drugs, write the types of drugs on the basis of their sources. SQ

Ans. Drugs:

- The chemical substances which used to diagnose, prevent, or treat diseases are called **drugs.**

Types of Drugs on the Basis of Source:

(i) **Natural Drugs:** Drugs which are **obtained** from **natural sources** such as plants, animals, and microorganisms are called natural drugs.

(ii) **Synthetic Drugs:** The drugs which are synthesized in laboratories ae called synthetic drugs.

Q.3 Define herbal medicine or phytotherapy. SQ

Ans. Phytotherapy:

- Medicines prepared from **plants** are commonly used in traditional systems of treatment and are known as herbal medicines or **Phytotherapy.**

DRUG DISCOVERY AND DEVELOPMENT PROCESS

- Drug discovery and drug development are important **processes** that help in the production of **safe and effective** medicines for the treatment of diseases.
- The process begins with the **identification** of disease-causing targets and the development of compounds that can interact with these targets before a drug is approved for public use, it undergoes several stages of testing to **evaluate** its safety, **efficacy,** and **quality.**
- Scientists, **researchers,** and **regulatory** authorities work together throughout this process to ensure that new medicines are beneficial and safe for human use.

Check Understanding!

Q.1 During the initial stages of drug discovery, what is the primary purpose of target validation experiments?

(A) To screen thousands of synthetic chemical compounds

(B) To confirm that acting on the target produces therapeutic effects

(C) To manufacture the drug on a large commercial scale

(D) To execute Phase 3 human clinical trials

Topic: Stages of Drug Discovery:

Q.4 Describe the essential steps for the drug discovery. LQ

Ans. Stages of Drug Discovery:

- There are following stages in the **discovery of modern drugs:**

(i) **Target Identification:**

- It is the initial stage of finding a new drug for any disease.
- In this step scientists identify a **specific molecule,** such as a protein or enzyme, that is involved in causing a disease.
- This target is selected because it can be affected by a drug to treat the disease.

(ii) **Target Validation:**

- During this step of drug discovery, researchers confirm that the **identified target plays** an important role in the disease process.
- Experiments are **carried out** to ensure that acting on the target can produce therapeutic effects.

CamScanner

(iii) Lead Compound Identification:

- In this step scientists screen thousands of **natural or synthetic compounds** to find substances that can interact effectively with the **target molecule**. These promising substances are called **lead compounds**.

(iv) Lead Optimization:

- During this stage the **lead compounds** are modified to **improve their effectiveness, reduce toxicity,** and enhance the **drug-like properties.**
- This is the final step of drug discovery, after that the drug development process is started.

Check Understanding!
Q.2 How do Phase 1 and Phase 2 clinical trials differ in terms of participant groups and objectives?

Topic: Drug Development Process:

Q.5 What is drug development process discuss the stages of drug development process? Exercise L/Q.1

Ans. Drug Developmental Process:

- It is the process of **testing** and **preparing** the discovered drug for public use.

➢ **Stages of Drug Development Process:**

- There are following stages to develop a newly discovered drug:

(i) Preclinical Research:

- In this stage the discovered compounds are tested in **vitro** (cell-based culture in lab) and in vivo (animal i.e. in living cell) to measure safety, toxicity, and efficacy before human trials.

(ii) Clinical Trials:

- Drugs are tested on humans to **ensure safety.**
- **Phase-1:** Testing in a **small group** (20 – 100) of healthy volunteers are taken to determine safety and dosage.
- **Phase-2:** Testing in a **larger group** (100-300) of patients to test the effectiveness and side effects of drugs.
- **Phase-3: Large-scale trials** (1000 – 3000) are taken to confirm the efficacy and monitor their adverse reactions in patients.

(iii) Drug Review:

- In the stage regulatory **agencies** like FDA thoroughly **examine** all the data collected through clinical research trials, to approve or reject the drugs before the final recommendations about drugs marketing.

(iv) Manufacturing and Marketing:

- Once approved, the drug is **produced** on a large scale in **pharmaceutical industries** and made available for medical use.

(v) Post-Marketing Surveillance:

- Even after release, the drug is **continuously monitored** for **long-term** effects and rare side effects to ensure ongoing safety in the population.

Multiple Choice Questions (MCQs)

		Key
1. Drug discovery begins with identifying: (A) Target. (B) Patient. (C) Disease. (D) Vaccine.		1.(A)
2. Drug development aims to produce medicines that are: (A) Expensive. (B) Safe. (C) Colorful. (D) Imported.		2.(B)
3. Before public use, a drug undergoes: (A) Packaging. (B) Marketing. (C) Testing. (D) Export.		3.(C)
4. Drug discovery mainly identifies: (A) Vaccines. (B) Hormones. (C) Vitamins. (D) Compounds.		4.(D)
5. Which process follows drug discovery? (A) Drug development. (B) Diagnosis. (C) Vaccination. (D) Mutation.		5.(A)
6. Drug development ensures: (A) Soil fertility. (B) Crop yield. (C) Drug quality. (D) Cell division.		6.(C)

		Key
7. Drug discovery mainly focuses on: (A) Disease targets. (B) Blood groups. (C) DNA copying (D) Food storage.		7.(A)
8. Regulatory authorities mainly evaluate: (A) Plant growth. (B) Drug safety. (C) Cell size. (D) Enzymes.		8.(B)
9. Why is target identification the first step? (A) Faster sales. (B) Lower price. (C) Specific action. (D) Easy storage.		9.(C)
10. Why are drugs tested before approval? (A) Improve taste. (B) Reduce color. (C) Increase weight. (D) Ensure safety.		10.(D)
11. Why do researchers collaborate during drug development? (A) Better results. (B) Reduce hospitals. (C) Increase diseases. (D) Grow bacteria.		11.(A)
12. Why is drug quality assessed before approval? (A) Product color. (B) Patient safety. (C) Easy transport. (D) Lower cost.		12.(B)
13. The first stage of drug discovery is: (A) Clinical trials. (B) Manufacturing. (C) Target identification. (D) Marketing.		13.(C)
14. Target identification involves finding a: (A) Tissue. (B) Organ. (C) Hormone. (D) Molecule.		14.(D)
15. Researchers confirm the target during: (A) Target validation. (B) Drug approval. (C) Marketing. (D) Packaging.		15.(A)
16. Lead compounds are identified by: (A) Injection. (B) Screening. (C) Digestion. (D) Fermentation.		16.(B)
17. Lead optimization also reduces: (A) Solubility. (B) Frequency. (C) Toxicity. (D) Dosage.		17.(C)
18. Why is target validation necessary? (A) Reduce price. (B) Increase color. (C) Speed marketing. (D) Confirm target.		18.(D)
19. Why are thousands of compounds screened? (A) Find leads. (B) Kill bacteria. (C) Reduce dosage. (D) Improve packaging.		19.(A)
20. Why are lead compounds optimized? (A) More weight. (B) Better efficacy. (C) Faster transport. (D) Lower volume.		20.(B)
21. Why is a protein often selected as a drug target? (A) Cell color. (B) Blood volume. (C) Body size. (D) Disease role.		21.(D)
22. Drug development begins with: (A) Marketing. (B) Manufacturing. (C) Preclinical research. (D) Distribution.		22.(C)
23. Preclinical studies are performed: (A) Before humans. (B) After approval. (C) During marketing. (D) After sales.		23.(A)
24. In vitro testing is carried out in: (A) Humans. (B) Patients. (C) Volunteers. (D) Cell culture.		24.(D)
25. In vivo testing is performed on: (A) Animals. (B) Plants. (C) Fungi. (D) Bacteria.		25.(A)
26. Phase 1 clinical trial mainly evaluates: (A) Cost. (B) Safety. (C) Packaging. (D) Marketing.		26.(B)
27. Phase 3 clinical trial confirms: (A) Color. (B) Flavor. (C) Solubility. (D) Efficacy.		27.(D)
28. FDA reviews data before: (A) Discovery. (B) Screening. (C) Approval. (D) Optimization.		28.(C)
29. Why is preclinical research performed before human trials? (A) Ensure safety. (B) Reduce cost. (C) Improve color. (D) Increase demand.		29.(A)
30. Why are Phase 3 trials conducted on many patients? (A) Reduce dosage. (B) Confirm efficacy. (C) Improve packaging. (D) Increase sales.		30.(B)
31. Why is post-marketing surveillance necessary? (A) Increase price. (B) Change formula. (C) Improve color. (D) Monitor safety.		31.(D)
32. Why do regulatory agencies review clinical data? (A) Public protection. (B) Faster marketing. (C) Lower taxes. (D) Product branding.		32.(A)

CLASSES OF ANTIBIOTIC

Q.6 What are antibiotics and name its 4-clases? Exercise L/Q.2

Ans. Antibiotics:

- The drugs that **treat bacterial infection** by killing bacteria or stopping their growth are called antibiotics.

➢ **Classification of Antibiotics:**

- Antibiotics are **classified** primarily by their **mechanism** of action, chemical nature and way of action against their targets/host.

CamScanner

- The major four classes of antibiotics are given below:
  (i) Penicillin. (ii) Tetracycline. (iii) Fluoroquinolones. (iv) Sulfonamides.

Topic: Class-Penicillin:

Q.7 Write a note on discovery, common side effects, & mode of action of penicillin. Exercise LQ.1

Ans. Penicillin:

- **Source:** Penicillin is a group of **bactericidal (kill bacterial)**, and it was derived from **Penicillium fungi.**
- **Action:** These are used to treat **various bacterial** infections by inhibiting bacterial cell wall synthesis.

Discovery of Penicillin:

- Penicillin was discovered by Alexander **Fleming (1928).**

Effectiveness of Penicillin:

- Penicillin is highly **effective** against **Gram-positive** bacteria. Including **streptococcal** and **staphylococcal** infections.

Common Side Effects of Penicillin Antibiotics:

- Include nausea, **vomiting, diarrhea, abdominal pain,** and **skin rashes.**

Check Understanding!

Q.3 How does penicillin achieve its bactericidal effect on bacterial cells?
(A) By interrupting peptidoglycan cross-linking to cause cell lysis.
(B) By binding to the 30S ribosomal subunit.
(C) By inhibiting human folic acid synthesis pathways.
(D) By trapping DNA gyrase to cause double-strand breaks.

➢ **Mode of Penicillin Action:**

- Penicillin adopt following way to **kill bacteria:**

(i) **Targeting Bacteria:** Penicillin target bacteria because **animal cells** lack the cell walls that are targeted by the drug.
(ii) **Cell Wall Inhibition:** It interrupt the **cross-linking of peptidoglycan** (murein) of cell wall chains, stopping new cell wall synthesis of bacteria.
(iii) **Lysing Bacterial Cell:** The bacterial cell wall can no **longer maintain structural** integrity and it may burst (lysis), after the attack of penicillin (kills rather than just inhibits growth).
(iv) **Resistance Mechanisms:** Some bacteria defend themselves from **penicillin** by producing specific enzymes like beta-lactamases.

Topic: Class-Tetracycline:

Q.8 What is tetracycline, discuss its common side effects & mode of action? Exercise LQ.1

Ans. Tetracycline:

- Tetracycline is an antibiotic which is derived from **soil-dwelling** bacteria of the genus Streptomyces.
- **Used Against:** It is a **bacteriostatic oral antibiotic** used to treat bacterial infections like **chlamydia** and **syphilis.**
- It inhibits bacterial protein synthesis.
- It should not be taken with dairy or **iron supplements.**

Common Side Effects:

- It common side effects include nausea, vomiting, diarrhea, and sun sensitivity.

➢ **Mode of Tetracycline Action:**

(i) **Bacteriostatic Effect:** They stop bacteria from **growing and multiplying** rather than killing them outright.
(ii) **Gram-Negative/Positive Action:** They are effective **against** both Gram-positive and Gram-negative bacteria.
(iii) **Targeting Ribosomes:** Tetracycline enter bacterial cells and it reversibly bind to the **30S ribosomal** subunit of its target cell.
(iv) **Blocking Protein Production:** By binding to the **30S ribosome,** they prevent aminoacyl-t RNA from binding to the acceptor site, to inhibit translation and protein synthesis.

Topic: Class-Fluoroquinolones:

Q.9 What are fluoroquinolones? Who discovered this class of antibiotics? Exercise LQ.1

Ans. Fluoroquinolones:

- **Fluoroquinolones** are a class of bactericidal antibiotics that treat bacterial infections by inhibiting bacterial DNA replication.

- **Fluoroquinolones are synthetic, antibacterial** agents derived as a **byproduct** of chloroquine (quinine) synthesis.
- **Chloroquine:** A synthetic drug derived from **structural modification of quinine.**
- **Quinine:** A natural alkaloid found in the bark of the South American Cinchona tree.

Check Understanding!

Q.4 Why are tetracyclines classified as bacteriostatic rather than bactericidal antibiotics?

Discovery of Fluoroquinolone:

- The quinolone class was **discovered** by **George Lesher** in 1962.
- Fluoroquinolones were developed subsequently by adding a fluorine atom.

Q.10 Discuss the common adverse effects & mode of action of fluoroquinolone. Exercise LQ.2

Ans. Common Adverse Effects:

- Rare adverse side effects, including **tendon ruptures, peripheral neuropathy, drug resistance** and **cardiac issues.**

Mode of Fluoroquinolones Action:

(i) **Bactericidal Effect:** Fluoroquinolones trap the enzymes involved in DNA replication, creating a complex that causes double-stranded DNA breaks. This prevents the bacteria from multiplying and forces them to die, so it classified as bactericidal (kills bacteria).
(ii) **Targeting Topoisomerases:** Fluoroquinolones enter the bacterial cells and inhibit their Type II topoisomerases.
(iii) **Targeting Topoisomerase IV:** Primarily targeted in **Gram-positive bacteria,** it stops the separation of replicated DNA.
(iv) **Targeting DNA Grase:** Primarily targeted in **Gram-negative bacteria,** it stopping the process of DNA uncoiling during replication.

Topic: Class-Sulfonamides:

Q.11 Give description of sulfonamides according to the following headings. Exercise LQ.2
(i) Definition. (ii) Brief Characteristics. (iii) Discovery.
(iv) Administration & Side Effects. (v) Mode of action.

Ans. (i) Sulfonamides:

- **Definition:** Sulfonamides are synthetic **pharmaceutical** compounds derived from sulfanilamide.

(ii) Characteristics of Sulfonamides:

- These are **antimicrobial** drugs that can treat bacterial infections by inhibiting **folate synthesis,** primarily used for urinary tract infections and skin infections.
- It **acts as competitive** inhibitors and bacteriostatic antibiotics to inhibit bacterial synthesis of folic acid, which is essential for DNA synthesis and bacterial growth.

(iii) Discovery of Sulfonamide:

- Discovered by Gerhard Domagk in 1932.

(iv) Administration of Sulfonamide + Side Effect:

- These are often **administered** orally but have a few side effects like **rashes, nausea, photosensitivity** and **kidney damage.**

(v) Mode of Sulfonamides Action:

(i) **Bacteriostatic Effect:** Sulfonamides do **not kill bacteria** immediately but inhibit their growth, allowing the body's **immune system** to destroy them.
(ii) **Selective Toxicity:** Sulfonamides are selectively toxic to bacteria because of how they handle folate. Bacteria **must build this** essential vitamin from scratch, whereas humans simply absorb it from food. This allows the **drug to starve** the bacteria of vital nutrients while leaving human cells untouched."

Check Understanding!

Q.5 Why are sulfonamides selectively toxic to bacteria while leaving human cells unharmed?
(A) Humans synthesize folate from scratch using PABA.
(B) Sulfonamides directly target human 80S ribosomes.
(C) Bacteria must build essential folate internally, whereas humans absorb it from food.
(D) Human cells lack cell walls entirely.

CamScanner

(iii) **Competitive Inhibition:** Sulfonamides bind to the enzyme responsible for creating folate, essentially taking para amino benzoic acid (PABA). Sulfonamides are structural analogues of PABA and competitively inhibit dihydropteroate synthase, blocking the folate synthesis.

(iv) **Combined Therapy:** They are often combined with other agents, like trimethoprim, to create a stronger bactericidal effect (killing bacteria).

(v) **Broad Spectrum:** They are effective against both Gram-positive and Gramnegative bacteria, often used for urinary tract infections, acne, and respiratory infections.

Q.12 Discuss the 4-classes of antibiotics, in relation to the following headings.
(a) Discovery. (b) Sources. (c) Reactions. (d) Target. L/Q

Ans.

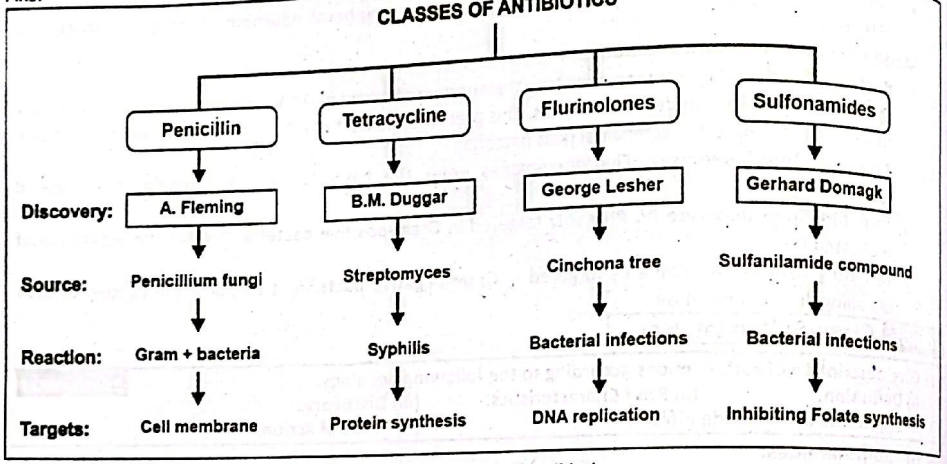


Figure: Classification of antibiotics

Multiple Choice Questions (MCQs)

		Key
1. Antibiotics are mainly classified by: (A) Mechanism. (B) Color. (C) Taste. (D) Price.		1.(A)
2. Which is a major class of antibiotics? (A) Insulin. (B) Penicillin. (C) Aspirin. (D) Paracetamol.		2.(B)
3. Which antibiotic class is derived from Streptomyces? (A) Penicillin. (B) Sulfonamides. (C) Tetracycline. (D) Fluoroquinolones.		3.(C)
4. Which antibiotic class is synthetic? (A) Fluoroquinolones. (B) Penicillin. (C) Tetracycline. (D) None.		4.(A)
5. Sulfonamides are derived from: (A) Penicillium. (B) Streptomyces. (C) Cinchona. (D) Sulfanilamide.		5.(D)
6. Why are antibiotics ineffective against viruses? (A) Low dose. (B) No target. (C) Poor taste. (D) High cost.		6.(B)
7. Why are antibiotics classified into different classes? (A) Different colors. (B) Different prices. (C) Different sizes. (D) Different actions.		7.(D)
8. Why do some antibiotics kill bacteria while others only stop growth? (A) Different mechanisms. (B) Same target. (C) Equal potency. (D) Same source.		8.(A)
9. Why is knowledge of antibiotic class important? (A) Faster packaging. (B) Better storage. (C) Correct therapy. (D) Easy transport.		9.(C)
10. Penicillin was discovered by: (A) Louis Pasteur. (B) Alexander Fleming. (C) Edward Jenner. (D) Robert Koch.		10.(B)
11. Penicillin is produced by: (A) Penicillium. (B) Aspergillus. (C) Rhizopus. (D) Saccharomyces.		11.(A)
12. Penicillin kills bacteria by preventing: (A) Protein synthesis. (B) DNA replication. (C) Cell wall synthesis. (D) ATP production.		12.(C)

		Key
13. Penicillin acts mainly during bacterial: (A) Resting. (B) Growth. (C) Sporulation. (D) Dormancy.		13.(B)
14. Why does penicillin have little effect on viruses? (A) No cell wall. (B) No nucleus. (C) No cytoplasm. (D) No enzymes.		14.(A)
15. Why is penicillin more effective against Gram-positive bacteria? (A) Thin capsule. (B) Large nucleus. (C) High ATP. (D) Thick peptidoglycan.		15.(D)
16. Why can some bacteria survive penicillin treatment? (A) More ribosomes. (B) β-lactamase. (C) Less DNA. (D) High glucose.		16.(B)
17. Tetracycline inhibits bacterial: (A) Cell wall. (B) DNA replication. (C) Protein synthesis. (D) Lipid synthesis.		17.(C)
18. Why is tetracycline called a broad-spectrum antibiotic? (A) Many bacteria. (B) One species. (C) One tissue. (D) One enzyme.		18.(A)
19. Why does tetracycline stop bacterial growth? (B) Breaks DNA. (C) Destroys walls. (D) Ruptures membrane. (A) Blocks proteins.		19.(D)
20. Why does tetracycline have little effect on human cells? (A) Different ribosomes. (B) No nucleus. (C) No enzymes. (D) No proteins.		20.(A)
21. Why is tetracycline ineffective against viruses? (A) No membrane. (B) No ribosomes. (C) No capsule. (D) No cytoplasm.		21.(B)
22. Fluoroquinolones mainly inhibit: (A) DNA gyrase. (B) Ribosomes. (C) Cell wall. (D) ATPase.		22.(A)
23. DNA gyrase is essential for: (A) Protein synthesis. (B) Cell division. (C) DNA replication. (D) Respiration.		23.(C)
24. Fluoroquinolones mainly interfere with: (A) Lipid synthesis. (B) Cell wall. (C) Glycolysis. (D) DNA synthesis.		24.(D)
25. DNA gyrase belongs to bacterial: (A) Enzymes. (B) Pigments. (C) Hormones. (D) Vitamins.		25.(A)
26. Why do fluoroquinolones kill bacteria? (A) Break proteins. (B) Destroy lipids. (C) Block DNA. (D) Remove capsule.		26.(C)
27. Why are fluoroquinolones ineffective against viruses? (A) No proteins. (B) No gyrase. (C) No membrane. (D) No capsule.		27.(B)
28. Why is DNA gyrase an effective drug target? (A) Cell pigment. (B) Energy source. (C) Waste product. (D) Essential enzyme.		28.(D)
29. Why are fluoroquinolones considered selective drugs? (A) Bacterial target. (B) Human target. (C) Plant target. (D) Viral target.		29.(A)
30. Sulfonamides mainly inhibit the enzyme: (A) DNA gyrase. (B) RNA polymerase. (C) Dihydropteroate synthase. (D) Ligase.		30.(C)
31. Sulfonamides mainly prevent: (A) Viral entry. (B) Fungal spores. (C) Cell lysis. (D) Bacterial growth.		31.(D)
32. Sulfonamides are generally: (A) Bacteriostatic. (B) Bactericidal. (C) Antiviral. (D) Antifungal.		32.(A)
33. Why are sulfonamides ineffective if excess PABA is present? (A) Cell rupture. (B) DNA mutation. (C) Competitive inhibition. (D) Protein loss.		33.(C)
34. Why do sulfonamides stop bacterial multiplication? (A) No folate. (B) No oxygen. (C) No glucose. (D) No membrane.		34.(A)
35. Why are sulfonamides considered selective drugs? (A) Human enzymes. (B) Human diet. (C) Human DNA. (D) Human ribosomes.		35.(B)

ANTIVIRAL AND ANTIRETROVIRALS DRUGS

Q.13 Differentiate between antiviral & antiretroviral drugs. S/Q

Ans.

Antiviral Drugs	Antiretroviral Drugs
• The drugs which are used to **treat viral infections** are called **antiviral drugs.** • They **prevent** the growth and multiplication of viruses within the body. • These medications can **combat** a wide range of viruses, including the **hepatitis, influenza, and herpes viruses.**	• The drugs which are designed to treat illnesses brought on by **retroviruses (like HIV)** are called **anti-retroviral drugs.** • They help in immune system defense and stop **HIV from proliferating.**

CamScanner

Q.14 What are retroviruses? S/Q

Ans. **Retroviruses:**

- The viruses that replicate by using enzyme reverse transcriptase and RNA as their genetic material are called **retroviruses.**
- **Example:** HIV (Human Immunodeficiency Virus).

> • All Antiretroviral are Antiviral but all Antiviral are not Antiretroviral.

