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BIOLOGY CLASS 10 — PUNJAB BOARD (PECTAA)

Biology Class 10 Complete Notes

All 10 Chapters — English Medium

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FBPK-BIO10-2026-11-FULLBOOK

Chapter 1: Human Digestive System

Chapter 1 follows food on its journey through the human body. Food contains large molecules (polymers) such as starch, proteins and fats that cannot pass through cell membranes. The digestive system breaks them into small soluble units (monomers) such as glucose, amino acids, fatty acids and glycerol, which are absorbed into blood and lymph and used by the cells.

These notes explain the five steps of nutrition, each region of the alimentary canal from the oral cavity to the anus, swallowing and peristalsis, the enzymes acting in each region, the structure of a villus, the many roles of the liver, and three common disorders of the gut: diarrhoea, constipation and peptic ulcer.

Learning Objectives

- Describe ingestion, digestion, absorption, assimilation and egestion.
- Describe the main regions of the alimentary canal and the accessory organs.
- Explain swallowing and peristalsis.
- State the enzymes of each region with their substrates and products.
- Describe the structure of a villus and the roles of capillaries and lacteals.
- State the roles of the liver and the causes, symptoms, treatment and prevention of diarrhoea, constipation and ulcers.

Key Concepts

1.1 Nutrition and Its Steps

Nutrition is the way an organism obtains and uses nutrients for energy, growth and repair. Plants show autotrophic nutrition: they make food from inorganic substances using light or chemical energy. Humans and other animals show heterotrophic nutrition: they obtain ready-made food from other organisms.

Nutrition in humans has five steps. Ingestion is taking food into the mouth. Digestion is breaking food down into small, soluble molecules. Absorption is the passage of these molecules into blood or lymph. Assimilation is the use of absorbed nutrients by body cells. Egestion is the removal of undigested waste through the anus.

Digestion is needed because carbohydrates, proteins and fats are large polymers that cannot cross cell membranes. They must be broken into monomers such as simple sugars, amino acids, fatty acids and glycerol.

1.2 Oral Cavity, Pharynx and Oesophagus

The alimentary canal is a long tube from mouth to anus. Accessory organs (salivary glands, liver and pancreas) pour their secretions into it.

In the oral cavity the teeth cut and grind food (mechanical digestion) while the tongue keeps it between the teeth; taste buds on the tongue detect taste. Three pairs of salivary glands secrete

saliva, which contains water and mucus to moisten food and the enzyme salivary amylase, which begins the chemical digestion of starch into maltose.

Swallowing: the chewed food, now a soft ball called a bolus, is pushed by the tongue to the back of the mouth into the pharynx. The soft palate rises to close the nasal passage, and the larynx moves up against the epiglottis so the glottis is closed and food does not enter the trachea.

The oesophagus, a tube about 25 cm long, carries food to the stomach by peristalsis: waves of contraction and relaxation of the muscles in its wall that squeeze food along. No new digestive juice is added in the oesophagus.

1.2 Stomach

The stomach is a J-shaped muscular bag in the upper left abdomen below the diaphragm. Food enters at the cardiac end through the cardiac (lower oesophageal) sphincter, which stops food flowing back, and leaves at the pyloric end through the pyloric sphincter.

The thick muscular wall churns food and mixes it with gastric juice from gastric glands. Gastric juice contains hydrochloric acid, which kills many bacteria and converts inactive pepsinogen into active pepsin; pepsin breaks proteins into shorter chains called peptides. Mucus lines the wall and protects it from the acid and pepsin.

Food stays in the stomach for about three to four hours and becomes a thick soup-like liquid called chyme. The pyloric sphincter releases chyme into the small intestine a little at a time (about 5 to 15 mL at a time).

1.2 Small Intestine and Digestion

The small intestine is a coiled tube about 7 m long with three parts: duodenum (about 25 cm), jejunum (about 2.5 m) and ileum (about 4 m).

In the duodenum, bile from the liver arrives through the common bile duct. Bile has no enzymes, but its bile salts break large fat globules into tiny droplets (emulsification), giving lipase a larger surface to act on. Pancreatic juice arrives through the pancreatic duct; it contains pancreatic amylase (starch → maltose), trypsin and chymotrypsin (proteins → peptides) and lipase (fats → fatty acids and glycerol), as well as sodium bicarbonate, which neutralises the acid chyme.

Glands in the intestinal wall complete digestion: peptidases and dipeptidases change peptides into amino acids, maltase changes maltose into glucose, sucrase changes sucrose into glucose and fructose, lactase changes lactose into glucose and galactose, and nucleases break nucleic acids into nucleotides.

1.2 Absorption: Villi

The inner wall of the small intestine is folded and covered with millions of finger-like villi, which give a very large surface area for absorption. The wall of each villus is only one cell thick, so the distance for absorption is short. Food molecules are absorbed by diffusion and active transport.

Each villus contains a network of blood capillaries and a central lymph vessel called a lacteal. Glucose and amino acids enter the capillaries, which join to form the hepatic portal vein carrying them to the liver; from there the hepatic vein carries them towards the heart. Fatty acids and

glycerol enter the lacteal and travel through the lymph vessels, which empty into the blood near the heart.

1.2 Large Intestine

Undigested material passes into the large intestine, which has three parts: caecum, colon and rectum. A small finger-like appendix hangs from the caecum; if it becomes infected (appendicitis) and is not removed, it may burst and spread infection.

The large intestine absorbs most of the remaining water, so the waste becomes semi-solid faeces, containing undigested fibre, bacteria, dead cells from the gut lining, bile pigments and water. Faeces are stored in the rectum and expelled through the anus (egestion).

1.2 Role of the Liver

The liver is the largest gland, weighing about 1.5 kg in an adult, lying on the right side below the diaphragm. It makes bile, which is stored in the gall bladder and released into the duodenum. Bile pigments come from the breakdown of old red blood cells and leave the body in the faeces.

Other functions: it stores glucose as glycogen and releases glucose when needed; stores fat-soluble vitamins; breaks down excess amino acids and turns the toxic ammonia produced into less toxic urea; breaks down toxins such as alcohol; breaks down old red blood cells; makes vitamin A from carotene; and produces heat by its high rate of metabolism.

1.3 Disorders of the Digestive System

Diarrhoea is the passing of frequent, loose, watery stools. Symptoms include abdominal cramps, bloating and signs of dehydration (thirst, dry mouth, dark urine). Causes include bacterial, viral or parasitic infection, food allergy, stress and some medicines. Treatment is plenty of fluids and oral rehydration solution (ORS), soft food, and medicines or antibiotics in severe cases. Prevention: wash hands before eating and after using the toilet and avoid contaminated food and water.

Constipation is infrequent (fewer than three times a week) or difficult passing of hard, dry faeces, with discomfort or bloating. Causes include a low-fibre diet, too little water, lack of exercise, some medicines (such as painkillers and iron tablets) and some diseases such as diabetes. Treatment and prevention: eat more fibre (fruits, vegetables, whole grains), drink plenty of water, exercise regularly and take medicine only on a doctor's advice.

A peptic ulcer is a sore in the lining of the stomach (gastric ulcer), duodenum (duodenal ulcer) or oesophagus. Symptoms include burning stomach pain, loss of appetite, weight loss and, in severe cases, vomiting blood. The main causes are infection by the bacterium Helicobacter pylori and long-term use of painkillers called NSAIDs; alcohol and smoking add to the risk and stress can worsen symptoms. Treatment uses antibiotics against H. pylori, antacids and acid-reducing medicines (proton pump inhibitors).

Important Definitions

Nutrition
The process by which an organism obtains and uses nutrients.

Heterotrophic nutrition
Obtaining ready-made food by consuming other organisms or organic matter.

Ingestion
Taking food and drink into the mouth.

Digestion
Breakdown of large food molecules into small soluble molecules.

Absorption
Passage of digested food molecules into the blood or lymph.

Assimilation
Use of absorbed nutrients by the body's cells.

Egestion
Removal of undigested food from the body as faeces.

Bolus
A soft ball of chewed food ready to be swallowed.

Epiglottis
A flap of elastic cartilage that keeps swallowed food out of the trachea.

Peristalsis
Waves of muscular contraction that push food along the alimentary canal.

Sphincter
A ring of muscle that controls the opening of a tube.

Chyme
The soup-like mixture of partly digested food leaving the stomach.

Emulsification
Breaking of large fat globules into tiny droplets by bile salts.

Villi
Finger-like projections of the small intestine wall that absorb food.

Lacteal
The lymph vessel inside a villus that absorbs fatty acids and glycerol.

Hepatic portal vein
The vein that carries absorbed sugars and amino acids from the intestine to the liver.

Diarrhoea
Frequent passing of loose, watery stools.

Constipation
Infrequent or difficult passing of hard, dry faeces.

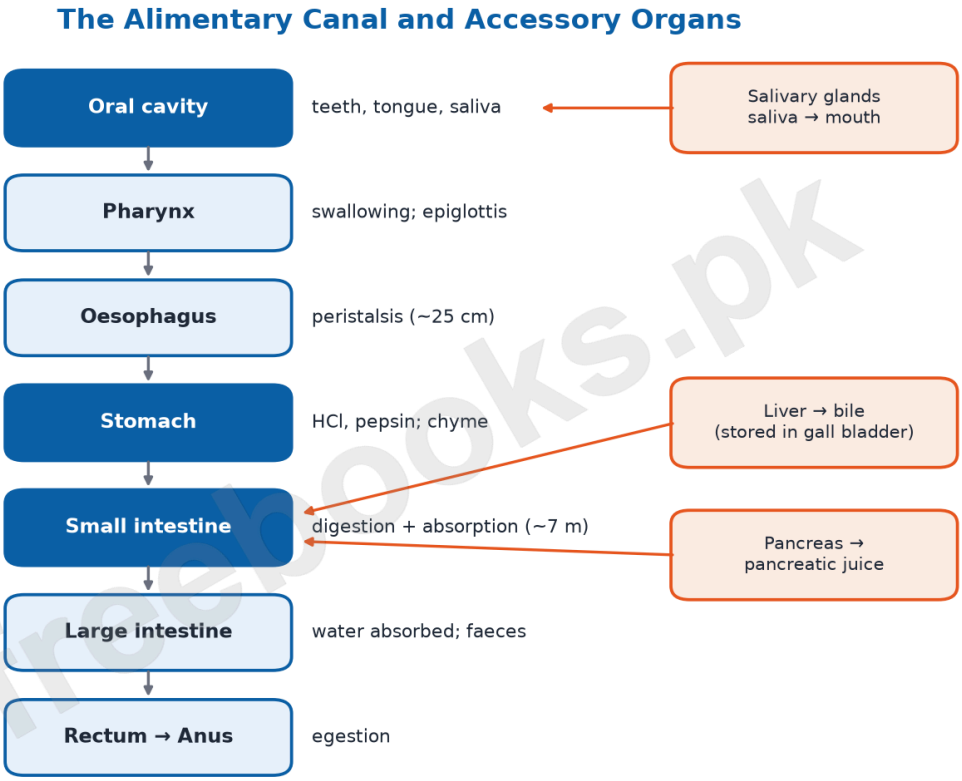
Peptic ulcer
A sore in the lining of the stomach, duodenum or oesophagus.

Key Facts at a Glance

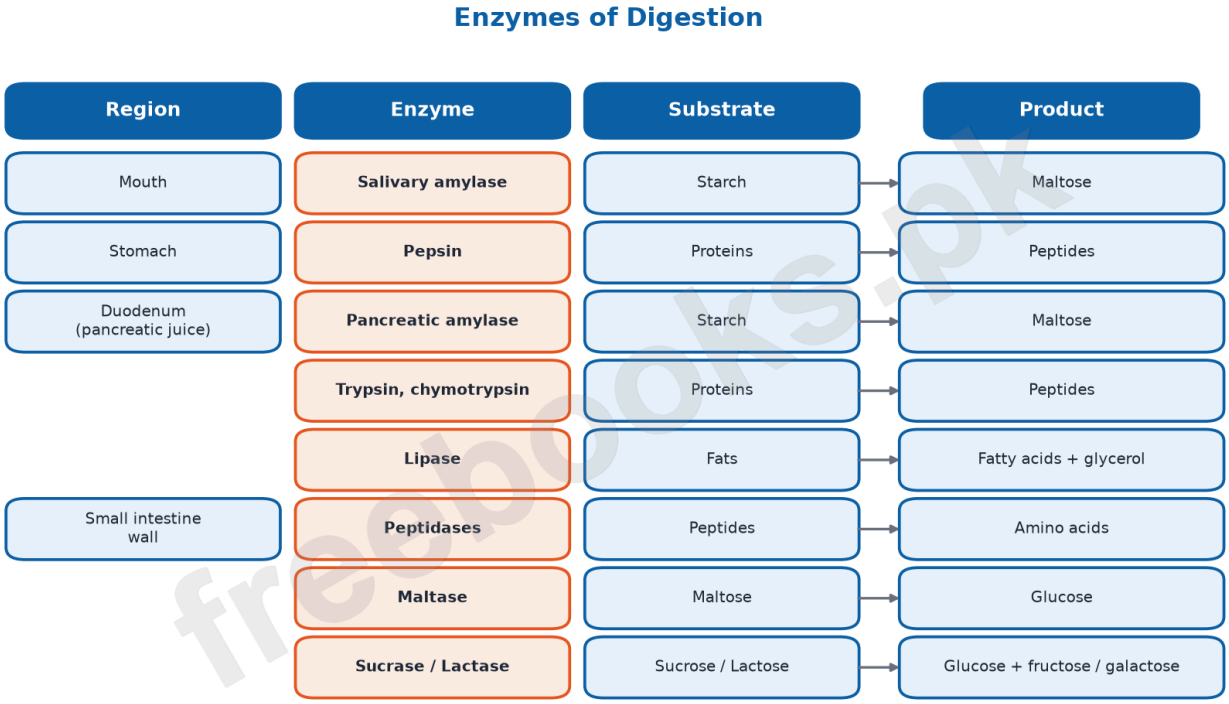
Region / organ	Key point
Salivary glands	3 pairs; saliva with salivary amylase (starch → maltose)
Oesophagus	About 25 cm; moves food by peristalsis
Stomach	HCl + pepsinogen → pepsin (proteins → peptides); food stays 3–4 h
Small intestine length	About 7 m: duodenum 25 cm, jejunum 2.5 m, ileum 4 m
Bile	No enzymes; bile salts emulsify fats
Pancreatic juice	Amylase, trypsin, chymotrypsin, lipase + sodium bicarbonate
Intestinal enzymes	Maltase, sucrase, lactase, peptidases, nucleases
Sugars & amino acids absorbed into	Blood capillaries → hepatic portal vein → liver
Fatty acids & glycerol absorbed into	Lacteals (lymph)
Large intestine	Caecum, colon, rectum; absorbs water
Liver mass	About 1.5 kg
Main cause of peptic ulcer	Helicobacter pylori infection; long-term NSAIDs

Diagrams

The alimentary canal: A flow chart of the alimentary canal from oral cavity to anus with the accessory organs and their secretions.



Enzymes of digestion: A chart of the main digestive enzymes in each region with their substrates and products.

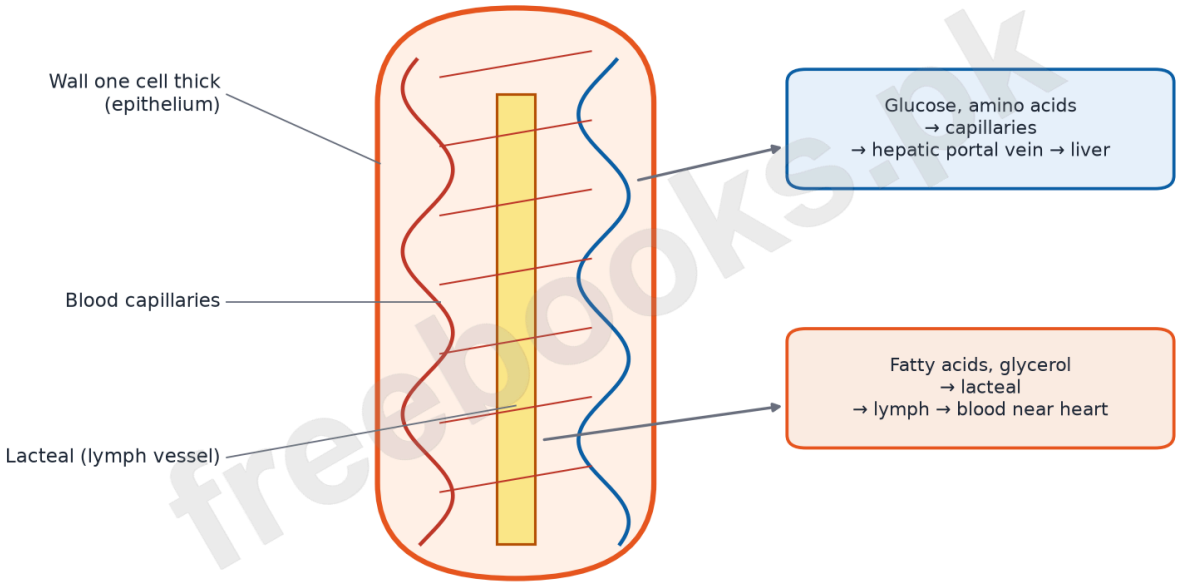


Structure of a villus: A simplified villus showing its one-cell-thick wall, blood capillaries, lacteal

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and where each nutrient goes.

Structure of a Villus



Millions of villi give a very large surface area

Short Questions and Answers

Why must food be digested before it can be used?
Starch, proteins and fats are large insoluble molecules that cannot cross cell membranes; digestion turns them into small soluble molecules that can be absorbed.

What is the difference between absorption and assimilation?
Absorption is the movement of digested food into the blood or lymph; assimilation is the use of these absorbed nutrients by the body cells.

What are the roles of saliva?
Its water and mucus moisten and lubricate food so it can be swallowed, and salivary amylase begins digesting starch into maltose.

How is food prevented from entering the windpipe?
During swallowing the larynx rises against the epiglottis, closing the glottis, so the bolus passes over it into the oesophagus.

Why can food reach the stomach even when a person is lying down?
Food is moved by peristalsis, muscular waves in the oesophagus wall, not by gravity.

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Give two functions of hydrochloric acid in the stomach.
It kills many bacteria present in food and converts inactive pepsinogen into active pepsin.

Why does the stomach not digest itself?
A layer of mucus covers its inner wall and protects it from acid and pepsin; pepsin is also secreted in an inactive form.

What is the role of the pyloric sphincter?
It controls the release of chyme from the stomach into the duodenum, a small amount at a time.

How does bile help digestion although it has no enzymes?
Bile salts emulsify fats into tiny droplets, increasing the surface area on which lipase can act.

Why is sodium bicarbonate present in pancreatic juice?
It neutralises the acidic chyme from the stomach, giving the alkaline conditions intestinal enzymes need.

Name the enzymes that act on maltose, sucrose and lactose.
Maltase (maltose → glucose), sucrase (sucrose → glucose + fructose) and lactase (lactose → glucose + galactose).

How are villi adapted for absorption?
They give a huge surface area, have walls one cell thick, and contain many blood capillaries and a lacteal to carry absorbed food away.

Why can a person with liver disease have trouble digesting fats?
The liver makes bile; without enough bile, fats are not emulsified and lipase works much more slowly.

Why is ORS given in diarrhoea?
It replaces the water and salts lost in watery stools and prevents dehydration, which is dangerous especially for children.

How does a high-fibre diet prevent constipation?
Fibre adds bulk and holds water in the faeces, keeping them soft and helping peristalsis move them along.

Long Questions and Answers

Describe digestion in the oral cavity, pharynx and oesophagus.

What happens to food in the oral cavity?

Teeth cut and grind food while the tongue moves it; saliva from three pairs of salivary glands moistens it and salivary amylase begins breaking starch into maltose.

How is food swallowed?

The tongue pushes the bolus into the pharynx; the soft palate closes the nasal passage and the epiglottis covers the glottis so food goes into the oesophagus.

What is peristalsis?

Waves of contraction and relaxation of the circular and longitudinal muscles in the oesophagus wall that squeeze food down to the stomach.

Does chemical digestion continue in the oesophagus?

No new enzymes are added, but salivary amylase mixed with the bolus can continue to act on starch until stomach acid stops it.

Describe the structure and functions of the stomach.

Where is the stomach and what are its parts?

A J-shaped bag in the upper left abdomen below the diaphragm, with a cardiac end guarded by the cardiac sphincter and a pyloric end guarded by the pyloric sphincter.

How is food broken down mechanically?

Strong contractions of its thick muscular wall churn the food and mix it with gastric juice.

What does gastric juice do?

Its HCl kills bacteria and activates pepsinogen to pepsin, which digests proteins into peptides; mucus protects the stomach lining.

What leaves the stomach?

After 3–4 hours food becomes chyme, which the pyloric sphincter releases into the duodenum in small amounts.

Explain digestion in the small intestine and the role of the liver and pancreas.

What are the parts of the small intestine?

Duodenum (about 25 cm), jejunum (about 2.5 m) and ileum (about 4 m), making about 7 m in all.

What is the role of the liver in digestion?

It makes bile, stored in the gall bladder; bile salts emulsify fats into small droplets so lipase can digest them quickly.

What is the role of the pancreas?

It secretes pancreatic juice containing amylase, trypsin, chymotrypsin and lipase to digest starch, proteins and fats, plus sodium bicarbonate to neutralise chyme.

How is digestion completed?

Enzymes from the intestinal wall (peptidases, maltase, sucrase, lactase, nucleases) turn peptides and disaccharides into amino acids and simple sugars.

Describe the absorption of food in the small intestine.

How is the surface area increased?

The inner wall is folded and covered in millions of finger-like villi.

What is the structure of a villus?

A projection with a wall one cell thick, containing a network of blood capillaries and a central lacteal.

Where do sugars and amino acids go?

They enter the blood capillaries, which join the hepatic portal vein to the liver; from there the hepatic vein carries them towards the heart.

Where do fatty acids and glycerol go?

They enter the lacteal, travel through the lymph vessels and reach the blood near the heart.

State the roles of the liver in the body.

What is the liver's role in digestion?

It makes bile, which emulsifies fats; bile pigments from broken-down red blood cells leave with the faeces.

How does it control food stores?

It stores glucose as glycogen and releases glucose when needed, and stores fat-soluble vitamins; it makes vitamin A from carotene.

How does it deal with wastes and toxins?

It breaks down excess amino acids, changes toxic ammonia into urea, breaks down alcohol and other toxins, and destroys old red blood cells.

How does it help keep the body warm?

Its high rate of metabolism releases a lot of heat, which increases in cold conditions.

Describe diarrhoea, constipation and peptic ulcer.

What are the causes and treatment of diarrhoea?

It is caused by infections, food allergy, stress or some medicines; treatment is fluids and ORS, soft food and medicine in severe cases.

What are the causes and prevention of constipation?