Multiple Choice Questions (MCQs)				Key
1. Antiviral drugs are primarily used against: (A) Bacteria.	(B) Viruses.	(C) Fungi.	(D) Protozoa.	1.(B)
2. Antiretroviral drugs are mainly used to treat: (A) Influenza.	(B) Malaria.	(C) Tuberculosis.	(D) HIV/AIDS.	2.(D)
3. HIV belongs to the group of: (A) Retroviruses.	(B) Adenoviruses.	(C) Bacteriophages.	(D) Poxviruses.	3.(A)
4. Reverse transcriptase is an enzyme of: (A) E. coli.	(B) Fungi.	(C) HIV.	(D) Protozoa.	4.(C)
5. Reverse transcriptase converts: (A) RNA→DNA.	(B) DNA→RNA.	(C) DNA→Protein.	(D) RNA→Protein.	5.(A)
6. Antiretroviral drugs mainly inhibit: (A) Cell division.	(B) Digestion.	(C) Respiration.	(D) Viral replication.	6.(D)
7. Antiviral drugs are most effective by: (A) Breaking cell wall.	(B) Blocking replication.	(C) Inhibiting folate.	(D) Destroying ribosomes.	7.(B)
8. HIV primarily attacks: (A) RBCs.	(B) Platelets.	(C) Helper T-cells.	(D) Neutrophils.	8.(C)
9. Why are antiviral drugs selective? (A) Target viruses.	(B) Target bacteria.	(C) Target fungi.	(D) Target plants.	9.(A)
10. Why is combination therapy used for HIV? (A) Increase dosage.	(B) Lower immunity.	(C) Faster digestion.	(D) Reduce resistance.	10.(D)
11. Why do antiretroviral drugs control HIV but rarely eliminate it? (A) Latent virus.	(B) Weak immunity.	(C) High glucose.	(D) Low oxygen.	11.(A)

MONOCLONAL ANTIBODIES

Q.15 Describe the Monoclonal Antibodies and their advantages? Exercise L/Q.3

Ans. **Monoclonal Antibodies (mAbs):**

- **Monoclonal Antibodies** (mAbs) are lab-made proteins, cloned from a single parent cell and target to a specific antigen (cancer cell, protein or virus) to block their growth.
- The identical antibody molecules made by identical clones of a single parent cell, each binding one specific antigen (typically via hybridoma technology).
- **Highly Specific:** Monoclonal **antibodies target** specific antigens, making them effective for treating cancer, autoimmune **disorders,** and **infectious diseases.**

> **Check Understanding!**
> **Q.6 What fundamental characteristic distinguishes antiretroviral drugs from general antiviral medications?**

Advantages of Monoclonal Antibodies:

- Monoclonal antibodies are integral to personalized medicine, enabling tailored treatment approaches based on **individual** patient profiles.
- Continued innovation in these antibodies in design and production is critical to improve its effectiveness of therapies, ensuring they are better suited to each patient's unique biology.
- Monoclonal antibodies have significant advantages as;
  - (i) **Have Long Lasting Effects:** As compared to traditional drugs, they offer lower toxicity, potential for longlasting effects.
  - (ii) **Have Least Side Effects:** These have least side effects as compared to conventional chemotherapeutics.
  - (iii) **Have High Specificity:** These have high specificity, binding to a single target with minimal variability.
  - (iv) **Targeted Therapy of Cancer:** They provide targeted therapy in cancer, reducing damage to healthy tissues.
  - (v) **Easy Preparation:** These are easily prepared and used for research purpose.
  - (vi) **Have Less Drug Interactions:** They reduced the risk of drug interactions.
- The modern technologies enable the simultaneous testing of thousands of potential antibodies, reducing development timelines and enabling faster responses to urgent health challenges like infectious diseases and cancer.

> **Check Understanding!**
> **Q.7 Which of the following is a key advantage of monoclonal antibodies compared to conventional chemotherapeutic agents?**
> (A) They target all rapidly dividing cells indiscriminately.
> (B) They exhibit high specificity with minimal side effects.
> (C) They rely exclusively on natural plant extraction.
> (D) They induce high rates of adverse drug interactions.

Multiple Choice Questions (MCQs)				Key
1. Monoclonal antibodies are produced by: (A) Single clone.	(B) Many clones.	(C) T cells.	(D) RBCs.	1.(A)
2. Monoclonal antibodies are identical because they originate from: (A) Many B-cells.	(B) One B-cell.	(C) Macrophages.	(D) Neutrophils.	2.(B)
3. Cells formed by fusion of B-cells and myeloma cells are called: (A) Plasmids.	(B) Lymphocytes.	(C) Fibroblasts.	(D) Hybridomas.	3.(D)
4. Monoclonal antibodies are produced using: (A) Hybridoma technology.	(B) PCR.	(C) Fermentation.	(D) Cloning vectors.	4.(A)
5. Myeloma cells contribute: (A) Antibodies.	(B) Antigens.	(C) Immortality.	(D) Enzymes.	5.(C)
6. B-lymphocytes contribute: (A) Cell wall.	(B) Antibody specificity.	(C) DNA gyrase.	(D) Histamine.	6.(B)
7. Why are monoclonal antibodies highly specific? (A) Single epitope.	(B) Many antigens.	(C) Mixed cells.	(D) Many clones.	7.(A)
8. Why are myeloma cells fused with B-cells? (A) More antigens.	(B) Less DNA.	(C) Cell division.	(D) Continuous growth.	8.(D)
9. Why are monoclonal antibodies preferred over polyclonal antibodies in diagnosis? (A) Lower cost.	(B) Higher specificity.	(C) More proteins.	(D) Rapid growth.	9.(B)
10. Why can monoclonal antibodies target cancer cells selectively? (A) Large tumors.	(B) High glucose.	(C) Specific antigens.	(D) Rapid division.	10.(C)
11. Monoclonal antibodies are highly: (A) Specific.	(B) Variable.	(C) Toxic.	(D) Random.	11.(A)
12. Monoclonal antibodies are useful in: (A) Photosynthesis.	(B) Respiration.	(C) Digestion.	(A) Cancer therapy.	12.(D)
13. Monoclonal antibodies reduce: (A) Side effects.	(B) Blood flow.	(C) Cell size.	(D) Digestion.	13.(A)
14. Hybridoma technology enables: (A) DNA replication.	(B) Mass production.	(C) Cell division.	(D) Fermentation.	14.(B)
15. Why do monoclonal antibodies produce fewer side effects? (A) Specific binding.	(B) High dosage.	(C) Rapid metabolism.	(D) Low immunity.	15.(A)
16. Why are monoclonal antibodies preferred in disease diagnosis? (A) Low price.	(B) Easy storage.	(C) Small size.	(D) High accuracy.	16.(D)
17. Why can monoclonal antibodies selectively destroy cancer cells? (A) Target antigens.	(B) Break DNA.	(C) Digest proteins.	(D) Kill viruses.	17.(A)
18. Why are monoclonal antibodies valuable in modern medicine? (A) Targeted therapy.	(B) Increase mutations.	(C) Lower oxygen.	(D) Promote infection.	18.(A)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(B)	• Target validation confirms that the identified disease-causing molecule plays a critical role and that affecting it yields therapeutic results.
2.	S/Q	• Phase 1 tests a small group of 20 to 100 healthy volunteers to determine baseline safety and dosage, whereas Phase 2 evaluates effectiveness and side effects in a larger group of 100 to 300 patients.

CamScanner

3.	(A)	• Penicillin stops new cell wall synthesis by interrupting peptidoglycan cross-linking, causing the bacterial cell to burst and undergo lysis.
4.	S/Q	• They reversibly bind to the 30S ribosomal subunit to block protein translation, stopping bacteria from growing and multiplying rather than killing them outright.
5.	(C)	• Bacteria must synthesize their own folate via the PABA pathway, whereas humans absorb it from food, allowing the drug to selectively starve bacterial cells.
6.	S/Q	• While all antiretrovirals are antivirals, antiretrovirals are specifically designed to treat retroviruses (like HIV) that replicate using RNA and the reverse transcriptase enzyme.
7.	(B)	• Monoclonal antibodies provide high specificity to a single target, minimizing damage to healthy tissues and resulting in fewer side effects than conventional chemotherapy.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQS

1. **The first step in drugs discovery is ___ .**
   (a) Lead optimization. (b) Preclinical Testing. (c) Target identification. (d) Hit identification.
2. **Testing in a larger group about 100-300 patients to test the effectiveness and side effects of drugs indicate _____.**
   (a) Phase 1 (b) Phase 2 (c) Phase 3 (d) Phase 4
3. **Penicillin is highly effective against ___**
   (a) Gram-positive bacteria. (b) Gram-negative bacteria.
   (c) Streptomyces. (d) Penicillium notatum.
4. **The ___ antibiotic derived from soil-dwelling bacteria of the genus Streptomyces:**
   (a) Penicillin. (b) Fluoroquinolones. (c) Sulfonamides. (d) Tetracycline.
5. **The ___ drugs are synthetic compounds derived from sulfanilamide:**
   (a) Penicillin. (b) Fluoroquinolones. (c) Sulfonamides. (d) Tetracycline.
6. **Monoclonal antibodies are considered highly effective because:**
   (a) Have broad spectrum action. (b) Are highly specific to antigens.
   (c) Do not bind to any target. (d) Are non-biological in nature.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(c)	Target identification.	• Target identification is the initial foundational step in drug discovery where a specific molecular mechanism or disease pathway is selected.
2.	(b)	Phase 2	• Phase 2 clinical trials involve expanded testing on a larger group (typically 100 to 300 patients) to evaluate therapeutic effectiveness and common side effects.
3.	(a)	Gram-positive bacteria.	• Penicillin's chemical structure primarily targets and disrupts the peptidoglycan cell walls of Gram-positive bacterial species.
4.	(d)	Tetracycline.	• Tetracyclines are a prominent class of broad-spectrum antibiotics originally isolated from soil-dwelling actinobacteria of the genus Streptomyces.
5.	(c)	Sulfonamides.	• Sulfonamides represent a group of synthetic antimicrobial drugs that are chemically derived from sulfanilamide.
6.	(b)	Are highly specific to antigens.	• Monoclonal antibodies are engineered to target one unique epitope with high precision, maximizing effectiveness while minimizing off-target interactions.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 Briefly describe stages of drug developmental process?

Ans. Stages of Drug Developmental Process:

(i) **Preclinical Research:** In this stage the discovered compounds are tested in **vitro** (cell-based culture in lab) and in **vivo** (animal i.e. in living cell) to measure safety, toxicity, and efficacy before human trials.

(ii) **Clinical Trials:** Drugs are tested on humans to **ensure safety.**
- **Phase-1:** Testing in a **small group** (20 – 100) of healthy volunteers are taken to determine safety and dosage.
- **Phase-2:** Testing in a **larger group** (100-300) of patients to test the effectiveness and side effects of drugs.
- **Phase-3: Large-scale trials** (1000 – 3000) are taken to confirm the efficacy and monitor their adverse reactions in patients.

(iii) **Drug Review:** In the stage regulatory **agencies** like FDA thoroughly **examine** all the data collected through clinical research trials, to approve or reject the drugs before the final recommendations about drugs marketing.

(iv) **Manufacturing and Marketing:** Once approved, the drug is **produced** on a large scale in **pharmaceutical industries** and made available for medical use.

(v) **Post-Marketing Surveillance:** Even after release, the drug is **continuously monitored** for **long-term** effects and rare side effects to ensure ongoing safety in the population.

Q.2 Write side effects of Penicillin?

Ans. Side Effects of Penicillin:
- **Allergic Reactions:** Has mild skin rashes.
- **Gastrointestinal Issues:** Frequently causes nausea, vomiting, diarrhea, or abdominal discomfort.

Q.3 Write a mode of Tetracycline action?

Ans. Mode of Tetracycline Action:
- Include nausea, **vomiting, diarrhea, abdominal pain,** and **skin rashes.**

Q.4 Differentiate between antiviral and antiretroviral drugs?

Ans.

Antiviral Drugs	Antiretroviral Drugs
• Broad-spectrum medications designed to treat various viral infections by inhibiting specific stages of the viral replication cycle.	• A specialized subclass of antivirals specifically targeted at retroviruses like HIV to suppress viral replication and reduce viral load.

Q.5 What are the advantages of monoclonal antibodies?

Ans. Advantages of Monoclonal Antibodies:
- Monoclonal antibodies are integral to personalized medicine, enabling tailored treatment approaches based on **individual** patient profiles.
- Continued innovation in these antibodies in design and production is critical to improve its effectiveness of therapies, ensuring they are better suited to each patient's unique biology.
- Monoclonal antibodies have significant advantages as;
  (i) **Have Long Lasting Effects:** As compared to traditional drugs, they offer lower toxicity, potential for longlasting effects.
  (ii) **Have Least Side Effects:** These have least side effects as compared to conventional chemotherapeutics.
  (iii) **Have High Specificity:** These have high specificity, binding to a single target with minimal variability.
  (iv) **Targeted Therapy of Cancer:** They provide targeted therapy in cancer, reducing damage to healthy tissues.
  (v) **Easy Preparation:** These are easily to prepare and used for research purpose.
  (vi) **Have Less Drug Interactions:** They reduced the risk of drug interactions.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Describe the essential steps for the drug discovery and developmental process?

Ans. See Page No. 322 (Q.5)

CamScanner

Q.2 Explain different type of antibiotics. Describe their mode of action.

Ans. See Page No. 323 – 325 (Q.6 ⟶ Q.11)

Q.3 Describe the Monoclonal Antibodies and their advantages?

Ans. See Page No. 328 (Q.15)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Predict the challenges the scientists may face during drug development process and propose possible solutions.

Ans. The Scientists may Face During Drug Development Process:

- **Challenges:** Scientists encounter high attrition rates during clinical trials, severe unexpected toxicity, poor pharmacokinetic profiles, and massive financial investments coupled with lengthy timelines.
- **Solutions:** Mitigate these challenges by employing computer-aided drug design (CADD) for early screening, utilizing high-throughput screening technologies, and implementing adaptive clinical trial designs to optimize safety and efficacy evaluations.

Q.2 Assess the possible consequences of the misuse and overuse of antibiotics on human health.

Ans. Consequences of the Misuse and Overuse of Antibiotics on Human Health:

- **Resistance:** Overuse accelerates the natural selection of resistant microbial strains, rendering standard treatments ineffective and leading to untreatable superbug infections.
- **Microbiome Disruption:** Broad-spectrum antibiotic misuse decimates beneficial commensal gut microflora, resulting in secondary opportunistic infections like Clostridioides difficile and long-term digestive imbalances.

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. **(1 x 6 = 06)**

(i) The ___ antibiotic derived from soil-dwelling bacteria of the genus Streptomyces:
(A) Penicillin. (B) Fluoroquinolones. (C) Sulfonamides. (D) Tetracycline.

(ii) Drug development ensures:
(A) Soil fertility. (B) Crop yield. (C) Drug quality. (D) Cell division.

(iii) Which antibiotic class is derived from Streptomyces?
(A) Penicillin. (B) Sulfonamides. (C) Tetracycline. (D) Fluoroquinolones.

(iv) Why are sulfonamides ineffective if excess PABA is present?
(A) Cell rupture. (B) DNA mutation. (C) Competitive inhibition. (D) Protein loss.

(v) Reverse transcriptase is an enzyme of:
(A) E. coli. (B) Fungi. (C) HIV. (D) Protozoa.

(vi) Why are monoclonal antibodies preferred over polyclonal antibodies in diagnosis?
(A) Lower cost. (B) Higher specificity. (C) More proteins. (D) Rapid growth.

Q.2 Write short answers of the following questions. **(2 x 8 = 16)**

(i) Define pharmacology, which type of studies are covered in this branch.
(ii) What are fluoroquinolones? Who discovered this class of antibiotics?
(iii) Differentiate between antiviral and antiretroviral drugs?
(iv) What are retroviruses?
(v) Write side effects of Penicillin?
(vi) What are antibiotics and name its 4-clases?
(vii) Differentiate between antiviral & antiretroviral drugs.
(viii) What are the advantages of monoclonal antibodies?

Q.3 Extensive Questions. **(4 x 2 = 8)**

(a) Write a note on discovery, common side effects, & mode of action of penicillin.
(b) Explain different type of antibiotics. Describe their mode of action.

24 CHAPTER

EVOLUTION

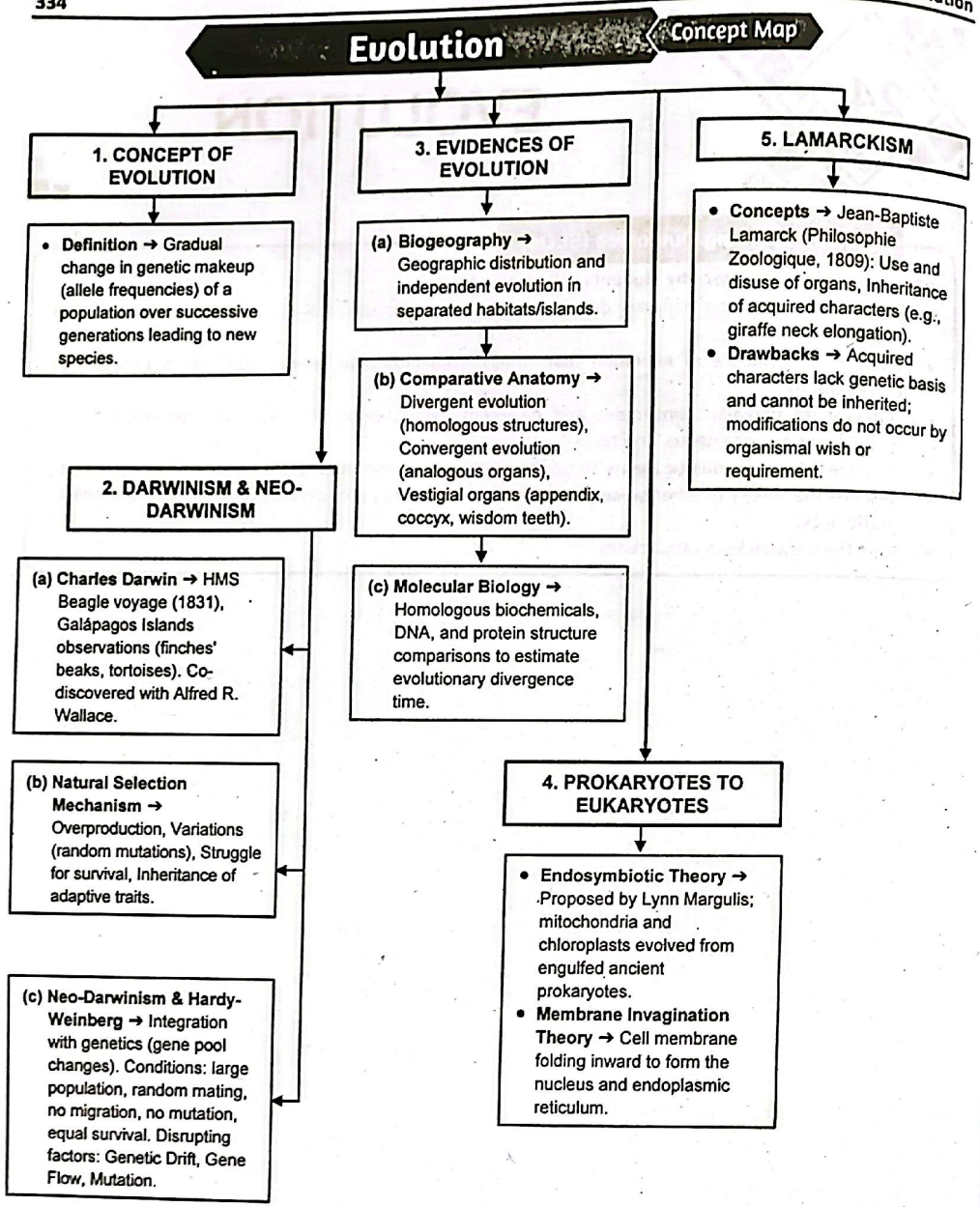
Student Learning Outcomes (SLOs)

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

- Explain that evolution happens due to variation in organisms and the selection pressures that organisms face.
- Analyze the evidence of evolution that comes from molecular biology and that is provided by biogeography.
- Differentiate between convergent and divergent evolution on the basis of inheritance of the homologous and analogous structures.
- Describe the endosymbiotic theory about the mechanism of evolution of eukaryotes from prokaryotes.
- Describe the theory of inheritance of acquired characters, as proposed by Lamarck with example of giraffe neck.
- State the drawbacks in Lamarckism.

CamScanner

Evolution Concept Map



INTRODUCTION

Chapter's Intro:

- This chapter would deliver us the concept of evolution of life through the theories put forwarded by different scientists.
- We will also analytically review the major evidence that form the basis of the most accepted theory of evolution.

Q.1 What is creationism? S/Q

Ans. Creationism:

- It is a theory also known as "Theory of Intelligent Design".
- **According to this theory:** All organisms were created as such as they exist today.

Q.2 Who are creationists? S/Q

Ans. Creationists:

- **Creationists:** These are the believers of creationism & claim that each type of organism was created individually and did not go or evolution through any change throughout the history.

THE CONCEPT OF EVOLUTION

Q.3 Define the term evolution & discuss the basic idea about evolution. L/Q

Ans. Evolution:

- The gradual change in the genetic makeup (allele frequencies) of a population over successive generations is called evolution.
- Evolution may lead to the formation of new species.

Basic Ideas About Evolution:

- In its earliest form, the concept of evolution had the following basic speculations:
  - Today's organisms the universe and organisms did not always exist in their present form.
  - Today's organisms were not created at once.
  - Today's organisms are the result of innumerable changes from the lower to the higher form.
- Evolution takes place due to variations in organisms and natural selection.
- According to this idea, organisms with beneficial traits are selected to produce next generations.
- On the other hand, the individuals with disadvantageous traits cannot produce next generations.
- It results in the increase in the percentage of individuals with better traits in populations.

Check Understanding!

Q.1 According to early speculations and modern scientific principles, how is evolution primarily defined in populations over successive generations?

(A) Spontaneous generation from non-living matter.
(B) Gradual change in the genetic makeup (allele frequencies).
(C) Independent creation of each species without historical change.
(D) Fixed permanence of physical traits across all individuals.

Q.4 What is spontaneous generation? S/Q

Ans. Spontaneous Generation:

- Early people also believed that living creatures can also develop from non-living matter. It was called idea of spontaneous generation.
- With the progress of science, the experiments disproved spontaneous generation but such experiments could not negate creationism.

CamScanner

Multiple Choice Questions (MCQs)

		Key
1.	Evolution is defined as the gradual change in the _____ of a population over successive generations. (A) Body size. (B) Genetic makeup. (C) Chromosome number. (D) Population size.	1.(B)
2.	The early idea that living organisms develop from non-living matter was called: (A) Natural selection. (B) Creationism. (C) Spontaneous generation. (D) Adaptation.	2.(C)
3.	According to the concept of evolution, evolution occurs due to: (A) Hybridization only. (B) Mutation & natural selection. (C) Artificial selection only. (D) Variations & natural selection.	3.(D)
4.	Charles Darwin travelled around the world as a naturalist aboard: (A) HMS Victory. (B) HMS Beagle. (C) HMS Discovery. (D) HMS Endeavour.	4.(B)
5.	Darwin's voyage lasted for approximately: (A) 2 years. (B) 3 years. (C) 5 years. (D) 10 years.	5.(C)
6.	Darwin observed giant tortoises with different shell shapes on the: (A) Hawaiian Islands. (B) Galapagos Islands. (C) Canary Islands. (D) Andaman Islands.	6.(B)
7.	According to Darwin, differences in the beaks of finches were adaptations for: (A) Feeding on different kinds of food. (B) Flying longer distances. (C) Escaping predators. (D) Building nests on different trees.	7.(A)
8.	Darwin published his book On the Origin of Species in: (A) 1831 (B) 1857 (C) 1858 (D) 1859	8.(D)
9.	Which of the following is the first point of Darwin's theory of natural selection? (A) Variations. (B) Struggle for survival. (C) Overproduction. (D) Inheritance of adaptive traits.	9.(C)

THEORY OF EVOLUTION - DARWINISM

Q.5 Who was Charles Darwin? Name the ship on which he travelled as a naturalist? S/Q

Ans. Charles Darwin:

- He was an English scientist.
- **In 1831,** he travelled as a naturalist on scientific **expedition** (Journey) on **His Majesty's Ship** called the **HMS Beagle.**
- He made a **5 -year** voyage around the world.

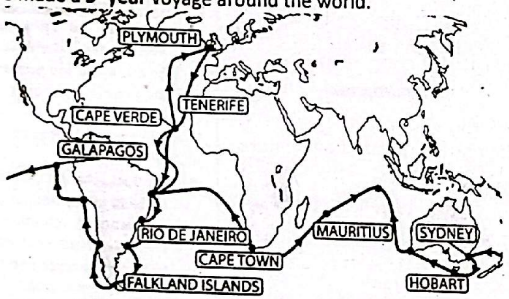


Figure: Main stop in the route of HMS Beagle



Figure: Charles Darwin

Q.6 What were observations made by Darwin during his voyage? L/Q

Ans. Darwin's Observations During His Voyage:

(i) Observe Great Diversity in Plants & Animals:

- During the **long voyage,** Darwin visited tropical rainforests and other new habitats where he saw great **diversity in plants** and animals that he had never seen before.

(ii) Observe Fossils:

- He also found rocks containing fossils.
- These observations suggested that continents and oceans had changed **dramatically** over time and continue to change.

- He dug up fossils of gigantic extinct mammals and found that organisms looked very different in the past. It suggested that living things change over time.

(iii) Observations At Galapagos Islands:

- He visited the **Galápagos Islands** (a group of **13 major and 6 minor islands**).
- He noticed that the plants and animals on different islands were very different.

Example:

(a) Observe Tortoises: The giant tortoises on one island had saddle-shaped shells, while those on another island had dome-shaped shells.

(b) Observe Plants & Animals: Many plants and animals resembled more with the plants and animals of **South America,** rather than with other islands.

(c) Observe Birds: Different species of the common birds i.e., finches had different beaks. He found that differences in the **sizes** and shapes of **beaks** were actually adaptations for feeding on completely different kinds of food at different islands.

Check Understanding!
Q.2 What did Charles Darwin conclude regarding the diverse sizes and shapes of beaks among finches on the Galápagos Islands?

Explanation of Darwin About the Origin of Separate Species:

- Darwin thought over the **adaptations** in birds, he observed at different islands and tried to **develop** an **explanation** for the distribution of finches species among the **islands.**
- He thought that the **origin of new** species and **adaptations** are closely related **processes.**
- A new **species** would arise from an ancestral form by the gradual accumulation of adaptations to different environment, separated from **original habitat.**
- Over many generations, the **two populations** could become dissimilar enough to be designated as **separate species.**

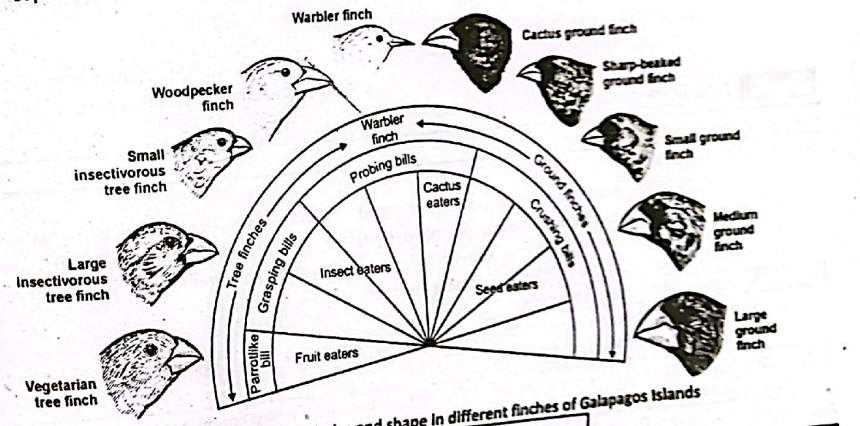


Figure: Adaptations in beak size and shape in different finches of Galapagos Islands

Topic: Mechanism of Evolution - Natural Selection: S/Q

Q.7 Who was Charles Darwin & what was his contribution with reference of evolution?

Ans. Charles Darwin:

- **Charles Darwin (1809 1882)** was the founder of the **modern theory of evolution.**
- **In 1859, he published** his book **"On the Origin of Species".**
- In this book, he proposed that **evolution** takes place due to variations in organisms through natural selection.

CamScanner

Q.8 Explain the theory of natural selection as proposed by Darwin.
OR Discuss the four points of Darwin's theory of Natural Section about evolution. Exercise L/Q.1, L/Q.2 L/Q

Ans. Darwin's Theory of Evolution (Natural Selection):

- The essence of his theory is as follows:

(i) Overproduction:

- All organisms have a far **greater reproductive** potential than is ever realized.
- **Example:** A female **sea star** releases about **1 million eggs** each season. What if all of **these eggs were fertilized** and developed to reproductive adults by the following year?
- A half million female sea stars (half of the million eggs would produce females and half would produce males), each producing another million eggs, repeated over just a few generations would soon fill up the oceans!

(ii) Variations:

- Genetic variations arise by **random mutations.** Seldom are any two individuals exactly alike.
- These genetic **variations** may be advantageous, harmful or neutral (neither helpful nor harmful). Inherited variations can be passed on to offspring.

(iii) Struggle for Survival:

- Because many **more offspring** are produced than resources can **support** thus individuals struggle for survival.
- The **individuals** with **disadvantageous** variations die or cannot **reproduce.**
- **Individuals with advantageous** variations remain successful in reproduction. Such variations are called adaptive traits.

(iv) Inheritance of Adaptive Traits:

- Adaptive traits are inherited to next generations. Because organisms with **disadvantageous** traits are less likely to reproduce, such traits become less frequent in a population and eventually are eliminated.

- **Alfred R. Wallace (1823-1913):** He was a British naturalist and biologist who also developed his own theory on the mechanism of evolution. In 1858, he wrote a letter to Darwin.
- In **Wallace's letter,** the proposed mechanism of evolution was very similar to the theory of Darwin.
- When **both Darwin's** and Wallace's theories were presented to the Linnaean Society in 1858, Wallace agreed to attribute the theory to Darwin. He convinced Darwin to publish his book **"On the Origin of Species".**

Topic: Neo-Darwinism:

Q.9 What is Neo-Darwinism? S/Q

Ans. Neo-Darwinism:

- In the early **20th century,** the Darwinism was **integrated** with modern genetics to develop Neo-Darwinism.
- According to **Neo-Darwinism,** a more **precise definition** of evolution is "a change in the frequency of alleles in a population or in the total genetic makeup of a population (the gene pool)" is called **evolution.**
- Neo-Darwinism is based on **Hardy-Weinberg Theorem.**

Topic: Hardy-Weinberg Theorem:

- In **1908,** English mathematician **Godfrey Hardy** and German physician **Wilhelm Weinberg** presented Hardy-Weinberg theorem.

Q.10 Define the Hardy-Weinberg theorem. According to this theorem if which conditions are not followed does evolution take place. Discuss. L/Q

Ans. Hardy-Weinberg Theorem:

- It **states** that the **frequencies** of alleles and genotypes in a large, randomly **mating population** remain constant from generation to generation, if no evolutionary forces are acting.

➢ **Condition which Inhibit Evolution:**

- According to Hardy-Weinberg theorem, if any of the following conditions is **not met,** allelic/gene frequencies change and evolution takes place.

(i) **Large Population Size:** The population size must be large.
(ii) **Random Mating:** Mating within the population must be random. Every individual must have an equal chance of mating with any other individual.
(iii) **No Migration:** Individuals must **not migrate** into or out of the population.
(iv) **No Mutation:** Mutations must **not occur.** If they do, mutations from the wild-type allele to mutant allele must be equal to mutations from the mutant form back to the wild type.
(v) **Equal Survival Chance:** All genotypes must have an equal chance of survival and **reproduction.**

For Information

- **Gene Pool:** The total collection of all alleles in individuals of a population is called **gene pool**
- **Allele (Gene) Frequency:** The number or proportion of a specific allele in the population is called **allele frequency.**
- **Example:** If 600 out of 1000 genes are for red colour, the allele frequency of red is 0.6(60%)
- **Genotype Frequency:** The number or proportion of individuals with a particular genotype in a population is called genotype frequency
- **Example:** If 40 out of 100 plants are RR, the genotype frequency of RR is 0.4(40%).

Q.11 Define allele frequency and discuss the factors which can change the allelic frequencies. L/Q

Ans. Allele Frequency:

- The number or proportion of a specific allele in the population is called **allele frequency.**

➢ **Factors Which Change the Allelic Frequencies:**

- The following are the **factors** due to which the **Hardy-Weinberg assumptions** are not met and changes in allelic frequencies occur from one generation to the next.

(1) Genetic Drift:

- The events by chance can influence or change the **frequencies of genes** in populations is called genetic drift.
- Unlike natural selection, these changes occur by chance - not fitness - and are most obvious in small populations.
- **Example:** A population of rabbits is reduced from **100 to 10** by a fire. The survivors happen to be mostly **brown,** not because they were better adapted, but by chance. The resulting population will have lower **genetic diversity.**

(2) Gene Flow:

- The **Hardy-Weinberg** theorem assumes that **no individuals** enter a population from the outside **(immigrate)**
- No individuals leave a population **(emigrate).**
- The **entry** of **individuals** from another population can introduce new alleles, instantly changing local gene **frequencies (evolution).**
- **Gene Flow:** Changes in gene **frequency** due to migration of individuals are called **gene flow.**

(3) Mutation:

- The Hardy-Weinberg theorem assumes that **no mutations** occur or that mutational **equilibrium** exists. Mutations, however, are a fact of life.
- Most importantly, mutations are the **origin** of all new genes and a source of variations that may prove adaptive for an organism.
- Mutations also **make sure** that variations will be present that allow a group to survive environmental shocks more successfully.

Check Understanding!

Q.3 Which of the following conditions **is not required for a population to maintain genetic equilibrium under the Hardy-Weinberg theorem?**
(A) Large population size.
(B) Random mating within the population.
(C) Migration of individuals into or out of the population.
(D) Absence of net mutations.

➢ **Effects of Mutations:**

- The effects of mutations vary.
- Most are **deleterious.** Some may be neutral or harmful in one **environment** and help an organism survive in another environment.

CamScanner

- **Mutational equilibrium** exists when a mutation from the wild-type allele to a mutant form is balanced by mutation from the mutant back to the wild type. This has the same effect on allelic frequency as if no mutation occurred. However, mutational equilibrium rarely exists.
- **Mutation Pressure:** A measure of the tendency for gene frequencies to change through mutation.

Multiple Choice Questions (MCQs)	Key
1. Neo-Darwinism was developed by integrating Darwinism with: (A) Cell biology. (B) Modern genetics. (C) Embryology. (D) Ecology.	1.(B)
2. According to Neo-Darwinism, evolution is defined as a change in the: (A) Number of species. (B) Number of chromosomes of population. (C) Body size of organisms. (D) Frequency of alleles in a population.	2.(D)
3. Neo-Darwinism is based on the: (A) Hardy-Weinberg Theorem (B) Cell Theory. (C) Lamarck's Theory. (D) Germ Theory.	3.(A)
4. The Hardy-Weinberg Theorem was presented in: (A) 1859. (B) 1831. (C) 1908. (D) 1953.	4.(C)
5. According to the Hardy-Weinberg Theorem, mating within a population must be: (A) Selective. (B) Random. (C) Seasonal. (D) Limited.	5.(B)
6. The total number of all genes for a trait in a population is called the: (A) Allele frequency. (B) Genotype frequency. (C) Mutation pressure. (D) Gene pool.	6.(D)
7. If 600 out of 1000 genes are for red flower colour, the allele frequency of the red allele is: (A) 0.4. (B) 0.5. (C) 0.6. (D) 0.8.	7.(C)
8. Changes in gene frequency due to migration of individuals are called: (A) Gene flow. (B) Mutation. (C) Genetic drift. (D) Natural selection.	8.(A)
9. Genetic drift is also known as: (A) Artificial selection. (B) Neutral selection. (C) Sexual selection. (D) Adaptive radiation.	9.(B)
10. Mutation pressure refers to the tendency for gene frequencies to change through: (A) Migration. (B) Random mating. (C) Overproduction. (D) Mutation.	10.(D)

EVIDENCES OF EVOLUTION

Topic: Evidence from Biogeography:

Q.12 Explain how does biogeography provide evidence for evolution. Exercise L/Q.3
OR Define biogeography & explain how does biogeography provide evidence for evolution? L/Q

Ans. Biogeography:

- The study of the **geographic distribution** of **plants and animals on planet Earth** is called biogeography.

Evidence of Evolution From Biogeography:

- Biogeography shows that **life-forms** in different parts of the world have distinctive evolutionary histories.

➢ **Examples From Biogeography As Evidence of Evolution:**

(i) African Ostrich + South American Rhea:

- Similar groups of organisms live in places separated by vast barriers. Obvious similarities suggest a common **ancestry,**
- Similarly obvious differences result from millions of years of independent evolution.
- **Examples:** The **African ostrich** and he **South American rhea** (large flightless bird) are both large, long-legged, flightless birds. They are **two species** but look remarkably alike.
- Their shared traits suggest they evolved from a common ancestor that lived on a single landmass before the continents drifted apart.
- Over millions of years of **separation, independent** evolution in their own environments led to the distinct differences seen between the **two species.**

(ii) Animals of Australia + Tasmania:

- Organisms separated by geographical barriers, are often very different in spite of similar environments.
- **Example:** Many animals living in d**Australia** and **Tasmania** are very different from animals in any other part of the world. Many species of kangaroos are the major **herbivores** of Australia and Tasmania.

Check Understanding!
Q.4 How does genetic drift differ from natural selection in affecting population gene frequencies?

(iii) Species on Islands:

- Islands often have relatively a few but unique species due to island colonization and subsequent evolutionary events.

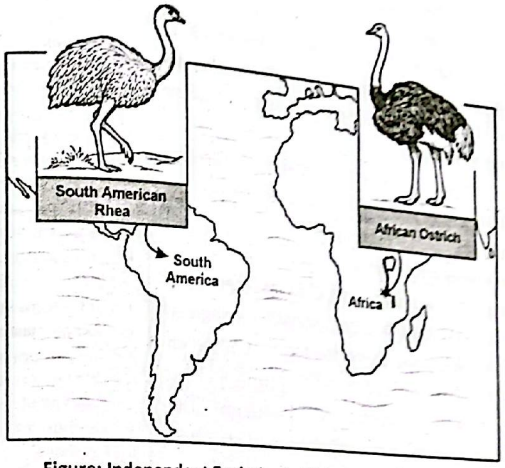


Figure: Independent Evolution in Flightless Birds

Topic: Evidence from Comparative Anatomy:

Q.13 Define the term comparative anatomy. S/Q

Ans. Comparative Anatomy:

- The scientific study of **similarities and difference** in the structure & body parts of different animals species is called **comparative anatomy.**

Q.14 Describe the evidences of evolution that come from comparative anatomy. Exercise L/Q.4, L/Q.5

- Comparative anatomists study the structure of fossils as well as **living organisms,** looking for similarities that could indicate evolutionary relationships.

➢ **Types of Evolution:**

- This study reveals two types of evolution.

(a) Divergent evolution:

- **Homologous Structure:** Body parts that are **similar** in structure but different in function are called **homologous structures** and this phenomenon is called **homology.**
- The evolution of homologous **structures** is called **divergent evolution** which means that the organisms with **homologous** structures have a common **ancestor** and **evolved** into different types and used their structures for different functions.

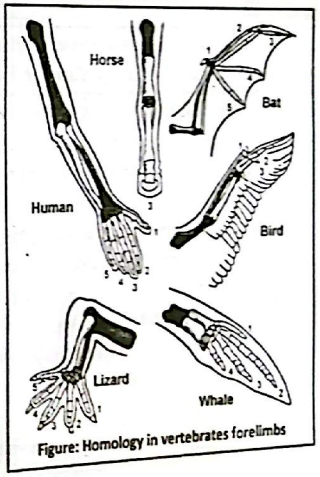


Figure: Homology in vertebrates forelimbs

Examples of Homologous Structures:

- Vertebrate appendages have a common arrangement of similar bones, even though the function of the appendages may vary.
  - **(i) Appendges for Flights:** Birds and Bats.
  - **(ii) Appendges for Swimming:** Whales and Dolphins.

CamScanner

(iii) **Appendges for Running:** Horses.

(iv) **Appendges for Climbing or Swinging from Tree Branches:** Arboreal lizard.

- All the above Appendges are homologous structures.

Check Understanding!

Q.5 Vertebrate forelimbs used for flying, swimming, running, or climbing that share a common bone structure demonstrate which evolutionary phenomenon?

(A) Divergent evolution via homologous structures.
(B) Convergent evolution via analogous organs.
(C) Spontaneous generation of functional traits.
(D) Vestigial regression of unused limbs.

(b) Convergent Evolution:

- **Analogous Organs:** The organs which are **similar in function** but **differ in structure** are called **analogous organs. The evolution of analogous organ is called convergent evolution.**
- The evolution in which unrelated organisms independently evolve similar structures in response to similar environmental demands.

Example of Analogous Structure:

- The wing of a **bird** and the **wing of an insect** are both adaptations for flight, but they are **not homologous.**
- Any similarities simply reflect the fact that, to fly, an animal must have a broad, flat gliding surface.

- **Vestigial organs As Evidence of Evolution:** The structures that have lost their usefulness and are often poorly developed and are called vestigial structures.

Vestigial Structures in Humans:

- There are about **90 vestigial structures** present in human body e.g.,
- **Vermiform appendix is** a vestige of the cecum.
- **Coccyx** or tailbone is the remnant of tail.
- The wisdom teeth are vestigial third molars that human ancestors used to help in grinding down plant tissue.
- **Ear muscles** are minimally developed and non-functional, but some people are able to move their ears in various directions.

Example of Vestigial Organism:

- Some snakes like **boa** constrictors and pythons have minute remnants of hind limb (pelvic) bones left over from appendages of their reptilian ancestors.
- Such remnants of once useful structures are clear indications of change i.e., evolution.

Topic: Evidence from Molecular Biology:

Q.15 Describe the evidences of evolution that come from molecular biology. Exercise L/Q.6
OR What is molecular biology, discuss molecular biology as evidence of evolution? L/Q

Ans. Molecular Biology As Evidence of Evolution:

- Recently, molecular biology has yielded a wealth of information on evolutionary relationships.
- As animals can have homologous structures, they may also have **homologous biochemical.**
- Ultimately, **structure and function** are based on the genetic blueprint (DNA molecule) found in all living animals.

Q. How microorganisms have evolved resistance to antibiotics?

Ans. Antibiotic resistance means that bacteria are able to survive under the exposure of an antibiotic. It may be due to mutations in bacterial genes. A gene for antibiotic resistance which had evolved via natural selection passes to next generations of bacteria.

(a) Similarity in DNA & Proteins:

- Related animals have similar DNA derived from their **common** ancestor.
- Because DNA carries the codes for proteins that make up each animal, related animals have similar proteins.
- Scientists can extract and analyse the structure of DNA and proteins of different organisms.
- By **looking** for **dissimilarities** in the **structure of related proteins** and DNA, and by assuming relatively constant **mutation rates,** scientists can estimate the **elapsed** time since evolution from a common ancestral molecule.

Check Understanding!

Q.6 What do human vestigial structures like the vermiform appendix or coccyx indicate about evolutionary history?

Multiple Choice Questions (MCQs)

	Key
1. Biogeography is the study of the geographic distribution of: (A) Rocks and minerals. (B) Plants and animals. (C) Fossils only. (D) Microorganisms only.	1.(B)
2. Similarities between the African lion and the mountain lion of America suggest: (A) Independent origin. (B) Artificial selection. (C) Spontaneous generation. (D) Common ancestry.	2.(D)
3. Animals in Australia and Tasmania are very different from those in other parts of the world mainly because of: (A) Similar climates. (B) Geographical isolation. (C) Artificial breeding. (D) Hybridization.	3.(B)
4. Islands often possess relatively few but unique species due to: (A) Colonization & subsequent evolutionary events. (B) Selective breeding. (C) Constant migration. (D) Random mating.	4.(A)
5. Structures that are similar in structure but different in function are called: (A) Analogous structures. (B) Vestigial structures. (C) Homologous structures. (D) Adaptive structures.	5.(C)
6. Homologous structures provide evidence for: (A) Convergent evolution. (B) Divergent evolution. (C) Artificial selection. (D) Mutation pressure.	6.(B)
7. Organs that are similar in function but different in structure are known as: (A) Homologous organs. (B) Vestigial organs. (C) Analogous organs. (D) Rudimentary organs.	7.(C)
8. The wing of a bird and the wing of an insect are examples of: (A) Analogous organs. (B) Homologous organs. (C) Vestigial organs. (D) Rudimentary organs.	8.(A)
9. Poorly developed structures that have lost their usefulness are called: (A) Adaptive organs. (B) Analogous organs. (C) Vestigial structures. (D) Homologous structures.	9.(C)
10. Which of the following is mentioned as a vestigial structure in humans? (A) Femur. (B) Vermiform appendix. (C) Liver. (D) Heart.	10.(B)

EVOLUTION FROM PROKARYOTES TO EUKARYOTES

Q.16 Who were the earliest organisms on Earth? When were those organisms originated? S/Q

Ans. Earliest Organisms on Earth:

- The earliest known organisms on the Earth **were prokaryotes.**
- **Origin of Earliest Organisms:** These organisms were originated in a very **unstable** environment from the reactions of organic molecules about **3.5 billion years ago.**
- **Evolved Eukaryotes from Prokaryotes:** About **2 billion** years ago, eukaryotes evolved from prokaryotes.

Q.17 Describe the endosymbiont theory about the evolution of eukaryotes from prokaryotes. L/Q

Ans. Endosymbiotic Theory And Evolution of Eukaryotes from Prokaryotes:

- The **"Endosymbiotic Theory"** is the most acceptable theory for the evolution of prokaryotes into eukaryotes.
- This theory was proposed by Lynn Margulis.
- According to this theory, large prokaryotes engulfed small prokaryotes.
- The small prokaryotes were **not digested** by the larger ones. Instead, they lived within the large cells and evolved into **organelles.**
- Then the large and small prokaryotes formed a symbiotic relationship in which both cells benefited.

Membrane Invagination Theory:

- Another theory called **"Membrane Invagination Theory"** also explains the evolution of eukaryotes.
- **According to this theory:** The cell membrane of prokaryotic cell invaginated in the cytoplasm.
- It gave rise to some membranous structures including nucleus and endoplasmic reticulum inside prokaryotic cell.
- It resulted in the formation of a eukaryotic cell.

(a) Evolution of Mitochondrion:

- Some of the small prokaryotes were able to do **aerobic respiration.**
- They supplied energy not only to themselves but also to the large cell.
- They became the mitochondria of eukaryotic cells.

CamScanner

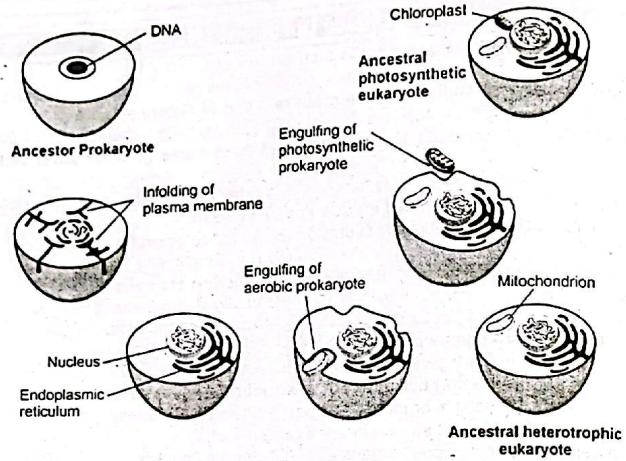


Figure: Evolution of Eukaryote

(b) Evolution of Chloroplast:

- Other small cells were able to use sunlight to make food. They **shared** the food with the **large cell.** They became the chloroplasts of **eukaryotic cells.**

(c) Evolution of Flagella:

- Similarly, it is proposed that flagella might have evolved through the ingestion of prokaryotes similar to spirochetes.
- Eukaryotic cells, evolved by endosymbiosis, were powerful and efficient. Their power and efficiency enabled them to evolve new characteristics e.g., multicellularity, cell specialization, and large size.
- They were the key to the spectacular diversity of animals, plants, and fungi that populate our world today.