It results from low fibre, too little water, lack of exercise or some medicines; a high-fibre diet, plenty of water and exercise prevent it.

What causes a peptic ulcer?

Mainly Helicobacter pylori infection and long-term use of NSAID painkillers, with alcohol and smoking adding to the risk.

How is a peptic ulcer treated?

With antibiotics to remove H. pylori and antacids or proton pump inhibitors to reduce stomach acid.

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Multiple Choice Questions (MCQs)

Using absorbed nutrients to build body cells is called: (A) Ingestion (B) Absorption (C) Assimilation (D) Egestion
Correct answer: (C) Assimilation. Assimilation is using absorbed food.

Salivary amylase converts starch into: (A) Glucose (B) Maltose (C) Sucrose (D) Peptides
Correct answer: (B) Maltose. Starch → maltose.

The flap that stops food entering the trachea is the: (A) Pharynx (B) Epiglottis (C) Palate (D) Sphincter
Correct answer: (B) Epiglottis. The epiglottis covers the glottis.

Food moves along the oesophagus by: (A) Gravity (B) Peristalsis (C) Diffusion (D) Emulsification
Correct answer: (B) Peristalsis. Muscular waves push food.

Pepsinogen is activated in the stomach by: (A) Bile (B) Mucus (C) HCl (D) Lipase
Correct answer: (C) HCl. HCl converts pepsinogen to pepsin.

The partly digested liquid leaving the stomach is: (A) Bolus (B) Chyme (C) Bile (D) Faeces
Correct answer: (B) Chyme. Chyme.

The longest part of the small intestine is the: (A) Duodenum (B) Jejunum (C) Ileum (D) Caecum
Correct answer: (C) Ileum. Ileum is about 4 m.

Bile helps digestion by: (A) Digesting proteins (B) Emulsifying fats (C) Digesting starch (D) Killing bacteria only
Correct answer: (B) Emulsifying fats. Bile salts emulsify fat.

Trypsin is secreted by the: (A) Stomach (B) Liver (C) Pancreas (D) Salivary glands
Correct answer: (C) Pancreas. It is in pancreatic juice.

Lactase breaks lactose into: (A) Two glucose (B) Glucose and fructose (C) Glucose and galactose (D) Amino acids
Correct answer: (C) Glucose and galactose. Lactose = glucose + galactose.

Fatty acids and glycerol are absorbed into the: (A) Hepatic portal vein (B) Lacteals (C) Capillaries only (D) Large intestine
Correct answer: (B) Lacteals. They enter the lymph in lacteals.

Most water from undigested food is absorbed in the: (A) Stomach (B) Large intestine (C) Oesophagus (D) Duodenum
Correct answer: (B) Large intestine. The colon absorbs water.

The liver converts toxic ammonia into: (A) Glycogen (B) Urea (C) Bile salts (D) Vitamin A
Correct answer: (B) Urea. Urea is less toxic.

A common bacterial cause of peptic ulcer is: (A) E. coli (B) Helicobacter pylori (C) Salmonella (D) Rhizopus
Correct answer: (B) Helicobacter pylori. H. pylori infects the stomach lining.

ORS is mainly used to treat dehydration caused by: (A) Constipation (B) Diarrhoea (C) Ulcer (D) Appendicitis
Correct answer: (B) Diarrhoea. It replaces water and salts.

Quick Revision Summary

- Steps: ingestion → digestion → absorption → assimilation → egestion.
- Mouth: teeth + tongue (mechanical); saliva with salivary amylase (starch → maltose). Swallowing: bolus → pharynx; epiglottis closes glottis.
- Oesophagus (~25 cm): peristalsis. Stomach: churning; HCl + pepsin (proteins → peptides); mucus protects; chyme; cardiac and pyloric sphincters.
- Small intestine (~7 m: duodenum, jejunum, ileum): bile emulsifies fats; pancreatic amylase, trypsin, chymotrypsin, lipase, $NaHCO_3$; intestinal maltase, sucrase, lactase, peptidases.
- Villi: large surface, one-cell wall; capillaries (sugars, amino acids → hepatic portal vein → liver), lacteal (fatty acids, glycerol → lymph).
- Large intestine: caecum, colon, rectum; absorbs water; faeces egested.
- Liver: bile, glycogen store, vitamins, urea from ammonia, detoxification, breaks old RBCs, vitamin A, heat.
- Diarrhoea (ORS), constipation (fibre, water), peptic ulcer (H. pylori, NSAIDs; antibiotics, antacids).

Exam Tips

- Learn the enzyme table (region – enzyme – substrate – product); it gives many MCQs and short questions.
- Remember: bile has NO enzyme. Questions often test this.
- Know where each nutrient is absorbed: sugars and amino acids into blood, fatty acids and glycerol into lacteals.
- Draw a labelled villus and a labelled digestive system; both are common drawing questions.
- For disorders, answer under four headings: symptoms, causes, treatment, prevention.

Note on Facts

The textbook says heat produced by stomach churning helps melt lipids. Fats in food are kept fluid mainly by normal body temperature; the heat from churning is very small.

The textbook lists 'avoiding spicy foods' as prevention of ulcers. Spicy food does not cause peptic

ulcers, though it can make the pain of an existing ulcer worse. The main causes are H. pylori infection and long-term NSAID use.

The textbook says mucus neutralises the stomach's acid. More precisely, the mucus layer traps bicarbonate secreted by the lining, which neutralises acid right next to the wall while the stomach contents stay strongly acidic.

Chapter 2: Human Respiratory System

Chapter 2 explains how the human body takes in oxygen and gets rid of carbon dioxide. Cells release energy from glucose by cellular respiration, which needs a steady supply of oxygen and produces carbon dioxide. Breathing moves air in and out of the lungs, and gaseous exchange in the alveoli moves oxygen into the blood and carbon dioxide out of it.

These notes cover the parts of the air passageway, the structure of the lungs and alveoli, blood flow around the alveoli, the mechanism of inhalation and exhalation, the control of breathing rate, the difference between inhaled and exhaled air, five respiratory disorders (bronchitis, emphysema, pneumonia, asthma and lung cancer) and the harmful effects of smoking and vaping.

Learning Objectives

- Distinguish between breathing, gaseous exchange and cellular respiration.
- Describe the parts of the air passageway and the role of each.
- Describe the structure of the lungs and how alveoli are suited to gas exchange.
- Explain inhalation and exhalation in terms of the ribs, intercostal muscles and diaphragm.
- Compare the composition of inhaled and exhaled air.
- Describe the causes, symptoms and treatment of common respiratory disorders and the effects of smoking.

Key Concepts

Breathing, Gaseous Exchange and Respiration

Cellular respiration is a chemical process inside cells in which glucose is oxidised to release energy; in aerobic respiration oxygen is used and carbon dioxide and water are produced.

Gaseous exchange is the diffusion of oxygen from the air in the lungs into the blood and of carbon dioxide from the blood into that air.

Breathing is the physical (mechanical) process of moving air into and out of the lungs. Breathing makes gaseous exchange possible, and gaseous exchange supplies the oxygen needed for respiration.

2.1 The Air Passageway

Nostrils and nasal cavity: air enters through the nostrils into two narrow nasal cavities. Hairs filter out larger dust particles, sticky mucus traps finer particles and moistens the air, and the air is warmed close to body temperature before it reaches the lungs.

Pharynx: the nasal cavity opens into the pharynx, a passage shared by food and air. In its floor is the glottis, the opening of the larynx, guarded by the epiglottis so that food and drink do not enter the windpipe.

Larynx: the voice box between the pharynx and trachea. It contains two vocal cords; air passing

over them makes them vibrate and produce sound, which the lips, tongue, cheeks and jaws shape into speech.

Trachea and bronchi: the trachea (windpipe), about 12 cm long, divides into two bronchi, one entering each lung. Their lining has mucus that traps dust and bacteria and cilia that sweep this mucus up towards the pharynx. C-shaped cartilage rings in the trachea and cartilage plates in the bronchi keep these tubes open.

Bronchioles and alveoli: inside the lungs each bronchus branches again and again into fine bronchioles, whose cartilage decreases and finally disappears. Each smallest bronchiole ends in an alveolar duct leading to a cluster of tiny thin-walled air sacs, the alveoli, each surrounded by blood capillaries.

2.1 The Lungs

The two lungs lie in the thoracic cavity, enclosed by the chest wall (12 pairs of ribs with intercostal muscles) and resting on the dome-shaped muscular diaphragm below. They are spongy and elastic. The right lung has three lobes; the left lung is slightly smaller and has two lobes, leaving room for the heart.

Each lung is covered by a double membrane, the pleura. The inner layer sticks to the lung and the outer layer lines the chest wall and diaphragm; pleural fluid between them reduces friction during breathing.

Blood supply: the pulmonary artery brings deoxygenated blood from the heart. It branches into arterioles and then capillaries around the alveoli, where oxygen enters and carbon dioxide leaves the blood. The capillaries join into venules and then the pulmonary vein, which returns oxygenated blood to the heart.

Alveoli suit gas exchange because there are millions of them giving a huge surface area, their walls are one cell thick, their surface is moist so gases dissolve, and they are covered with a dense network of capillaries.

2.2 Mechanism of Breathing

Inhalation (inspiration): the external intercostal muscles contract and pull the ribcage upward and outward; at the same time the diaphragm contracts and flattens (moves down). The volume of the chest increases, the pressure inside the lungs falls below atmospheric pressure, and air rushes in.

Exhalation (expiration): the intercostal muscles relax and the ribcage moves down and in; the diaphragm relaxes and domes upward. The volume of the chest decreases, the pressure inside the lungs rises above atmospheric pressure, and air is pushed out. Quiet exhalation is mostly passive, helped by the elastic recoil of the lungs.

Breathing rate: at rest an adult breathes about 16 to 20 times per minute. During exercise, muscles respire faster and make more carbon dioxide; the respiratory centre in the brain detects the rise in blood CO_2 and sends faster nerve impulses to the rib muscles and diaphragm, so the rate can rise to about 30 to 40 breaths per minute.

Exhaled air contains less oxygen (about 16%) and much more carbon dioxide (about 4%) than inhaled air (about 21% oxygen and 0.04% carbon dioxide). Nitrogen stays the same. Exhaled air is saturated with water vapour, is near body temperature and is almost free of dust. We lose roughly

half a litre of water a day in exhaled air.

2.3 Respiratory Disorders

Bronchitis: inflammation of the bronchi or bronchioles that narrows the airways. It may be acute (lasting one to two weeks) or chronic; in chronic bronchitis mucus-secreting cells multiply and thick mucus blocks the airways. Causes: viral or bacterial infection and irritants such as tobacco smoke. Symptoms: cough, wheezing, fever, chills and shortness of breath. Treatment: medicines to ease coughing and breathing, antibiotics or antivirals as needed, and avoiding smoke and pollution.

Emphysema: the walls between alveoli weaken and break, so many small alveoli merge into fewer large spaces. The surface area for gas exchange falls and the patient becomes breathless. It is caused by long-term exposure to tobacco smoke, chemical fumes and polluted air. Symptoms are shortness of breath, chronic cough, wheezing and chest tightness. It cannot be fully cured; medicines only relieve symptoms.

Pneumonia: infection and inflammation of the lungs in which alveoli fill with fluid and pus. It is caused by bacteria, viruses or fungi. Symptoms: high fever, chills, breathlessness and a cough with sputum. Treatment depends on the cause: antibiotics, antivirals or antifungals. Vaccines can prevent some forms of bacterial pneumonia.

Asthma: an inflammatory condition in which the bronchi and bronchioles swell and narrow. Attacks bring shortness of breath, wheezing, coughing and chest tightness. Triggers include allergens (dust mites, pollen, mould, pet dander), smoke and fumes, strong scents and cold air; it often runs in families. Bronchodilator inhalers widen the airways during an attack.

Lung cancer: uncontrolled division of cells in the lungs forming masses of non-functional cells. It is the most commonly diagnosed cancer worldwide. Causes include carcinogens in tobacco smoke, passive smoking, ionising radiation and some viral infections. Symptoms: breathlessness, persistent cough (sometimes with blood) and weight loss. Treatment may involve surgery, chemotherapy and radiotherapy.

Effects of Smoking and Vaping

Tobacco smoke contains thousands of chemicals, dozens of which are carcinogens (cancer-causing). Nicotine is addictive, raises heart rate and blood pressure and damages blood vessels. Carbon monoxide binds to haemoglobin in red blood cells and reduces the oxygen the blood can carry. Tar settles in the lungs and reduces the surface for gas exchange. Benzene and formaldehyde are carcinogens; ammonia and other irritants damage the airways.

Smokers also face higher risks of heart disease, cancers of many organs, tuberculosis and pneumonia, as well as stained teeth, bad breath and tooth loss. Passive smokers breathing others' smoke also face greater risk of heart disease and lung cancer.

Vaping (using e-cigarettes) heats a liquid that may contain nicotine and other chemicals. It is not a safe alternative: it can inflame and injure the lungs and raise heart rate and blood pressure. World No Tobacco Day is observed on 31 May.

Important Definitions

Cellular respiration
Oxidation of food such as glucose inside cells to release energy.

Gaseous exchange
Diffusion of oxygen into the blood and carbon dioxide out of it in the lungs.

Breathing
The physical movement of air into and out of the lungs.

Glottis
The opening in the floor of the pharynx leading into the larynx.

Epiglottis
A flap that covers the glottis during swallowing.

Larynx
The voice box, containing the vocal cords.

Trachea
The windpipe, about 12 cm long, supported by C-shaped cartilage rings.

Bronchioles
Fine branches of the bronchi inside the lungs.

Alveoli
Tiny thin-walled air sacs where gas exchange takes place.

Pleura
The double membrane surrounding each lung.

Diaphragm
The dome-shaped sheet of muscle below the lungs.

Intercostal muscles
Muscles between the ribs that move the ribcage.

Inhalation
Taking air into the lungs (inspiration).

Exhalation
Moving air out of the lungs (expiration).

Bronchitis
Inflammation of the bronchi or bronchioles.

Emphysema
Breakdown of alveolar walls reducing the surface for gas exchange.

Pneumonia
Infection of the lungs in which alveoli fill with fluid and pus.

Asthma
Swelling and narrowing of the airways causing attacks of breathlessness.

Carcinogen
A substance that can cause cancer.

Vaping
Inhaling vapour produced by an e-cigarette.

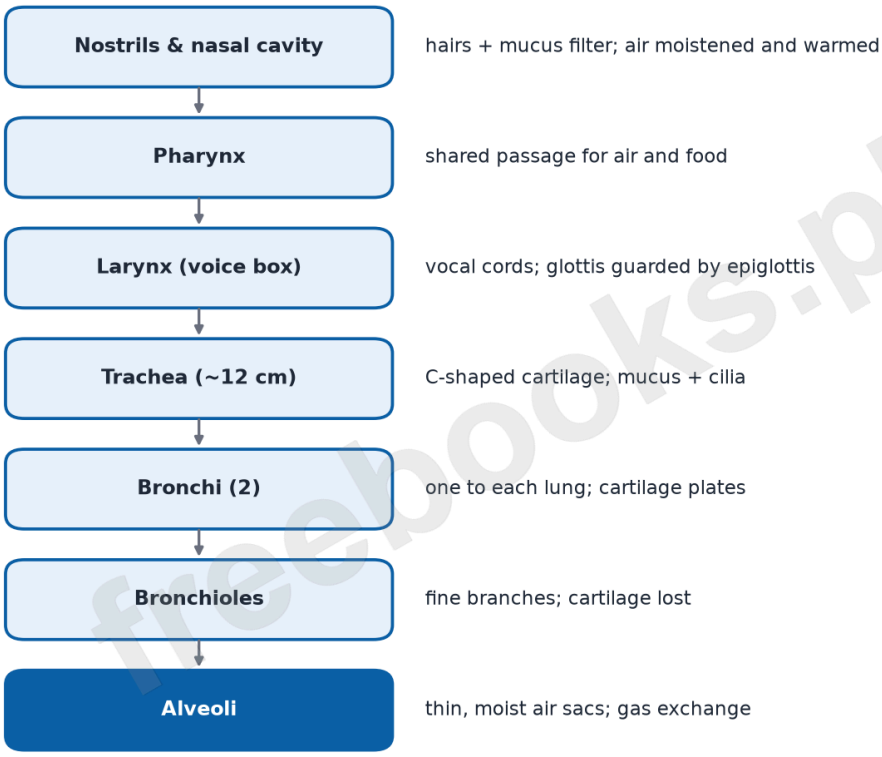
Key Facts at a Glance

Feature	Value / fact
Length of trachea	About 12 cm
Cartilage in trachea / bronchi	C-shaped rings / plates
Lobes of lungs	Right lung 3, left lung 2
Chest wall	12 pairs of ribs + intercostal muscles
Breathing rate at rest	16–20 per minute
Breathing rate in exercise	Up to 30–40 per minute
Oxygen: inhaled / exhaled air	About 21% / 16%
Carbon dioxide: inhaled / exhaled air	About 0.04% / 4%
Water lost by breathing	About half a litre a day
Alveolar walls broken	Emphysema
Alveoli filled with pus	Pneumonia
World No Tobacco Day	31 May

Diagrams

The air passageway: A flow chart of the route taken by air from the nostrils to the alveoli, with the role of each part.

The Air Passageway



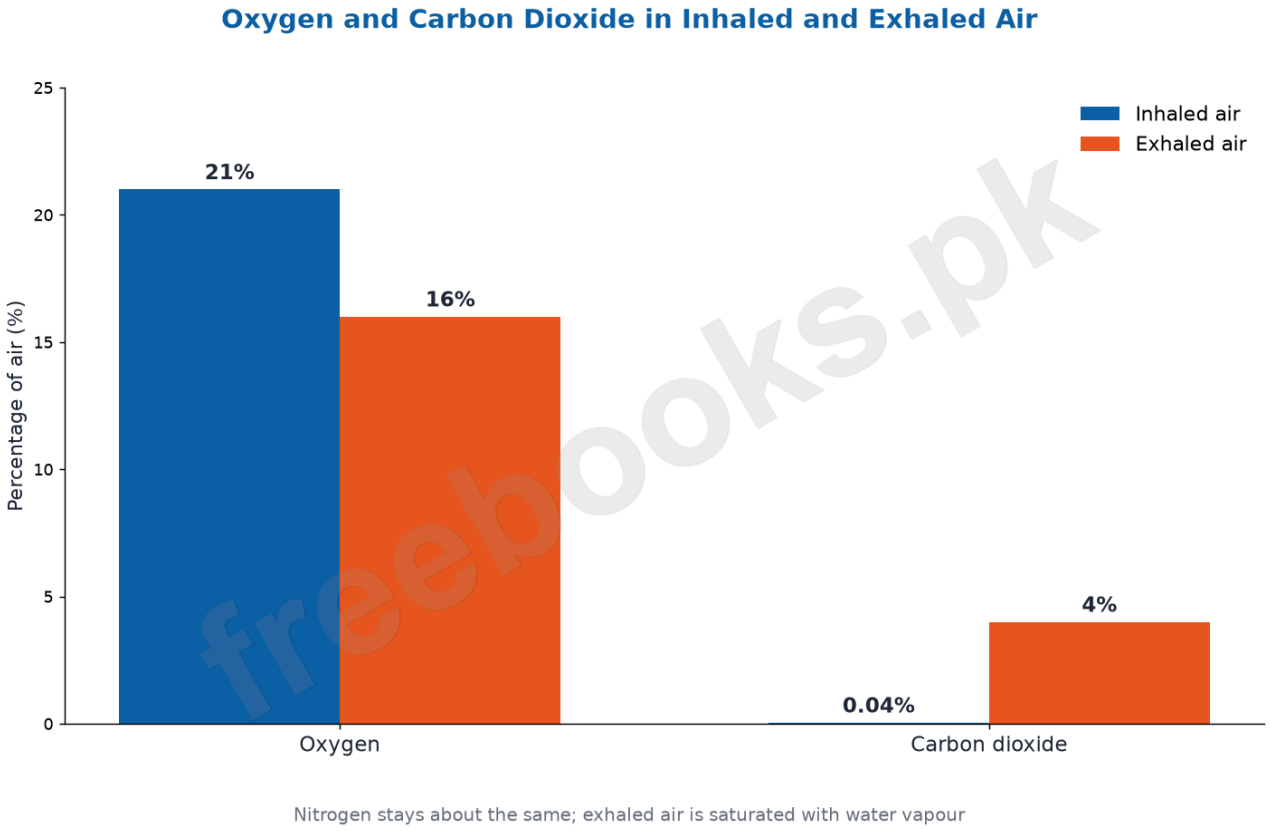
Inhalation and exhalation: A comparison of rib, intercostal muscle, diaphragm, volume and pressure changes during inhalation and exhalation.

Inhalation vs Exhalation

Feature	Inhalation	Exhalation
Intercostal muscles	Contract	Relax
Ribcage	Moves up and out	Moves down and in
Diaphragm	Contracts, flattens (down)	Relaxes, domes (up)
Chest volume	Increases	Decreases
Pressure in lungs	Falls below outside air	Rises above outside air
Air movement	Air rushes IN	Air pushed OUT

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Inhaled and exhaled air: A bar chart comparing the percentages of oxygen and carbon dioxide in inhaled and exhaled air.



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Short Questions and Answers

Why is breathing called a physical process and respiration a chemical process?
Breathing only moves air in and out by muscle action; respiration breaks chemical bonds in glucose inside cells to release energy.

How does the nasal cavity clean the air we breathe?
Hairs filter out larger dust particles and mucus on the walls traps finer particles and germs.

Why is breathing through the nose better than through the mouth?
Air passing through the nose is filtered, moistened and warmed before it reaches the delicate lungs.

What is the role of cilia in the trachea?
They beat and sweep mucus containing trapped dust and bacteria upward to the pharynx, away from the lungs.

Why does the trachea not collapse when we breathe in?
C-shaped rings of cartilage in its wall hold it open even when the pressure inside falls.

Why is the left lung smaller than the right lung?

Space is needed on the left side of the chest for the heart.

What is the function of pleural fluid?
It reduces friction between the lungs and the chest wall as the lungs expand and shrink.

Give three features of alveoli that speed up gas exchange.
A very large total surface area, walls only one cell thick, and a moist surface surrounded by many capillaries.

What happens to the diaphragm during inhalation?
It contracts and flattens, moving downward and increasing the volume of the chest.

Why does air move into the lungs when the chest expands?
The larger volume lowers the pressure inside the lungs below atmospheric pressure, so air flows in.

Why does breathing rate rise during exercise?
Muscles produce more CO2; the respiratory centre in the brain detects this and speeds up the breathing muscles.

Why does exhaled air contain more water vapour?
Air picks up moisture from the moist lining of the airways and alveoli and leaves saturated.

How does emphysema make a person breathless?
Broken alveolar walls reduce the surface area for gas exchange, so less oxygen enters the blood.