Check Understanding!

Q.7 Which cellular organelles are credited by the Endosymbiotic Theory to have originated from engulfed small prokaryotes living symbiotically within larger cells?

(A) Ribosomes and Lysosomes.
(B) Mitochondria and Chloroplasts.
(C) Endoplasmic reticulum and Golgi bodies.
(D) Centrioles and Nuclear membranes.

Q.18 Discuss are the evidences for endosymbiotic theory. S/Q

Ans. Evidences For Endosymbiotic Theory:

(i) Similarity in Size: Mitochondria (and chloroplasts) are of the same size as prokaryotic cells.

(ii) Similarity in DNA: Mitochondria (and chloroplasts) have their own DNA. Their DNA is organized in a circular chromosome like a prokaryotic chromosome.

(iii) Division By Binary Fission: Mitochondria (and chloroplasts) can reproduce by binary fission like prokaryotes. In contrast, eukaryotic cells reproduce by mitosis.

(iv) Similarity in membrane Composition: The membrane composition of mitochondria (and chloroplasts) is more similar to prokaryotic membranes than to eukaryotic membranes.

Multiple Choice Questions (MCQs)

		Key
1.	**The earliest organisms on Earth were:** (A) Eukaryotes. (B) Prokaryotes. (C) Fungi. (D) Algae.	1.(B)
2.	**The earliest prokaryotes originated about:** (A) 2 billion years ago. (B) 3.5 billion years ago. (C) 4.5 billion years ago. (D) 500 billion years ago.	2.(B)
3.	**Eukaryotic cells evolved from prokaryotes approximately:** (A) 500 million years ago. (B) 1 billion years ago. (C) 2 billion years ago. (D) 3.5 billion years ago.	3.(C)
4.	**The most acceptable theory explaining the evolution of prokaryotes into eukaryotes is the:** (A) Cell Theory. (B) Membrane Invagination Theory. (C) Endosymbiotic Theory. (D) Germ Theory.	4.(C)

		Key
5.	**The Endosymbiotic Theory was proposed by:** (A) Charles Darwin. (B) Alfred R. Wallace. (C) Lynn Margulis. (D) Godfrey Hardy.	5.(C)
6.	**According to the Endosymbiotic Theory, mitochondria originated from small prokaryotes capable of:** (A) Photosynthesis. (B) Aerobic respiration. (C) Nitrogen fixation. (D) Fermentation.	6.(B)
7.	**Chloroplasts originated from small prokaryotes that could:** (A) Perform aerobic respiration. (B) Produce spores. (C) Use sunlight to make food. (D) Carry out mitosis.	7.(C)
8.	**Flagella may have originated from prokaryotes similar to:** (A) Cyanobacteria. (B) Spirochetes. (C) Archaea. (D) Cocci.	8.(B)
9.	**According to the Membrane Invagination Theory, invagination of the cell membrane of prokaryote gave rise to the:** (A) Nucleus & endoplasmic reticulum. (B) Cell wall & ribosomes. (C) Chloroplast & mitochondria. (D) Golgi apparatus & Ribosomes.	9.(A)
10.	**Mitochondria and chloroplasts reproduce in a manner similar to prokaryotes by:** (A) Mitosis. (B) Meiosis. (C) Binary fission. (D) Budding.	10.(C)
11.	**Which observation provides evidence supporting the Endosymbiotic Theory?** (A) Mitochondria reproduce like eukaryotic cells. (B) Mitochondria and chloroplasts DNA similar to prokaryotes. (C) Chloroplasts lack genetic material. (D) Mitochondria are larger than prokaryotic cells.	11.(B)

LAMARCKISM

Q.19 Who was Lamarck & name his book in which he published his idea. S/Q

Ans. Lamarck:

- **Jean-Baptiste Lamarck (1744-1829)** was a **French naturalist.**
- He was an **early** proponent of the idea that **evolution occurs.**
- **Name of Book:** In **1809**, he **published** a book **'Philosophie Zoologique'** (Zoological Philosophy).
- In this book, he presented the idea of progression (change) known as Lamarckism.

Q.20 What is Lamarckism? Name two main points which explain mechanism of evolution? L/Q

Ans. Lamarckism:

- The idea according to which the organisms are changed from simplest to complex is called as **Lamarckism.**
- He claimed that **changes** occur in **organisms** when they are adapted to **environment.**

Check Understanding!

Q.8 How did Jean-Baptiste Lamarck explain the gradual elongation of a giraffe's neck through generations?

Main Points of Mechanism of Lamarckism:

- The mechanism of evolution proposed by Lamarck can be explained by main points:

(i) Use and Disuse of Organs. **(ii) Inheritance of Acquired Characters.**

Q.21 Describe the theory of inheritance of acquired characters, as proposed by Lamarck. Exercise L/Q.8

Ans. Explanation of Lamarckism Also Called Theory of Inheritance of Acquired Characters:

(i) Use and Disuse of Organs:

- **Lamarck believed** that when an **organism** faces changes in its environment, it begins to use some body parts / organs more or disuses **some organs.**
- **More Use More Strong:** He believed that the organs which are used **more frequently** are **developed and become strong.**
- **Less use Became weak:** The organs which are not properly used are **deteriorated** or become weak.
- He named **such changes** in body parts, which occur due to long term use or disuse, as **"acquired characters".**



Figure: J.B.Lamarck

CamScanner

(ii) Inheritance of Acquired Characters:

- Lamarck believed that the **characters** acquired during the **lifetime** of an organism were passed on to the **offspring of that organism.**
- When acquired characters are inherited **generations to generations,** they ultimately cause modifications in organism to **better "cope"** with the changes in the environment.
- **Examples:** Lamarck explained his idea by considering the long necked giraffe of present days.

Q.22 Outline the steps of the evolution of the giraffe, as illustrated in Lamarckism. Exercise L/Q.7

Ans. Steps of Evolution of Giraffe Neck: (As Illustrated in Lamarckism)

- The evolution of a giraffe's neck is **often used as the example** to prove Lamarckism.

(i) Ancestors of Present Day Giraffes:

- The ancestors of giraffe did not have **long necks.**
- They used to eat grass or the leaves of **small plants.**

(ii) Changes Occur in Environment:

- Changes occurred in the environment and **small plants** were no more available to them.
- In the **new situation,** some individuals of the **population began stretching** their necks to reach the leaves of **tall trees** as alternative.
- When they constantly did so, their necks became strong and long during their lifetime. This was an acquired character.

(iii) Generation to Generation Reproduction:

- When the individuals with long necks reproduced, this acquired character was inherited to their next generation i.e., new individuals were born with **slightly longer** necks. When these individuals grew up, they continued the same practice of **stretching their necks.**
- In this way, their necks **became even stronger and longer.** This gave rise to an **acquired character.**
- When this acquired character was inherited to many generations, the generation with **long necks evolved.**

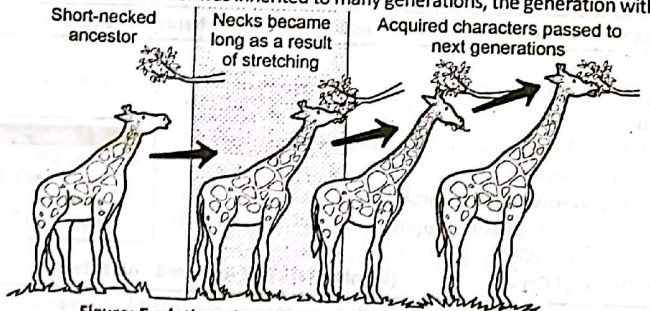


Figure: Evolution of giraffe neck - according to Lamarckism

Topic: Drawbacks of Lamarckism:

Q.23 Why didn't scientists accept the idea of Lamarckism and on what bases was it disproved? L/Q

Ans. Drawbacks of Lamarckism: (Reason of Lamarckism's Rejection)

(i) No Available Evidence:

- The scientists **did not accept the ideas** of change as proposed by Lamarck.
- **At the times** when **Lamarckism** was proposed, there was no available evidence that could explain the mechanism of **evolution.** Thus, Lamarck was criticized more for advocating **ideas of evolutionary** change than for the mechanism he proposed for **that change.**

Initiating and Planning:

- Hypothesize whether Lamarck was criticized in his day for advocating the ideas of evolution or for the mechanism he proposed.

(ii) Basis of Disprove of Lamarckism:

- After his times, when **scientists discovered** the inheritance mechanisms, they disproved Lamarckism on the **following basis.**

(i) The **acquired** characters have **no genetic basis** and therefore cannot be inherited to the next generations.

(ii) Organs are not modified by the wish or requirements of an organism.

Multiple Choice Questions (MCQs)

		Key
1.	**According to Lamarckism, organisms changed from:** (A) Complex to simple. (B) Simple to complex. (C) Plants to animals. (D) Vertebrates to invertebrates.	1.(B)
2.	**Lamarck believed that changes in organisms occur when they:** (A) Adapt to the environment. (B) Undergo mutations only. (C) Are artificially selected. (D) Migrate to new habitats.	2.(A)
3.	**According to Lamarck, organs that are used frequently become:** (A) Smaller and weaker. (B) Stronger and more developed. (C) Vestigial & strong. (D) Non-functional & weak.	3.(B)
4.	**Changes in body parts resulting from long-term use or disuse were called:** (A) Adaptive traits. (B) Genetic variations. (C) Acquired characters. (D) Homologous structures.	4.(C)
5.	**According to Lamarck, acquired characters are:** (A) Lost after death. (B) Passed on to offspring. (C) Produced only by mutations. (D) Never inherited.	5.(B)
6.	**In Lamarck's explanation, the ancestors of giraffes originally fed on:** (A) Grass and leaves of small plants. (B) Fruits of tall trees. (C) Insects. (D) Aquatic plants.	6.(A)
7.	**According to Lamarckism, giraffes developed long necks because they:** (A) Were born with long necks by mutation. (B) Migrated to colder regions. (C) Continuously stretched necks to reach leaves. (D) Crossbred with another species.	7.(C)
8.	**Scientists later rejected Lamarckism mainly after the discovery of:** (A) Fossils. (B) Inheritance mechanisms. (C) DNA fingerprinting. (D) Natural selection.	8.(B)
9.	**Acquired characters have no:** (A) Ecological importance. (B) Environmental influence. (C) Adaptive value. (C) Genetic basis.	9.(D)

Check Understanding (Solutions)

Q.#	Option	Explanation
1.	(B)	• Evolution is formally defined as the gradual change in a population's genetic makeup over generations, leading to potential new species formation.
2.	S/Q	• He concluded that beak variations were specific adaptations for feeding on completely different kinds of food sources available across the various isolated islands.
3.	(C)	• Migration introduces gene flow which alters allele frequencies, violating the Hardy-Weinberg assumption that no individuals migrate in or out.
4.	S/Q	• Genetic drift changes gene frequencies purely by chance events (especially in small populations) rather than through adaptive environmental fitness, which drives natural selection.
5.	(A)	• Homologous structures have similar embryonic origins and bone layouts but different functions, indicating they evolved divergently from a common ancestor.
6.	S/Q	• They are poorly developed, non-functional remnants of once useful organs inherited from ancestral species, serving as clear physical evidence of anatomical change over time.
7.	(B)	• The endosymbiotic theory proposes that engulfed aerobic bacteria and photosynthetic cyanobacteria evolved into modern mitochondria and chloroplasts.
8.	S/Q	• He claimed that ancestral giraffes constantly stretched their necks to reach high leaves, acquiring longer necks during their lifetimes that were subsequently inherited by their offspring.

CamScanner

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. **Who developed a theory of natural selection essentially identical to Darwin's?**
   (a) Hardy-Weinberg. (b) Alfred Wallace. (c) Malthus. (d) Lyell.
2. **Which statement is incorrect?**
   (a) Homologous organs are functionally different but structurally alike.
   (b) Analogous organs are functionally different but structurally alike.
   (c) Examples of analogous structures are arms of a man, forelimb of a cat, flipper of a whale.
   (d) Examples of homologous structures are wings of bats, birds and insects.
3. **Which of the following is an example of homologous organs?**
   (a) Wings of bird and insect. (b) Forelimbs of human and whale.
   (c) Fin of fish and wing of bird. (d) Eye of octopus and human.
4. **According to the theory of natural selection, variations arise due to;**
   (a) Mutations. (b) Use and disuse of organs.
   (c) Selective breeding. (d) Splitting of population.
5. **Which condition is NOT required for Hardy-Weinberg equilibrium?**
   (a) Random mating. (b) No mutation.
   (c) Natural selection. (d) Large population size.
6. **Genetic drift is the change in gene frequency due to:**
   (a) Chance events. (b) Natural selection.
   (c) Emigration of individuals. (d) Immigration of individuals.
7. **Which of the following ideas is common to both Lamarckism and Darwinism?**
   (a) Mutations are the source of genetic variations.
   (b) Adaptations enable individuals to cope with environmental challenges.
   (c) Use and disuse of organs results in the development of acquired characters.
   (d) Acquired characters are inherited to next generations.
8. **Changes in gene frequency due to migration of individuals are called:**
   (a) Homologous organs are functionally different but structurally alike.
   (b) Analogous organs are functionally different but structurally alike.
   (c) Examples of analogous structures are arms of a man, forelimb of a cat, flipper of a whale.
   (d) Examples of homologous structures are wings of bats, birds and insects.
9. **Changes in gene frequency due to migration of individuals are called;**
   (a) Genetic drift. (b) Mutation. (c) Gene flow. (d) Genetic recombination.
10. **What may be the best evidence for the endosymbiotic evolution of eukaryotes?**
    (a) Presence of a nucleus in eukaryotes. (b) Circular DNA in mitochondria.
    (c) Single-layered membranes around mitochondria. (d) Large volume of eukaryotic cells.

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(b)	Alfred Wallace.	• Alfred Russel Wallace independently formulated a theory of natural selection virtually identical to Charles Darwin's evolution theory.
2.	(b)	Analogous organs are functionally different but structurally alike.	• This statement is incorrect because analogous organs actually share similar functions but have entirely different structural origins and anatomies.
3.	(b)	Forelimbs of human and whale.	• Human arms and whale flippers share a common evolutionary ancestry and basic skeletal plan, making them classic homologous organs.
4.	(a)	Mutations.	• Genetic variations that fuel natural selection primarily arise through random genetic mutations and recombination.
5.	(c)	Natural selection.	• Hardy-Weinberg equilibrium specifically requires the complete absence of natural selection, along with other factors like no mutation and random mating.
6.	(a)	Chance events.	• Genetic drift is an evolutionary mechanism driven by random chance events that alter allele frequencies, especially in small populations.
7.	(b)	Adaptations enable individuals to cope with environmental challenges.	• Both evolutionary frameworks recognize that adaptive traits help organisms survive and cope with pressures in their surrounding environments.
8.	(a)	Homologous organs are functionally different but structurally alike.	• Homologous organs have a common ancestor and share a similar embryonic development and basic structure, but may differ in function.
9.	(c)	Gene flow.	• Gene flow refers to the transfer of alleles and genes from one population to another resulting from the migration of individuals.
10.	(b)	Circular DNA and 70S ribosomes in mitochondria.	• Mitochondria possessing their own bacterial-like circular DNA and 70S ribosomes strongly supports the endosymbiotic theory of eukaryotic evolution.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 What is the concept of evolution?

Ans. Evolution:
- Evolution is the cumulative genetic change in populations of organisms over successive generations.
- It explains how life on Earth diversified from common ancestors over long periods.

Q.2 How does homology provide an evidence of divergent evolution?

Ans. Homology An Evidence of Divergent Evolution:
- Homologous organs share a common internal structure and embryonic origin despite serving different functions in various species.
- This structural similarity proves that these species branched out from a common ancestral origin.

Q.3 How analogous organs represent convergent evolution?

Ans. Analogous Organs Represent Convergent Evolution:
- Analogous organs perform **similar functions** in different species but possess entirely separate evolutionary origins and internal structures.
- This demonstrates how **unrelated species** independently evolve similar adaptations under comparable environmental pressures.

Q.4 What is Hardy-Weinberg theorem?

Ans. Hardy-Weinberg Theorem:
- It states that allele and genotype frequencies in a population remain constant from generation to generation in the absence of evolutionary influences.
- It serves as a mathematical baseline for studying evolutionary changes in natural populations.

Q.5 What are the factors that change allele frequencies?

Ans. Factors that Change Allele Frequencies:
- **The major factors include:**
  (i) Natural selection. (ii) Genetic drift. (iii) Mutations.
  (iv) Gene flow (migration). (v) Non-random mating.
- These forces disrupt genetic equilibrium and drive evolutionary changes.

CamScanner

Q.6 Justify Lamarck as an early proponent of evolution.

Ans. Lamarck as an Early Proponent of Evolution:

- Jean-Baptiste Lamarck was the **first scientist** to propose a comprehensive, testable theory that species change over time rather than remaining fixed.
- He argued that organisms adapt to **their environment** through the inheritance of acquired characteristics.

Q.7 Describe the drawbacks of Lamarckism.

Ans. Drawbacks of Lamarckism:

- It incorrectly assumed that **physical traits** acquired during an organism's lifetime can be genetically passed on to its offspring.
- Modern genetics has proven that somatic modifications do not alter DNA in germ cells for inheritance.

Q.8 Differentiate between;

• Lamarckism and Darwinism. • Homologous and analogous. • Natural selection and genetic drift.

Ans. Lamarckism and Darwinism:

Lamarckism	Darwinism
• Lamarckism suggests species evolve via the inheritance of acquired traits.	• Darwinism states they evolve through natural selection acting on inherited variations.

Homologous and Analogous:

Homologous	Analogous
• Homologous organs share a common ancestry and internal structure with different functions.	• Analogous organs perform similar functions but have independent origins.

Natural Selection and Genetic drift:

Natural Selection	Genetic Drift
• Natural selection is the process where individuals with traits better adapted to their environment are more likely to survive and reproduce, passing those advantageous traits to future generations.	• Genetic drift is a random change in the frequency of gene variants (alleles) in a population purely by chance. It effects are most significant in small populations.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 Explain that evolution takes place due to variations in organisms and natural selection.

Ans. See Page No. 338 (Q.8)

Q.2 Explain the theory of natural selection as proposed by Darwin.

Ans. See Page No. 338 (Q.8)

Q.3 Explain how biogeography provides evidence for evolution.

Ans. See Page No. 340 (Q.12)

Q.4 Describe the evidences of evolution that come from comparative anatomy.

Ans. See Page No. 341 (Q.14)

Q.5 Differentiate between convergent and divergent evolution on the basis of inheritance of the homologous and analogous structures.

Ans. See Page No. 341 (Q.14)

Q.6 Describe the evidences of evolution that come from molecular biology.

Ans. See Page No. 342 (Q.15)

Q.7 Outline the steps of the evolution of the giraffe, as illustrated in Lamarckism.

Ans. See Page No. 346 (Q.22)

Q.8 Describe the theory of inheritance of acquired characters, as proposed by Lamarck.

Ans. See Page No. 345 (Q.21)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Interpret different homologous and analogous structures through observation in plants.

Ans. Homologous and Analogous Structures through Observation in Plants:

(a) Homologous Structures in Plants:

- These structures share a **common evolutionary** origin despite serving different functions.
- Such as the tendrils of a pea plant and the spines of a cactus, both of which are modified leaves.
- **Examples:** Potato tuber & Ginger rhizome.

(b) Analogous Structures:

- These structures perform similar functions but have independent evolutionary origins.
- **Examples:** Tendrils of Pea plant & Tendrils of grapevine.
- Root tuber of sweet potato & stem tuber of potato.

Q.2 Hypothesize whether Lamarck was criticized in his day for advocating the ideas of evolution or for the mechanism he proposed.

Ans.

- **Acceptance of Evolution:** Lamarck was not criticized for advocating evolution itself, as other thinkers of his era had already proposed transformism; the scientific community was open to the concept of species changing over time.
- **The Mechanism:** He faced **heavy criticism** and **ridicule primarily** for his proposed mechanism—the inheritance of acquired characteristics—as experimental evidence failed to show that traits acquired during an organism's lifetime could be passed to offspring.

Q.3 Justify, on the grounds that both Wallace's and Darwin's papers were published in the Journal of the proceedings of the Linnaean Society, why the theory was attributed to Darwin.

Ans. Reasons of Attributed to Darwin Note Wallace's:

- **Priority and Extensiveness:** Darwin had spent over two decades for gathering massive empirical data, observational evidence, and comprehensive theoretical frameworks before publishing, whereas Wallace submitted a **much shorter essay.**
- **Institutional Support and Publication:** Darwin's social standing within the British scientific establishment, combined with his detailed book On the Origin of Species published shortly after the Linnean Society papers, cemented his primary role in **establishing the theory.**

Q.4 Describe and analyse examples of technology that have extended or modified the scientific understanding of evolution (e.g., the contribution of radiometric dating to the palaeontological analysis of fossils).

Ans. Contribution of Radiometric Dating to the Palaeontological Analysis of Fossils:

- **Radiometric Dating:** Techniques like **potassium-argon and carbon** dating allow scientists to determine the absolute age of rock layers enclosing fossils, transforming paleontology from relative dating into a precise, quantifiable timeline of evolutionary history.
- **Molecular Sequencing:** Modern DNA and protein sequencing technologies have extended evolutionary understanding by revealing deep phylogenetic relationships and genetic divergence rates that morphology alone could not detect.

CamScanner

SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. (1 x 6 = 06)

(i) Who developed a theory of natural selection essentially identical to Darwin's?
(A) Hardy-Weinberg. (B) Alfred Wallace. (C) Malthus. (D) Lyell.

(ii) The Hardy-Weinberg Theorem was presented in:
(A) 1859. (B) 1831. (C) 1908. (D) 1953.

(iii) Changes in gene frequency due to migration of individuals are called:
(A) Genetic drift. (B) Mutation. (C) Gene flow. (D) Genetic recombination.

(iv) Structures that are similar in structure but different in function are called:
(A) Analogous structures. (B) Vestigial structures.
(C) Homologous structures. (D) Adaptive structures.

(v) The earliest prokaryotes originated about:
(A) 2 billion years ago. (B) 3.5 billion years ago. (C) 4.5 billion years ago. (D) 500 billion years ago.

(vi) Scientists later rejected Lamarckism mainly after the discovery of:
(A) Fossils. (B) Inheritance mechanisms. (C) DNA fingerprinting. (D) Natural selection.

Q.2 Write short answers of the following questions. (2 x 8 = 16)

(i) What is spontaneous generation?
(ii) What is Hardy-Weinberg theorem?
(iii) What is Neo-Darwinism?
(iv) Differentiate between Homologous and analogous.
(v) Define the term comparative anatomy.
(vi) Discuss are the evidences for endosymbiotic theory.
(vii) Describe the drawbacks of Lamarckism.
(viii) Who was Lamarck & name his book in which he published his idea.

Q.3 Extensive Questions. (4 x 2 = 8)

(a) Explain the theory of natural selection as proposed by Darwin.
(b) Describe the theory of inheritance of acquired characters, as proposed by Lamarck.

ENTRANCE TEST MDCAT

1. From evolutionary point of view, which respiratory protein is common in many organisms? (UHS 2015)
A. Cytochrome a. B. Cytochrome c. C. Cytochrome b. D. Cytochrome d

2. Which one of the following is considered as strong evidence of evolution? (UHS 2016)
A. Embryology record. B. Biochemical record. C. Molecular record. D. Fossil record.

3. The total number of genes in a population is called: (UHS 2016)
A. Gene pool. B. Genome. C. Allele pool. D. Genomic library.

4. Process by which unrelated species evolve to functionally resemble each other is called: (UHS 2017)
A. Convergent evolution. B. Co-evolution. C. Divergent evolution. D. Parallel evolution.

5. Which one of the followings show evidence of evolution from Molecular Biology? (UHS 2017)
A. Development of bronchial arches in vertebrate embryo.
B. Comparison of genes and proteins in different species.
C. Distribution of species.
D. Study of vestigial organs.