How does carbon monoxide from smoking harm the body?
It binds to haemoglobin more strongly than oxygen, so the blood carries less oxygen.

Why is vaping not a safe alternative to smoking?
Vapes can contain nicotine and other chemicals that inflame and injure the lungs and raise heart rate and blood pressure.

Long Questions and Answers

Describe the parts of the human air passageway.

What happens in the nostrils and nasal cavity?

Air is filtered by hairs and mucus, moistened and warmed to near body temperature.

What are the roles of the pharynx and larynx?

The pharynx is a shared passage for air and food; the larynx (voice box) contains vocal cords that vibrate to make sound, and its opening is guarded by the epiglottis.

Describe the trachea and bronchi.

The 12 cm trachea, held open by C-shaped cartilage, divides into two bronchi with cartilage plates; mucus and cilia in their lining trap and remove dust and germs.

Where do bronchioles lead?

They branch repeatedly, losing cartilage, and end in alveolar ducts that open into clusters of alveoli surrounded by capillaries.

Describe the structure of the lungs and their blood supply.

Where are the lungs and what protects them?

In the thoracic cavity, enclosed by the ribs and intercostal muscles, with the diaphragm below.

How do the two lungs differ?

The right lung has three lobes; the left lung is smaller with two lobes to leave room for the heart.

What is the pleura?

A double membrane around each lung; the fluid between its layers reduces friction.

How does blood flow through the lungs?

The pulmonary artery brings deoxygenated blood, which flows through capillaries around the alveoli and returns oxygenated to the heart in the pulmonary vein.

Explain the mechanism of breathing.

What happens to the ribs during inhalation?

The intercostal muscles contract and lift the ribcage upward and outward.

What happens to the diaphragm during inhalation?

It contracts and flattens, moving down; together these raise chest volume, lower lung pressure, and air flows in.

What happens during exhalation?

The intercostal muscles and diaphragm relax; the ribcage falls, the diaphragm domes up, chest volume falls, pressure rises and air flows out.

How is the rate of breathing controlled?

The respiratory centre in the brain responds to the level of CO_2 in the blood, increasing the rate from 16–20 to about 30–40 per minute in exercise.

Compare inhaled and exhaled air and explain the differences.

How does oxygen content change?

It falls from about 21% to about 16% because oxygen diffuses into the blood in the alveoli.

How does carbon dioxide content change?

It rises from about 0.04% to about 4% because CO_2 diffuses out of the blood into the alveoli.

What happens to nitrogen?

It stays about the same because the body does not use nitrogen gas.

How do water vapour, temperature and dust differ?

Exhaled air is saturated with water vapour, close to body temperature and nearly dust-free.

Describe bronchitis, emphysema and pneumonia.

What is bronchitis and what causes it?

Inflammation and narrowing of the bronchi or bronchioles, caused by infections and irritants such as smoke; chronic cases produce thick mucus.

What happens in emphysema?

Alveolar walls break and merge into large spaces, reducing the area for gas exchange; it is linked to long-term smoke and fume exposure and cannot be fully cured.

What is pneumonia?

An infection of the lungs by bacteria, viruses or fungi in which alveoli fill with fluid and pus, causing fever and a productive cough.

How is pneumonia treated and prevented?

With antibiotics, antivirals or antifungals according to the cause; vaccines prevent some bacterial forms.

Explain the harmful effects of smoking.

How does nicotine affect the body?

It is addictive, raises heart rate and blood pressure, and damages blood vessels.

How do carbon monoxide and tar harm the lungs and blood?

Carbon monoxide reduces the oxygen-carrying capacity of haemoglobin; tar deposits in the lungs and reduces the surface for gas exchange.

Which smoke chemicals cause cancer?

Carcinogens such as benzene, formaldehyde and substances in tar; they can cause cancers of the lungs and many other organs.

What are other effects of smoking?

Higher risk of heart disease, TB and pneumonia; stained teeth, bad breath and tooth loss; harm to passive smokers.

Multiple Choice Questions (MCQs)

The physical movement of air into and out of the lungs is called: (A) Respiration (B)

Breathing (C) Gaseous exchange (D) Diffusion
Correct answer: (B) Breathing. Breathing is the mechanical process.

Large dust particles in the nose are trapped mainly by: (A) Cilia (B) Hairs (C) Alveoli (D) Vocal cords
Correct answer: (B) Hairs. Nasal hairs filter large particles.

The vocal cords are found in the: (A) Pharynx (B) Trachea (C) Larynx (D) Bronchi
Correct answer: (C) Larynx. The larynx is the voice box.

The trachea is kept open by: (A) Bone (B) C-shaped cartilage rings (C) Muscle only (D) Pleura
Correct answer: (B) C-shaped cartilage rings. Cartilage rings prevent collapse.

Gas exchange takes place in the: (A) Bronchi (B) Trachea (C) Alveoli (D) Larynx
Correct answer: (C) Alveoli. Alveoli are surrounded by capillaries.

The number of lobes in the right lung is: (A) One (B) Two (C) Three (D) Four
Correct answer: (C) Three. Right lung has three lobes.

During inhalation the diaphragm: (A) Relaxes and moves up (B) Contracts and moves down (C) Does not move (D) Contracts and moves up
Correct answer: (B) Contracts and moves down. It flattens downward.

During exhalation the pressure inside the lungs: (A) Falls (B) Rises (C) Stays the same (D) Becomes zero
Correct answer: (B) Rises. Lower volume raises pressure.

The normal breathing rate of an adult at rest is about: (A) 5–8 per minute (B) 16–20 per minute (C) 30–40 per minute (D) 70 per minute
Correct answer: (B) 16–20 per minute. 16–20 breaths per minute.

Exhaled air contains about this much carbon dioxide: (A) 0.04% (B) 1% (C) 4% (D) 16%
Correct answer: (C) 4%. About 4%.

The gas whose percentage hardly changes in exhaled air is: (A) Oxygen (B) Carbon dioxide (C) Nitrogen (D) Water vapour
Correct answer: (C) Nitrogen. Nitrogen is not used.

A bronchodilator is used to treat: (A) Pneumonia (B) Asthma (C) Lung cancer (D) Emphysema only
Correct answer: (B) Asthma. It widens the airways.

Alveoli filled with pus are a sign of: (A) Bronchitis (B) Pneumonia (C) Asthma (D) Emphysema

Correct answer: (B) Pneumonia. Pneumonia.

The chemical in tobacco smoke that reduces oxygen carried by blood is: (A) Tar (B) Nicotine (C) Carbon monoxide (D) Ammonia
Correct answer: (C) Carbon monoxide. CO binds haemoglobin.

World No Tobacco Day is observed on: (A) 29 September (B) 31 May (C) 7 April (D) 1 December
Correct answer: (B) 31 May. 31 May each year.

Quick Revision Summary

- Breathing (physical) → gaseous exchange (diffusion in alveoli) → cellular respiration (chemical, in cells).
- Air route: nostrils → nasal cavity → pharynx → larynx → trachea → bronchi → bronchioles → alveolar ducts → alveoli.
- Nose filters, moistens, warms air; cilia + mucus clean trachea and bronchi; cartilage keeps them open.
- Lungs: right 3 lobes, left 2; pleura with pleural fluid; pulmonary artery in, pulmonary vein out.
- Inhalation: intercostals contract, ribs up/out, diaphragm contracts/down → volume up, pressure down, air in. Exhalation is the reverse.
- Rate: 16–20/min at rest, 30–40/min in exercise; controlled by brain sensing CO2.
- Inhaled vs exhaled: O2 21% → 16%; CO2 0.04% → 4%; N2 same; exhaled air saturated, warm, dust-free.
- Disorders: bronchitis, emphysema, pneumonia, asthma, lung cancer. Smoking: nicotine, CO, tar, carcinogens.

Exam Tips

- Write the air route in the correct order; examiners often ask what comes after the larynx or before the alveoli.
- For the breathing mechanism, always link muscle action → volume change → pressure change → air movement.
- Learn the inhaled vs exhaled air table exactly; it is a common fill-in question.
- Do not confuse emphysema (broken alveoli) with pneumonia (alveoli filled with pus).
- For diseases, write symptoms, causes and treatment under separate headings.

Note on Facts

The textbook says mucus in the nasal cavity warms the incoming air. The warming is mainly done by the rich blood supply in the lining of the nasal cavity; mucus mainly traps particles and moistens the air.

The textbook gives nitrogen as 79% of inhaled air. Pure nitrogen is about 78%; the remaining 1% is mostly argon and other gases, which are often counted together with nitrogen in this table.

The textbook says carbon monoxide combines with RBCs. More exactly, it binds to the haemoglobin inside red blood cells, as the book itself explains in Chapter 3.

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Chapter 3: Human Blood Circulatory System

Chapter 3 describes the blood circulatory system, the body's main transport system. It has three parts: blood, which carries materials; the heart, which pumps it; and blood vessels, which carry it to and from every tissue. Blood takes oxygen from the lungs and nutrients from the gut to the cells, carries hormones to target organs, and removes carbon dioxide and other wastes.

These notes cover plasma and the blood cells, the structure of the heart and its valves, pulmonary and systemic circulation, the heartbeat and heart sounds, arteries, capillaries and veins, the main arteries and veins of the body, and three cardiovascular disorders (coronary heart disease, myocardial infarction and angina) along with the effects of smoking on the heart.

Learning Objectives

- State the composition of blood and the roles of plasma and its components.
- Describe red blood cells, the types of white blood cells, and platelets with their functions.
- Describe the structure of the heart, its chambers and valves.
- Trace the flow of blood through the heart, lungs and body (double circulation).
- Compare arteries, veins and capillaries and name the major vessels.
- Explain coronary heart disease, heart attack and angina and how smoking harms the heart.

Key Concepts

3.1 Blood and Plasma

Blood is a fluid connective tissue. An adult has about 5 litres. About 55% of blood is plasma (the liquid part) and about 45% is cells and cell fragments.

Plasma is about 90–92% water, 7–9% proteins and about 1% other substances. Its proteins include antibodies (defence against germs), fibrinogen (needed for clotting) and albumin (maintains the osmotic pressure of blood). Plasma without fibrinogen is called serum.

Plasma also carries salts (mainly sodium, chloride and bicarbonate ions, with small amounts of calcium, potassium and others), digested nutrients such as glucose, amino acids and lipids, wastes such as urea, hormones from endocrine glands, and small amounts of dissolved oxygen and carbon dioxide.

3.1 Red Blood Cells

Red blood cells (erythrocytes) are biconcave discs with no nucleus or organelles in mature form, which leaves more room for haemoglobin. Haemoglobin carries oxygen (bright red when oxygenated, dark red when not) and a little carbon dioxide.

There are about 4 to 5.5 million RBCs in each cubic millimetre of blood. Before and just after birth they are made in the liver and spleen; in adults they are made in the red bone marrow of bones such as the sternum, ribs and vertebrae. Each lives about 120 days and old cells are removed by the liver and spleen.

3.1 White Blood Cells and Platelets

White blood cells (leukocytes) are colourless, irregular, larger and far fewer than RBCs (about 7,000 per mm^3). They are made in red bone marrow and some mature in lymph nodes, tonsils, thymus or spleen. They defend the body against disease.

Granulocytes have granules in their cytoplasm: neutrophils engulf bacteria and clear dead cells; eosinophils fight parasites and take part in allergies; basophils release histamine, which causes inflammation. Agranulocytes have clear cytoplasm: monocytes become macrophages that engulf germs and debris, and lymphocytes make antibodies.

Platelets (thrombocytes) are small fragments of large bone-marrow cells, without a nucleus, living 7 to 12 days, about 250,000 per mm^3. When a vessel is damaged they gather at the site and start the clotting process: fibrinogen is changed into threads of fibrin that form a net, trapping red cells to make a clot that stops bleeding.

3.2 Structure of the Heart

The heart is a muscular pump lying in the chest between the two lungs, beneath the sternum. It is enclosed in a sac, the pericardium, whose fluid reduces friction as the heart beats.

A wall called the septum divides the heart into left and right sides. Each side has an upper thin-walled atrium and a lower thick-walled ventricle. The left ventricle has the thickest wall because it pumps blood to the whole body.

Valves let blood flow one way only. The tricuspid valve (three flaps) lies between the right atrium and right ventricle; the bicuspid valve (two flaps) between the left atrium and left ventricle. Semilunar valves at the bases of the pulmonary artery and aorta stop blood flowing back into the ventricles.

3.2 Double Circulation and Heartbeat

The superior and inferior venae cavae bring deoxygenated blood from the body into the right atrium → right ventricle → pulmonary arteries → lungs, where CO_2 is lost and O_2 is gained. Pulmonary veins return oxygenated blood to the left atrium → left ventricle → aorta → body.

Heart to lungs and back is pulmonary circulation; heart to body and back is systemic circulation. Because blood passes through the heart twice in one complete circuit, the heart works as a double pump. High pressure in the systemic circuit pushes blood to all organs; lower pressure in the lungs lets blood flow slowly, giving time for gas exchange.

One heartbeat is one contraction (systole) and relaxation (diastole) of the heart chambers; the average rate is about 70 beats per minute. During ventricular systole the ventricles pump blood into the arteries; in diastole the chambers relax and refill. The first sound 'lubb' comes from the closing of the tricuspid and bicuspid valves as the ventricles contract; the second sound 'dubb' comes from the closing of the semilunar valves.

3.3 Blood Vessels

Arteries carry blood away from the heart (all carry oxygenated blood except the pulmonary arteries). Their thick, strong, elastic walls have three layers: inner endothelium, a middle layer of

smooth muscle and elastic tissue, and an outer layer of connective tissue. They branch into arterioles and then capillaries.

Capillaries are the smallest vessels, with walls only one cell (endothelium) thick, so water, nutrients and oxygen pass out to the tissue fluid and carbon dioxide and wastes pass in. Capillaries join to form venules, which join to form veins.

Veins carry blood towards the heart (all carry deoxygenated blood except the pulmonary veins). They have the same three layers, but the middle layer is thinner, the lumen is wider, and most veins have valves that prevent backflow.

3.4 Arterial and Venous Systems

Arteries: the pulmonary trunk from the right ventricle splits into two pulmonary arteries, one to each lung. The aorta from the left ventricle gives coronary arteries to the heart muscle and branches to the head and arms, then runs down as the dorsal aorta, giving the hepatic artery (liver), renal arteries (kidneys) and finally the vessels that supply the legs (femoral arteries).

Veins: two pulmonary veins from each lung return blood to the left atrium. The superior vena cava drains the head, shoulders and arms; the inferior vena cava drains the lower body, receiving the femoral veins (legs), renal veins (kidneys) and the hepatic vein (liver). The hepatic portal vein carries blood from the gut to the liver. Coronary veins return blood from the heart muscle to the right atrium.

3.5 Cardiovascular Disorders

Coronary heart disease (CHD) is narrowing or blockage of the coronary arteries, mainly by atherosclerosis: fatty plaques containing cholesterol build up inside the arteries. Causes and risk factors include high LDL cholesterol, high blood pressure, smoking, diabetes, obesity, inactivity and family history. It may cause no symptoms at first, later chest pain. Prevention: healthy diet, exercise, no smoking and control of blood pressure and cholesterol.

Myocardial infarction (heart attack) is death of part of the heart muscle when its blood supply is blocked for a long time, usually by a clot forming on a plaque in a coronary artery. Symptoms: chest pain or pressure, breathlessness, sweating, pain spreading to the arm, neck or jaw; some attacks are 'silent'. Treatment includes clot-dissolving medicines, angioplasty and stents. Complications: heart failure, arrhythmia and cardiac arrest.

Angina pectoris is chest pain or pressure caused by reduced blood flow to the heart muscle; it is a warning symptom of CHD. It is treated with lifestyle changes, medicines, angioplasty or stents, and if untreated can lead to a heart attack.

Smoking harms the heart by damaging artery linings and speeding up atherosclerosis, making platelets clump and clots form, narrowing vessels and raising blood pressure, increasing heart rate and causing arrhythmias, and letting carbon monoxide reduce the oxygen carried by haemoglobin.

Important Definitions

Plasma
The liquid part of blood, mostly water with dissolved substances.

Serum
Plasma from which fibrinogen has been removed.

Haemoglobin
The iron-containing red pigment in RBCs that carries oxygen.

Erythrocytes
Red blood cells.

Leukocytes
White blood cells that defend the body.

Macrophage
A large cell formed from a monocyte that engulfs germs and debris.

Platelets
Cell fragments that start blood clotting.

Fibrin
Insoluble protein threads that form the net of a blood clot.

Pericardium
The membrane sac around the heart.

Septum
The wall dividing the left and right sides of the heart.

Tricuspid valve
The three-flapped valve between the right atrium and right ventricle.

Bicuspid valve
The two-flapped valve between the left atrium and left ventricle.

Semilunar valves
Valves at the bases of the aorta and pulmonary artery.

Pulmonary circulation
Flow of blood from the heart to the lungs and back.

Systemic circulation
Flow of blood from the heart to the body and back.

Systole
Contraction phase of the heart.

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Diastole
Relaxation phase of the heart, when chambers refill.

Lumen
The hollow space inside a blood vessel.

Atherosclerosis
Build-up of fatty plaque inside arteries.

Myocardial infarction
Death of part of the heart muscle; a heart attack.

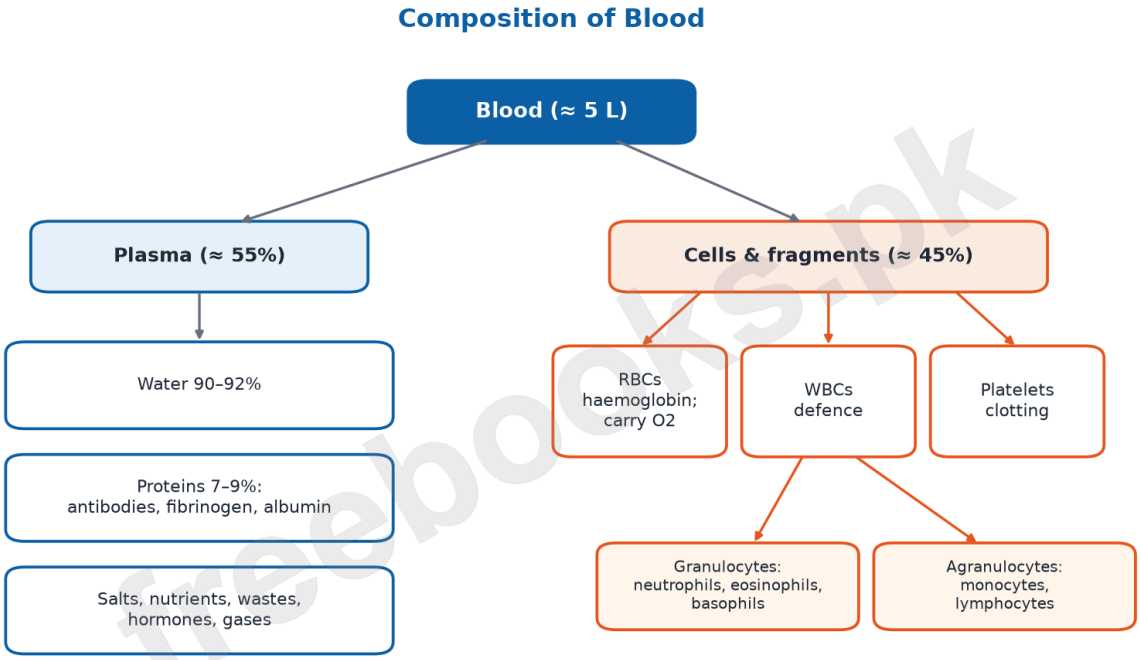
Angina pectoris
Chest pain due to reduced blood flow to the heart muscle.

Key Facts at a Glance

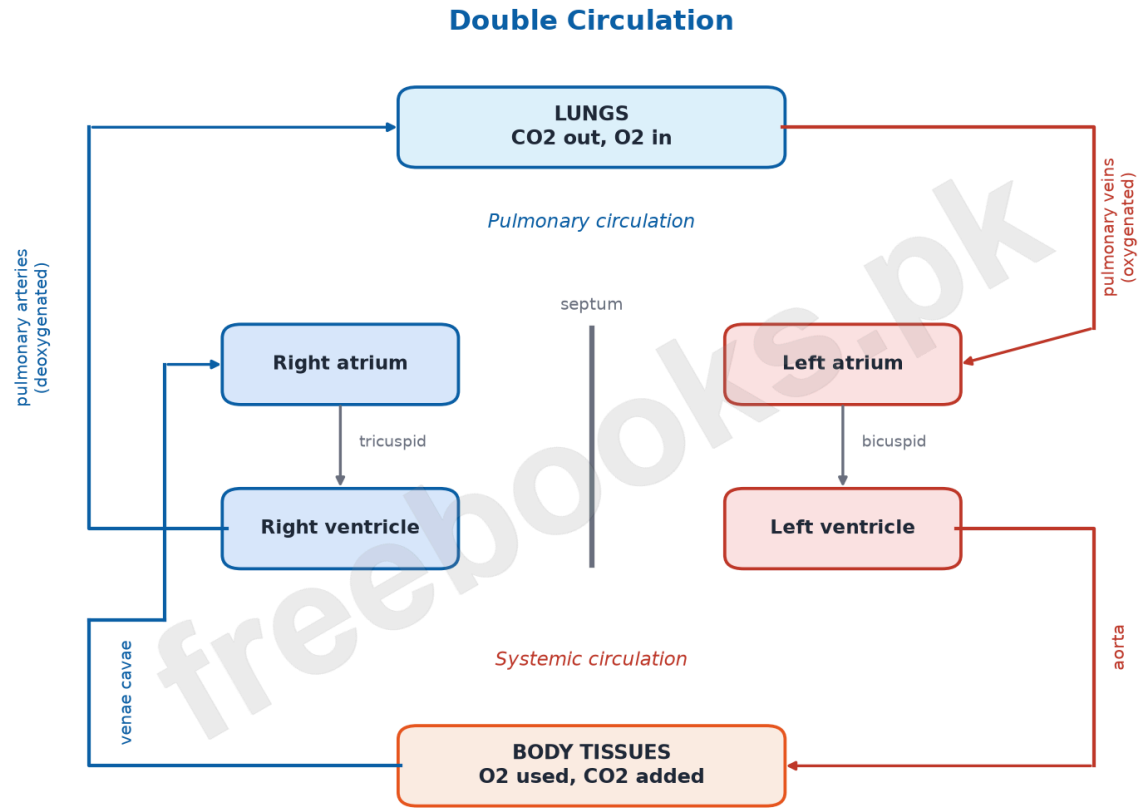
Item	Value / fact
Blood volume in an adult	About 5 litres
Plasma : cells	About 55% : 45%
Water in plasma	About 90–92%
RBC count	4–5.5 million per mm^3
RBC life span	About 120 days
WBC count	About 7,000 per mm^3
Platelet count / life span	About 250,000 per mm^3 / 7–12 days
Average heart rate	About 70 beats per minute
Thickest heart chamber	Left ventricle
Artery carrying deoxygenated blood	Pulmonary artery
Vein carrying oxygenated blood	Pulmonary vein
World Heart Day	29 September

Diagrams

Composition of blood: A chart of blood components: plasma and its contents, and the types of blood cells with their roles.



Double circulation: A flow diagram of blood through the right side of the heart to the lungs and the left side to the body.



Arteries, capillaries and veins: A comparison of the structure and function of the three types of

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blood vessels.

Arteries, Capillaries and Veins

Feature	Artery	Capillary	Vein
Direction	Away from heart	Links arterioles and venules	Towards heart
Wall	Thick, muscular, elastic	One cell thick	Thinner, less muscle
Lumen	Narrow	Very narrow	Wide
Valves	Absent	Absent	Present
Pressure	High	Falling	Low
Function	Carry blood under pressure	Exchange with tissue fluid	Return blood; valves stop backflow

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Short Questions and Answers

Why is blood called a connective tissue?
It consists of cells suspended in a liquid matrix (plasma) and links all parts of the body by transporting materials.

What is the difference between plasma and serum?
Serum is plasma without fibrinogen, so it cannot clot.

Give the roles of three plasma proteins.
Antibodies fight germs, fibrinogen helps blood clot, and albumin maintains the osmotic pressure of blood.

How is the shape of an RBC useful?
The biconcave disc shape gives a large surface for oxygen to diffuse in and out quickly.

Why do mature RBCs have no nucleus?
Lacking a nucleus and organelles leaves more space for haemoglobin, so each cell carries more oxygen.

Distinguish granulocytes from agranulocytes.
Granulocytes (neutrophils, eosinophils, basophils) have granules in their cytoplasm; agranulocytes (monocytes, lymphocytes) have clear cytoplasm.

What is pus?
A white fluid at an infection site made of dead white blood cells, dead germs and tissue debris.

How do platelets help stop bleeding?
They gather at a wound and start a process in which fibrinogen forms fibrin threads that trap blood cells into a clot.

Why is the wall of the left ventricle thicker than that of the right ventricle?
The left ventricle pumps blood around the whole body at high pressure, while the right pumps only to the nearby lungs.

What is the role of heart valves?
They let blood flow in one direction only and prevent backflow into the atria or ventricles.

Why is the human heart called a double pump?
Its right side pumps blood to the lungs and its left side pumps blood to the body, so blood passes through the heart twice per circuit.

What causes the 'lubb' and 'dubb' heart sounds?
'Lubb' is the closing of the tricuspid and bicuspid valves; 'dubb' is the closing of the semilunar valves.

Name an artery carrying deoxygenated blood and a vein carrying oxygenated blood.
The pulmonary artery carries deoxygenated blood; the pulmonary vein carries oxygenated blood.

Why do veins have valves but arteries usually do not?
Blood in veins is at low pressure and could flow backward; valves prevent this. High pressure in arteries keeps blood moving forward.

What is the difference between angina and a heart attack?
Angina is chest pain from reduced blood flow without lasting damage; in a heart attack the blood supply is blocked long enough for heart muscle to die.

Long Questions and Answers

Describe the composition of blood.

What are the main parts of blood?

About 55% plasma and 45% cells and cell fragments; an adult has about 5 litres.

What does plasma contain?

90–92% water, 7–9% proteins (antibodies, fibrinogen, albumin), and salts, nutrients, wastes, hormones and dissolved gases.

Describe red blood cells.

Biconcave cells without a nucleus, full of haemoglobin, 4–5.5 million per mm^3, made in red bone marrow and living about 120 days.

Describe white blood cells and platelets.

WBCs (granulocytes and agranulocytes) defend the body; platelets are cell fragments that start clotting.

Describe the types of white blood cells and their functions.

What are neutrophils?

Granulocytes that engulf bacteria and clear dead cells at infection sites.

What do eosinophils and basophils do?

Eosinophils fight parasites and take part in allergies; basophils release histamine, causing inflammation.

What are monocytes?

Agranulocytes that become macrophages, which engulf germs and dead cells.

What do lymphocytes do?

They make antibodies against specific pathogens.

Describe the structure of the human heart.

Where is the heart and what covers it?

In the chest between the lungs, beneath the sternum, enclosed by the pericardium with fluid to reduce friction.

What are its chambers?

Two thin-walled atria above and two thick-walled ventricles below, separated into left and right sides by the septum.

Which valves are found between the chambers?

The tricuspid valve on the right and the bicuspid valve on the left, between each atrium and ventricle.

What are semilunar valves?

Valves at the openings of the pulmonary artery and aorta that stop blood returning to the ventricles.

Trace the path of blood through the heart, lungs and body.

How does blood enter the right side?

The superior and inferior venae cavae bring deoxygenated blood to the right atrium, which passes it to the right ventricle.

What is pulmonary circulation?

The right ventricle pumps blood through the pulmonary arteries to the lungs; oxygenated blood

returns via pulmonary veins to the left atrium.

What is systemic circulation?

The left ventricle pumps oxygenated blood into the aorta and its branches to all body tissues; it returns via the venae cavae.

Why is this called double circulation?

Blood passes through the heart twice in one complete circuit; high systemic pressure reaches all organs while slower lung flow allows gas exchange.

Compare arteries, veins and capillaries.

Describe arteries.

Carry blood away from the heart; thick, elastic, muscular walls; narrow lumen; no valves (except at the heart).

Describe veins.

Carry blood to the heart; thinner middle layer; wide lumen; valves prevent backflow.

Describe capillaries.

Smallest vessels with walls one cell thick, allowing exchange between blood and tissue fluid.

Which vessels are exceptions in the oxygen they carry?

Pulmonary arteries carry deoxygenated blood and pulmonary veins carry oxygenated blood.

Describe coronary heart disease, heart attack and angina.

What is coronary heart disease?

Narrowing or blockage of the coronary arteries, mostly by atherosclerosis, linked to high cholesterol, high blood pressure, smoking, diabetes and inactivity.

What is myocardial infarction?

Death of part of the heart muscle when a coronary artery is blocked, often by a clot on a plaque; it causes chest pain, sweating and breathlessness.

How is a heart attack treated?

With clot-dissolving medicines, angioplasty to open the artery and stents to keep it open.

What is angina and how does smoking add to heart disease?

Angina is chest pain from reduced blood flow to the heart; smoking damages artery linings, promotes clots, raises blood pressure and heart rate, and lowers oxygen supply.

Multiple Choice Questions (MCQs)

The percentage of plasma in blood is about: (A) 45% (B) 55% (C) 75% (D) 90%
Correct answer: (B) 55%. About 55% plasma.

The plasma protein needed for clotting is: (A) Albumin (B) Fibrinogen (C) Antibody (D) Haemoglobin
Correct answer: (B) Fibrinogen. Fibrinogen forms fibrin.

Mature red blood cells lack a: (A) Cell membrane (B) Haemoglobin (C) Nucleus (D) Cytoplasm
Correct answer: (C) Nucleus. No nucleus, more room for haemoglobin.

The average life span of an RBC is about: (A) 7–12 days (B) 30 days (C) 120 days (D) 1 year
Correct answer: (C) 120 days. About 120 days.

Cells that release histamine are: (A) Neutrophils (B) Basophils (C) Monocytes (D) Lymphocytes
Correct answer: (B) Basophils. Basophils.

Antibodies are made by: (A) Lymphocytes (B) Platelets (C) RBCs (D) Eosinophils
Correct answer: (A) Lymphocytes. Lymphocytes make antibodies.

Platelets are best described as: (A) Complete cells (B) Cell fragments (C) Proteins (D) Antibodies
Correct answer: (B) Cell fragments. Fragments of large marrow cells.

The valve between the left atrium and left ventricle is the: (A) Tricuspid (B) Bicuspid (C) Semilunar (D) Pulmonary
Correct answer: (B) Bicuspid. Bicuspid has two flaps.

The chamber with the thickest wall is the: (A) Right atrium (B) Left atrium (C) Right ventricle (D) Left ventricle
Correct answer: (D) Left ventricle. It pumps to the whole body.

Blood from the lungs enters the heart at the: (A) Right atrium (B) Left atrium (C) Right ventricle (D) Left ventricle
Correct answer: (B) Left atrium. Via pulmonary veins.

The 'dubb' sound is caused by closing of the: (A) Tricuspid valve (B) Bicuspid valve (C) Semilunar valves (D) Septum
Correct answer: (C) Semilunar valves. Semilunar valves close.

Vessels with walls one cell thick are: (A) Arteries (B) Veins (C) Capillaries (D) Venae cavae
Correct answer: (C) Capillaries. Capillaries.

Most veins contain: (A) Thick muscle (B) Valves (C) Cartilage (D) Haemoglobin
Correct answer: (B) Valves. Valves stop backflow.

Blood from the gut is carried to the liver by the: (A) Hepatic artery (B) Hepatic vein (C) Hepatic portal vein (D) Renal vein
Correct answer: (C) Hepatic portal vein. Hepatic portal vein.

Death of heart muscle due to blocked blood supply is: (A) Angina (B) Atherosclerosis (C) Myocardial infarction (D) Arrhythmia
Correct answer: (C) Myocardial infarction. Heart attack.

Quick Revision Summary

- Blood ≈ 5 L: plasma 55% (water 90–92%, proteins, salts, nutrients, wastes, hormones, gases) + cells 45%.
- RBCs: biconcave, no nucleus, haemoglobin, 4–5.5 million/mm³, 120 days. WBCs: ~7,000/mm³; neutrophils, eosinophils, basophils, monocytes, lymphocytes. Platelets: 250,000/mm³, clotting.
- Heart: pericardium, septum, 2 atria + 2 ventricles; tricuspid (right), bicuspid (left), semilunar valves.
- Path: venae cavae → RA → RV → pulmonary arteries → lungs → pulmonary veins → LA → LV → aorta → body.
- Heartbeat ~70/min; systole/diastole; lubb = AV valves close, dubb = semilunar valves close.
- Arteries (thick, elastic, away from heart), capillaries (one cell thick, exchange), veins (thin, wide lumen, valves, to heart).
- CHD (atherosclerosis), myocardial infarction (heart attack), angina (chest pain). Smoking worsens all of them.

Exam Tips

- Practise tracing the path of blood through the heart in order; it is a frequent long question.
- Learn the exceptions: pulmonary artery (deoxygenated) and pulmonary vein (oxygenated).
- Draw and label the heart with chambers, valves and the four main vessels.
- Make a three-column table comparing arteries, veins and capillaries.
- Remember the numbers: 5 L blood, 55/45, 120 days, 7,000 WBCs, 250,000 platelets, 70 beats per minute.

Note on Facts

The textbook calls the sternum, ribs and vertebrae 'short bones'. The sternum and ribs are flat bones and the vertebrae are irregular bones; the point to learn is that adult RBCs are made in the red marrow of these bones.

The textbook describes diastole as the relaxation of the atria. In diastole the ventricles relax as well and the whole heart refills with blood; contraction of the ventricles is systole.

The textbook says platelets convert fibrinogen into fibrin and that pus forms from dead macrophages. Platelets start a chain of reactions in which the enzyme thrombin converts

fibrinogen to fibrin, and pus is made mostly of dead neutrophils along with germs and debris.

Chapter 4: Human Urinary System

Chapter 4 explains how the body removes nitrogenous wastes, extra water and extra salts from the blood. The urinary system, made of the kidneys, ureters, urinary bladder and urethra, filters the blood, forms urine and keeps the water and salt content of body fluids steady.

These notes cover the position and structure of the kidney, the parts of a nephron, the three steps of urine formation (pressure filtration, reabsorption and tubular secretion), the kidney's role in osmoregulation, and two important disorders, kidney stones and kidney failure, with their treatments including lithotripsy, dialysis and kidney transplantation.

Learning Objectives

- Name the organs of the urinary system and state their roles.
- Describe the external and internal structure of the kidney.
- Describe the parts of a nephron and the role of each part.
- Explain pressure filtration, reabsorption and tubular secretion.
- Explain how the kidneys carry out osmoregulation.
- Describe the causes, symptoms and treatment of kidney stones and kidney failure.

Key Concepts

4.1 The Urinary System

The urinary (excretory) system has a pair of kidneys, a pair of ureters, a urinary bladder and a urethra. The kidneys filter blood and make urine; each ureter carries urine from a kidney to the bladder; the bladder stores urine for a time; and the urethra carries urine out of the body.

The kidneys are bean-shaped, dark red organs in the abdomen below the diaphragm, one on each side of the vertebral column, with the concave side facing the backbone. The left kidney sits slightly higher than the right. Each is roughly 10 cm long, 5 cm wide and 4 cm thick. Renal arteries bring blood containing wastes such as urea; renal veins carry the cleaned blood away.

4.1 Structure of the Kidney

Externally, each kidney is wrapped in a tough renal capsule. The hilus is a notch on the concave side where the renal artery enters and the renal vein and ureter leave.

Internally, a section shows an outer renal cortex and an inner renal medulla. The medulla contains cone-shaped renal pyramids whose broad bases face the cortex and whose tips point into a funnel-shaped cavity, the renal pelvis, which continues as the ureter.

4.1 The Nephron

The nephron is the structural and functional unit of the kidney; each kidney has more than a million nephrons. A nephron has two parts: the renal corpuscle and the renal tubule.

The renal corpuscle consists of the glomerulus, a knot of blood capillaries, and the Bowman's capsule, a cup-shaped structure that surrounds it.

The renal tubule leads from the Bowman's capsule and has three parts: the coiled proximal convoluted tubule, the U-shaped loop of Henle, and the coiled distal convoluted tubule. The distal tubules of many nephrons drain into one collecting duct, and collecting ducts open into the renal pelvis.

4.2 Formation of Urine

Pressure filtration: the renal artery branches into arterioles that form the glomerulus. Blood pressure in the glomerulus is high, so water and small molecules such as salts, glucose, amino acids and urea are forced into the Bowman's capsule. Blood cells and large proteins stay in the blood. The fluid collected is the glomerular filtrate, about one-fifth of the plasma entering the glomerulus.

Reabsorption: as the filtrate flows along the tubule, useful substances return to the capillaries around it. In the proximal convoluted tubule a large amount of water, nearly all glucose and amino acids, and most salts are reabsorbed. Some water leaves the descending limb of the loop of Henle and many salts leave the ascending limb. More water is reabsorbed from the distal tubule and collecting duct.

Tubular secretion: some wastes still in the blood are actively transported from the capillaries into the tubule. The fluid that remains is urine, which passes through the collecting ducts to the renal pelvis, down the ureters to the bladder, and out through the urethra.

4.2 Osmoregulation

Osmoregulation is keeping the water and solute content of the body at the right level. The kidneys are the main organs of osmoregulation; by controlling the solutes in blood they also control those in other body fluids.

When the body has too much water, less water is reabsorbed from the tubules and a large volume of dilute urine is produced. When the body is short of water, more water is reabsorbed from the tubules and collecting ducts, so a small volume of concentrated urine is produced and water is kept in the blood.

4.3 Kidney Stones

Kidney stones are hard crystalline deposits formed when minerals and salts from the filtrate, such as calcium oxalate, calcium or ammonium phosphate and uric acid, collect in the kidney. Some move into the ureter or bladder and can get stuck.

Symptoms: severe pain in the side or lower abdomen, burning when passing urine, frequent urination, foul-smelling urine, blood or pus in urine, nausea and vomiting. Causes include drinking too little water, a diet very high in oxalate or certain salts, excess vitamin C or D supplements, high uric acid in blood, urinary infections and alcohol.

Treatment: small stones may pass out if the patient drinks plenty of water. In lithotripsy, shock waves aimed at the kidney from outside the body break stones into small pieces that pass out in urine. Large stones may need surgery.

4.3 Kidney Failure and Its Treatment

Kidney (renal) failure is when one or both kidneys can no longer remove wastes from the blood properly. Wastes and fluid build up, causing swelling of the legs, feet and face, weight loss and sometimes blood in urine. Causes include long-term diabetes and high blood pressure, severe dehydration, serious kidney infections, overuse of painkillers such as NSAIDs, large kidney stones, injury, and heart or liver failure.

Haemodialysis: the patient's blood is pumped through a dialyser containing thin tubes surrounded by dialysis fluid; wastes and extra water diffuse out of the blood into the fluid and the cleaned blood is returned to the body.

Peritoneal dialysis: dialysis fluid is put into the peritoneal cavity of the abdomen; wastes pass from blood vessels in the peritoneal membrane into the fluid, which is drained out after some time.

Kidney transplantation: a healthy kidney from a living or deceased donor, matched to the patient's immune system, is placed in the patient's body (usually leaving the damaged kidneys in place). A well-matched kidney can work for many years. In Punjab, organ transplants are regulated by the Punjab Human Organ Transplant Authority.

Important Definitions

Excretion
Removal of metabolic wastes such as urea from the body.

Ureter
The tube that carries urine from a kidney to the urinary bladder.

Urethra
The tube that carries urine from the bladder to the outside.

Hilus
The notch on the concave side of the kidney where vessels and ureter enter or leave.

Renal cortex
The outer region of the kidney.

Renal medulla
The inner region of the kidney containing the renal pyramids.

Renal pelvis
The funnel-shaped cavity of the kidney leading to the ureter.

Nephron
The functional unit of the kidney.

Glomerulus

A network of capillaries inside the Bowman's capsule.

Bowman's capsule
The cup-shaped start of the nephron that receives the filtrate.

Loop of Henle
The U-shaped middle part of the renal tubule.

Collecting duct
The duct receiving urine from many nephrons.

Glomerular filtrate
The fluid filtered from the glomerulus into the Bowman's capsule.

Pressure filtration
Forcing of small molecules out of the glomerulus by high blood pressure.

Reabsorption
Return of useful substances from the tubule into the blood.

Tubular secretion
Active transfer of wastes from blood into the renal tubule.

Osmoregulation
Control of the water and solute content of the body.

Lithotripsy
Breaking kidney stones with shock waves from outside the body.

Dialysis
Artificial removal of wastes from blood using dialysis fluid.

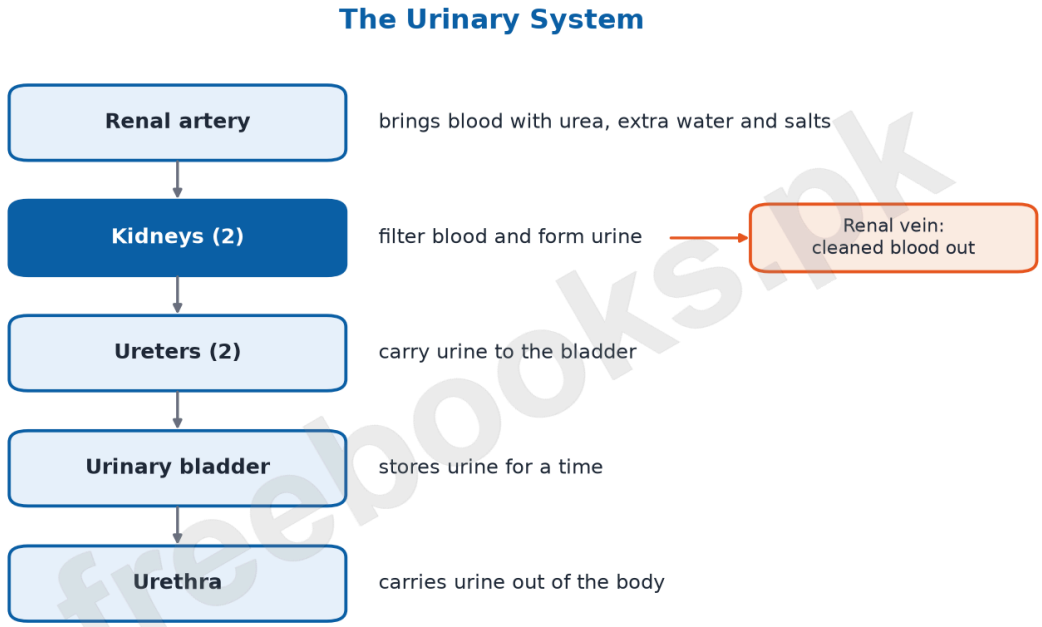
Key Facts at a Glance

Item	Value / fact
Size of a kidney	About 10 cm × 5 cm × 4 cm
Higher kidney	Left kidney
Nephrons per kidney	More than one million
Parts of renal corpuscle	Glomerulus + Bowman's capsule
Parts of renal tubule	PCT, loop of Henle, DCT

Glomerular filtrate	About 20% of plasma entering glomerulus
Glucose reabsorbed in	Proximal convoluted tubule (nearly 100%)
Salts reabsorbed mainly in loop's	Ascending limb
Tubular secretion	Active transport
Excess water in body	Large volume of dilute urine
Water shortage	Small volume of concentrated urine
Two types of dialysis	Haemodialysis and peritoneal dialysis

Diagrams

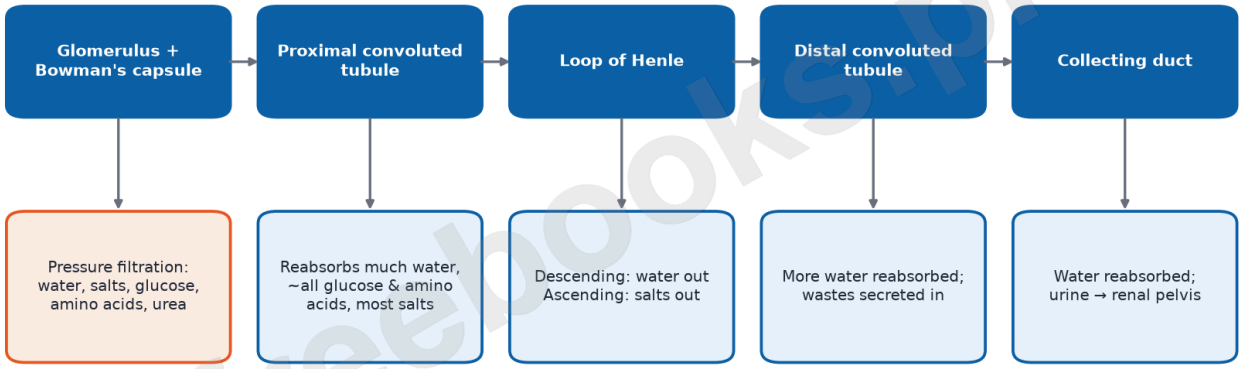
The urinary system: A flow chart of the organs of the urinary system and the path of urine.



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Parts of a nephron: A simplified flow diagram of a nephron and what happens in each part.