6. Large population size, random mating, no mutation and no emigration or immigration are postulates of: (UHS 2017)
A. Hardy-Weinberg equation. B. Mendel's law of independent assortment.
C. Mendel's law of segregation. D. Theory presented by Schlieden and Schwann.

7. Organs specialized to perform different functions but structurally allke are: (UHS 2018)
A. Analogous organs. B. Autologous organs. C. Homologous organs. D. Anuclogous organs

8. The actual or preserved remains of the organisms that lived in the ancient past are called: (UHS 2018)
A. Fossils. B. Ancient prints. C. Impression. D. Ancient cast.

9. Divergent evolution produces: (UHS 2018)
A. Vital organs. B. Vestigial organs. C. Homologous organs. D. Analogous organs.

10. Change in frequency of alleles that occurs by chance is called as: (UHS 2019)
A. Natural selection. B. Mutation. C. Migration. D. Genetic drift.

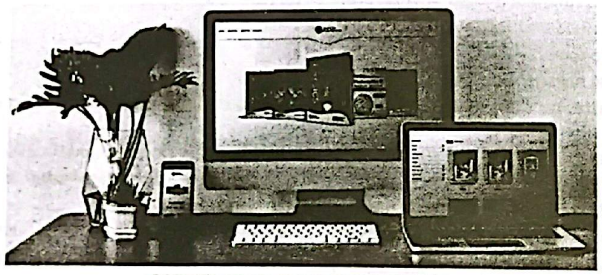
11. According to the theory of natural selection, organisms produce: (UHS 2019)
A. More offspring than supported. B. Less offspring than supported.
C. Offspring according to the resources available. D. Offspring to create resource.

ANSWERS KEY

1. B	2. C	3. A	4. A	5. B	6. A	7. A	8. A	9. C	10. D	11. A

CamScanner

SCHOLAR PUBLICATIONS'
ONLINE STORE
: www.scholarseries.com



BUY ONLINE
Cash on Delivery (COD) Services
Available Now...!!

SCHOLAR PUBLICATIONS

25 CHAPTER

ECOLOGY

Student Learning Outcomes (SLOs)

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

- Define biogeochemical cycles and locate the primary reservoirs of the chemicals in these cycles.
- Describe the water cycle in detail.
- Discuss nitrogen cycle in detail.
- Discuss the loss of energy between trophic levels.
- Describe characteristics of a population, such as growth, density, distribution, carrying capacity, minimum/viable size.
- Explain the effect of growth of human population on the ecosystem.
- Explain the greenhouse effect with examples of gases that exhibit this behavior.
- Describe the harmful effects of greenhouse gases on the environment.
- Describe four important ecosystems of Pakistan.

CamScanner

Ecology — Concept Map

1. LEVELS OF ECOLOGICAL ORGANIZATION

- **(a) Species →** Basic unit of biological classification; group sharing characteristics that interbreed to produce fertile offspring (e.g., Indus River Dolphin).
- **(b) Population →** Individuals of the same species in a specific geographic area at the same time (e.g., Markhors in Chitral GoI).
- **(c) Community →** All different populations of various species interacting in the same area (e.g., Karachi mangrove forest).
- **(d) Ecosystem →** Biotic and abiotic components interacting; unidirectional energy flow and nutrient cycling (e.g., Thar Desert).
- **(e) Biome →** Large geographical region with specific climate, soil, and adapted flora/fauna (e.g., Coniferous, Desert, Freshwater).
- **(f) Biosphere →** Global sum of all biomes where life exists; the "Global Ecosystem".

2. BIOGEOCHEMICAL CYCLES

- **Gaseous Cycles →** Reservoir in air/oceans (Water, Nitrogen, Oxygen, Carbon).
- **Sedimentary Cycles →** Reservoir in Earth's crust (Phosphorus, Sulfur, Calcium).
- **(a) Water Cycle →** Abiotic loop (Evaporation, Condensation, Precipitation, Infiltration/Runoff) & Biotic loop (Root absorption, Transpiration, Respiration, Excretion).
- **(b) Nitrogen Cycle →** Nitrogen Fixation (Biological/Atmospheric/Industrial), Nitrification (Nitrosomonas → Nitrobacter), Assimilation, Ammonification, Denitrification.

3. FLOW OF ENERGY

- **Trophic Levels →** Level 1 (Producers), Level 2 (Primary Consumers/Herbivores), Level 3 (Secondary Consumers/Carnivores), Level 4 (Tertiary Consumers), Decomposers/Detritivores.
- **0% Rule →** Only about 10% of energy is transferred to each successive trophic level; energy is lost as heat.

4. CHARACTERISTICS OF POPULATION

- **Survivorship Curves →** Type I (convex - mammals/humans), Type II (diagonal - birds/lizards), Type III (concave - fishes/invertebrates).
- **Growth Models →** Exponential (unlimited) vs. Logistic (sigmoid curve reaching carrying capacity).
- **Dispersion →** Random, Uniform, Clumped.
- **Concepts →** Carrying Capacity (max sustainable size) & Minimal Viable Population (extinction risk threshold).

5. GREENHOUSE EFFECT & CLIMATE CHANGE

- **Greenhouse Gases →** CO_2 (~80%), Methane (~11%), Nitrous Oxide (~6%), Fluorinated Gases (~3%).
- Impacts → Global Warming (IPCC: ~1.1°C increase), Extreme Heatwaves, Erratic Floods, Glacial Melting & GLOFs, Sea Level Rise, Food Insecurity.

6. IMPORTANT ECOSYSTEMS OF PAKISTAN

- **Temperate (Himalayan) Forest →** Moist northern mountains (Shogran, Murree); moderate temps, rich humus soil, pine/cedar trees, rhesus monkeys.
- **Tropical Thorn Forest →** Indus plains; arid/semi-arid, up to 50°C, xerophytic thorn plants (Kikar, Jhand), highly degraded for agriculture.
- **Alpine & Sub-Alpine Meadows →** High-altitude cold deserts (Deosai Plains); heavy snow, stunted junipers, snow leopards, brown bears.
- **Mangrove Forest →** Coastal Indus Delta and Balochistan; brackish water, anaerobic mudflats, Avicennia marina (Timmar), threatened by reduced river flow.

INTRODUCTION

Chapter's Intro:

- All organisms have certain requirements for life.
- They fulfill the requirements by interacting with other organisms and with the physical environment.
- In this chapter, you would get learning on the basic concepts of environment and the cycling of materials and energy between the environment and organisms.

Q.1 Define the term ecology. S/Q

Ans. Ecology:

- Ecology is the study of the relationships of organisms with other organisms and the environment.

LEVELS OF ECOLOGICAL ORGANIZATION

- To understand how life works, we must look through different "levels" on which natural world is organized into layers of increasing complexity.

Q.2 Name the level of biological organization. S/Q

Ans. Names of Level of Biological Organization:

- Arranged from lowest level (species) to highest level (Bio-sphere).

Species → Population → Community → Ecosystem → Biome → Biosphere

Topic: (1) Species:

Q.3 Define the term species & explain with the example of "Indus River Dolphin". S/Q

Ans. The Unit of Life:

- A group of **related organisms** that share similar physical and genetic characteristics and, most importantly, can interbreed **naturally** to produce **fertile offspring** is called species.
- A species is the basic unit of biological classification.
- **Example:** The **Indus River Dolphin** is a distinct species.
- All Indus dolphins **can breed** with one another, but they **cannot breed naturally** with other types of **dolphins** to produce fertile youngs.

Check Understanding!

Q.1 If a wildlife researcher is studying all individual Markhors living specifically within the boundaries of Chitral GoI National Park, which level of ecological organization is being observed?

(A) Species. (B) Population.
(C) Community. (D) Ecosystem.

Topic: (2) Population:

Q.4 What is Population? S/Q

Ans. Population:

- A population is a group of **individuals** belonging to the same species living in the same geographic area at the **same time.**

Q.5 How is population different from species justify with the help of "Markhor" example. S/Q

Ans.

- A species refers to a **"type"** of organisms globally, while a population refers to a specific group in a specific location.
- **Example:** All the Markhors living in the **Chitral GoI National Park** form a **single population.**
- If we **consider Markhors across all of Pakistan,** we are referring to the species; if we consider only abou those in Chitral, we are referring to a population.

Topic: (3) Community:

Q.6 What is community? Clarify the concept by taking the example of "Mangrove"? S/

Ans. Community:

- A **community** consists of **all the different populations of various species living and interacting in t same area.** This includes **plants, animals, fungi, and bacteria.**

CamScanner

Example of Mangrove:

- A Mangrove Forest in Karachi refers to a community that includes the Mangrove trees, the mudskipper fish, the crabs, and the various shorebirds.
- They all share the same space and interact with one another (e.g., birds feed on fish).

Topic: (4) Ecosystem:

Q.7 Define the concept of ecosystem, explain it with the help of an example. L/Q

Ans. Ecosystem:

- A system consists of the **biotic (living) components (Plants, Animals, Decomposers)** and the abiotic **(non-living) components** of the environment, (such as **sunlight, soil, water,** and **air**) is called **ecosystem.**
- In an ecosystem, energy flows unidirectionally while the nutrients cycle between the living and the non-living parts.

Communities live in Ecosystems:

- **Example of Ecosystems:** The **Thar Desert** is a vast ecosystem.
- It not only contains the **snakes, blackbucks,** and **shrubs** (the community); but also has the **baking heat,** the **shifting sand dunes,** and the **rare rainfall** (the abiotic factors) that influence the lifestyle of the organisms living in it.

Topic: (5) Biome:

Q.8 Define "Biome" & give some examples of biomes in Pakistan. L/Q

Ans. Biome:

- A **large, distinct geographical** region characterized by its **specific climate, soil altitude,** and types of **plants and animals** which are adapted to those conditions is called **biome.**
- In Pakistan, the **diverse geography** makes several biomes.

Examples of Biomes in Pakistan:

(i) Coniferous Forest Biome:

- It is located in the high-altitude areas of Murree and Swat, where cold winters and pine trees dominate.

(ii) Desert Biome:

- It is located in the **Thal** and **Thar** regions, characterized by low rainfall and specialized "succulent" plants like cacti.

(iii) Freshwater Biomes:

- It include the massive Indus River system.

Check Understanding!
Q.2 Why is the biosphere referred to as the "Global Ecosystem"?

Topic: (6) Biosphere:

Q.9 Write a short note on "Biosphere". L/Q

Ans. Biosphere:

- The every part of the **Earth** where life exists from the **deepest trenches** of the **Arabian Sea** to the **highest peaks** of the Himalayas, and even several kilometers **up into** the atmosphere is called **biosphere.**
- The biosphere is the **highest and most inclusive** level of ecological organization.
- **Biosphere** is the **global sum** of all biomes.

Tidbit
Global Ecosystem:

- The biosphere is often called the **"Global Ecosystem".**
- Biosphere is a thin **"envelope"** around the Earth where the **lithosphere** (land), **hydrosphere** (water), and **atmosphere** (air) interact to **support life.**

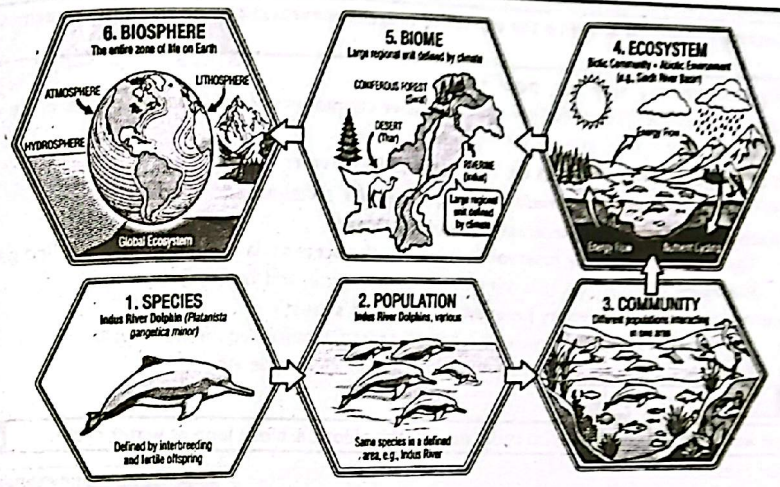


Figure: Levels of ecological organization

Multiple Choice Questions (MCQs)	Key
1. What is the basic unit of biological classification? (A) Population. (B) Community. (C) Species. (D) Ecosystem.	1.(C)
2. A species refers to organisms that can interbreed to produce: (A) Sterile offspring. (B) Fertile offspring. (C) Asexual clones. (D) Hybrid variations.	2.(B)
3. The Indus River Dolphin is cited as an example of a distinct: (A) Population. (B) Community. (C) Species. (D) Biome.	3.(C)
4. A population consists of individuals of the same species living in the same area at the: (A) Same time. (B) Different times. (C) Various seasons. (D) Unrecorded times.	4.(A)
5. All Markhors in Chitral GoI National Park form a single: (A) Community. (B) Species. (C) Population. (D) Ecosystem.	5.(C)
6. A community consists of different populations living and interacting in the: (A) Same area. (B) Isolated regions. (C) Different continents. (D) Entire biosphere.	6.(A)
7. A Mangrove Forest in Karachi is an example of a: (A) Population. (B) Community. (C) Species. (D) Biome.	7.(B)
8. An ecosystem consists of biotic components and: (A) Abiotic components. (B) Geographic barriers. (C) Other biomes. (D) Human influences.	8.(A)
9. In an ecosystem, energy flows unidirectionally while nutrients: (A) Are lost. (B) Cycle. (C) Disappear. (D) Remain static.	9.(B)
10. The Thar Desert is given as an example of a vast: (A) Community. (B) Population. (C) Ecosystem. (D) Species.	10.(C)
11. A large geographical region characterized by climate and soil is a: (A) Biosphere. (B) Ecosystem. (C) Community. (D) Biome.	11.(D)
12. In Pakistan, the Coniferous Forest Biome is located in areas like: (A) Thal and Thar. (B) Murree and Swat. (C) The Indus River. (D) Karachi coast.	12.(B)
13. The highest and most inclusive level of ecological organization is the: (A) Community. (B) Biome. (C) Biosphere. (D) Ecosystem.	13.(C)

BIOGEOCHEMICAL CYCLES

Exercise L/Q.1

Q.10 Define biogeochemical cycle & give two examples.

Ans. Biogeochemical Cycle:

- The **cyclic movements** of chemical elements - such as **carbon, nitrogen, oxygen, phosphorus, sulphur** - between the living **(biotic)** and non-living **(abiotic)** components of ecosystem are called **biogeochemical cycles.**
- **Examples:** Water cycle, Nitrogen cycle.

CamScanner

Q.11 Define primary reservoir & define the classes of biogeochemical cycles on the basis of primary reservoir. U/Q

Ans. **Primary Reservoirs: ("sink" or "pool")**

- A primary reservoir ("sink" or "pool") is a **massive** component of the **biosphere** where the element of a biogeochemical cycle is **stored for long** periods of time.

Types of Biogeochemical Cycles on The Basis of Reservoir:

- On the basis of **primary reservoir**, the biogeochemical cycles are classified as;

(i) **Gaseous Cycles: (Primary Reservoirs ⟶ Air + Ocean)**

- The cycles in which the **reservoir is the air** or the **oceans** (via evaporation) are called gaseous cycle.
- **Examples:** Nitrogen cycle, Oxygen cycle, Carbon cycle, and Water cycle.

(ii) **Sedimentary Cycles: (Primary Reservoirs ⟶ Earth's Crust)**

- The cycles in which the **reservoir is Earth's crust** are called sedimentary cycle.
- **Examples:** Phosphorus cycle, Sulfur cycle, and Calcium cycle etc.

Topic: The Water Cycle:

Q.12 Define water cycle or hydrological cycle, discuss the abiotic & biotic loop of water cycle. Exercise L/Q.1

Ans. **Water Cycle:**

- The water cycle (hydrological cycle) is the continuous movement of water between **abiotic** components (air, soil, and sea) and **biotic** components.

Tidbit

- In a country like Pakistan, where our agriculture and economy depend entirely on the Indus River system, the water cycle is the literal lifeline of the nation.

(1) Abiotic Loop of Water Cycle:

(i) Evaporation:

- The sun powers the **entire water cycle**.
- **Solar radiation** heats the surface water in **oceans** and lakes. It provides enough energy for water molecules to evaporate in the form of vapors.
- About **86% of global evaporation** occurs from the oceans.
- **In Pakistan**, the **Arabian Sea serves** as the massive primary source of vapor that eventually **travels inland.**

(ii) Condensation:

- When water **vapors rise** into the atmosphere, they **lose heat.** When the air becomes cold enough, the vapors turn back into liquid droplets or ice crystals.
- These droplets cling to dust particles in the **air to form clouds.**

Check Understanding!

Q.3 Which natural water cycle process involves plants releasing water vapors into the atmosphere through leaf stomata?
(A) Transpiration. (B) Infiltration.
(C) Condensation. (D) Precipitation.

(iii) Precipitation (Snow Fall, Rain Fall etc.):

- When the **water droplets** in clouds become too heavy, they fall due to gravity.
- Depending on the temperature, water falls as rain, snow, or sleet (a mix of rain and snow or ice pellets).

(iv) Infiltration and Runoff:

- Once water hits the land, it takes one of two main paths to **complete the cycle:**

Tidbit

- In **Pakistan**, surface runoff feeds the **Indus River**, while infiltration recharges the aquifers, we use for **drinking water.**

(a) Infiltration: Water **seeps** into the soil (percolation). It moves **downward** to reach the water table. This stores water underground as groundwater.

(b) Surface Runoff: It is the **unconfined** flow of water over the land surface. It occurs when water can no **longer infiltrate** into the soil. The surface runoff water flows into **streams, rivers**, and eventually to the oceans.

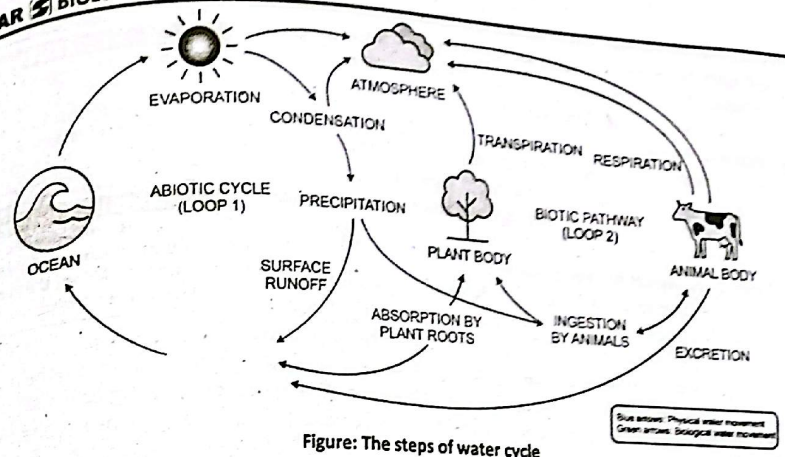


Figure: The steps of water cycle

(2) Biotic Loop of Water Cycle:

(i) Water Entry into the Biotic Component:

- Water **enters** biotic components primarily through **two methods.**
- **Terrestrial plants** use root hairs to absorb water from the soil and use it for photosynthesis and as a structural support (turgor pressure).
- **Animals** take in water by drinking directly from freshwater sources and by eating food.

(ii) Water Exit from the Biotic Component:

- Once water has **served** its purpose inside an organism it returns into the **abiotic environment.**
  - **(a) Transpiration:** In plants, it is the major exit point for water. Plants release water vapors in atmosphere through the stomata present in their leaves.
  - **(b) Respiration:** In plants and animals, respiration also produces water as a byproduct. This "metabolic water" is exhaled as vapors.
  - **(c) Excretion & Egestion:** In **excretion** and **egestion**, animals also release water **through urine and feces,** returning it to the soil or water bodies. **During perspiration** (sweating), animals release water through skin pores, which evaporates to the atmosphere.
  - **(d) Decomposition:** Decomposition of organisms' dead bodies also **releases** water back into the soil or atmosphere.

Topic: The Nitrogen Cycle:

Q.13 Describe nitrogen cycle in detail. Exercise L/Q.1, L/Q. 2

Ans. **Nitrogen Cycle:**

- The Nitrogen Cycle is a complex process by which nitrogen circulates between the **biotic** and **abiotic components** of the ecosystem.
- It involves the **transformation** of atmospheric nitrogen (N_2) into compounds that can be used by living organisms, and the subsequent return of N_2 to the atmosphere.

Tidbit

- While the **water cycle** moves a molecule we can notice, the Nitrogen Cycle deals with an invisible gas that makes up about **78%** of our atmosphere.

The Cyclic Path of Nitrogen:

- The nitrogen cycle moves in a **continuous loop**, passing through the following **five essential steps:**

Steps Involve in Nitrogen Cycle:

(1) Nitrogen Fixation (Entry into the Soil):

- The atmosphere is **78%** nitrogen gas (N_2).
- Its atoms are joined by a strong triple bond. Plants cannot break these bonds.

CamScanner

- **Nitrogen Fixation:** A process of converting N_2 into inorganic compounds like ammonia (NH_3) is called nitrogen fixation.
- Nitrogen fixation is done in three ways;

(a) Biological Fixation:

- The fixation of nitrogen with the help of living organisms like bacteria is called **biological nitrogen fixation.**
- More than **90%** of all **nitrogen fixation** is done by soil microorganisms.

Types of Biological Nitrogen Fixation:

- There are **two kinds** of nitrogen-fixing microorganisms:
  - **(i) Nitrogen fixation by freeliving** (non-symbiotic) organisms Cyanobacteria or blue-green algae, Azotobacter, and Clostridium.
  - **(ii) Nitrogen fixation by mutualistic** (symbiotic) Bacteria like Rhizobium present in the root nodules of many pulses (legumes) plants like Chana (Chickpeas) or Moong (Mung beans).
- These nitrogen-fixing microorganisms "fix" nitrogen directly from the air in the soil and convert it to ammonia.

(b) Atmospheric Fixation:

- During **rains and storms**, lightning provides the massive energy needed to combine atmospheric nitrogen with oxygen. So, N_2 is converted into nitrogen oxides and then into nitrates.
- Only a small amount (5-10%) of nitrogen is fixed in this way.

(c) Industrial Fixation:

- The synthesis of **nitrogen** containing fertilizers is called industrial fixation.
- In this process, **atmospheric** nitrogen and hydrogen are combined to produce ammonia.

Concept Clarity

Nitrogen Fixation:

- Simply we can say conversion of unavailable form of Nitrogen (N_2) into available or useable form of nitrogen for plants.

Check Understanding!

Q.4 What is the specific role of Nitrosomonas and Nitrobacter bacteria during the nitrification step of the nitrogen cycle?

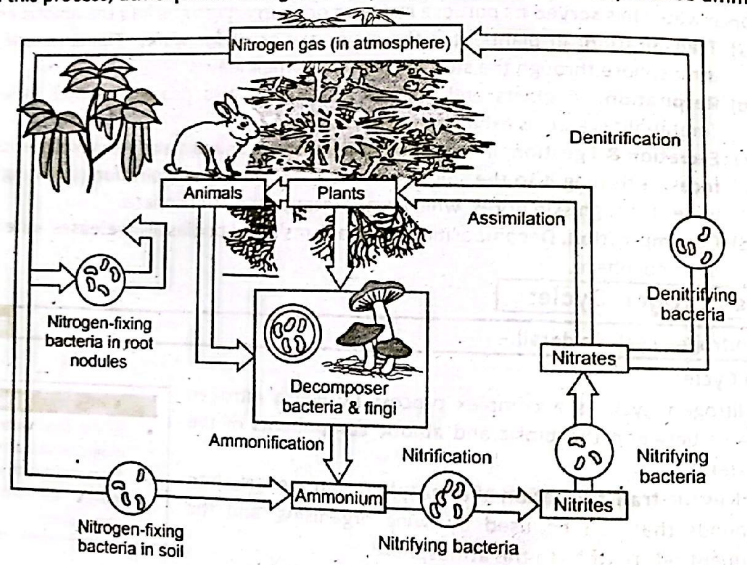


Figure: The nitrogen cycle

(2) Nitrification (Conversion to Plant Food):

- The process of conversion of **ammonia into nitrite & nitrates** is called **nitrification.**
- Ammonia is often toxic or difficult for plants to use in large amounts. Soil bacteria (such as Nitrosomonas and Nitrobacter) act as converters.
- **Nitrosomonas** converts ammonia to nitrite (NO_2^-).

- **Nitrobacter** converts this nitrite to Nitrate (NO_3^-).
- **Nitrates** are easily absorbed by plants.

(3) Assimilation (Entry into the Biotic World):

- A process in which plants and microbes absorb nitrates from the soil and use them to make proteins, DNA, and chlorophyll is called **assimilation.**
- Animals assimilate nitrogen by consuming plants and other animals.

(4) Ammonification (The Recycling Step):

- The process of **conversion of nitrite or nitrates** back into **ammonia** is called **ammonification.**
- When plants and **animals die**, or when animals release nitrogenous waste, **decomposers** (fungi and bacteria) break down the complex proteins. They convert the **organic nitrogen** back into **Ammonia.**

(5) Denitrification (Exit to the Atmosphere):

- To keep the cycle **balanced**, nitrogen must eventually return to the air.
- In waterlogged soils, **denitrifying bacteria** (e.g., ***Pseudomonas and Thiobacillus***) convert nitrates back into Nitrogen gas (N_2) which is then released into the atmosphere.

Multiple Choice Questions (MCQs)				Key
1. **Elements cycle between biotic and:** (A) Abiotic.	(B) Atmosphere.	(C) Oceans.	(D) Crust.	1.(A)
2. **The primary reservoir for sedimentary cycles is:** (A) Air.	(B) Oceans.	(C) Earth's crust.	(D) Organisms.	2.(C)
3. **Water cycle moves water between biotic and:** (A) Abiotic.	(B) Sun.	(C) Ice caps.	(D) Deserts.	3.(A)
4. **What powers the entire water cycle?** (A) Wind.	(B) The sun.	(C) Earth's rotation.	(D) Gravity.	4.(B)
5. **86% of global evaporation occurs from:** (A) Lakes.	(B) Rivers.	(C) Plants.	(D) Oceans.	5.(D)
6. **Vapors rise and cool to form:** (A) Clouds.	(B) Groundwater.	(C) Snow.	(D) Glaciers.	6.(A)
7. **Flow of water over land surface is called:** (A) Infiltration.	(B) Surface runoff.	(C) Percolation.	(D) Transpiration.	7.(B)
8. **Plants release vapors through:** (A) Roots.	(B) Stomata.	(C) Flowers.	(D) Stems.	8.(B)
9. **Nitrogen gas (N2) makes up what % of atmosphere?** (A) 50%.	(B) 21%.	(C) 78%.	(D) 90%.	9.(C)
10. **Nitrogen fixation converts N2 into compounds like:** (A) Ammonia.	(B) Proteins.	(C) Oxygen.	(D) Nitrates.	10.(A)
11. **Rhizobium bacteria live in root nodules of:** (A) Cacti.	(B) Algae.	(C) Legumes.	(D) Grasses.	11.(C)
12. **Nitrobacter converts nitrites into:** (A) Ammonia.	(B) Nitrogen gas.	(C) Nitrates.	(D) Proteins.	12.(C)
13. **Denitrifying bacteria convert nitrates back into:** (A) N2 gas.	(B) Ammonia.	(C) Oxygen.	(D) Nitrites.	13.(A)

THE FLOW OF ENERGY

- Along with the **matter**, energy also flows between the **physical environment** and organisms. But, unlike the cycling of matter, the flow of energy is **unidirectional.**

Topic: Trophic Levels: Exercise L/Q.3

Q.14 What are trophic levels? Explain the flow of energy in successive trophic levels.

Ans. Trophic Levels:

- **Definition:** In an ecosystem the organisms are **arranged** in different feeding groups, known as **trophic levels.**
- In successive trophic levels, energy flows from **one trophic** level to the other **trophic** level.
- In trophic levels energy flow is unidirectional.

CamScanner

(i) Trophic level-1:
- It consists of green **plants, algae** and **photosynthetic bacteria.** These are the primary producers of an ecosystem.

(ii) Trophic level-2:
- A trophic level which consists of **primary consumers** (herbivores) which feed directly on the **producers. Examples:** Insects, Rabbit.

(iii) Trophic level-3:
- It consists of **secondary consumers** (carnivores) and the parasites of animals which feed on the herbivores. **Examples:** Frog, Snake.

(iv) Trophic level-4:
- This level consists of tertiary consumers (animals that eat carnivores). **Examples:** Wolf, Hawk.

(v) Decomposers and Detritivores:
- They make a separate level.
- Detritivores and scavengers e.g., **crabs, vultures,** and jackals mechanically consume dead organic matter from all trophic levels.
- **Decomposers e.g.,** saprotrophic bacteria and fungi secrete digestive enzymes to chemically break down detritus and fecal matter.

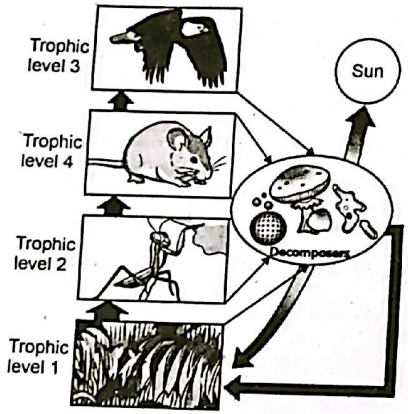


Figure: Trophic levels

Check Understanding!

Q.5 Why are short food chains fundamentally more energy efficient than long food chains in an ecosystem?

(A) Producers fix more solar energy in short chains.
(B) Less energy is lost as heat since fewer transfer steps are involved.
(C) Tertiary consumers consume less food overall.
(D) Decomposers bypass the lower trophic levels completely.

Topic: The Loss of Energy Between Trophic Levels:

Q.15 Describe the flow of energy in ecosystem, considering the example if 10,000 kcal energy is fixed by producers how much will be transferred to tertiary consumers. Exercise L/Q.15

Ans. Loss of Energy Between Trophic Levels:

- There are generally **three or four** trophic levels in an ecosystem.
- **About 1 to 2% of the solar energy** that falls on a first trophic level i.e., **producers is converted** to the bond-energy of organic matter.
- During the flow of energy to the next trophic levels, only about **10%** is transferred to the **next trophic level.** Energy is **lost** at each trophic level.
- In this way, very little usable **energy remains** in the system after it has been used and incorporated into the bodies of organisms at different trophic levels.

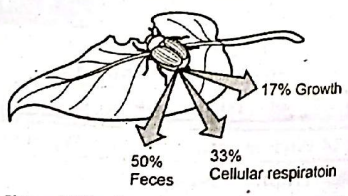


Figure: Utilization of energy by a heterotroph

Example:
- If producers fix **10,000 kcal** energy by photosynthesis.
- The primary consumers would get **only 1,000 kcal** of it.
- Of these, about **100 kcal** are incorporated into the bodies of **secondary consumers.**
- If tertiary consumers eat **secondary consumers,** they gain about **10 kcal** of the 10,000 kcal that originally entered the system.

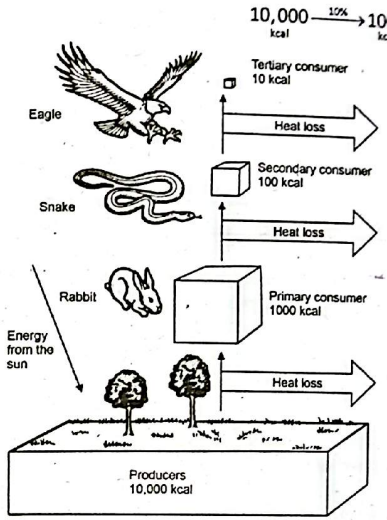


Figure: Energy flow in trophic levels

Tidbit

Q. Why short food chain is much more energy efficient than long food chain?

Ans. Short food chains (with a smaller number of trophic levels) are more **energy efficient than long food chains** (with more trophic levels).
- This is because, energy is lost as heat during energy transfer at each trophic level. So, efficiency is higher when fewer steps are involved in the food chains.

Multiple Choice Questions (MCQs)	Key
1. Energy flows between the physical environment and organisms in which manner? (A) Bi-directionally. (B) Unidirectionally. (C) Cyclically. (D) Multi-directionally.	1.(B)
2. Feeding groups in an ecosystem are known as: (A) Food chains. (B) Ecological pyramids. (C) Biomes. (D) Trophic levels.	2.(D)
3. Trophic level 1 consists of primary producers, which include: (A) Herbivores. (B) Carnivores. (C) Green plants. (D) Decomposers.	3.(C)
4. Which organisms constitute Trophic level 2? (A) Primary consumers. (B) Secondary consumers. (C) Tertiary consumers. (D) Decomposers.	4.(A)
5. Primary consumers are also known as: (A) Carnivores. (B) Herbivores. (C) Omnivores. (D) Autotrophs.	5.(B)
6. Examples of organisms in Trophic level 2 include: (A) Frog and snake. (B) Wolf and hawk. (C) Insects and rabbit. (D) Algae and fungi.	6.(C)
7. Trophic level 3 consists of secondary consumers, which are: (A) Herbivores. (B) Carnivores. (C) Producers. (D) Detritivores.	7.(B)
8. Which of the following are examples of secondary consumers? (A) Insects and rabbit. (B) Wolf and hawk. (C) Frog and snake. (D) Algae and bacteria.	8.(C)
9. Animals that eat carnivores belong to: (A) Trophic level 1. (B) Trophic level 2. (C) Trophic level 3. (D) Trophic level 4.	9.(D)
10. Decomposers and detritivores feed on: (A) Only producers. (B) Only herbivores. (C) All trophic levels. (D) Only carnivores.	10.(C)
11. Examples of detritivores given in the text include: (A) Wolf and hawk. (B) Crabs and vultures. (C) Frog and snake. (D) Green plants.	11.(B)
12. Producers convert what percentage of solar energy falling on them? (A) 1 to 2%. (B) 10%. (C) 50%. (D) 100%.	12.(A)
13. During energy flow to the next trophic level, approximately what % is transferred? (A) 1%. (B) 5%. (C) 10%. (D) 50%.	13.(C)

CHARACTERISTICS OF POPULATION

Q.16 Define demography & name the most important feature of demography. S/Q

Ans. Demography & Most Important Feature of Demography:

- **Demography:** A statistical study of the characteristics of populations is called **demography.**
- **Population size** is the **most important** feature of **demography** because it is directly related to the ability of a given population to survive.

Q.17 Enlist the characteristics of population. S/Q

Ans. Characteristics of Population:

(1) Population Survivorship. (2) Population Growth.
(3) Population Density. (4) Population Dispersion or Distribution.
(5) Population Carrying Capacity. (6) Minimal Viable Population Size.

Topic: (1) Population Survivorship:

Q.18 What is population survivor ship? Discuss three survivor ship curve. L/Q

Ans. Population Survivor Ship:

- Population **survivorship** is the **percentage** of **members of a group** that are alive at a **given age.**
- It is often **visualized via survivorship** curves in survivorship graphs.
- In such graphs:
  (a) The **Y -axis shows** the numbers of survivors.
  (b) The **X -axis mentions age.**
- Such graphs make three kinds of survivorship.

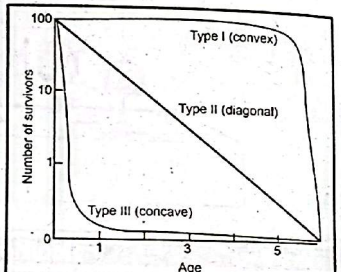


Figure: Survivorship curves

(i) Type-I (Convex) Populations:

- In such populations, individuals survive to an **old age,** then die rapidly.
- Environmental factors have very less impact on mortality and most individuals live their potential life span.
- **Examples: Humans'** and **mammals'** populations make type-I survivorship.

(ii) Type-II (Diagonal) Populations:

- In such populations, individuals have a **constant probability of death** throughout their lives.
- The environment has an important influence on death and is no harsher on the young than on the old.
- **Examples:** Populations of **birds, lizards,** and **rodents exhibit type-II survivorship curves.**

(iii) Type-III (Concave) Populations:

- In such populations, individuals experience very **high juvenile** mortality rates.
- Those reaching adulthood, however, have a much lower mortality rate.
- **Examples:** Fishes and many invertebrates display **type-III** survivorship curves.

Check Understanding!
Q.6 How does the logistic population growth model differ from the exponential growth model?

Topic: (2) Population Growth:

Q.19 What is population growth, name & describe its two models? L/Q

Ans. Population Growth:

- The increase in the **number of individuals** within a population over a specific time period is called population growth.
- It is an important attribute of populations.

Models of Population Growth:

- There are **two population** growth models.

(i) Exponential Growth Model:

- According to this model, the population grows without limits at its maximal rate.
- Rather than increasing by adding a constant number of individuals to the population in every generation, the population increases by the same ratio per unit time.
- Not all populations display **exponential growth.**

(ii) Logistic Growth Model:

- In this model, the growing population eventually reaches a limit due to shortage of resources **like space, light, water, or nutrients.**
- Such population stabilizes at a certain size, called the carrying **capacity** of the particular place where it lives.
- In these **situations,** growth curves assume a **sigmoid,** or **flattened S,** shape.

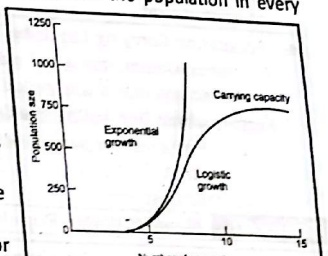


Figure: Population growth models

Topic: (3) Population Density:

Q.20 Define population density, write its examples and effects of high population density. L/Q

Ans. Population Density:

- The number of individuals **per unit area** or volume is called population density.
- **Examples:**
  (i) The number of **mulberry trees** per square kilometer in Muzaffarabad
  (ii) The number of **E. coli bacteria** per milliliter in a test tube.

Effects of Population Density:

- In populations with **high density,** when populations approach their carrying capacity, **competition** for resources can be severe, leading to decreased birth rate and increased risk of mortality.
- High population densities can also result in **high rates of pollution.**

Topic: (4) Population Dispersion or Distribution:

Q.21 Define population dispersion or distribution and describe its three characteristics. L/Q

Ans. Population Dispersion or Distribution:

- A way in which individuals of a population are **dispersed** or **distributed** within the population is called **population dispersion or distribution.**

Characteristics of Population Dispersion:

- Key characteristics of population dispersion are described below:

(1) Random Spacing:

- In random spacing, the individuals within **populations** do not interact strongly with one another.
- It is not common in nature.
- **Example:** It occurs in some plants that have wind-dispersed seeds that germinate wherever they fall in a favorable environment.

(2) Uniform Spacing:

- In some populations, individuals are uniformly **distributed.**
- **Example:** Some plant species inhibit the growth of nearby individuals, leading to a uniform distance between **each plant.** Similarly, animals that **maintain defined** territories, such as nesting penguins, also exhibit uniform dispersion.

(3) Clumped Spacing:

- In some populations, individuals clump into groups or clusters due to uneven distribution of resources.
- **Clumped spacing** is common in nature because individual animals, plants, and microorganisms tend to prefer resourceful habitats.
- **Clumped spacing** is seen in plants that **drop their seeds** straight to the ground, or animals that live in groups.

CamScanner

Topic: (5) Population Carrying Capacity:

Q.22 Define population carrying capacity & give the factors which determine the population carrying capacity of environment. L/Q

Ans. Population Carrying Capacity:

- The maximum number of individuals of a particular species that a specific environment can support sustainably over a long period is called **carrying capacity of a population.**

➢ **Factors which Determine the Carrying Capacity of Population:**

- Carrying capacity is determined by **"limiting factors"** such as:
  (i) Availability of food. (ii) Water Availability. (iii) Shelter Availability.
  (iv) Nesting sites. (v) Presence of predators and diseases.

Topic: (6) Minimal Viable Population Size:

Q.23 What is minimal viable population size & discuss the disadvantage if population falls below critical size. L/Q

Ans. Minimal Viable Population Size:

- The smallest number of **individuals** required for a population to **survive and persist** in the ecosystem is called **minimal viable population size.**

➢ **Effects When Population Falls Below Critical Size:**

- If a **population** falls below its **critical size**, it faces a high risk of **extinction.**
- In a **very small population** (like the few remaining Himalayan Brown Bears in Pakistan) inbreeding occurs. This leads to genetic **weaknesses** and a lower immunity against diseases.
- Moreover, a single natural disaster (e.g., flood or forest fire) may wipe out a **population** that is below its minimal viable size.

Day of Eight Billion:

- It took **11 years** for the **global population** to grow from **7 to 8 billion.**
- In 2022, it reached **8 billion.** Now, it will take about **15 years** (until 2037) to reach **9 billion.** By 2050, the global population will reach nearly **10 billion,** with the vast majority still residing in developing regions.

Topic: Rapid Growth of Human Populations:

Q.24 What changes do human make to expand the carrying capacity of their habitats? S/Q

Ans. Human Induced Changes for Expansion of Habitat Carrying Capacity:

(i) More Control Over Food Supply:

- Starting in the early **1700 s,** changes in **technology** have given humans more control over their food supply.

(ii) Protection Against Predators:

- Due to changing technology in early 1700 s, human were enabled them to develop **superior** weapons to **ward off predators.**

(iii) Remedies Against Diseases:

- Led to the development of remedies against many diseases.

(iv) Less Vulnerable to Environment Uncertainties:

- Humans have become less vulnerable to **climatic uncertainties.**
- These changes allowed humans to expand the carrying capacity of their habitats.

Q.25 What is the distribution of population in developed & developing countries & what is the population of Pakistan according to census in 2023? S/Q

Ans. Distribution of Population in Developed & Developing Countries:

- **About 16%** (1.28 billion) of the world's population lives in **developed countries.**
- While the **remaining 84%** (6.72 billion) reside in **developing countries.**

➢ **Pakistan's Population (2023):**

- According to the Pakistan **Bureau of Statistics,** the last census in 2023 recorded Pakistan's population to be **241.49 million.**
- Pakistan's population growth rate is officially recorded at **2.55%** annually.

Q.26 Discuss the effects of rapid growth of human population on ecosystem? Exercise LQ.4

Ans. Effects of Rapid Growth of Human Population on Ecosystem:

- The rapidly growing human population is perhaps the greatest challenge to the future of the **biosphere.**
- It is placing severe strains on the **global environment.**
- The following are some of these impacts:
  - **Habitat destruction** and changes in land use.
  - **Depletion** of natural resources (freshwater, fossil fuels etc.).
  - **Poverty** and inflation.
  - **Increased waste** generation and elevated pollution.
  - **Climate change.**
  - **Deforestation** and loss of biodiversity.
  - **Increased** chances of new epidemics and pandemics, starvation and malnutrition.

For Information

- According to the UNO, the population of Pakistan has now crossed **250 million.**
- Pakistan maintains its rank as the 5th most populous country in the world.

For Information

- If you **weigh** all life on Earth, the human population only makes up **about 0.01%** of the biomass on Earth.
- About **82%** of the Earth's biomass is made by plants while bacteria make about **13% of the biomass.**

Multiple Choice Questions (MCQs)

		Key
1.	What shows the percentage of group members alive at a given age? (A) Growth rate. (B) Survivorship. (C) Density. (D) Carrying capacity.	1.(B)
2.	Humans and mammals exhibit which type of survivorship curve? (A) Type I. (B) Type II. (C) Type III. (D) Type IV.	2.(A)
3.	Birds, lizards, and rodents exhibit which survivorship curve? (A) Type I. (B) Type II. (C) Type III. (D) Type IV.	3.(B)
4.	Fishes and many invertebrates display which survivorship curve? (A) Type I. (B) Type II. (C) Type III. (D) Type IV.	4.(D)
5.	In survivorship graphs, what is represented on the Y-axis? (A) Age. (B) Time. (C) Number of survivors. (D) Growth rate.	5.(C)
6.	Population density can be measured as the number of E. coli bacteria per: (A) Square kilometer. (B) Milliliter. (C) Liter. (D) Cubic meter.	6.(B)
7.	In which type of spacing do individuals inhibit the growth of nearby individuals? (A) Random spacing. (B) Clumped spacing. (C) Uniform spacing. (D) Diffuse spacing.	7.(C)
8.	Clumped spacing is common in nature because organisms prefer: (A) Barren areas. (B) Resourceful habitats. (C) Isolated zones. (D) High altitudes.	8.(B)
9.	Carrying capacity is determined by limiting factors such as food, water, shelter, and: (A) Solar radiation. (B) Tectonic plates. (C) Predators and diseases. (D) Wind currents.	9.(C)
10.	A small population of Himalayan Brown Bears facing inbreeding suffers from: (A) Increased size. (B) Genetic weaknesses. (C) Faster growth. (D) Higher immunity.	10.(B)
11.	Which model shows population growing without limits at its maximal rate? (A) Logistic model. (B) Density model. (C) Dispersion model. (D) Exponential model.	11.(D)
12.	In which model does a population reach a limit due to resource shortage? (A) Exponential model. (B) Logistic model. (C) Random model. (D) Clumped model.	12.(B)
13.	Logistic growth curves assume what shape? (A) Bell shape. (B) Linear shape. (C) Sigmoid shape. (D) Exponential shape.	13.(C)
14.	Population density is the number of individuals per unit area or: (A) Volume. (B) Weight. (C) Height. (D) Time.	14.(A)
15.	In which spacing do individuals not interact strongly with one another? (A) Uniform. (B) Clumped. (C) Random. (D) Aligned.	15.(C)
16.	Nesting penguins exhibit which type of spacing? (A) Random. (B) Uniform. (C) Clumped. (D) Dispersed.	16.(B)
17.	Which spacing is most common in nature due to uneven resource distribution? (A) Random. (B) Uniform. (C) Clumped. (D) Linear.	17.(C)

CamScanner

18. The maximum number of individuals a specific environment can sustainably support is the:	(A) Carrying capacity.	(B) Biotic potential	(C) Density limit.	(D) Growth rate.	18.(A)
19. If a population falls below its minimal viable size, it faces a high risk of:	(A) Migration.	(B) Extinction.	(C) Mutation.	(D) Speciation.	19.(B)
20. In 2022, the global population reached:	(A) 6 billion.	(B) 7 billion.	(C) 8 billion.	(D) 9 billion.	20.(C)
21. According to the 2023 census, Pakistan's population was recorded at:	(A) 200.50 million.	(B) 221.30 million.	(C) 241.49 million.	(D) 260.10 million.	21.(C)
22. Pakistan's population growth rate is officially recorded at:	(A) 1.55%.	(B) 2.55%.	(C) 3.55%.	(D) 4.55%.	22.(B)

GREENHOUSE EFFECT

Q.27 What is greenhouse effects? S/Q

Ans. Greenhouse Effect:

- Greenhous effect is the **natural process** where gases present in Earth's **atmosphere** trap the heat **radiated** from Earth's surface.
- The greenhouse gases behave like glass shield in Greenhouse (where plants are grown inside glass house) that's why it is called greenhouses effects.

Topic: Major Greenhouse Gases

Q.28 What are greenhouse gases name the major greenhouse gases. S/Q

Ans. Greenhouse Gases (GHGs):

- The gases which cause greenhouse effect are called **Greenhouse Gases (GHGs).**

➢ **Name of Major Greenhouse Gases:**

(i) Carbon Dioxide (CO_2). (ii) Methane (CH_4).
(iii) Nitrous Oxide (N_2O). (iv) Fluorinated Gases (Chlorofluorocarbons).

Q.29 How do greenhouse gases effect life on Earth? Also name the factors which are increasing their concentration. S/Q

Ans. Effects of Greenhouse Gases of Earth:

- These gases allow sunlight to pass through while prevent heat from **escaping directly** back into space. So, they keep the Earth warm enough to **sustain life.**

Factors Increasing Concentration of Greenhouse Gases:

- There has been a **marked increase** in the concentrations of GHGs, **particularly CO_2.**
- It is mainly due to activities in which fossil fuels are used for running machinery, driving vehicles, heating homes and generating electricity.
- The enhanced, **unnatural warming** of Earth's atmosphere caused by excessive GHGs is the major negative impact of human activities on our environment.