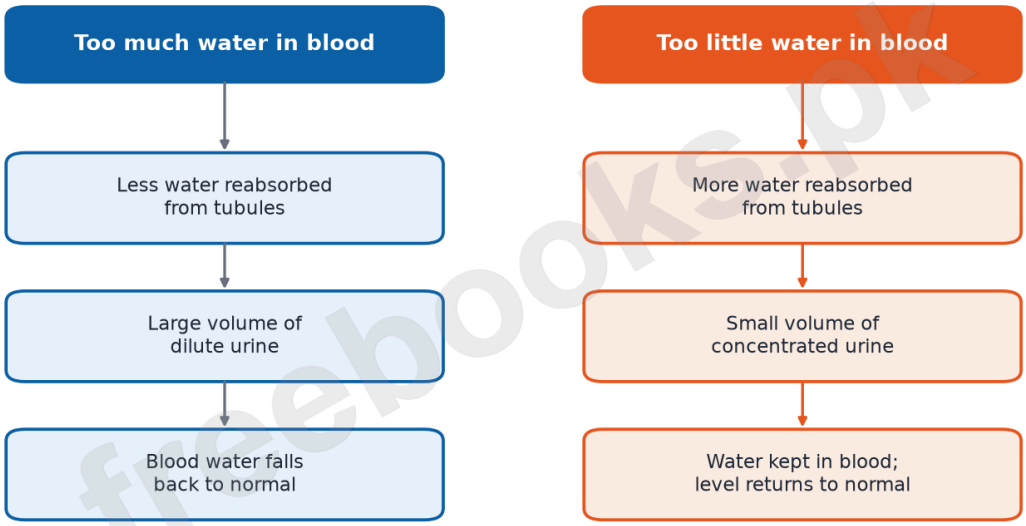
Parts of a Nephron and Their Work



Filtrate → urine as useful materials return to the blood

Osmoregulation by the kidneys: A comparison of how the kidneys respond to too much and too little water in the body.

Osmoregulation by the Kidneys



Short Questions and Answers

Name the organs of the urinary system.

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Two kidneys, two ureters, one urinary bladder and one urethra.

What is the hilus of the kidney?
A depression on the concave side where the renal artery enters and the renal vein and ureter leave.

Distinguish between renal cortex and renal medulla.
The cortex is the outer region; the medulla is the inner region containing cone-shaped renal pyramids.

What are the two parts of a renal corpuscle?
The glomerulus (capillary network) and the Bowman's capsule surrounding it.

Why is blood pressure high in the glomerulus?
Blood comes directly from the renal artery through arterioles, and this high pressure drives filtration.

Why are proteins and blood cells normally absent from urine?
They are too large to be filtered out of the glomerulus into the Bowman's capsule.

Why is glucose not found in the urine of a healthy person?
Almost all glucose in the filtrate is reabsorbed into the blood in the proximal convoluted tubule.

What happens in the loop of Henle?
Some water is reabsorbed from its descending limb and many salts from its ascending limb.

How is tubular secretion different from filtration?
Filtration is passive and driven by pressure; secretion actively moves extra wastes from blood into the tubule.

Why is urine pale and plentiful after drinking a lot of water?
With excess water, less water is reabsorbed from the tubules, so a large amount of dilute urine is produced.

Why is urine dark and small in volume on a hot day?
Water lost in sweat makes the kidneys reabsorb more water, so the urine becomes concentrated.

Give two ways to reduce the risk of kidney stones.
Drink plenty of water and avoid excess vitamin C and D supplements and very high-oxalate diets.

What is lithotripsy?
A non-surgical method in which shock waves break kidney stones into small pieces that pass out with urine.

Give two causes of kidney failure.
Long-term diabetes and high blood pressure (also infections, NSAID overuse, large stones).

Distinguish between haemodialysis and peritoneal dialysis.
Haemodialysis cleans blood in an outside machine; peritoneal dialysis uses fluid in the abdominal cavity and the peritoneal membrane as the filter.

Long Questions and Answers

Describe the structure of the human kidney.

Where are the kidneys located?

In the abdomen below the diaphragm on either side of the backbone, the left one slightly higher.

Describe the external structure.

Bean-shaped, about 10 × 5 × 4 cm, covered by a renal capsule, with a hilus on the concave side for vessels and ureter.

Describe the internal structure.

An outer cortex and an inner medulla with renal pyramids pointing into the renal pelvis.

How does urine leave the kidney?

From the collecting ducts into the renal pelvis and then into the ureter.

Describe the structure of a nephron.

What is a nephron?

The functional unit of the kidney; each kidney has over a million.

Describe the renal corpuscle.

The glomerulus, a knot of capillaries, enclosed by the cup-shaped Bowman's capsule.

Describe the renal tubule.

Proximal convoluted tubule, U-shaped loop of Henle and distal convoluted tubule.

Where does the tubule drain?

Distal tubules of many nephrons open into a collecting duct, which opens into the renal pelvis.

Explain the formation of urine.

What is pressure filtration?

High pressure in the glomerulus forces water, salts, glucose, amino acids and urea into the Bowman's capsule as glomerular filtrate.

What is reabsorbed in the proximal tubule?

Much water, almost all glucose and amino acids, and most salts.

What is reabsorbed later in the tubule?

Water from the descending limb, salts from the ascending limb of the loop of Henle, and more water from the DCT and collecting duct.

What is tubular secretion?

Active transport of remaining wastes from capillaries into the tubule; the final fluid is urine.

Explain the role of the kidneys in osmoregulation.

What is osmoregulation?

Keeping the water and solute concentration of body fluids at the correct level.

What happens when there is excess water?

Less water is reabsorbed from the tubules, producing plenty of dilute urine.

What happens when water is short?

More water is reabsorbed from the tubules and collecting ducts, producing a little concentrated urine.

Why is this important?

It keeps the concentration of blood and tissue fluid steady so cells neither swell nor shrink.

Describe kidney stones and their treatment.

What are kidney stones?

Hard crystals of calcium oxalate, phosphates or uric acid formed in the kidney.

What are their symptoms?

Severe pain in the side or lower abdomen, burning and frequent urination, blood or pus in urine, nausea.

What causes them?

Low water intake, diets high in oxalate or salts, excess vitamin C or D supplements, high uric acid, infections and alcohol.

How are they treated?

Small stones pass with plenty of water; lithotripsy breaks larger ones; very large stones need surgery.

Describe kidney failure and its treatments.

What is kidney failure and its symptoms?

Kidneys cannot remove wastes properly; wastes and fluid build up, with swelling of face, legs and feet.

What are its causes?

Diabetes, high blood pressure, dehydration, infections, NSAID overuse, large stones, injury, heart or liver failure.

How does dialysis help?

Haemodialysis or peritoneal dialysis removes wastes and extra water from the blood artificially.

What is kidney transplantation?

Placing a matched healthy kidney from a living or deceased donor into the patient.

Multiple Choice Questions (MCQs)

Urine is carried from the kidney to the bladder by the: (A) Urethra (B) Ureter (C) Renal vein (D) Collecting duct
Correct answer: (B) Ureter. Ureter.

The functional unit of the kidney is the: (A) Neuron (B) Nephron (C) Alveolus (D) Glomerulus
Correct answer: (B) Nephron. Nephron.

The renal artery enters the kidney at the: (A) Cortex (B) Pelvis (C) Hilus (D) Pyramid
Correct answer: (C) Hilus. Hilus.

Renal pyramids are found in the: (A) Cortex (B) Medulla (C) Ureter (D) Bladder
Correct answer: (B) Medulla. Medulla.

The cup-shaped part of the nephron is the: (A) Glomerulus (B) Loop of Henle (C) Bowman's capsule (D) Collecting duct
Correct answer: (C) Bowman's capsule. Bowman's capsule.

Filtration in the glomerulus is driven by: (A) Active transport (B) High blood pressure (C) Osmosis only (D) Hormones only
Correct answer: (B) High blood pressure. Pressure filtration.

Which is normally NOT filtered into the Bowman's capsule? (A) Glucose (B) Urea (C) Plasma proteins (D) Salts
Correct answer: (C) Plasma proteins. Proteins are too large.

Nearly all glucose is reabsorbed in the: (A) Proximal convoluted tubule (B) Loop of Henle (C) Collecting duct (D) Ureter
Correct answer: (A) Proximal convoluted tubule. PCT.

Moving extra wastes from blood into the tubule is: (A) Filtration (B) Reabsorption (C) Tubular secretion (D) Egestion
Correct answer: (C) Tubular secretion. Tubular secretion.

Glomerular filtrate is about what fraction of plasma entering the glomerulus? (A) 5% (B) 20% (C) 50% (D) 100%
Correct answer: (B) 20%. About one-fifth.

When the body is short of water, the kidneys produce: (A) Dilute urine (B) Concentrated urine (C) No urine (D) Urine with glucose
Correct answer: (B) Concentrated urine. More water is reabsorbed.

A common mineral in kidney stones is: (A) Sodium chloride (B) Calcium oxalate (C) Glucose (D) Iron oxide
Correct answer: (B) Calcium oxalate. Calcium oxalate.

Breaking kidney stones with shock waves is called: (A) Dialysis (B) Lithotripsy (C) Transplant (D) Angioplasty
Correct answer: (B) Lithotripsy. Lithotripsy.

In peritoneal dialysis the filter is the: (A) Glomerulus (B) Peritoneal membrane (C) Dialyser tube (D) Bladder wall
Correct answer: (B) Peritoneal membrane. Peritoneal membrane.

A long-term cause of kidney failure is: (A) Common cold (B) Diabetes (C) Constipation (D) Asthma
Correct answer: (B) Diabetes. Diabetes and hypertension.

Quick Revision Summary

- Urinary system: 2 kidneys → 2 ureters → bladder → urethra.
- Kidney: bean-shaped, ~10 × 5 × 4 cm, left higher; renal capsule, hilus; cortex, medulla (pyramids), pelvis.
- Nephron (>1 million per kidney): glomerulus + Bowman's capsule; PCT → loop of Henle → DCT → collecting duct.
- Urine formation: pressure filtration → reabsorption → tubular secretion.
- PCT: water, ~all glucose and amino acids, most salts reabsorbed; loop: water (descending), salts (ascending).
- Osmoregulation: excess water → dilute urine; water shortage → concentrated urine.
- Kidney stones: water, lithotripsy, surgery. Kidney failure: haemodialysis, peritoneal dialysis, transplant.

Exam Tips

- Learn the three steps of urine formation in order and the part of the nephron where each happens.
- Draw a labelled nephron and a section of the kidney; both are common diagram questions.
- In osmoregulation answers, always state the amount of reabsorption and the type of urine

produced.

- Compare haemodialysis and peritoneal dialysis in a table.
- For disorders, write symptoms, causes and treatment separately.

Note on Facts

The textbook says more water is filtered into the Bowman's capsule when there is excess water in the blood. The main control is actually in reabsorption: a hormone (ADH) adjusts how much water the distal tubule and collecting duct take back, so filtration stays fairly steady.

The textbook lists green vegetables, fats and dairy products as causes of kidney stones. Normal amounts of these foods are healthy; doctors usually advise avoiding very high-oxalate foods and drinking enough water rather than cutting out dairy, since dietary calcium can actually reduce oxalate stones.

Chapter 5: Coordination

Chapter 5 explains how the body's parts work together and respond to changes around and inside it. Two systems do this job: the nervous system, which sends fast electrical messages along neurons, and the endocrine system, which sends slower chemical messages (hormones) through the blood.

These notes cover the five parts of a coordinated action, the structure and types of neurons, synapses and neurotransmitters, the central and peripheral nervous systems, the parts of the brain and spinal cord, somatic and autonomic systems, the reflex arc, and the major endocrine glands and their hormones, including diabetes and blood glucose testing.

Learning Objectives

- State the five components of a coordinated action with examples.
- Describe the structure of a neuron and name the three types of neurons.
- Explain how a nerve impulse crosses a synapse.
- Describe the parts of the CNS and PNS and their functions.
- Explain the reflex arc using the example of touching a hot object.
- Name the major endocrine glands, their hormones and their functions.

Key Concepts

Coordinated Action

Coordination means the working together of different body parts in response to stimuli. A coordinated action has five components: stimulus, receptor, coordinator, effector and response.

A stimulus is any change inside or outside the body that can produce a response, such as light, sound, heat, touch or infection. Receptors (such as the eyes, ears or skin) detect stimuli. Coordinators (the brain and spinal cord in nervous coordination, endocrine glands in chemical coordination) process the information. Effectors (muscles and glands) carry out the response, for example pulling the hand away from a flame.

5.1 Neurons

Neurons (nerve cells) carry messages as nerve impulses: waves of electrochemical change travelling along the neuron's membrane.

A neuron has a cell body containing the nucleus; short branched dendrites that carry impulses towards the cell body; and a long axon that carries impulses away from it to other neurons, muscles or glands.

Supporting cells called neuroglia help neurons. Schwann cells wrap many axons in a fatty myelin sheath, which has gaps called nodes of Ranvier. Impulses jump from node to node, so myelinated axons conduct much faster than non-myelinated ones. In the CNS, myelinated axons form white matter; cell bodies, dendrites and non-myelinated axons form grey matter.

Sensory neurons carry impulses from receptors to the CNS; inter-neurons, inside the brain and spinal cord, pass impulses from sensory to motor neurons; motor neurons carry impulses from the CNS to effectors. Groups of cell bodies outside the CNS are called ganglia.

5.1 Synapse, Neurotransmitters and Nerves

A synapse is a tiny gap between two neurons or between a neuron and an effector cell. The impulse cannot jump this gap. When it reaches the axon ending, chemicals called neurotransmitters are released; they cross the gap and bind to the next cell, starting a new impulse there. Examples are acetylcholine, dopamine and serotonin.

A nerve is a bundle of axons wrapped in connective tissue. Sensory nerves contain only sensory axons, motor nerves only motor axons, and mixed nerves contain both.

5.2 Central Nervous System: the Brain

The CNS is the brain and spinal cord. The brain lies inside the cranium, covered by three membranes called meninges. Its cavities (ventricles) and the central canal of the spinal cord contain cerebrospinal fluid (CSF).

Forebrain: the cerebrum is the largest part, divided into right and left hemispheres; each hemisphere controls the opposite side of the body. Its folded outer cortex is grey matter, with white matter beneath. Each hemisphere has four lobes: frontal (thinking, judgement, speech, movement), parietal (touch and language), temporal (hearing, memory, learning, feelings) and occipital (vision). The thalamus relays sensory information to the cerebrum and is involved in pain and consciousness. The almond-sized hypothalamus regulates body temperature, hunger, thirst, sleep and emotions and controls the pituitary gland.

Midbrain: links the forebrain and hindbrain, relays information between them, helps adjust movements, and is involved in alertness, sleep and wakefulness.

Hindbrain: the medulla oblongata controls heartbeat, breathing and blood pressure and reflexes such as coughing, sneezing and vomiting; the cerebellum, the second largest part, coordinates balance and muscle movement; the pons connects the spinal cord, cerebellum and cerebrum and helps regulate sleep. The medulla, pons and midbrain together form the brain stem.

5.2 Spinal Cord and PNS

The spinal cord runs from the brain down the back inside the vertebral column, covered by meninges. Its outer part is white matter and its central butterfly-shaped part is grey matter around the central canal. It carries impulses between the brain and body and is the coordinating centre for simple reflexes.

The PNS consists of nerves and ganglia: 12 pairs of cranial nerves (sensory, motor or mixed) and 31 pairs of spinal nerves (all mixed). Each spinal nerve has a dorsal root carrying sensory axons, with a ganglion of cell bodies, and a ventral root carrying motor axons.

The somatic nervous system controls voluntary actions of skeletal muscles. The autonomic nervous system controls cardiac muscle, smooth muscle and glands without conscious control. Its sympathetic division prepares the body for emergencies ('fight or flight': pupils widen, heart and breathing speed up, digestion slows); its parasympathetic division restores calm ('rest and digest':

pupils narrow, digestion resumes, heart rate returns to normal).

5.2 Reflex Action

A reflex action is a rapid, automatic, involuntary response to a stimulus. The pathway of neurons used in a reflex is a reflex arc. Voluntary actions, in contrast, are controlled consciously by the cerebrum.

Example, touching a hot object: heat receptors in the skin are stimulated → a sensory neuron carries the impulse to the spinal cord → an inter-neuron passes it to a motor neuron → the motor neuron carries it to the arm muscles (effector) → the muscles contract and the hand is pulled away. The brain is informed afterwards, which is why pain is felt slightly later.

5.3 Endocrine System

The endocrine system is made of ductless glands that release hormones directly into the blood. Hormones are chemical messengers that regulate growth, metabolism, reproduction, blood glucose and other functions.

Pituitary gland (hangs from the hypothalamus): its anterior lobe makes growth hormone (too much in childhood causes gigantism, too little causes dwarfism), ACTH (stimulates the adrenal cortex), TSH (stimulates the thyroid), LH and FSH (control the ovaries and testes). Its posterior lobe stores two hypothalamus hormones: ADH (vasopressin), which increases water reabsorption in the kidneys, and oxytocin, which causes uterine contractions in childbirth and milk flow.

Thyroid gland (in the neck below the larynx): thyroxine raises the rate of metabolism and heat production; too little causes lethargy, weight gain and low body temperature, too much causes weight loss and a fast heart rate. Iodine is needed to make thyroxine; lack of it enlarges the gland (goitre), now uncommon in Pakistan because of iodised salt. Calcitonin lowers blood calcium by moving calcium into bone. The four parathyroid glands make parathormone, which raises blood calcium by moving calcium out of bone; too little causes tetany (muscle spasms).

Adrenal glands (above the kidneys): the medulla secretes adrenaline and noradrenaline for the fight-or-flight response (faster heart, higher blood pressure and glucose, wider airways and pupils). The cortex secretes cortisol (makes glucose from proteins) and aldosterone (makes the kidneys keep salt and water).

Pancreas: besides digestive enzymes, its islets of Langerhans secrete insulin, which lowers blood glucose by making cells take it up and store it, and glucagon, which raises blood glucose by making the liver release glucose. Gonads: ovaries secrete oestrogen and progesterone (female characteristics and the reproductive cycle); testes secrete androgens such as testosterone (male characteristics).

Diabetes Mellitus

In diabetes mellitus the cells cannot take in enough glucose, so blood glucose stays high. In type 1 diabetes the pancreas makes too little insulin and daily insulin injections are needed. In type 2 diabetes insulin is made but cells do not respond well; it is managed with diet, exercise and medicines.

Extra glucose in the filtrate reduces water reabsorption, so the patient passes large amounts of

urine, becomes thirsty and dehydrated, and may lose weight and feel tired; long-term high glucose can damage the kidneys.

A blood glucose test diagnoses diabetes. After an 8–10 hour fast, 70–99 mg/100 mL is normal, 100–125 is pre-diabetes and 126 or more is diabetes. Two hours after a 75 g glucose drink, below 140 is normal, 140 to just under 200 is pre-diabetes and 200 or more is diabetes.

Important Definitions

Coordination
Working together of body parts in response to stimuli.

Stimulus
Any change in the environment that can produce a response.

Receptor
A cell, tissue or organ that detects a stimulus.

Effector
A muscle or gland that carries out a response.

Nerve impulse
A wave of electrochemical change travelling along a neuron.

Dendrite
A short branch carrying impulses towards the cell body.

Axon
A long fibre carrying impulses away from the cell body.

Myelin sheath
A fatty insulating covering around many axons.

Nodes of Ranvier
Gaps in the myelin sheath where impulses jump.

Synapse
The junction between two neurons or a neuron and an effector.

Neurotransmitter
A chemical that carries a signal across a synapse.

Ganglion
A group of nerve cell bodies outside the CNS.

Meninges
Three protective membranes around the brain and spinal cord.

Cerebrospinal fluid
Fluid in the brain ventricles and spinal canal.

Brain stem
Midbrain, pons and medulla oblongata together.

Reflex action
A rapid automatic response to a stimulus.

Reflex arc
The pathway of neurons used in a reflex action.

Hormone
A chemical messenger secreted into the blood by an endocrine gland.

Endocrine gland
A ductless gland that secretes hormones into the blood.

Goitre
Enlargement of the thyroid gland, often due to lack of iodine.

Diabetes mellitus
A disorder in which blood glucose stays too high.

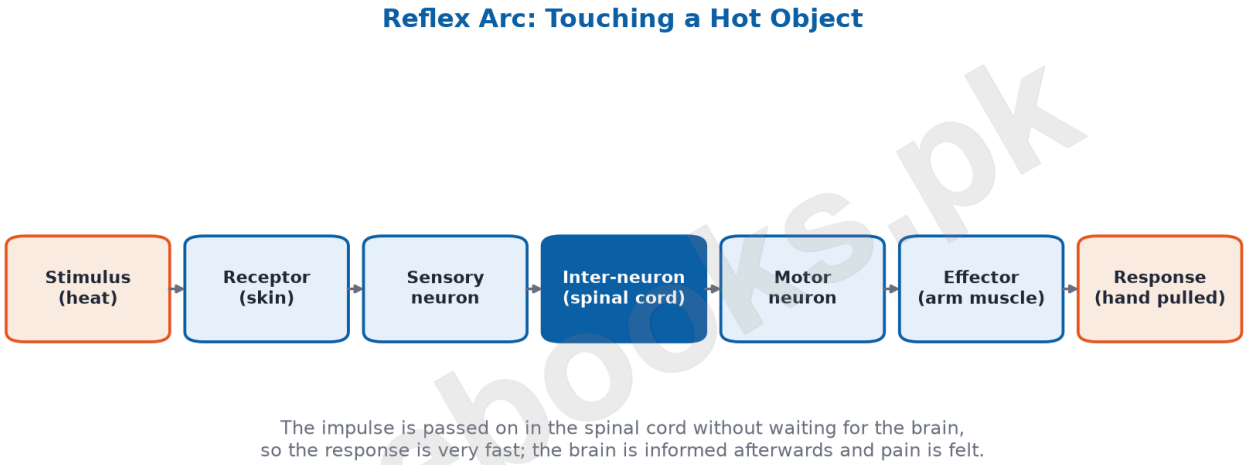
Key Facts at a Glance

Item	Fact
Pairs of cranial nerves	12
Pairs of spinal nerves	31 (all mixed)
Largest part of brain	Cerebrum
Balance and muscle coordination	Cerebellum
Heartbeat and breathing centre	Medulla oblongata
Controls pituitary; body temperature	Hypothalamus
Fight or flight	Sympathetic system + adrenaline
Hormone lowering blood glucose	Insulin

Hormone raising blood calcium	Parathormone
Hormone for water reabsorption	ADH (vasopressin)
Iodine needed for	Thyroxine
Fasting glucose for diabetes	126 mg/100 mL or more

Diagrams

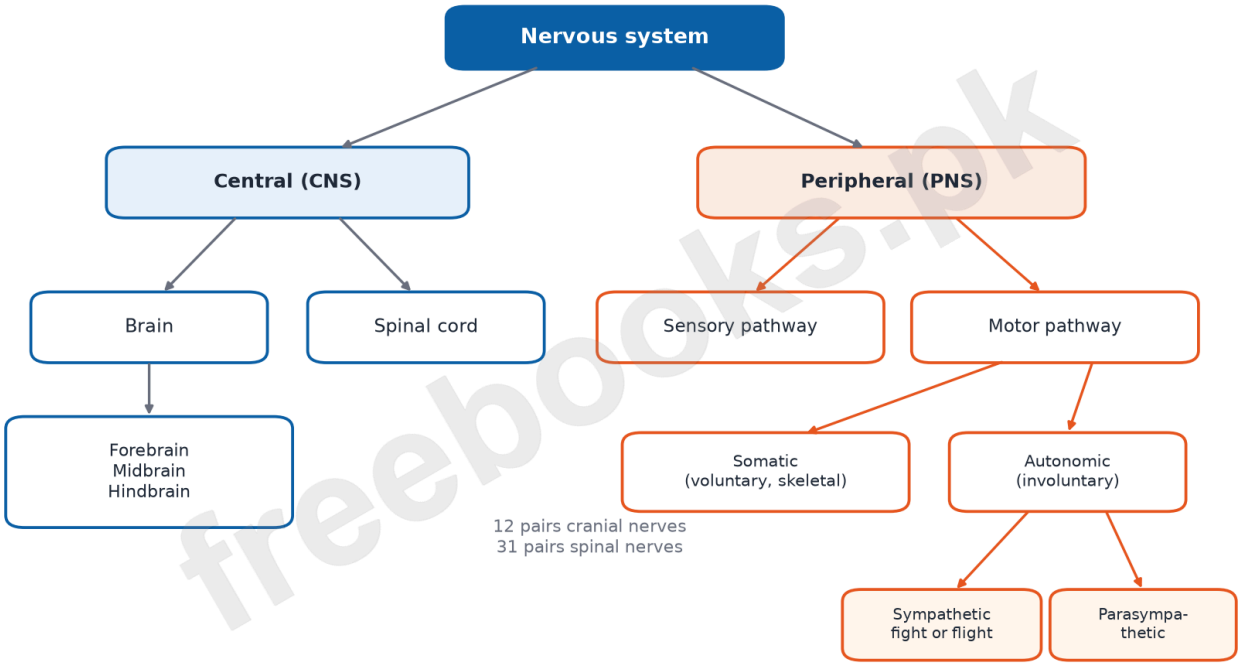
Reflex arc: A flow diagram of the reflex arc when a hand touches a hot object.



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Divisions of the nervous system: A tree chart showing the CNS and PNS and their subdivisions.

Divisions of the Nervous System



Major endocrine glands: A chart of the main endocrine glands with their key hormones and effects.

Major Endocrine Glands and Hormones

Gland	Hormone(s)	Main effect
Pituitary (anterior)	GH, ACTH, TSH, LH, FSH	Growth; controls other glands
Pituitary (posterior)	ADH, oxytocin	Water reabsorption; childbirth, milk
Thyroid	Thyroxine, calcitonin	Metabolic rate; lowers blood Ca
Parathyroid	Parathormone	Raises blood calcium
Adrenal medulla	Adrenaline, noradrenaline	Fight or flight
Adrenal cortex	Cortisol, aldosterone	Glucose from protein; salt & water
Pancreas (islets)	Insulin, glucagon	Lowers / raises blood glucose
Ovaries / Testes	Oestrogen, progesterone / testosterone	Sex characteristics, reproduction

Short Questions and Answers

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List the five components of a coordinated action.
Stimulus, receptor, coordinator, effector and response.

Distinguish between dendrites and axon.
Dendrites are short branches carrying impulses towards the cell body; the axon is a long fibre carrying impulses away from it.

How does the myelin sheath speed up a nerve impulse?
It insulates the axon so the impulse jumps from one node of Ranvier to the next instead of travelling along every part.

Why are neurotransmitters needed?
An impulse cannot jump the synaptic gap; neurotransmitters carry the signal across it to the next cell.

Name the three types of neurons by function.
Sensory neurons, inter-neurons and motor neurons.

Distinguish white matter and grey matter.
White matter is made of myelinated axons; grey matter contains cell bodies, dendrites and non-myelinated axons.

What protects the brain?
The bony cranium, the three meninges and the cushioning cerebrospinal fluid.

Why does damage to the left side of the cerebrum affect the right side of the body?
Each cerebral hemisphere receives information from and controls the opposite side of the body.

What would happen if the cerebellum were injured?
Balance and smooth coordination of muscle movements would be lost, so walking would be unsteady.

Why are all spinal nerves called mixed nerves?
Each contains sensory axons in its dorsal root and motor axons in its ventral root.

Give two effects of the sympathetic nervous system.
It speeds up the heartbeat and widens the pupils (also increases breathing and slows digestion).

Why are endocrine glands called ductless glands?
They release hormones directly into the blood rather than through ducts.

Why has goitre become rare in Pakistan?
Iodine is now added to common table salt, so the thyroid can make enough thyroxine.

How do calcitonin and parathormone work against each other?

Calcitonin lowers blood calcium by moving it into bone; parathormone raises it by releasing calcium from bone.

Distinguish type 1 and type 2 diabetes.
In type 1 the pancreas makes too little insulin; in type 2 insulin is present but the cells do not respond to it properly.

Long Questions and Answers

Describe the structure of a neuron and how impulses cross a synapse.

What are the parts of a neuron?

A cell body with the nucleus, branched dendrites bringing impulses in, and a long axon carrying impulses out.

What is the role of the myelin sheath?

Made by Schwann cells, it insulates the axon; impulses jump between nodes of Ranvier, increasing speed.

What is a synapse?

A tiny gap between a neuron and the next neuron or effector cell.

How does the impulse cross it?

The axon ending releases neurotransmitters such as acetylcholine, which cross the gap and start an impulse in the next cell.

Describe the main parts of the human brain.

What does the cerebrum do?

It is the largest part, with two hemispheres and four lobes controlling thinking, speech, movement, touch, hearing, memory and vision.

What are the roles of the thalamus and hypothalamus?

The thalamus relays sensory information; the hypothalamus controls temperature, hunger, thirst, sleep, emotions and the pituitary.

What does the midbrain do?

It connects the forebrain and hindbrain and helps with movement adjustments, alertness and sleep.

What are the parts of the hindbrain?

The medulla (heartbeat, breathing, coughing), the cerebellum (balance and coordination) and the pons (connections and sleep).

Describe the peripheral nervous system.

What does the PNS consist of?

12 pairs of cranial nerves and 31 pairs of spinal nerves with their ganglia.

What is the somatic nervous system?

Motor neurons to skeletal muscles controlling voluntary actions.

What is the autonomic nervous system?

Motor neurons to cardiac and smooth muscle and glands, working without conscious control.

Compare sympathetic and parasympathetic systems.

Sympathetic prepares for 'fight or flight' (faster heart, wider pupils, slower digestion); parasympathetic restores 'rest and digest'.

Explain a reflex action with the help of a reflex arc.

What is a reflex action?

A quick, involuntary, automatic response to a stimulus.

What is the first step when you touch a hot pan?

Heat receptors in the skin detect the stimulus and a sensory neuron carries the impulse to the spinal cord.

What happens in the spinal cord?

An inter-neuron passes the impulse directly to a motor neuron without waiting for the brain.

How is the response produced?

The motor neuron carries the impulse to arm muscles, which contract and pull the hand away.

Describe the hormones of the pituitary gland.

Where is the pituitary gland?

At the base of the brain, attached to the hypothalamus by a stalk.

What does growth hormone do?

Stimulates growth of bones and muscles; excess causes gigantism and deficiency causes dwarfism.

Which other anterior lobe hormones are there?

ACTH (adrenal cortex), TSH (thyroid), and LH and FSH (ovaries and testes).

What are the posterior lobe hormones?

ADH increases water reabsorption in the kidneys; oxytocin causes uterine contractions and milk flow.

Describe the thyroid, adrenal glands and pancreas as endocrine glands.

What does the thyroid secrete?

Thyroxine, which raises metabolism (needs iodine), and calcitonin, which lowers blood calcium.

What does the adrenal medulla secrete?

Adrenaline and noradrenaline for the fight-or-flight response.

What does the adrenal cortex secrete?

Cortisol (glucose from proteins) and aldosterone (salt and water retention).

What do the islets of Langerhans secrete?

Insulin lowers blood glucose and glucagon raises it; failure of insulin action causes diabetes.

Multiple Choice Questions (MCQs)

Muscles and glands in nervous coordination act as: (A) Receptors (B) Coordinators (C) Effectors (D) Stimuli
Correct answer: (C) Effectors. They carry out responses.

Impulses are carried towards the cell body by: (A) Axons (B) Dendrites (C) Myelin (D) Synapses
Correct answer: (B) Dendrites. Dendrites.

The myelin sheath is produced by: (A) Neurons (B) Schwann cells (C) Red blood cells (D) Ganglia
Correct answer: (B) Schwann cells. Schwann cells.

Neurons that connect sensory and motor neurons are: (A) Inter-neurons (B) Effectors (C) Receptors (D) Ganglia
Correct answer: (A) Inter-neurons. Inter-neurons in the CNS.

An example of a neurotransmitter is: (A) Insulin (B) Acetylcholine (C) Thyroxine (D) Haemoglobin
Correct answer: (B) Acetylcholine. Acetylcholine.

Balance is controlled by the: (A) Cerebrum (B) Cerebellum (C) Thalamus (D) Pons
Correct answer: (B) Cerebellum. Cerebellum.

Breathing and heartbeat are controlled by the: (A) Medulla oblongata (B) Occipital lobe (C) Thalamus (D) Cerebellum
Correct answer: (A) Medulla oblongata. Medulla.

The lobe of the cerebrum concerned with vision is the: (A) Frontal (B) Parietal (C) Temporal (D) Occipital
Correct answer: (D) Occipital. Occipital.

Number of pairs of spinal nerves in humans: (A) 12 (B) 21 (C) 31 (D) 43

Correct answer: (C) 31. 31 pairs.

The 'rest and digest' response is due to the: (A) Sympathetic system (B) Parasympathetic system (C) Somatic system (D) Cerebrum
Correct answer: (B) Parasympathetic system. Parasympathetic.

In a reflex arc the impulse goes from the sensory neuron to the: (A) Effector (B) Inter-neuron (C) Receptor (D) Brain only
Correct answer: (B) Inter-neuron. Then to the motor neuron.

Gigantism results from excess of: (A) Thyroxine (B) Growth hormone (C) Insulin (D) ADH
Correct answer: (B) Growth hormone. Growth hormone.

The hormone that helps the kidneys reabsorb water is: (A) Oxytocin (B) ADH (C) Glucagon (D) Calcitonin
Correct answer: (B) ADH. ADH (vasopressin).

Goitre is caused mainly by lack of: (A) Iron (B) Iodine (C) Calcium (D) Vitamin C
Correct answer: (B) Iodine. Iodine.

The hormone that raises blood glucose is: (A) Insulin (B) Glucagon (C) Calcitonin (D) Oxytocin
Correct answer: (B) Glucagon. Glucagon.

Quick Revision Summary

- Coordinated action: stimulus → receptor → coordinator → effector → response.
- Neuron: cell body, dendrites (in), axon (out); myelin + nodes of Ranvier speed impulses.
- Synapse: neurotransmitters (acetylcholine, dopamine, serotonin) carry signals across.
- Neurons: sensory → inter → motor. Nerves: sensory, motor, mixed.
- Brain: forebrain (cerebrum, thalamus, hypothalamus), midbrain, hindbrain (medulla, cerebellum, pons).
- PNS: 12 pairs cranial + 31 pairs spinal nerves; somatic vs autonomic (sympathetic / parasympathetic).
- Reflex arc: receptor → sensory neuron → inter-neuron (spinal cord) → motor neuron → effector.
- Glands: pituitary (GH, ACTH, TSH, LH, FSH; ADH, oxytocin), thyroid (thyroxine, calcitonin), parathyroid (parathormone), adrenal (adrenaline; cortisol, aldosterone), pancreas (insulin, glucagon), gonads.

Exam Tips

- Draw and label a motor neuron and a reflex arc; both are frequent diagram questions.
- Make a table of brain parts and their functions for quick revision.

- Learn each endocrine gland with its hormone and one effect; the book's gland table is ideal for MCQs.
- Know the pairs of opposites: sympathetic vs parasympathetic, insulin vs glucagon, calcitonin vs parathormone.
- Remember the diabetes test cut-offs: fasting 126 and two-hour 200 mg/100 mL.

Note on Facts

The textbook says the brain is not involved in reflex actions. This is true of spinal reflexes such as pulling the hand from a flame, but many reflexes (blinking, coughing, sneezing, the pupil reflex) pass through the brain stem; they are still involuntary because the cerebrum does not decide them.

The textbook's glucose table gives 'over 200' as diabetes for the two-hour test. The WHO cut-off is 200 mg/100 mL or more, so a reading of exactly 200 also counts as diabetes.

The textbook says oestrogen and progesterone cause the release of the egg. The release of the egg (ovulation) is triggered mainly by a surge of LH from the pituitary, as the same chapter says; oestrogen helps bring on that surge, and progesterone prepares the uterus.

Chapter 6: Reproductive System

Chapter 6 explains sexual reproduction in humans. Gametes (sperms and eggs) are formed in the gonads by meiosis, so they carry half the normal number of chromosomes. When a sperm and an egg fuse at fertilization, a diploid zygote is formed that can develop into a new individual.

These notes cover spermatogenesis and oogenesis, the steps of fertilization, the hormones that control male and female sexual development, the parts of the male and female reproductive systems with their functions, and sexually transmitted diseases with AIDS as the main example.

Learning Objectives

- Describe gametogenesis: spermatogenesis and oogenesis.
- Describe the steps of fertilization.
- State the roles of GnRH, FSH, LH, testosterone, oestrogen and progesterone.
- Identify the parts of the male reproductive system and their functions.
- Identify the parts of the female reproductive system and their functions.
- Describe AIDS: its cause, spread, symptoms and treatment.

Key Concepts

6.1 Gametogenesis

Gonads are the organs that make gametes: testes in males make sperms, and ovaries in females make eggs (ova). Gametogenesis, the formation of gametes, involves meiosis, which halves the chromosome number from diploid (2n) in body cells to haploid (n) in gametes.

Spermatogenesis takes place in the seminiferous tubules of the testes, stimulated by FSH from the anterior pituitary and testosterone from the testes. A diploid primary spermatocyte undergoes meiosis I to form two haploid secondary spermatocytes; each undergoes meiosis II, giving four haploid spermatids in total. The spermatids then mature into motile sperms.

Oogenesis takes place inside a fluid-filled follicle in the ovary, stimulated by FSH. A diploid primary oocyte undergoes meiosis I, dividing unequally into a large secondary oocyte and a small first polar body. In meiosis II the secondary oocyte divides unequally again into a large egg and a small second polar body. So one primary oocyte gives one functional egg, while one primary spermatocyte gives four sperms.

6.1 Fertilization

Fertilization is the fusion of a male and a female gamete to form a zygote. In humans it takes place inside the female body, in the fallopian tube, after ovulation (release of the egg from the ovary).

Steps: (1) sperms swim towards the egg, guided by chemical signals; (2) the acrosome, a cap on the sperm head, releases enzymes that digest the egg's outer layers; (3) the membranes of the sperm and egg fuse, and the egg's outer layers change so that no more sperms can enter; (4) the sperm nucleus enters the egg; (5) the two haploid nuclei fuse to form a diploid zygote.

6.2 Hormones in Sexual Development

GnRH from the hypothalamus stimulates the anterior pituitary to release FSH and LH in both sexes.

In males: FSH stimulates the testes to produce sperms; LH stimulates the testes to make testosterone; testosterone is needed for sperm production and brings about male secondary sexual characteristics at puberty, such as a deeper voice, facial and body hair and greater muscle mass.

In females: FSH stimulates the growth of follicles and the production of oestrogen; LH triggers ovulation and the production of progesterone. Oestrogen brings about female secondary sexual characteristics at puberty and regulates the reproductive cycle. Progesterone, made after ovulation, prepares the lining of the uterus for implantation and maintains pregnancy by preventing uterine contractions.

6.3 Male Reproductive System

Testes: a pair of oval glands producing sperms and testosterone. Epididymis: a long coiled tube on each testis where sperms are stored and mature. Vas deferens: a muscular tube carrying sperms from the epididymis to the urethra.

Accessory glands add fluid to form semen: the seminal vesicles (behind the bladder) produce a sugary fluid that nourishes sperms, and the walnut-sized prostate gland (below the bladder) adds a protective fluid. The urethra carries semen (and, at other times, urine) through the penis to the outside, and the penis transfers sperms into the female reproductive tract.

6.3 Female Reproductive System

Ovaries: a pair of almond-shaped glands producing eggs and the hormones oestrogen and progesterone. Fallopian tubes (oviducts): carry the egg from the ovary towards the uterus; fertilization takes place here.

Uterus: a hollow muscular organ where the fertilized egg implants and develops into a foetus. Cervix: the narrow lower part of the uterus. Vagina: a muscular canal connecting the cervix to the outside.

6.4 Sexually Transmitted Diseases and AIDS

Sexually transmitted diseases (STDs) are infections passed mainly through sexual contact, caused by bacteria, viruses or parasites; examples are HIV/AIDS, syphilis and herpes. Many show no symptoms at first, so people can spread them unknowingly. Untreated, they may cause infertility and damage to organs. Low awareness, particularly in rural areas, delays treatment.

AIDS (Acquired Immunodeficiency Syndrome) is caused by HIV (Human Immunodeficiency Virus), which attacks the immune system so the body can no longer fight infections and some cancers.

HIV spreads through sexual contact, sharing contaminated needles or syringes, transfusion of infected blood, and from an infected mother to her baby during birth or breastfeeding. In Pakistan, unsafe injections and unscreened blood transfusions are important causes of rising cases. It does not spread by shaking hands, sharing food or ordinary social contact.

Early symptoms include fever, tiredness, swollen lymph nodes and rashes; later, severe infections such as pneumonia, chronic diarrhoea, weight loss and certain cancers appear. There is no cure, but antiretroviral therapy (ART) controls the virus and lets patients live longer, healthier lives. Prevention: use only new or sterilised syringes, screened blood, safe practices and awareness.

Important Definitions

Gonads
Organs that produce gametes: testes and ovaries.

Gametogenesis
Formation of gametes by meiosis.

Spermatogenesis
Formation of sperms in the seminiferous tubules of the testes.

Oogenesis
Formation of eggs inside follicles of the ovary.

Haploid
Having one set of chromosomes (n).

Diploid
Having two sets of chromosomes (2n).

Spermatid
An immature haploid cell that develops into a sperm.

Follicle
A small fluid-filled sac in the ovary in which an egg develops.

Polar body
A small cell formed during oogenesis that usually degenerates.

Ovulation
Release of an egg from the ovary.

Fertilization
Fusion of male and female gametes to form a zygote.

Acrosome
A cap on the sperm head containing enzymes to penetrate the egg.

Zygote
The diploid cell formed by fertilization.

Epididymis
A coiled tube on the testis where sperms mature and are stored.

Vas deferens
The tube carrying sperms from the epididymis to the urethra.

Fallopian tube
The tube carrying the egg from ovary to uterus; site of fertilization.

Uterus
The muscular organ in which the foetus develops.

STD
An infection spread mainly through sexual contact.

AIDS
A disease caused by HIV that destroys the immune system.

ART
Antiretroviral therapy used to control HIV.

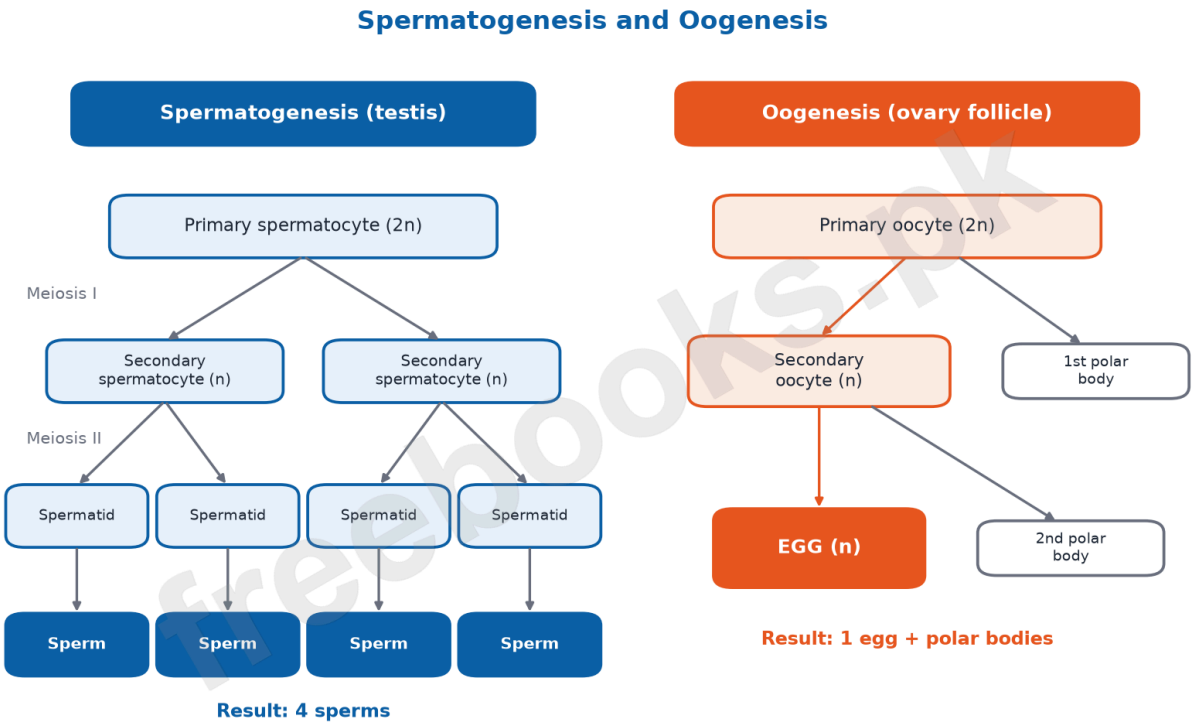
Key Facts at a Glance

Item	Fact
Site of spermatogenesis	Seminiferous tubules of testes
Site of oogenesis	Follicle in the ovary
Products of one primary spermatocyte	4 sperms
Products of one primary oocyte	1 egg + polar bodies
Site of fertilization	Fallopian tube
Hormone triggering ovulation	LH
Hormone stimulating testosterone production	LH
Hormone releasing FSH and LH	GnRH (hypothalamus)
Hormone maintaining pregnancy	Progesterone
Sugary fluid for sperms	Seminal vesicles
Cause of AIDS	HIV (a virus)

Treatment of HIV	Antiretroviral therapy (no cure)

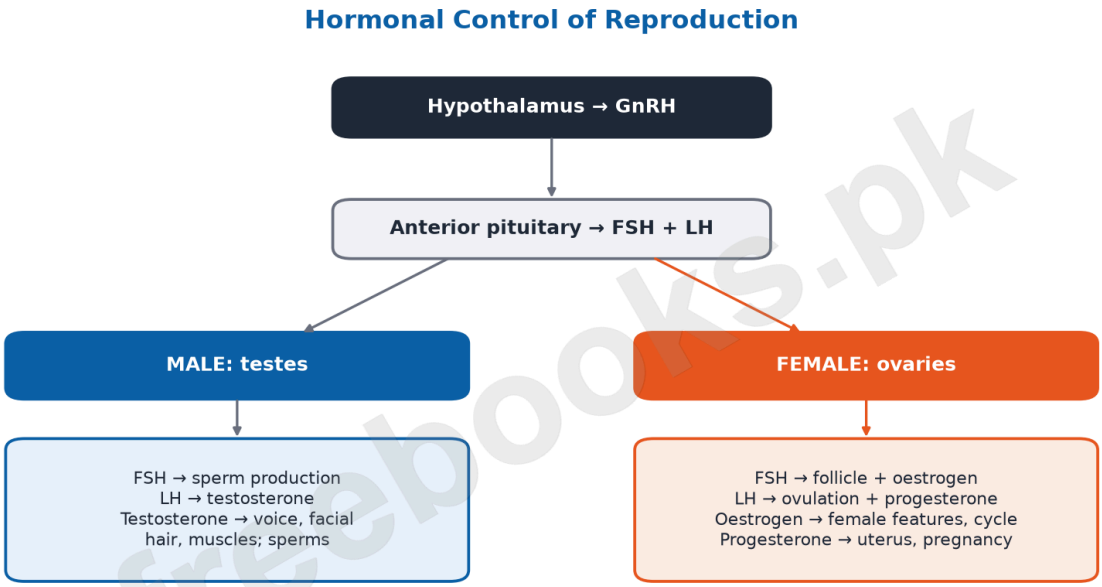
Diagrams

Spermatogenesis and oogenesis: A comparison of the meiotic divisions in spermatogenesis and oogenesis and their products.