For Information

- The **wealthiest 20%** of the world's population consumes **86%** of the world's resources and produces **53%** of the world's carbon dioxide emissions.
- Whereas, the **poorest 20%** of the world consumes only **1.3% resources** and emits **only 3% of CO_2.** biodiversity

Q.30 Write a Detailed Note on Important Greenhouse Gases. Exercise L/Q.5

Ans. Detailed Note Major Greenhouse Gases:

- Important greenhouse gases include:

(i) Carbon Dioxide (CO_2):

- It is the most significant GHG.
- It is released through burning fossil fuels (coal, oil, and gas) and deforestation. It contributes about 80% of global warming.

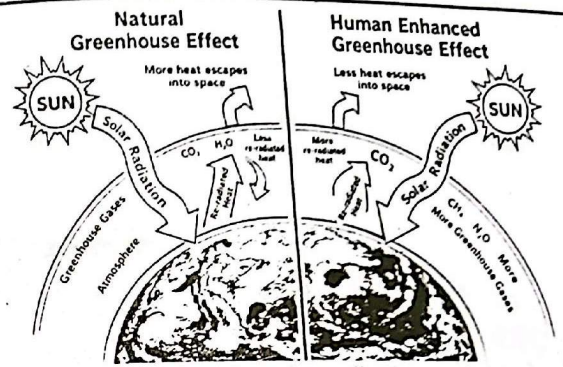


Figure: Natural and enhanced greenhouse effect (a cause of global warming)

(ii) Methane (CH_4):

- It is produced during the production of coal and gas, and by livestock (enteric fermentation in cattle) and agricultural practices.
- It contributes about 11% of global warming.

(iii) Nitrous Oxide (N_2O):

- It is emitted during agricultural and industrial activities, and during combustion of fossil fuels.
- It contributes about 6% of global warming.

(iv) Fluorinated Gases (Chlorofluorocarbons):

- These are synthetic gases and contribute about **3% of global warming.**
- **Examples include:** Hydrofluorocarbons used in old refrigerators and air conditioners, Chlorofluorocarbons used in aerosol sprays and air conditioners, Perfluorocarbons emitted as industrial byproducts, Sulfur hexafluoride used as electrical insulator in power grids and circuit breakers, and Nitrogen trifluoride used during the microelectronics manufacturing process.

Tidbits

- According to the World **Meteorological Organization in the pre-industrial era (~1750),** the global atmospheric CO_2 concentration was about 280 parts per million (ppm). During 1900, it rose to ~295 – 300 ppm. Now it has elevated to 428 ppm in 2026 and continues to rise.
- The actual mean global temperature has increased about 1°C since 1900, a change known as global warming.

Topic: Harmful Effects of Greenhouse Gases (GHGs)

Q.31 Discuss the harmful effects of greenhouse gases. Exercise L/Q.5

Ans. Harmful Effects of Greenhouse Gases (GHGs):

(i) Cause of Global Warming:

- The **intensified** greenhouse effect due to emission of excessive **GHGs** primarily causes global warming.
- **It refers** to the long-term increase in the **Earth's average** surface temperature due to human activities.
- According to the **Inter-governmental Panel on Climate Change** (IPCC) Report (2023), global surface temperature has increased by roughly **1.1°C** as compared to the pre-industrial era (1850-1900).

(ii) Cause of Heatwaves:

- Global warming has turned cities like **Jacobabad** and **Sibi** into some of the **hottest places on Earth.**
- When atmospheric temperature **crosses 50°C,** the human body cannot adjust normal body temperature, leading to fatal heatstroke.
- Livestock also **experiences heat stress.**
- Winters become shorter and warmer allowing pests and mosquitoes to survive longer.

Check Understanding!

Q.7 According to the provided text data, approximately what percentage of global warming is attributed specifically to carbon dioxide (CO_2) emissions?
(A) 11% (B) 50%
(C) 80% (D) 95%

Tidbits

- For Pakistan, which contributes less **than 1% of global** GHG emissions but is ranked among the top 10 most vulnerable countries to the devastating effects of climate change.

CamScanner

- Moreover, heat can **worsen the drought conditions**. The hot, dry weather increases the risks of wild fires.

(iii) Cause of Floods:

- A warmer **atmosphere** holds more moisture, leading to erratic and intense rainfall. This leads to erratic and **"turbo-charged"** monsoons and floods.
- The floods cause significant damage to **forests**, homes, and agriculture.
- They also **cause** long term damage such as soil erosion, **nutrient depletion**, and contamination of water resources.
- Floods also lead to rapid pathogen growth and spread of water-borne diseases.

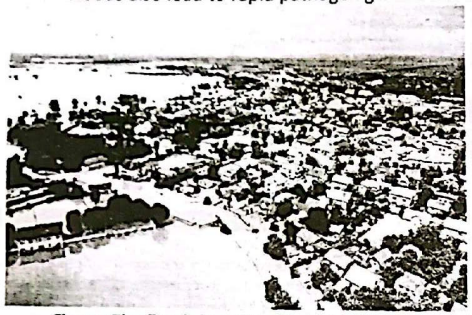


Figure: The floods in parts of Pakistan in 2025

Tidbits

- In **June 2025**, intense rains in Pakistan caused **worst floods.**
- These floods caused over 1,000 deaths, **displacement** of over 3 million people, destruction of over 200,000 homes, widespread agricultural and infrastructure losses across all provinces and **Gilgit Baltistan**. This **disaster** was due to heavy pre-monsoon rains, glacial-lake outburst floods, and cloudbursts.

(iv) Cause of Glacial Melting:

- Elevated greenhouse effect causes melting of glaciers.
- Pakistan has more **glaciers** than anywhere outside the **polar regions.**
- Rising temperatures cause these glaciers (like Baltoro and Batura) to melt rapidly. This leads to **Glacial Lake Outburst Floods.**
- In 2025, several such bursts occurred in Gilgit-Baltistan and Chitral, destroying bridges and entire villages.
- In the long run, once the glaciers vanish, the Indus River-the lifeline of our agriculture-could run dry.

Tidbits

- A **Glacial Lake Outburst Flood** (GLOF) is a sudden release of water from a glacial lake due to the breaking of its natural dam (e.g., ice).
- The water of **GLOF** can travel over 100 km from its source, affecting areas far downstream.
- A **cloudburst** is a sudden and extremely heavy rainfall in a short period over a small area.

(v) Cause of Sea Level Rise and Coastal Erosion:

- As polar ice melts and seawater expands due to heat, sea levels rise.
- **Example:** The coastal areas in **Thatta and Badin** are threatened, where seawater intrusion is already turning fertile agricultural land into salty marshes.

(vi) Cause of Food Insecurity:

- High temperatures during the flowering stage of **Wheat and Rice** can significantly reduce grain yield.
- Similarly, intense heat evaporates soil moisture, turning fertile lands into deserts (Desertification).

(vii) Cause of Ecosystem Disruption:

- Rapid shifts in temperature and rainfall patterns cause serious threats to biodiversity.
- Such disruptions force the species for changing their habitats or migrate. It further leads to species threatening and even extinction.

Multiple Choice Questions (MCQs)	Key
1. **The natural process where atmospheric gases trap heat radiated from Earth is called:** (A) Global warming. (B) Greenhouse effect. (C) Ozone depletion. (D) Photosynthesis.	1.(B)
2. **Which greenhouse gas contributes about 80% of global warming?** (A) Methane (CH_4). (B) Nitrous Oxide (N_2O). (C) Carbon Dioxide (CO_2). (D) Fluorinated gases.	2.(C)
3. **Methane is produced during the production of coal and gas, and by livestock through:** (A) Photosynthesis. (B) Enteric fermentation. (C) Transpiration. (D) Respiration.	3.(B)
4. **Fluorinated gases are synthetic gases emitted from industrial processes like old:** (A) Vehicles. (B) Brick kilns. (C) Refrigerators and air conditioners. (D) Water pumps.	4.(C)

		Key
5.	**According to the IPCC Report (2023), global surface temperature has increased by roughly:** (A) 0.5°C. (B) 1.1°C. (C) 2.0°C. (D) 3.5°C.	5.(B)
6.	**What traps Earth's radiated heat?** (A) Ozone layer. (B) Greenhouse gases. (C) Nitrogen gas. (D) Oxygen molecules.	6.(B)
7.	**Which gas contributes most to global warming?** (A) Methane. (B) Nitrous oxide. (C) Carbon dioxide. (D) Fluorinated gas.	7.(C)
8.	**Methane comes from livestock via:** (A) Transpiration. (B) Fermentation. (C) Respiration. (D) Photosynthesis.	8.(B)
9.	**Synthetic gases are emitted from old:** (A) Cars. (B) Heaters. (C) Fridges. (D) Tractors.	9.(C)
10.	**Global warming has turned cities like Jacobabad and Sibi into some of the hottest places on Earth when temperatures cross:** (A) 40°C. (B) 45°C. (C) 50°C. (D) 55°C.	10.(C)
11.	**A warmer atmosphere holds more moisture, leading to erratic and intense rainfall and:** (A) Stable seasons. (B) Gentle breezes. (C) Floods. (D) Increased snowfall everywhere.	11.(C)
12.	**Pakistan has more glaciers than anywhere outside the:** (A) Equator. (B) Polar regions. (C) Desert regions. (D) Tropical zones.	12.(B)
13.	**Seawater intrusion is already turning fertile agricultural land into salty marshes in coastal areas like:** (A) Lahore and Faisalabad. (B) Murree and Swat. (C) Thatta and Badin. (D) Multan and Bahawalpur.	13.(C)
14.	**High temperatures during the flowering stage of Wheat and Rice can significantly reduce:** (A) Root length. (B) Grain yield. (C) Plant height. (D) Leaf count.	14.(B)
15.	**Intense heat evaporates soil moisture, turning fertile lands into deserts in a process known as:** (A) Deforestation. (B) Desertification. (C) Urbanization. (D) Salinization.	15.(B)

IMPORTANT ECOSYSTEMS OF PAKISTAN

Q.32 Name the four major ecosystem of Pakistan. SQ

Ans. Major Ecosystem of Pakistan:

- Pakistan's **geography** ranges from the **highest peaks** in the north to the **Arabian Sea** in the south.
- It creates a **"miniature world"** of ecological diversity.
- The following are the four most significant ecosystems of Pakistan.
  (i) Temperate Deciduous Forest. (ii) Tropical Thorn Forest.
  (iii) Alpine and Sub-Alpine Meadows. (iv) Mangrove Forest (Coastal Ecosystem).

Topic: Temperate (Himalayan) Coniferous Forests:

Q.33 Write a detailed note on the Temperate (Himalayan) Coniferous Forest in Pakistan. Exercise Q.no 7

Ans. Temperate (Himalayan) Coniferous Forest:

- These forests are high-altitude, mountain ecosystems located in the middle-to-upper elevations of the mountain ranges of Pakistan.

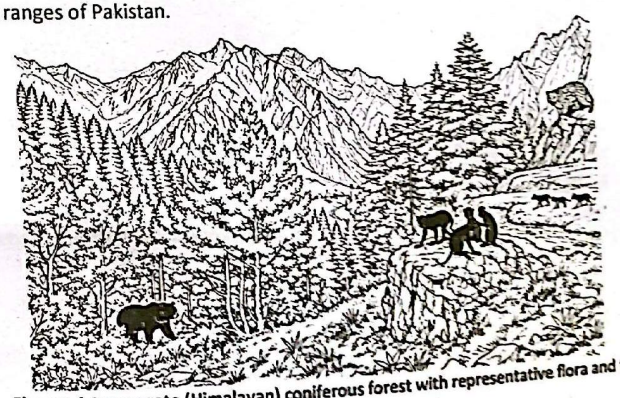


Figure: A temperate (Himalayan) coniferous forest with representative flora and fauna.

CamScanner

- **Location:** Punjab/KP Border (Murree, Nathia Gali), Khyber Pakhtunkhwa (Abbottabad, Mansehra, Kalam), Azad Jammu & Kashmir (Sharda, Rawalakot, Bagh, Muzaffarabad), and Gilgit-Baltistan (Gilgit, Chilas, Skardu).
- **Abiotic Profile Soil:** Rich, grayish-brown soil with high organic matter (humus).
- **Climate:** Moderate temperatures (4°C to 30°C).
- **Annual Rainfalls:** Annual rainfall between 1000 mm and 1500 mm.
- **Key Flora:** Taxus baccata (Yew), Pinus wallichiana (Blue Pine), Cedrus deodara (Himalayan Cedar), and shrubs like Berberis lycium (Sumbal).
- **Key Fauna:** Rhesus monkey (Macaca mulatta), Black bear, Leopard cat, wolves, rock lizards, and various bird species.
- **Current Status:** Degraded. Many large predators have been wiped out, and the forest is under pressure from the lumber industry and agricultural expansion.

Topic: Tropical Thorn Forest:

Q.34 Provide a comprehensive account of the Tropical Thorn Forest of Pakistan. Give its location, key flora and fauna, and its current ecological state. Exercise Q.6 LQ
OR Discuss the important characteristics of tropical thorn forest.

Ans. Important Characteristics of Tropical Thorn Forest:

- This is the most **widespread** terrestrial ecosystem of the plains in Pakistan.
- It is characterized by **xerophytic** (drought-resistant) plants with thorns to **deter herbivores** and reduce water loss.

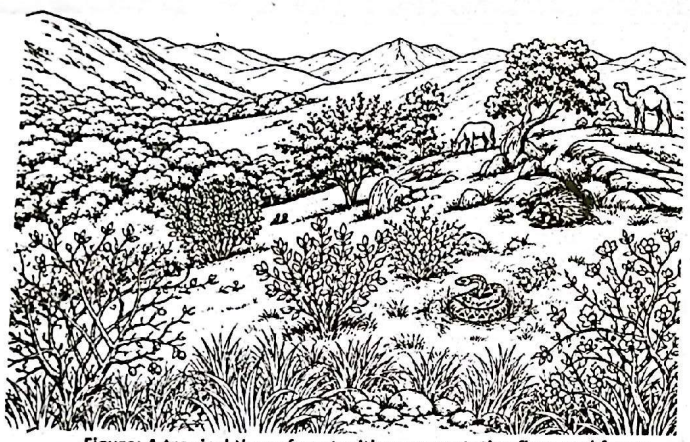


Figure: A tropical thorn forest with representative flora and fauna

- **Location:** The Indus Plains, covering much of Punjab (Bahawalpur, Khanewal, Mianwali, Dera Ghazi Khan), Sindh (southern regions bordering the Indus River), and Balochistan (western regions).
- **Abiotic Profile Climate:** Arid to semi-arid; summer temperatures can reach **50°C**.
- **Annual Rainfall:** Scanty rainfall **(200 mm to 750 mm annually).**
- **Key Flora:** Prosopis cineraria (Jhand/Kandi), Salvadora oleoides (Peelu/Wan), and Capparis aphylla (Karir) and Vachellia nilotica (Kikar).
- **Key Fauna:** Camels, houbara bustard, chinkara, golden jackal, Balochistan gerbil, porcupines, and rattlesnakes.
- **Current Status:** Heavily Degraded. Most of these "natural jungles" have been cleared for human settlements and the massive canal-irrigation agriculture of the Punjab.

Topic: Alpine and Sub-Alpine Meadows:

Q.35 Write a detailed note on alpine & sub-alpine meadows. LQ

Ans. Alpine and Sub-Alpine Meadows:

- These are **high-altitude "cold deserts" or grasslands,** where the climate is too harsh for large trees to grow.
  - **Location:** Mountain tops of Gilgit-Baltistan, Chitral, Swat, Azad Jammu & Kashmir, and the Deosai Plains.
  - **Abiotic Profile:** Temperature: Severe cold; mean **annual temperature** between 1°C and 10°C.
  - **Heavy Snowfall:** Precipitation mostly in the form of heavy snow (up to 6 feet).
  - **Key Flora:** Stunted Junipers, Birch (Betula utilis), willow, and various alpine grasses and wildflowers.
  - **Key Fauna:** Snow leopard, Himalayan brown bear, Himalayan Ibex, musk deer and Marmots. Birds like snowcock, monal, golden eagle are also found here.
  - **Current Ecological Status:** Fragile. These areas are highly sensitive to **Global Warming,** as melting snow caps alter the delicate balance of the meadow.

Check Understanding!
Q.8 What primary abiotic factor makes the tropical thorn forest ecosystem in Pakistan's plains heavily characterized by xerophytic plants?



Figure: An alpine Meadow with representative flora and fauna

Topic: Mangrove Forest (Coastal Ecosystem):

Q.36 Write a note on coastal ecosystem or forest of the sea also discuss its location abiotic profile, soil condition flora, fauna & its current ecological status in Pakistan. LQ

Ans. Mangrove Forest (Coastal Ecosystem):

- Often called **"The Forests of the Sea"** these are salt-tolerant forests located at the interface of land and sea.
  - **Location:** Sindh (Keti Bandar and Mirpur Sakro mangroves in Indus River Delta) and along the Balochistan coast (Miani Hor, Kalmat Khor, Jiwani & Gawatar Bay).
  - **Abiotic Profile: Water:** Brackish (a mix of fresh river water and salty seawater). Soil: Anaerobic (oxygen-poor) mudflats; trees have "breathing roots").
  - **Key Flora:** Avicennia marina (Timmar) makes up 95% of the forest.
  - **Key Fauna:** Crocodiles, shrimps, mudskippers, crabs, lobsters, turtle, snakes, dolphins and birds like flamingo, crane, pelican.

CamScanner

- **Current ecological Status in Pakistan:** This ecosystem is threatened by a reduction in freshwater flow from the Indus and pollution from Karachi, though recent restoration projects have helped save the area.

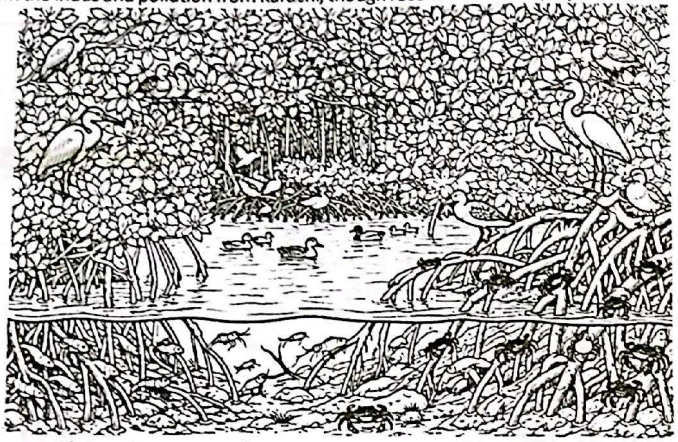


Figure: A mangrove forest with representative flora and fauna

Multiple Choice Questions (MCQs)	Key
1. Temperate deciduous forests are found in moist regions with distinct seasons and cold: (A) Summers. (B) Winters. (C) Springs. (D) Autumns.	1.(B)
2. The soil profile of temperate deciduous forests is grayish-brown and rich in: (A) Sand. (B) Humus. (C) Clay. (D) Silt.	2.(B)
3. Annual rainfall in temperate deciduous forests ranges between: (A) 100 mm to 500 mm. (B) 200 mm to 750 mm. (C) 750 mm to 1500 mm. (D) 2000 mm to 3000 mm.	3.(C)
4. Which of the following is listed as a key flora in temperate deciduous forests? (A) Avicennia marina. (B) Taxus baccata. (C) Prosopis cineraria. (D) Stunted Juniper.	4.(B)
5. What is the current status of temperate deciduous forests according to the text? (A) Degraded. (B) Pristine. (C) Expanding. (D) Protected.	5.(A)
6. Tropical thorn forests are characterized by drought-resistant plants known as: (A) Halophytic. (B) Xerophytic. (C) Epiphytic. (D) Mesophytic.	6.(B)
7. In tropical thorn forests, summer temperatures can reach up to: (A) 30°C. (B) 40°C. (C) 50°C. (D) 60°C.	7.(C)
8. Most tropical thorn forest jungles have been cleared for human settlements and: (A) Mining. (B) Canal-irrigation agriculture. (C) Urban parks. (D) Industrial hubs.	8.(B)
9. Alpine and sub-alpine meadows are high-altitude ecosystems known as: (A) Hot deserts. (B) Wet grasslands. (C) Salt marshes. (D) Cold deserts.	9.(D)
10. In alpine meadows, precipitation mostly occurs in the form of heavy: (A) Rain. (B) Hail. (C) Snow. (D) Sleet.	10.(C)
11. Which animal is specifically listed as key fauna in alpine and sub-alpine meadows? (A) Rhesus monkey. (B) Snow leopard. (C) Golden jackal. (D) Dolphin.	11.(B)
12. Mangrove forests are often called the: (A) Forests of the Sea. (B) Jungles of the Plains. (C) Woods of the Mountains. (D) Thickets of the Rivers.	12.(A)
13. The soil in mangrove forest mudflats is oxygen-poor, meaning it is: (A) Aerobic. (B) Anaerobic. (C) Hyperoxic. (D) Oxic.	13.(B)
14. Which plant species makes up 95% of the mangrove forest flora? (A) Cedrus deodara. (B) Vachellia nilotica. (C) Avicennia marina. (D) Betula utilis.	14.(C)
15. Mangrove fauna includes breathing-root zones inhabited by mudskippers, shrimps, and: (A) Wolves. (B) Crocodiles. (C) Bears. (D) Camels.	15.(B)
16. Mangrove forests are threatened by pollution from Karachi and a reduction in freshwater flow from the: (A) Ravi River. (B) Chenab River. (C) Indus River. (D) Jhelum River.	16.(C)

Check Understanding (Solutions)		
Q.#	Option	Explanation
1.	(B)	• A population specifically refers to a group of individuals of the same species living in a designated geographic area at the same time.
2.	S/Q	• It serves as the highest and most inclusive level where the lithosphere, hydrosphere, and atmosphere interact globally to encompass every zone supporting life.
3.	(A)	• Transpiration is specifically defined as the major biotic exit point where plants release water vapors through their stomata.
4.	S/Q	• Nitrosomonas bacteria convert toxic ammonia into nitrites, after which Nitrobacter bacteria further convert those nitrites into plant-absorbable nitrates.
5.	(B)	• Energy is lost as heat at each trophic level transfer, meaning fewer steps preserve a higher overall efficiency of usable energy.
6.	S/Q	• Exponential growth increases populations limitlessly at maximal rates, whereas logistic growth stabilizes near a carrying capacity due to environmental resource limitations, forming an S-shape.
7.	(C)	• The text explicitly states that carbon dioxide is the most significant greenhouse gas, contributing approximately 80% of global warming.
8.	S/Q	• These regions experience arid to semi-arid climates with scanty annual rainfall ranging from 200 mm to 750 mm alongside high summer temperatures reaching 50°C.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS MCQs

1. **If you study the interaction between a herd of Markhors, the grass they eat, and the snow leopards that hunt them, which level of ecological organization are you focusing on?**
   (a) Species. (b) Population. (c) Community. (d) Biosphere.
2. **Nitrogen-fixers are present in the groups:**
   (a) Bacteria and fungi. (b) Bacteria only. (c) Fungi only. (d) Bacteria, fungi and viruses.
3. **In an ecosystem, the energy flow is:**
   (a) Always unidirectional. (b) Always bidirectional. (c) Non-directional. (d) Cyclic.
4. **Absorption and re-emission of heat radiation by the atmosphere is called:**
   (a) Global warming. (b) Ozone depletion. (c) Acid rain. (d) Greenhouse effect.
5. **A population's carrying capacity.**
   (a) Can be accurately calculated. (b) Generally, remains constant over time.
   (c) May change as environmental conditions change. (d) Can never be exceeded.
6. **During energy flow in ecosystems, how much of the energy at a trophic level enters the next level?**
   (a) 100% (b) 50% (c) 25% (d) 10%
7. **Which group of bacteria is involved in nitrification?**
   (a) Azotobacter. (b) Nitrosomonas. (c) Clostridium. (d) Rhizobium.
8. **Which step of nitrogen cycle is accomplished by Pseudomonas?**
   (a) Ammonification. (b) Nitrification. (c) Nitrogen fixation. (d) De-nitrification.
9. **How do nitrogen-fixing bacteria contribute to the nitrogen cycle?**
   (a) Return nitrogen (N_2) to the atmosphere. (b) Change ammonium to nitrate.
   (c) Change N_2 to ammonium. (d) Absorb nitrate from the soil.
10. **According to 2025-2026 climate data, the "Enhanced Greenhouse Effect" is considered as climate injustice for Pakistan because:**
    (a) Pakistan produces the majority of global greenhouse gases.
    (b) Greenhouse Effect only occurs in South Asia.
    (c) Pakistan emits less than 1% of global GHGs but suffers extreme warming and floods.
    (d) Industrialized nations have successfully stopped all carbon emissions.