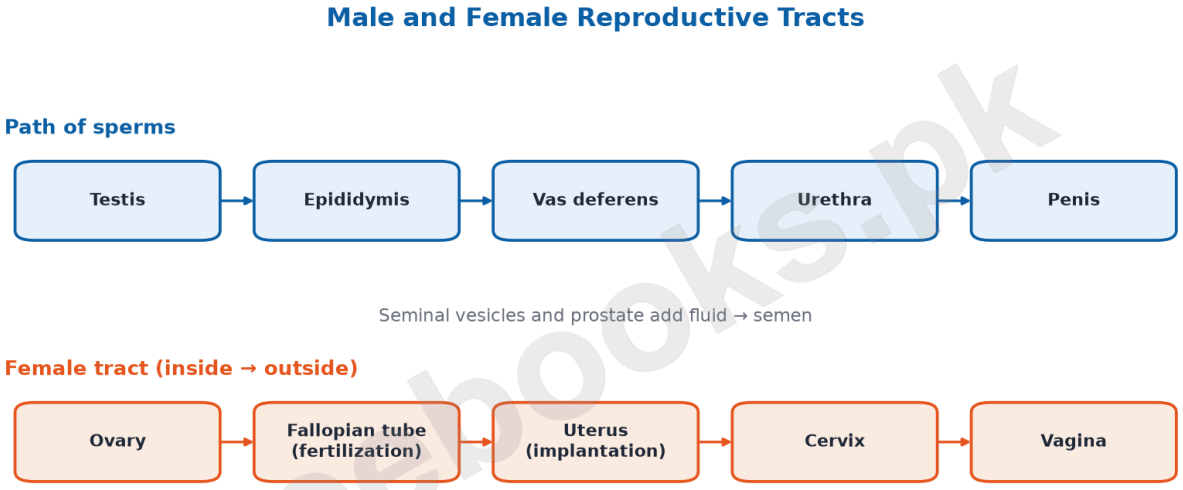


Hormonal control of reproduction: A flow chart from GnRH to FSH and LH and their effects in males and females.

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Male and female reproductive tracts: Flow charts of the path of sperms in the male system and the order of organs in the female system.



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Short Questions and Answers

Why must gametes be haploid?

So that when two gametes fuse, the zygote gets the normal diploid number of chromosomes.

Where does spermatogenesis take place and which hormones control it?

In the seminiferous tubules of the testes, under the control of FSH and testosterone.

How many sperms are formed from one primary spermatocyte?
Four haploid sperms, after meiosis I and meiosis II.

Why does oogenesis produce only one egg from a primary oocyte?
The divisions are unequal; most cytoplasm goes to one cell, the egg, while the small polar bodies degenerate.

What is the role of the acrosome?
It releases enzymes that digest the egg's outer layers so the sperm can reach the egg membrane.

How is entry of more than one sperm prevented?
After one sperm's membrane fuses with the egg, the egg's outer layers change and become impermeable to other sperms.

Where does fertilization take place in humans?
In the fallopian tube, after ovulation.

What is the role of GnRH?
It stimulates the anterior pituitary to release FSH and LH.

Give two functions of LH.
In females it triggers ovulation and progesterone production; in males it stimulates testosterone production.

Give two male secondary sexual characteristics.
Deepening of the voice and growth of facial hair (also increased muscle mass).

What is the role of progesterone?
It prepares the uterine lining for implantation and maintains pregnancy.

What is the function of the epididymis?
Sperms are stored there and complete their maturation.

Name the accessory glands of the male system.
Seminal vesicles and prostate gland.

How does HIV cause AIDS?
It attacks and weakens the immune system so the body cannot fight infections and some cancers.

Give three ways HIV spreads.
Sexual contact, sharing contaminated needles, and transfusion of infected blood (also mother to

baby).

Long Questions and Answers

Describe spermatogenesis.

Where and under which hormones does it occur?

In the seminiferous tubules of the testes, stimulated by FSH and testosterone.

What happens in meiosis I?

A diploid primary spermatocyte divides into two haploid secondary spermatocytes.

What happens in meiosis II?

Each secondary spermatocyte divides, giving four haploid spermatids in all.

How are sperms formed?

The spermatids change shape and mature into motile sperms.

Describe oogenesis and compare it with spermatogenesis.

Where does oogenesis occur?

In a follicle in the ovary, stimulated by FSH.

What happens in meiosis I?

The primary oocyte divides unequally into a large secondary oocyte and a small first polar body.

What happens in meiosis II?

The secondary oocyte divides into an egg and a second polar body.

How does it differ from spermatogenesis?

It produces one egg per primary oocyte with unequal divisions, while spermatogenesis produces four equal sperms.

Describe the process of fertilization.

How do sperms reach the egg?

They swim towards it, guided by chemical signals.

How does the sperm penetrate the egg layers?

Enzymes from the acrosome digest the egg's outer layers.

What happens after membrane fusion?

The egg's outer layers become impermeable to other sperms and the sperm nucleus enters.

How is the zygote formed?

The haploid sperm and egg nuclei fuse to form a diploid zygote.

Explain the role of hormones in male and female sexual development.

Which hormones start the process in both sexes?

GnRH from the hypothalamus causes the pituitary to release FSH and LH.

What do FSH and LH do in males?

FSH stimulates sperm production; LH stimulates testosterone production.

What do FSH and LH do in females?

FSH stimulates follicle growth and oestrogen; LH triggers ovulation and progesterone.

What do the sex hormones do?

Testosterone and oestrogen produce secondary sexual characteristics; progesterone prepares the uterus and maintains pregnancy.

Describe the male and female reproductive systems.

What are the main male organs?

Testes, epididymis, vas deferens, urethra and penis.

What are the male accessory glands?

Seminal vesicles (sugary fluid) and prostate gland (protective fluid), forming semen.

What are the main female organs?

Ovaries, fallopian tubes, uterus, cervix and vagina.

What are their roles?

Ovaries make eggs and hormones; fertilization is in the fallopian tube; the foetus develops in the uterus.

Describe AIDS.

What causes AIDS?

The Human Immunodeficiency Virus (HIV), which damages the immune system.

How is HIV transmitted?

Through sexual contact, contaminated needles, infected blood and from mother to baby.

What are its symptoms?

Early fever, tiredness, swollen lymph nodes and rash; later severe infections, weight loss, diarrhoea and some cancers.

How is it treated and prevented?

No cure; ART controls the virus. Prevention: sterile syringes, screened blood, safe behaviour and awareness.

Multiple Choice Questions (MCQs)

Gametes are formed by: (A) Mitosis (B) Meiosis (C) Budding (D) Binary fission
Correct answer: (B) Meiosis. Meiosis halves chromosome number.

Sperms are produced in the: (A) Epididymis (B) Seminiferous tubules (C) Prostate (D) Vas deferens
Correct answer: (B) Seminiferous tubules. Seminiferous tubules.

One primary spermatocyte forms: (A) One sperm (B) Two sperms (C) Four sperms (D) Eight sperms
Correct answer: (C) Four sperms. Four sperms.

The small cells formed in oogenesis are: (A) Spermatids (B) Polar bodies (C) Follicles (D) Zygotes
Correct answer: (B) Polar bodies. Polar bodies.

The egg develops inside a: (A) Follicle (B) Seminiferous tubule (C) Uterus (D) Cervix
Correct answer: (A) Follicle. Follicle.

Enzymes that digest the egg's layers come from the: (A) Sperm tail (B) Acrosome (C) Polar body (D) Follicle
Correct answer: (B) Acrosome. Acrosome.

In humans fertilization occurs in the: (A) Ovary (B) Uterus (C) Fallopian tube (D) Vagina
Correct answer: (C) Fallopian tube. Fallopian tube.

GnRH is released by the: (A) Ovary (B) Testis (C) Hypothalamus (D) Thyroid
Correct answer: (C) Hypothalamus. Hypothalamus.

Ovulation is triggered by: (A) FSH (B) LH (C) Testosterone (D) Insulin
Correct answer: (B) LH. LH surge.

The hormone that maintains pregnancy is: (A) Oestrogen (B) Progesterone (C) Testosterone (D) GnRH
Correct answer: (B) Progesterone. Progesterone.

Sperms mature and are stored in the: (A) Epididymis (B) Urethra (C) Prostate (D) Seminal vesicle
Correct answer: (A) Epididymis. Epididymis.

The sugary fluid nourishing sperms comes from the: (A) Prostate (B) Seminal vesicles (C) Testes (D) Bladder
Correct answer: (B) Seminal vesicles. Seminal vesicles.

The narrow lower part of the uterus is the: (A) Vagina (B) Cervix (C) Oviduct (D) Ovary
Correct answer: (B) Cervix. Cervix.

AIDS is caused by a: (A) Bacterium (B) Virus (C) Fungus (D) Worm
Correct answer: (B) Virus. HIV is a virus.

HIV infection is controlled by: (A) Antibiotics (B) Antiretroviral therapy (C) Vaccination (D) Insulin
Correct answer: (B) Antiretroviral therapy. ART; there is no cure.

Quick Revision Summary

- Gonads: testes (sperms), ovaries (eggs). Meiosis: 2n → n.
- Spermatogenesis: primary spermatocyte → 2 secondary spermatocytes → 4 spermatids → 4 sperms (FSH + testosterone).
- Oogenesis: primary oocyte → secondary oocyte + 1st polar body → egg + 2nd polar body (FSH).
- Fertilization (fallopian tube): chemical attraction → acrosome enzymes → membrane fusion (block to other sperms) → nucleus enters → zygote (2n).
- GnRH → FSH + LH. Male: FSH (sperms), LH (testosterone). Female: FSH (follicle, oestrogen), LH (ovulation, progesterone).
- Male: testes → epididymis → vas deferens → urethra → penis; seminal vesicles + prostate add fluid.
- Female: ovaries → fallopian tubes → uterus → cervix → vagina.
- AIDS: HIV; spread by sex, needles, blood, mother to child; no cure; ART.

Exam Tips

- Compare spermatogenesis and oogenesis in a table (site, divisions, products, hormones).
- Learn the five steps of fertilization in order.
- Match each hormone with its source and effect; GnRH, FSH and LH are common MCQs.
- Practise labelling diagrams of both reproductive systems.
- For AIDS, write cause, spread, symptoms, treatment and prevention as headings.

Note on Facts

The textbook shows meiosis II of the secondary oocyte as if it happens before fertilization. In humans the secondary oocyte is released at ovulation and completes meiosis II only after a sperm enters it; the first polar body may also divide.

Chapter 7: Inheritance

Chapter 7 explains how characteristics pass from parents to offspring. This passing of traits is called inheritance or heredity. The instructions for every trait are stored in DNA inside chromosomes; a cell reads a gene to make a protein, and proteins decide the cell's and the organism's characteristics.

These notes cover the structure of a chromosome, the structure of DNA and RNA, how a gene is used to make a protein (transcription and translation), the terms gene, allele, genotype, phenotype, homozygous, heterozygous, dominant and recessive, and Mendel's experiments on pea plants with the law of segregation and the law of independent assortment.

Learning Objectives

- Describe the structure and chemical make-up of a chromosome.
- Compare the structure of DNA and RNA.
- Explain how information in DNA is turned into a protein through mRNA.
- Define gene, allele, genotype, phenotype, homozygous, heterozygous, dominant and recessive.
- Explain Mendel's monohybrid and dihybrid crosses with ratios.
- State the law of segregation and the law of independent assortment.

Key Concepts

7.1 Structure of a Chromosome

Chromosomes are made of chromatin. In eukaryotes chromatin consists of DNA and proteins called histones; the long DNA molecule is wound around bundles of histones. In a non-dividing cell chromatin is spread through the nucleus as fine threads; before division it coils tightly into compact chromosomes.

A chromosome seen during cell division is rod-shaped and made of two identical sister chromatids joined at a point called the centromere. The centromere holds the chromatids together until they separate during division, so that each daughter cell gets one copy.

Body cells are diploid (2n): their chromosomes are in homologous pairs, and every cell of a species has the same chromosome number. Prokaryotes have a single circular DNA molecule lying in the cytoplasm, not enclosed in a nucleus.

7.2 DNA and RNA

DNA (deoxyribonucleic acid) is a double-stranded helix made of nucleotides. Each nucleotide has deoxyribose sugar, a phosphate group and one of four bases: adenine (A), thymine (T), cytosine (C) or guanine (G). The two strands are held together by base pairing: A with T and C with G.

RNA (ribonucleic acid) is usually a single strand of nucleotides. Its sugar is ribose and its bases are adenine, uracil (U), cytosine and guanine; uracil replaces thymine.

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A gene is a segment of DNA with the information to make a particular protein. Transcription: the gene acts as a template and a messenger RNA (mRNA) copy is made in the nucleus. Translation: the mRNA moves to the cytoplasm, ribosomes attach to it and join amino acids in the order it specifies, producing a protein. This flow, DNA → mRNA → protein, is called the central dogma.

7.2 Genes, Alleles and Genotype

Genes for traits such as eye colour or earlobe shape sit at fixed positions (loci) on chromosomes. Because chromosomes come in homologous pairs, genes also come in pairs.

Alleles are different forms of the same gene, for example one allele for free earlobes and another for attached earlobes. The pair of alleles an organism carries is its genotype. If both alleles are the same (TT or tt) the genotype is homozygous; if they differ (Tt) it is heterozygous.

In a heterozygote, the allele whose effect shows is dominant (written with a capital letter) and the allele that is hidden is recessive (small letter). The visible trait produced by the genotype is the phenotype. In peas, T (tall) is dominant over t (dwarf), so TT and Tt plants are both tall and only tt plants are dwarf.

7.3 Mendel and the Garden Pea

Gregor Mendel, a monk, carried out experiments on garden peas from 1856 to 1863. Peas were a good choice because they grow quickly, show seven clearly contrasting traits (such as tall/dwarf, round/wrinkled seeds, yellow/green seeds and purple/white flowers), and normally self-pollinate, while cross-pollination can be done by hand by removing the stamens of one flower and dusting it with pollen from another.

Mendel began with true-breeding plants, which always produce offspring like themselves when self-pollinated. At that time many people believed in blending inheritance, expecting a tall × dwarf cross to give medium plants; Mendel's results disproved this.

7.3 Monohybrid Cross and Law of Segregation

A monohybrid cross studies one trait. Mendel crossed true-breeding tall (TT) with true-breeding dwarf (tt) plants (P generation). All F1 plants were tall (Tt). When F1 plants self-pollinated, the F2 generation was about 3 tall : 1 dwarf (75% : 25%).

Genotypes in F2: 1 TT : 2 Tt : 1 tt (25% : 50% : 25%). TT and Tt are tall; tt is dwarf. The dwarf trait reappeared in F2 because the recessive allele had been present but hidden in F1.

Concept of dominance: when two different alleles are together, one may mask the other. Law of segregation: the two alleles of a gene separate during gamete formation, so each gamete receives only one of them; the pair is restored at fertilization.

7.3 Dihybrid Cross and Law of Independent Assortment

A dihybrid cross studies two traits at once. Mendel crossed true-breeding round yellow (RRYY) with wrinkled green (rryy) plants. All F1 were round yellow (RrYy), showing that round (R) is dominant over wrinkled (r) and yellow (Y) over green (y).

Each F1 plant formed four kinds of gametes in equal numbers: RY, Ry, rY and ry. Self-pollination

gave 16 combinations in F2, with phenotypes in the ratio 9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green.

Law of independent assortment: alleles of different genes separate independently of one another during gamete formation, so the inheritance of seed shape does not affect the inheritance of seed colour.

Important Definitions

Inheritance
Passing of characteristics from parents to offspring.

Chromatin
The DNA–histone material of which chromosomes are made.

Histones
Proteins around which DNA is wound.

Chromatid
One of the two identical halves of a replicated chromosome.

Centromere
The point where two sister chromatids are joined.

Gene
A segment of DNA carrying information for a protein or trait.

Locus
The position of a gene on a chromosome.

Allele
An alternative form of a gene.

Genotype
The pair of alleles an organism has for a trait.

Phenotype
The observable trait produced by a genotype.

Homozygous
Having two identical alleles of a gene.

Heterozygous
Having two different alleles of a gene.

Dominant allele
An allele that shows its effect in a heterozygote.

Recessive allele
An allele hidden in a heterozygote.

True-breeding
Always producing offspring with the same trait on self-pollination.

Monohybrid cross
A cross studying one trait.

Dihybrid cross
A cross studying two traits at the same time.

Transcription
Making mRNA from a DNA template.

Translation
Making a protein from the information in mRNA at ribosomes.

Central dogma
The flow of genetic information DNA → RNA → protein.

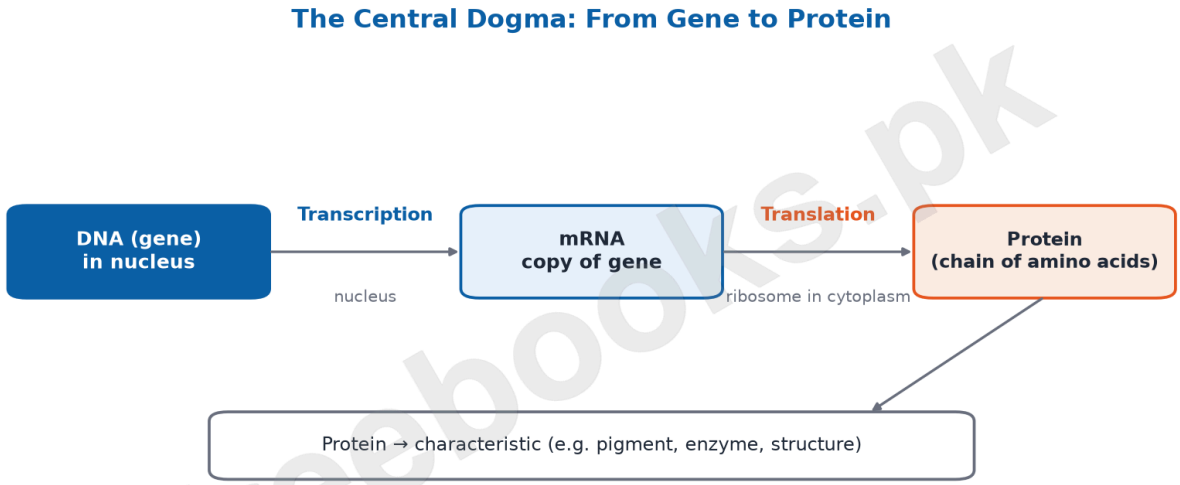
Key Facts at a Glance

Item	Fact
Chromatin consists of	DNA + histone proteins
DNA bases	A, T, C, G (A–T, C–G)
RNA bases	A, U, C, G
Sugar in DNA / RNA	Deoxyribose / ribose
Strands in DNA / RNA	Two (double helix) / one
Site of transcription / translation	Nucleus / ribosomes in cytoplasm
Years of Mendel's experiments	1856–1863
Contrasting traits studied in pea	Seven
Monohybrid F2 phenotype ratio	3 : 1
Monohybrid F2 genotype ratio	1 TT : 2 Tt : 1 tt

Dihybrid F2 phenotype ratio	9 : 3 : 3 : 1
Gametes from RrYy	RY, Ry, rY, ry

Diagrams

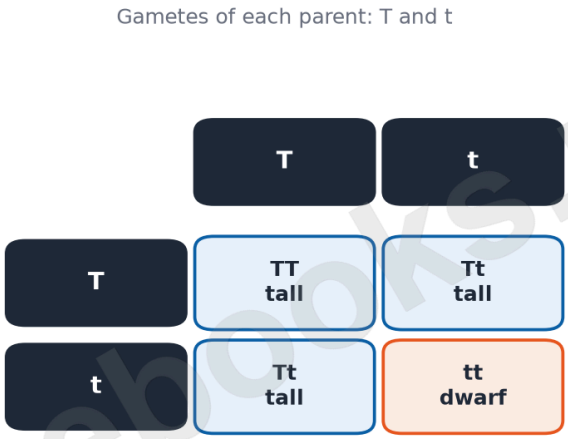
The central dogma: A flow diagram showing how a gene is transcribed into mRNA and translated into a protein.



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Monohybrid cross: A Punnett square of Tt × Tt showing the 1 : 2 : 1 genotype and 3 : 1 phenotype ratios.