CamScanner

Answer Key with Explanations

Sr.No.	Optior	Answer	Explanations
1.	(c)	Community.	• Studying multiple interacting species (Markhors, grass, and snow leopards) in a shared habitat represents the community level of ecological organization.
2.	(b)	Bacteria only.	• Biological nitrogen fixation is exclusively carried out by specialized prokaryotes such as bacteria and cyanobacteria, not fungi.
3.	(a)	Always unidirectional.	• Energy flows through an ecosystem in a single direction, entering as sunlight and dissipating as heat without being recycled.
4.	(d)	Greenhouse effect.	• The trapping and re-emission of thermal infrared radiation by atmospheric greenhouse gases is known as the greenhouse effect.
5.	(c)	May change as environmental conditions change.	• A population's carrying capacity is dynamic and fluctuates depending on resource availability and environmental alterations.
6.	(d)	10%	• According to the ten percent rule, only about 10% of the energy is transferred from one trophic level to the next.
7.	(b)	Nitrosomonas.	• Nitrosomonas bacteria are key nitrifiers that convert ammonia into nitrites during the nitrification process.
8.	(d)	De-nitrification.	• Pseudomonas species act as denitrifying bacteria that reduce nitrates back into nitrogen gas, returning it to the atmosphere.
9.	(c)	Change N2 to ammonium.	• Nitrogen-fixing bacteria convert inert atmospheric nitrogen gas into usable ammonium for biological use.
10.	(c)	Pakistan emits less than 1% of global GHGs but suffers extreme warming and floods.	• Pakistan contributes a negligible share of global greenhouse gas emissions yet faces disproportionate climate vulnerabilities and disasters.

SECTION 2: SHORT ANSWER QUESTIONS SAQ

Q.1 What are the primary reservoirs of the chemicals of biogeochemical cycles?

Ans. Primary Reservoirs of the Chemicals of Biogeochemical Cycles:

- The primary reservoirs are the **atmosphere, oceans,** and **rocks** (lithosphere).
- These reservoirs store vast amounts of essential elements like carbon, nitrogen, and phosphorus.

Q.2 Write notes on de-nitrification and ammonification.

Ans. Denitrification:

- It is the process by which specialized bacteria convert soil **nitrates (NO_3) into nitrogen gas (N_2).**
- This gas is returned to the atmosphere, completing the nitrogen cycle.

Ammonification:

- It is the conversion of organic nitrogen from dead organisms and waste products into ammonia.
- This process is carried out by decomposer bacteria and fungi in the soil.

Q.3 Briefly describe the role of bacteria in the nitrogen cycle. Enlist their names and roles.

Ans. Nitrogen-fixing bacteria ($N_2 \xrightarrow{\text{Rhizobium, Azotobacter}} NH_3$):

- They fix free atmospheric nitrogen into ammonia that plants can utilize.

Nitrifying bacteria ($NH_3 \xrightarrow{\text{Nitrosomonas, Nitrobacter}} NO_2^-$):

- Nitrosomonas converts ammonia into nitrites.
- Nitrobacter converts nitrites into nitrates.

$$NO_2^- \xrightarrow{\text{Nitrobacter}} NO_3^-$$

Denitrifying bacteria (Pseudomonas):

- They convert soil nitrates back into gaseous nitrogen to be released into the atmosphere.

Q.4 Write a brief note on the flow of energy in trophic levels.

Ans. Flow of Energy in Trophic Levels:

- Energy enters ecosystems via **producers** through photosynthesis and flows in a single, non-cyclic direction.
- Only about **10 percent** of energy is transferred from one trophic **level to the next.**
- The remaining energy is lost to the environment as heat during cellular respiration and metabolic activities.

$$10{,}000\ \text{Kcal} \longrightarrow 1000\ \text{Kcal} \longrightarrow 100\ \text{Kcal} \longrightarrow 10\ \text{Kcal}$$

Q.5 Write brief notes on population density and population growth.

Ans. Population Density:

- It is defined as the total number of individuals of a **single species** present per **unit area** or volume at a given time.

Population Growth:

- It represents the overall change in the number of individuals of a population over a specific period.
- It is governed by **mortality, immigration,** and **emigration.**

Q.6 Investigate the effects of human population growth on the environment.

Ans. Effects of Human Population Growth on the Environment:

- Accelerated resource **consumption** leads to widespread deforestation and the destruction of natural habitats.
- Increased burning of fossil fuels causes severe air pollution, acid rain, and climate change.
- Unchecked waste generation results in water contamination and the rapid loss of global biodiversity.

Q.7 How does the increased greenhouses gases in atmosphere result in global warming?

Ans. Increased Greenhouses Gases in Atmosphere Result in Global Warming:

- **Increased greenhouse** gases form an **insulating layer** in the lower atmosphere, like a glass shield in **"greenhouse".**
- They allow incoming short-wave solar radiation to pass through and heat the Earth's surface.
- They absorb and trap outgoing long-wave infrared radiation, preventing it from escaping into space and raising **global temperatures.**

Q.8 What are the long-term effects of global warming?

Ans. Long-term Effects of Global Warming:

- Melting of polar ice caps and glaciers leads to a steady rise in global sea levels.
- Increased frequency of extreme weather anomalies such as severe droughts, floods, and storms.
- Disruption of natural ecosystems, leading to species extinction and shifts in agricultural productivity.

Q.9 Describe the unique adaptations of flora in the Mangrove ecosystem.

Ans.

(i) Specialized upward-growing roots **emerge from waterlogged,** oxygen-deficient mud to absorb oxyger from the air.

(ii) Seeds germinate while still attached to the **parent plant,** producing seedlings equipped for immediat establishment in soft sediment.

(iii) Salt-secreting glands or specialized root membranes filter out excess salt from seawater intake.

CamScanner

Q.10 Distinguish between the Abiotic profiles of a Temperate (Himalayan Coniferous) Forest and a Tropical Thorn Forest.

Ans.

Temperate (Himalayan) Coniferous Forest	Tropical Thorn Forest
• Characterized by a moderate climate with four distinct seasons and adequate, well-distributed rainfall.	• Characterized by an arid or semi-arid climate with sparse, highly erratic rainfall and high temperatures.
• Features fertile, nutrient-rich soils formed from abundant organic leaf litter.	• Features dry, sandy, or stony soils deficient in organic matter and moisture.

Q.11 Enlist the key fauna and flora of a temperate (Himalayan) coniferous forest, tropical rain forest, and mangrove forest.

Ans. Temperate Deciduous Forest:

- **Flora:** Oak, maple, beech, and elm trees.
- **Fauna:** Deer, black bears, wolves, foxes, and squirrels.

Tropical Rain Forest:

- **Flora:** Broad-leaved evergreen trees, orchids, lianas, and ferns.
- **Fauna:** Jaguars, toucans, sloths, poison dart frogs, and spider monkeys.

Mangrove Forest:

- **Flora:** Red mangroves, black mangroves, and saltworts.
- **Fauna:** Mudskippers, fiddler crabs, saltwater crocodiles, and wading birds.

Q.12 Differentiate between:

- **Biome and biosphere.**
- **Population growth and population density.**
- **Nitrification and nitrogen-fixation.**
- **Biogeochemical cycle and energy flow**
- **Convex population and concave population.**
- **Nitrification and denitrification**

Ans. Biome and Biosphere:

Biome	Biosphere
• A biome is a large regional ecological community defined by distinct climate and vegetation.	• The biosphere encompasses all global ecosystems where life exists.

Biogeochemical Cycle and Energy Flow:

Biogeochemical Cycle	Energy Flow
• A biogeochemical cycle involves the continuous recycling of chemical elements between biotic and abiotic components.	• Energy flow is a one-way linear passage of energy through trophic levels.

Population Growth and Population Density:

Population Growth	Population Density
• Population growth is the change in population size over time.	• Population density is the numerical concentration of individuals per unit area at a given moment.

Convex Population and Concave Population:

Convex Population	Concave Population
• A convex population curve (Type I survivorship) shows high survival rates through early and middle life with most individuals dying in old age.	• A concave curve (Type III survivorship) shows high juvenile mortality with few individuals reaching advanced age.

Nitrification and nitrogen-fixation:

Nitrification	Nitrogen-Fixation
• Nitrification is the conversion of toxic ammonia into nitrites and nitrates by soil bacteria.	• Nitrogen-fixation is the conversion of atmospheric nitrogen gas into reactive ammonia or nitrates.

Nitrification and denitrification:

Nitrification	Denitrification
• Nitrification converts ammonia into plant-available nitrates.	• Denitrification converts soil nitrates back into unreactive nitrogen gas released into the atmosphere.

SECTION 3: LONG ANSWER QUESTIONS LAQ

Q.1 What is a biogeochemical cycle? Describe water cycle in detail.

Ans. See Page No. 359 – 361 (Q.10,Q.12,Q.13)

Q.2 Describe nitrogen cycle in detail.

Ans. See Page No. 361 (Q.13)

Q.3 Explain the flow of energy in successive trophic levels.

Ans. See Page No.363 – 364 (Q.14, Q.15)

Q.4 Explain the problems related to the rapid growth of human populations and the effects of that growth on ecosystem.

Ans. See Page No. 369 (Q.26)

Q.5 Describe the causes and impacts of the increasing concentration of greenhouse gases in the atmosphere.

Ans. See Page No. 370 – 371 (Q.30, Q.31)

Q.6 Provide a comprehensive account of the Tropical Thorn Forest of Pakistan. Give its location, key flora and fauna, and its current ecological state.

Ans. See Page No. 374 (Q.34)

Q.7 Write a detailed note on the Temperate (Himalayan) Coniferous Forests in Pakistan.

Ans. See Page No. 373 (Q.33)

INQUISITIVE ANSWER QUESTIONS IAQ

Q.1 Justify the fact that humans are responsible for climate change.

Ans. Humans are Responsible for Climate Change:

- Burning fossil fuels for energy releases massive amounts of greenhouse gases into the atmosphere.
- Human activities like driving vehicles and running factories produce emissions that trap solar heat, raising global temperatures.
- Human land clearing and widespread deforestation remove essential trees that naturally absorb carbon dioxide.
- Intensive agriculture and industrial processes release large amounts of powerful greenhouse gases like methane.

Q.2 Justify why science education has become necessary for everyone to understand the steps man has to take to save the biosphere.

Ans.

- Science education equips individuals with the critical thinking skills and ecological literacy needed to understand complex environmental issues like climate change and habitat degradation.
- Informed citizens are better prepared to make sustainable daily choices, support evidence-based conservation policies, and actively participate in saving the biosphere.

CamScanner

Q.3 Investigate the careers related to the study of environmental resources.

Ans. Careers Related to the Study of Environmental Resources:

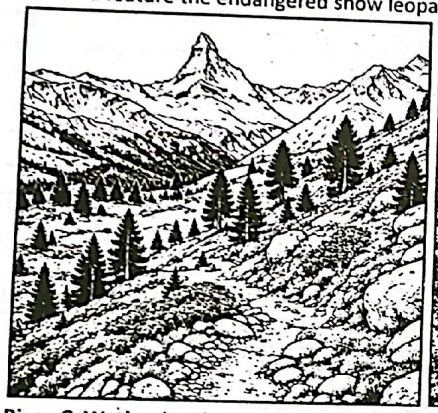
(i) Environmental Scientist / Consultant: Professionals who assess pollution levels, conduct environmental impact assessments, and help industries or governments comply with ecological regulations.

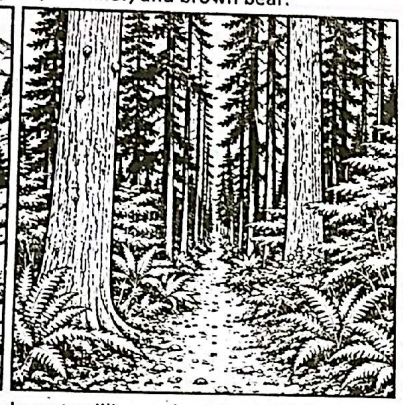
(ii) Conservation Biologist / Wildlife Manager: Specialists who protect endangered species, manage natural habitats, and restore degraded ecosystems to preserve biodiversity.

(iii) Sustainability Specialist: Experts who design and implement eco-friendly operational strategies, waste reduction frameworks, and renewable energy programs for organizations.

Q.4 Activity: Search internet and collect the pictures of the key fauna and flora of different ecosystems in Pakistan.

Ans. • **Alpine & Coniferous Forests:** Key flora include the Deodar cedar (Cedrus deodara) and blue pine, while notable fauna feature the endangered snow leopard, markhor, and brown bear.



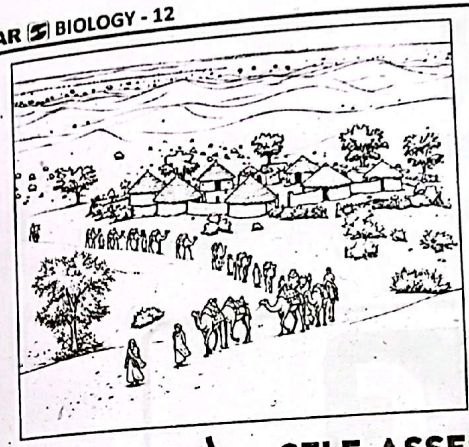


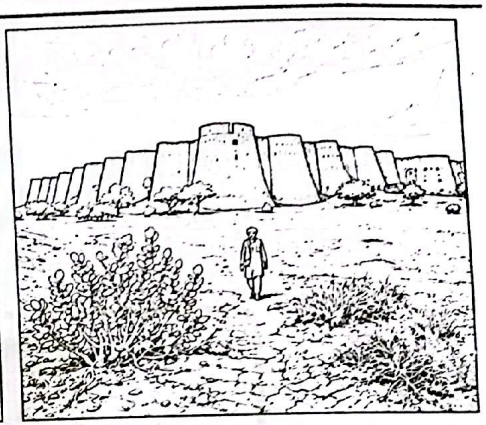
- **Indus River & Wetlands:** Characteristic flora include water lilies and reeds, providing vital habitats for fauna such as the critically endangered Indus River dolphin and various migratory waterbirds.





- **Desert & Arid Regions (Thar/Cholistan):** Predominant flora include acacia and xerophytic shrubs, supporting specialized fauna like the chinkara gazelle, desert monitor, and various sand-adapted reptiles.





SELF-ASSESSMENT

Total Mark: 30

Q.1 Encircle the correct option. **(1 x 6 = 06)**

(i) Nitrogen-fixers are present in the groups:
(A) Bacteria and fungi. (B) Bacteria only.
(C) Fungi only. (D) Bacteria, fungi and viruses.

(ii) The Indus River Dolphin is cited as an example of a distinct:
(A) Population. (B) Community. (C) Species. (D) Biome.

(iii) How do nitrogen-fixing bacteria contribute to the nitrogen cycle?
(A) Return nitrogen (N_2) to the atmosphere. (B) Change ammonium to nitrate.
(C) Change N_2 to ammonium. (D) Absorb nitrate from the soil.

(iv) 86% of global evaporation occurs from:
(A) Lakes. (B) Rivers. (C) Plants. (D) Oceans.

(v) Primary consumers are also known as:
(A) Carnivores. (B) Herbivores. (C) Omnivores. (D) Autotrophs.

(vi) Birds, lizards, and rodents exhibit which survivorship curve?
(A) Type I. (B) Type II. (C) Type III. (D) Type IV.

Q.2 Write short answers of the following questions. **(2 x 8 = 16)**

(i) Name the level of biological organization.
(ii) What is Population?
(iii) Define biogeochemical cycle & give two examples.
(iv) Write notes on de-nitrification and ammonification.
(v) Differentiate between Biome and biosphere.
(vi) Enlist the characteristics of population.
(vii) What is greenhouse effects?
(viii) Name the four major ecosystem of Pakistan.

Q.3 Extensive Questions. **(4 x 2 = 8**

(a) Describe nitrogen cycle in detail.
(b) Write a detailed note on the Temperate (Himalayan) Coniferous Forests in Pakistan.

CamScanner

FIND US ON
Facebook
LIKE OUR PAGE TODAY
@SCHOLARPUBLICATIONS.PK

SCHOLAR
PUBLICATIONS

The Stockists' Network

LAHORE DIVISION

1. Book town, Johar town
2. Iqra book centre,
3. City book center, Mansura
4. Azhar book centre,
5. Lala book centre,
6. Khokhar book center, Township
7. National book & sports
8. Bhai bhai book centre, Iqbal Town.
9. Lala book centre, Dharampura 042-368578100
10. Amir book depot, **Phool nagar** 0336-4362625
11. Bilal book depot, **Kasoor**
12. Waheed book depot **Kasoor**
13. Lucky book depot, **Mureedkay** 0300-80833600
14. Shaukat book depot, **Pattoki** 0300-4275262
15. MS book depot, **Sheikhupura**
16. Mirza book depot, **Sheikhupura**
17. Amjad book depot, **Sheikhupura**
18. Hamdard book depot, **Nankana sahib**

GUJRANWALA DIVISION

1. Fazal Book Depot, **GRW** 0300-9645664
2. Junaid Dar, **GRW** 03226404090
3. Anwar Book Depot, **GRW**
4. Saleem Dar, **GRW**
5. Nadeem Dar, **GRW**
6. Awaisi book Depot, **Kamoki**
7. Punjab Book Depot, **Wazirabad**
8. Lateef Book Depot, **Qila didar singh**
9. Munir Book Depot, **Qila didar singh**
10. Al-Badar Book Center, **Gujrat**
11. College Book Center, **Gujrat**
12. Khan Book Centre, **Gujrat** 053-3516245
13. Ideal book depot, **Kharian** Mr. Books, Lala Musa
14. Ilyas Book Depot, **Jalal pur jatta**
15. Ilmi Book Depot, **Jalal pur jatta**
16. College Book Depot, **Hafizabad**
17. Abid Book Depot, **Mandi Bhauddin**
18. Punjab Book Depot, **Phalian**
19. Talha Book Depot, **NAROWAL** 0345-6375064
20. Madina Book Depot, **NAROWAL**
21. Raja Book Depot, **Shakargarh**
22. Talha Book Depot, **Zafarwal**
23. Hafiz Brothers, **Zafarwal**
24. Ilmi Center Book Center, **Sialkot**, 051-4595539
25. Inam Book Center, **Daska** 051-6617617
26. Haideri Book Center, **Daska**
27. Al Qamar book depot, **Pasrur**

FAISALABAD DIVISION

1. Kitab Markaz, Aminpur Bazar, **FSD** - 041-2642707
2. Imran Book Centre, **FSD**
3. Al-Hasan Book Centre, **Aminpur Bazar, FSD**
4. Shakeel Book Depot, **Samundri** 0334-6292762
5. Waqas Book Depot, **Tandlianwala** 0302-7436450
6. Student Book Depot, **Jaranwala** 0300-6532538
7. Punjab Book Stall, **Chiniot**
8. Sargodha Book Depot **Chiniot** 0333-7690119
9. Nafees Book Depot, **Jhang** 0302-6083456
10. College Book Depot, **Jhang** 047-7612838
11. Hafiz Stationers Kitab Ghar, **Jhang**
12. Hamdard Book Depot, **Shorkot-** 0300-7502313
13. Iqbal Book Corner **Toba Tek Singh** 046-2515223

SAHIWAL DIVISION

1. Shahzad Book Depot, Farid Town, **SWL** 040-4550116
2. Bharwan Di Hatti, SWL Kitab Ghar **SWL**
3. Ashraf Book Depot, **Okara** 0300-6952583
4. Madina Book Depot, **Pakpattan**
5. Riaz Book Depot, **Pakpattan**
6. Nazeer Book Depot, **Renala khurd**
7. Lahore Book Depot, **Haveli lakhan**
8. Adil Book Depot , **Haveli Lakhan** 0334-9600327
9. Mirza Book Depot, **Depalpur**
10. Paracha Book Depot, **Hujra** Al-Hilal Book Depot, **Arifwala**
11. 0300-8758799
12. Student Book Depot, **Arifwala**

BALAWALPUR DIVISION

1. Al-Badr Book Center,University Square, **BWP** 062-2283138
2. New Student Book Depot, **Bahawalpur**
3. Mian Brother Book Centre, **Bahawalpur**
4. Saleemi Book Depot **Ahmad pur** sharqia 0300-313888/ 062-2272357
5. Saif Book Depot **Hasilpur** 0308-7297290
6. Punjab Book Depot Bahawalnagar 063-2271461
7. Royal Book Depot Bahawalnagar
8. Lasani Book Depot, **Haroonabad**
9. Dawn Book Depot, **Chishtian**
10. Ghazi Book Depot, **Fort abbas** 0300-7587922
11. Darul Kutab, **Khan pur**
12. Islam Book Depot, **Khanpur** 0321-8401147
13. Book Palace, **R Yar Khan**
14. Book Land, **R Yar Khan**
15. Akhtar Book Depot, **Sadiqabad** 068-5703834
16. Waqas book Depot, **Sadiqabad** 0307-8177222
17. Al Saeed Book Depot, **Liaqut pur** 03364630000

RAWALPINDI DIVISION

1. Kashmir Book Depot, Urdu Bazaar, **RWP** **051-5558321**
2. Rehman Book Depot College Road, **RWP** **051-5532282**
3. Iqra Book Centre, College Road, **RWP**
4. Idrees Book Bank, **RWP**
5. New Tashkeel Book Depot, **Attock**
6. Shani Book Depot, **JEHLUM**
7. Chaudhari Book Depot, Dina 0300-9460374
8. Tariq Book Depot, Chakwal
9. Maktaba Alkareem, Chakwal
10. College Book Depot, Talagang 0331-5632524
11. Hamdard Book Depot, Talagang 0336-1214321
12. Aftab Book Depot, Kahuta 0300-5032356

MULTAN DIVISION

1. College Book Depot, Purana Gala Mandi **MTN 061-4588149**
2. City Book Depot, **MTN**
3. Raza Book Depot, Golbagh Gulgasht Colony, **MTN 061-6224080**
4. Mr. Books, **Multan**
5. News Corner, **Multan 061-6223450**
6. Kitabistan Plus Near Shah Rukn-e-Alam, **MTN**
7. Ismail Book Depot, **MTN**
8. Punjab Kitab Ghar, BCG Chowk , **Multan**
9. Kaleem Rabbani Book Depot, **Jalalpur Pirwala** 0300-7828899
10. Awami Book Depot, **Lodhran**
11. Ghafoor Photostate, **Khanewal**
12. Hafeez Book Centre, **Kabbir wala** 0300-6892968
13. Hamza Book Depot, **Kabbir wala** 0301-1044607
14. Ittefaq Book Depot, **VEHARI** 0302-7999769
15. Ahmad Book Depot, **Mailsi**
16. Munir Book Depot, **Burewala**
17. Babar Book Depot **Burewala** 0333-4442352

SARGODHA DIVISION

1. The School Mall, Zafar Chowk, Sargodha **0321-6003651**
2. Sargodha Book Depot, **SGD** 048-3716043
3. New Nafees Book Depot, Mianwali Adbi Duniya, Mianwali
4. Mehria Book Depot, BHAKKAR 0336-7520823
5. College Book Depot, BHAKKAR
6. Khalid Book Depot, Quaidabad

D.G. KHAN DIVISION

1. Amir Book Depot, **DGK 064-2463230**
2. New Taunsa Kitab Ghar, Kalma Chowk, Taunsa 0333-8585185
3. Kaleem Book Depot, Taunsa 0333-7400743
4. Nafees Book Depot, Kot addu
5. Ali Book Depot, Rajanpur 0333-6448606
6. Fayyaz Book Centre, LAYYAH
7. Al Faisal Book Depot, Chowk Azam 0300-6558006
8. Times Book Depot, MUZAFFARGARH
9. Subhan Book Depot, Kot Sultan
10. Al-Kareem Book Depot, Ali Pur 0303-6585619
11. Lasani Book Depot, Chowk Munda 0301-5493097
12. Khalid Book Depot, Kot Sultan 0334-9600327

CamScanner