Monohybrid Cross: Tt × Tt (F1 self-pollinated)



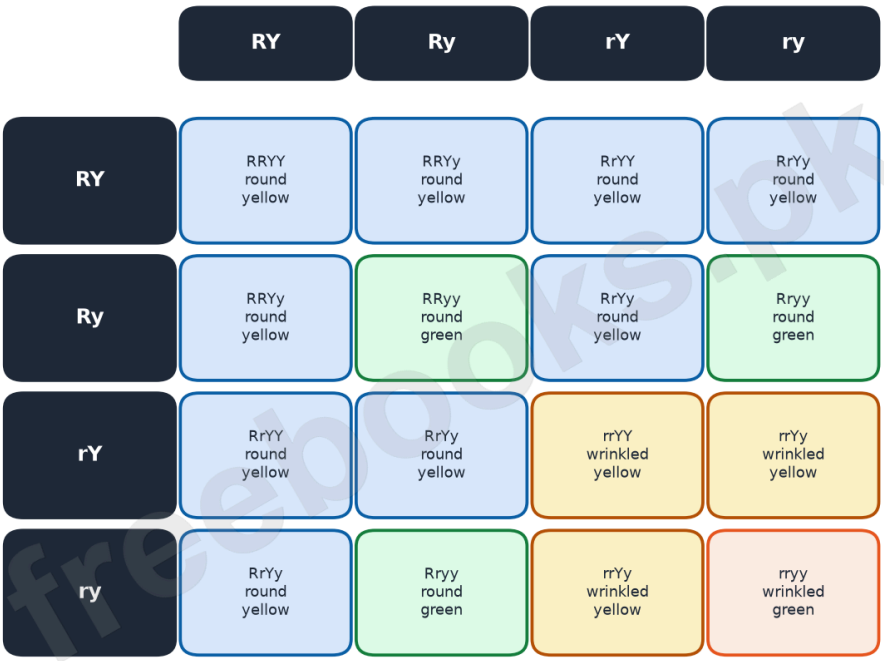
Genotypes 1 TT : 2 Tt : 1 tt

Phenotypes 3 tall : 1 dwarf (75% : 25%)

Dihybrid cross: A 4 × 4 Punnett square of RrYy × RrYy showing the 9 : 3 : 3 : 1 ratio.

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Dihybrid Cross: RrYy × RrYy



9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green

Short Questions and Answers

What is chromatin made of?
DNA wound around bundles of histone proteins.

What is the role of the centromere?
It holds the two sister chromatids together until they separate during cell division.

Give two differences between DNA and RNA.
DNA is double-stranded with deoxyribose and thymine; RNA is single-stranded with ribose and uracil.

If one DNA strand reads ATGC, what is the matching strand?
TACG, because A pairs with T and C pairs with G.

Distinguish transcription and translation.
Transcription copies a gene into mRNA in the nucleus; translation uses mRNA at ribosomes to join amino acids into a protein.

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How do proteins decide our characteristics?
Proteins such as enzymes and structural proteins control cell activities and build structures, producing traits like pigment colour.

Distinguish gene and allele.
A gene is the DNA segment for a trait; alleles are different forms of that gene.

Distinguish genotype and phenotype.
Genotype is the allele pair (e.g., Tt); phenotype is the visible trait (e.g., tall).

Why are TT and Tt plants both tall?
T is dominant, so one T allele is enough to produce tallness.

Why did Mendel use true-breeding plants?
So that he knew the parents' alleles were identical and results could be traced clearly.

Why was the garden pea a good choice?
Short generation time, seven clear contrasting traits, and easy control of self- and cross-pollination.

How did Mendel's results reject blending inheritance?
F1 plants were all tall, not medium, and dwarf plants reappeared unchanged in F2.

State the law of segregation.
The two alleles of a gene separate during gamete formation, so each gamete gets only one.

What gametes are formed by a plant of genotype RrYy?
Four kinds in equal numbers: RY, Ry, rY and ry.

State the law of independent assortment.
Alleles of different genes separate independently of one another during gamete formation.

Long Questions and Answers

Describe the structure of a chromosome.

What is a chromosome made of?

Chromatin, which is DNA wrapped around histone proteins.

How does chromatin change in cell division?

Fine threads in a resting nucleus coil up into short, thick chromosomes before division.

What are chromatids and centromere?

A replicated chromosome has two identical sister chromatids joined at the centromere.

How do prokaryotic chromosomes differ?

Prokaryotes have one circular DNA molecule in the cytoplasm without a nuclear envelope.

Compare DNA and RNA and explain how a protein is made from a gene.

Describe DNA.

A double helix of nucleotides with deoxyribose, phosphate and bases A, T, C, G paired A–T and C–G.

Describe RNA.

A single strand of nucleotides with ribose, phosphate and bases A, U, C, G.

What is transcription?

A gene acts as a template to make a complementary mRNA in the nucleus.

What is translation?

Ribosomes read the mRNA in the cytoplasm and join amino acids in the right order to form a protein.

Explain the terms used in genetics with examples.

What are gene and alleles?

A gene is a DNA segment for a trait; alleles are its alternative forms, e.g., free and attached earlobe alleles.

What are homozygous and heterozygous?

Homozygous has identical alleles (TT, tt); heterozygous has different alleles (Tt).

What are dominant and recessive?

In Tt, T shows its effect (dominant) and t is hidden (recessive).

What are genotype and phenotype?

Genotype is the allele combination; phenotype is the observable trait it produces.

Describe Mendel's monohybrid cross.

What was the parent cross?

True-breeding tall (TT) × true-breeding dwarf (tt).

What was the F1 result?

All plants tall with genotype Tt.

What was the F2 result?

3 tall : 1 dwarf phenotypes; genotypes 1 TT : 2 Tt : 1 tt.

What conclusions did Mendel draw?

Dominance, and the law of segregation: alleles separate into different gametes.

Describe Mendel's dihybrid cross.

What was the parent cross?

True-breeding round yellow (RRYY) × wrinkled green (rryy).

What was the F1 result?

All round yellow (RrYy), showing R and Y are dominant.

What gametes did F1 make?

RY, Ry, rY and ry in equal proportions, giving 16 combinations in F2.

What was the F2 ratio and conclusion?

9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green; alleles assort independently.

State and explain Mendel's laws of inheritance.

What is the concept of dominance?

In a heterozygote one allele masks the other's effect.

What is the law of segregation?

Each gamete receives only one allele of each gene because the pair separates during gamete formation.

What is the law of independent assortment?

Alleles of different genes are distributed to gametes independently of one another.

Which crosses demonstrate each law?

Segregation by the monohybrid 3 : 1 ratio; independent assortment by the dihybrid 9 : 3 : 3 : 1 ratio.

Multiple Choice Questions (MCQs)

Chromatin is made of DNA and: (A) Lipids (B) Histones (C) Starch (D) Ribose
Correct answer: (B) Histones. Histone proteins.

Two sister chromatids are joined at the: (A) Gene (B) Centromere (C) Locus (D) Ribosome
Correct answer: (B) Centromere. Centromere.

In DNA, adenine pairs with: (A) Cytosine (B) Guanine (C) Thymine (D) Uracil
Correct answer: (C) Thymine. A–T.

The base found in RNA but not DNA is: (A) Adenine (B) Thymine (C) Uracil (D) Guanine
Correct answer: (C) Uracil. Uracil.

Making mRNA from DNA is called: (A) Translation (B) Transcription (C) Replication (D)

Segregation
Correct answer: (B) Transcription. Transcription.

Proteins are assembled on: (A) Ribosomes (B) Centromeres (C) Histones (D) Nucleolus only
Correct answer: (A) Ribosomes. Ribosomes.

Alternative forms of a gene are called: (A) Loci (B) Alleles (C) Chromatids (D) Histones
Correct answer: (B) Alleles. Alleles.

A genotype with two identical alleles is: (A) Heterozygous (B) Homozygous (C) Recessive (D) Hybrid
Correct answer: (B) Homozygous. Homozygous.

The visible trait of an organism is its: (A) Genotype (B) Phenotype (C) Allele (D) Locus
Correct answer: (B) Phenotype. Phenotype.

A plant with genotype tt will be: (A) Tall (B) Dwarf (C) Medium (D) Half tall
Correct answer: (B) Dwarf. Both recessive alleles.

F1 of TT × tt are: (A) All dwarf (B) All tall (C) Half tall (D) 3 tall : 1 dwarf
Correct answer: (B) All tall. All Tt, tall.

The F2 phenotype ratio in a monohybrid cross is: (A) 1 : 1 (B) 1 : 2 : 1 (C) 3 : 1 (D) 9 : 3 : 3 : 1
Correct answer: (C) 3 : 1. 3 : 1.

Percentage of Tt plants in F2 of Tt × Tt: (A) 25% (B) 50% (C) 75% (D) 100%
Correct answer: (B) 50%. 2 of 4.

In F2 of a dihybrid cross, wrinkled green seeds form: (A) 9/16 (B) 3/16 (C) 1/16 (D) 4/16
Correct answer: (C) 1/16. rryy is 1/16.

The law of independent assortment comes from the: (A) Monohybrid cross (B) Dihybrid cross (C) Test of blending (D) Self-pollination only
Correct answer: (B) Dihybrid cross. Dihybrid cross.

Quick Revision Summary

- Chromosome = chromatin (DNA + histones); two sister chromatids joined at centromere.
- DNA: double helix, deoxyribose, A–T, C–G. RNA: single strand, ribose, uracil instead of thymine.
- Central dogma: DNA → (transcription, nucleus) → mRNA → (translation, ribosome) → protein.

- Gene, locus, allele; genotype (TT, Tt, tt), phenotype; homozygous vs heterozygous; dominant (capital) vs recessive (small).
- Mendel (1856–1863), garden pea: short life cycle, seven traits, controlled pollination.
- Monohybrid: TT × tt → F1 Tt (all tall) → F2 3 tall : 1 dwarf; 1 TT : 2 Tt : 1 tt. Law of segregation.
- Dihybrid: RRYY × rryy → F1 RrYy → F2 9 : 3 : 3 : 1. Law of independent assortment.

Exam Tips

- Always show gametes and a Punnett square when solving a cross; examiners give marks for each step.
- Learn the ratios 3 : 1, 1 : 2 : 1 and 9 : 3 : 3 : 1 and which cross gives each.
- Use capital letters for dominant and small letters of the same letter for recessive alleles.
- Practise defining the genetics terms in one line each; they are frequent short questions.
- Compare DNA and RNA in a table: strands, sugar, bases.

Note on Facts

The textbook describes every chromosome as having two identical chromatids. This is true only after the DNA has copied itself before cell division; before replication each chromosome is a single DNA molecule (one chromatid).

Chapter 8: Biotechnology

Chapter 8 introduces biotechnology: the use of living cells or organisms to make useful products or carry out useful processes. It ranges from the ancient use of yeast in baking to modern genetic engineering, in which genes are edited or moved between organisms.

These notes cover the meaning and history of biotechnology, the role of yeast in bread and ethanol production, the uses of bacteria, gene editing and gene transfer using plasmids, products made by genetic engineering, applications in food, medicine, environment, marine science and industry, and the possible risks of genetically modified organisms.

Learning Objectives

- Define biotechnology and give examples of its techniques.
- Explain the role of yeast in bread making and ethanol production.
- Explain why bacteria are useful in biotechnology and genetic modification.
- Describe the basic steps of gene transfer using a plasmid.
- Give examples of products and applications of biotechnology.
- Discuss the advantages and possible risks of genetic modification.

Key Concepts

8.1 Introduction to Biotechnology

Biotechnology is the use of living cells or organisms to produce products or processes for specific purposes. It benefits health, agriculture, industry and the environment. The term was first used in 1919 by the Hungarian engineer Karl Ereky.

Through biotechnology, the hereditary characteristics of organisms can be changed, new organisms with desired traits can be developed from a cell or part of an organism, and useful substances can be obtained from modified organisms.

Fermentation is the oldest form of biotechnology, used for thousands of years to make bread, yogurt and other foods. Modern biotechnology grew after the structure of DNA was worked out in 1953 and includes recombinant DNA technology, gene editing, cell and tissue culture and cloning. In 1996 a team led by Ian Wilmut produced Dolly the sheep, the first mammal cloned from an adult body cell (announced in 1997).

8.1 Yeast and Fermentation

Yeast is a microscopic, single-celled fungus. In fermentation it breaks down sugar without oxygen, producing ethanol (alcohol) and carbon dioxide.

Bread making: yeast ferments sugars in the dough; the carbon dioxide forms bubbles that make the dough rise and the bread soft and light. The small amount of alcohol produced evaporates during baking.

Ethanol production: yeast ferments sugars from crops such as sugarcane and maize to produce ethanol. The ethanol is purified and used as a biofuel (often blended with petrol) and in industry.

8.1 Bacteria in Biotechnology

Bacteria are widely used because they are simple, reproduce very quickly and easily take up new genetic material.

Useful products: some bacteria make antibiotics (Streptomyces makes streptomycin); many make enzymes used in cheese making and detergents; some make vitamins such as vitamin B12; Lactobacillus ferments milk into yogurt and cheese. In bioremediation, bacteria break down oil spills and wastes.

In genetic modification, plasmids (small circular DNA loops in bacteria) carry new genes into bacterial cells, which then make the protein coded by the foreign gene, such as human insulin, human growth hormone or vaccine proteins. Some bacteria are also used to carry new genes into plant cells.

8.2 Genetic Engineering: Gene Editing

Genetic engineering is changing the genes of an organism or transferring genes from one organism to another. Special enzymes cut and join DNA at precise places. The organisms produced are called genetically modified organisms (GMOs).

Gene editing changes the DNA of an organism by adding, removing or replacing specific parts. It is being researched to correct genetic disorders such as sickle cell anaemia and cystic fibrosis, to produce crops that grow faster and resist pests, diseases and drought, and to help make medicines. It must be done carefully because changes to DNA can have unexpected effects.

8.2 Gene Transfer and Cloning

Genes are carried into a new organism by vectors. The commonest vectors for bacteria are plasmids and bacteriophages (viruses that infect bacteria).

Steps: (1) the desired gene is identified and isolated from the donor's DNA; (2) a plasmid is taken from a bacterium and cut open, and the donor gene is joined into the gap, forming recombinant DNA; (3) the recombinant plasmid is put into a bacterial cell. As the bacterium multiplies, every cell of the colony carries the gene, giving many copies (gene cloning) and producing the protein.

Examples: human insulin and human growth hormone made by bacteria; interferon (an antiviral protein) from bacteria; a hepatitis B vaccine made in modified yeast; Bt cotton and Bt maize carrying a bacterial gene for an insect-killing toxin that is harmless to humans; Golden Rice, which makes beta-carotene (converted to vitamin A in the body) to help prevent vitamin A deficiency and blindness; gene therapy, which introduces genes into a patient's cells to treat disorders such as thalassaemia. Some COVID-19 vaccines use mRNA carrying instructions for a harmless virus protein.

8.3 Applications of Biotechnology

Food and agriculture: pest-, virus- and drought-resistant crop varieties; microbial enzymes for food

and alcohol industries. In Pakistan, disease- and pest-resistant rice varieties have been developed and tissue culture is used to multiply high-yield mangoes and citrus.

Medicine: hormones and enzymes for treatment, vaccines, correction of defective genes, targeted antibodies for diagnosis and treatment, and early detection of inherited conditions. The Human Genome Project mapped the location of human genes.

Environment: bioremediation of pollutants by bacteria, plants or fungi; tissue-cultured saplings for rapid reforestation; bacteria to extract metals such as copper; microbes to make manure.

Marine: faster-growing modified fish; new drugs from sponges, corals and marine bacteria; marine bacteria to clean oil spills; algae for biofuels; marine enzymes for industry.

Industry: biofuels (ethanol, biodiesel, biogas), biodegradable plastics from plant starch, and medicines such as penicillin (from the mould Penicillium) and insulin (from bacteria).

8.4 Potential Risks of Biotechnology

Health concerns: some people fear GM foods may cause allergies or long-term effects.

Environmental impact: genes from GM crops may spread to wild relatives by cross-pollination. Loss of biodiversity: if farmers grow only a few GM varieties, traditional varieties may disappear.

Resistant pests and weeds: insects and weeds repeatedly exposed to GM crops may evolve resistance. Ethical issues: some people believe it is wrong to alter the genes of living things. Careful testing and regulation are needed to balance benefits and risks.

Important Definitions

Biotechnology
Use of living cells or organisms to make useful products or processes.

Fermentation
Breakdown of sugar by microorganisms without oxygen.

Yeast
A single-celled fungus used in baking and brewing.

Bioremediation
Use of organisms to remove or neutralise pollutants.

Genetic engineering
Changing genes or transferring genes between organisms.

GMO
An organism whose genetic material has been altered by genetic engineering.

Gene editing
Adding, removing or replacing specific parts of an organism's DNA.

Vector
A carrier, such as a plasmid, used to transfer a gene.

Plasmid
A small circular DNA molecule found in bacteria.

Bacteriophage
A virus that infects bacteria.

Recombinant DNA
DNA formed by joining DNA from two different sources.

Gene cloning
Making many copies of a gene by multiplying the host cells.

Interferon
An antiviral protein made by cells.

Bt crop
A crop carrying a bacterial gene for an insect-killing toxin.

Golden Rice
Genetically modified rice that produces beta-carotene.

Gene therapy
Introducing genes into a patient's cells to treat a disorder.

Tissue culture
Growing cells or tissues in a nutrient medium to produce new plants.

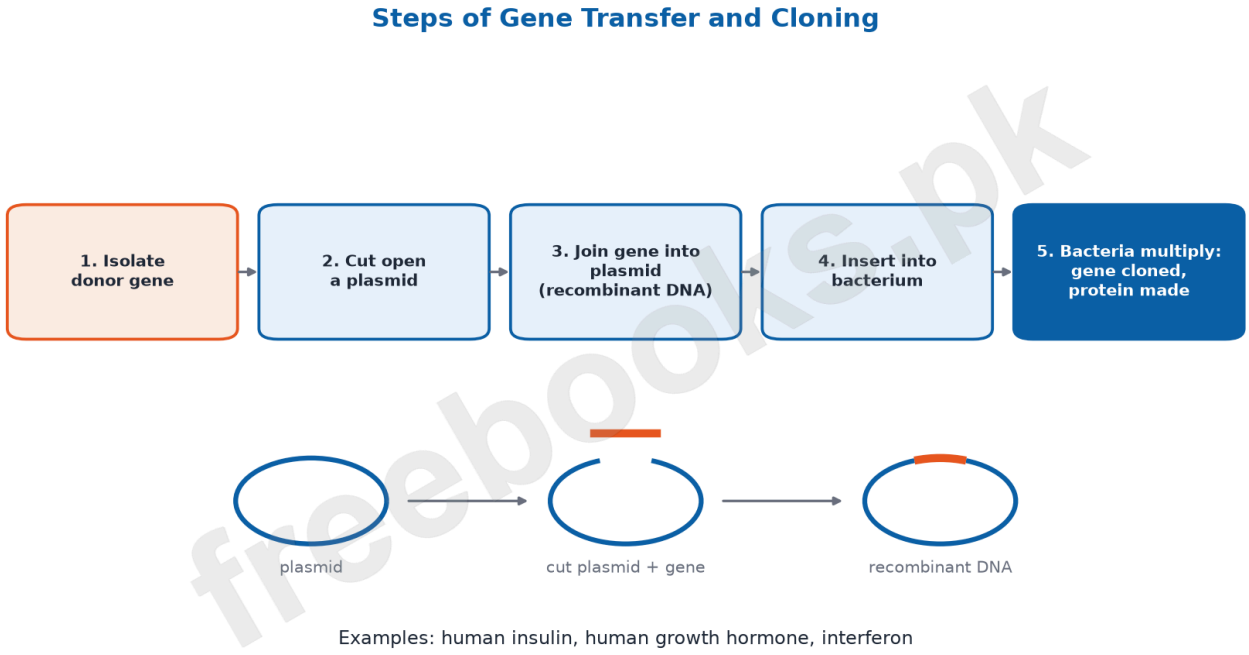
Key Facts at a Glance

Item	Fact
Term 'biotechnology' first used	1919, Karl Ereky
Structure of DNA worked out	1953
Dolly the sheep	First mammal cloned from an adult cell
Gas that makes dough rise	Carbon dioxide
Antibiotic from Streptomyces	Streptomycin
Bacterium in yogurt	Lactobacillus

Common vectors	Plasmids and bacteriophages
Insulin made by	Genetically modified bacteria
Hepatitis B vaccine made in	Modified yeast
Bt crops	Cotton and maize; insect resistance
Golden Rice	Beta-carotene → vitamin A
Penicillin made from	The mould Penicillium

Diagrams

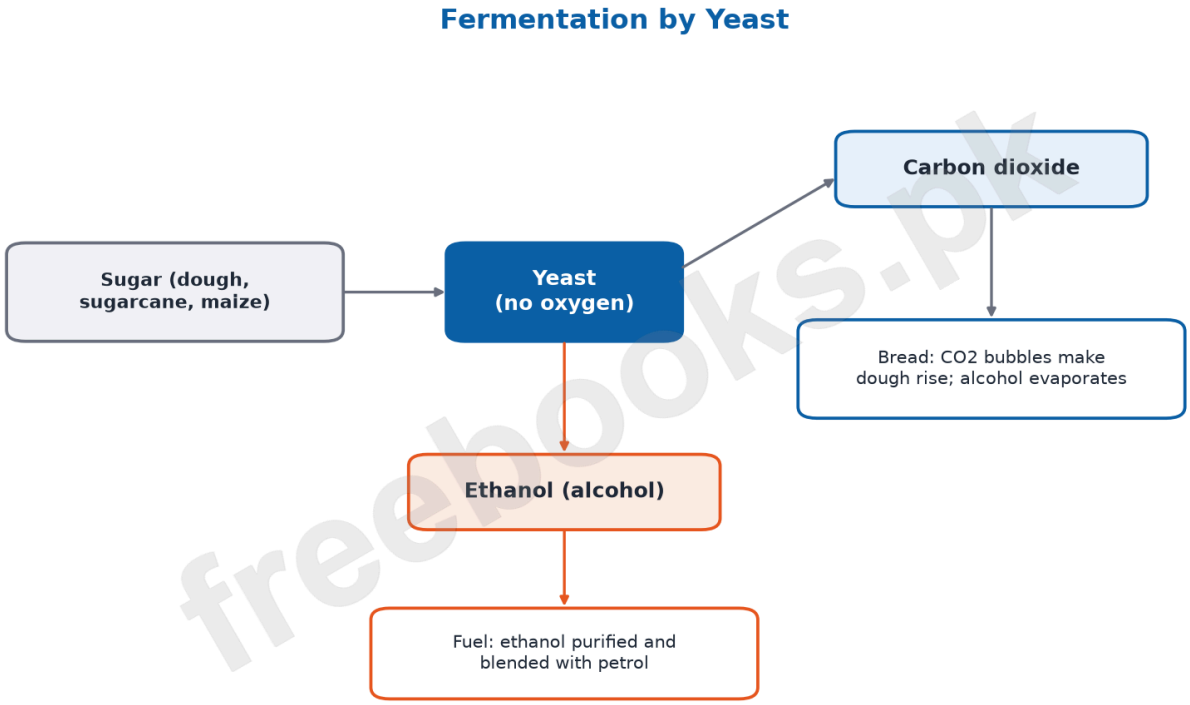
Steps of gene transfer: A flow chart of isolating a gene, forming recombinant DNA in a plasmid, and cloning it in bacteria.



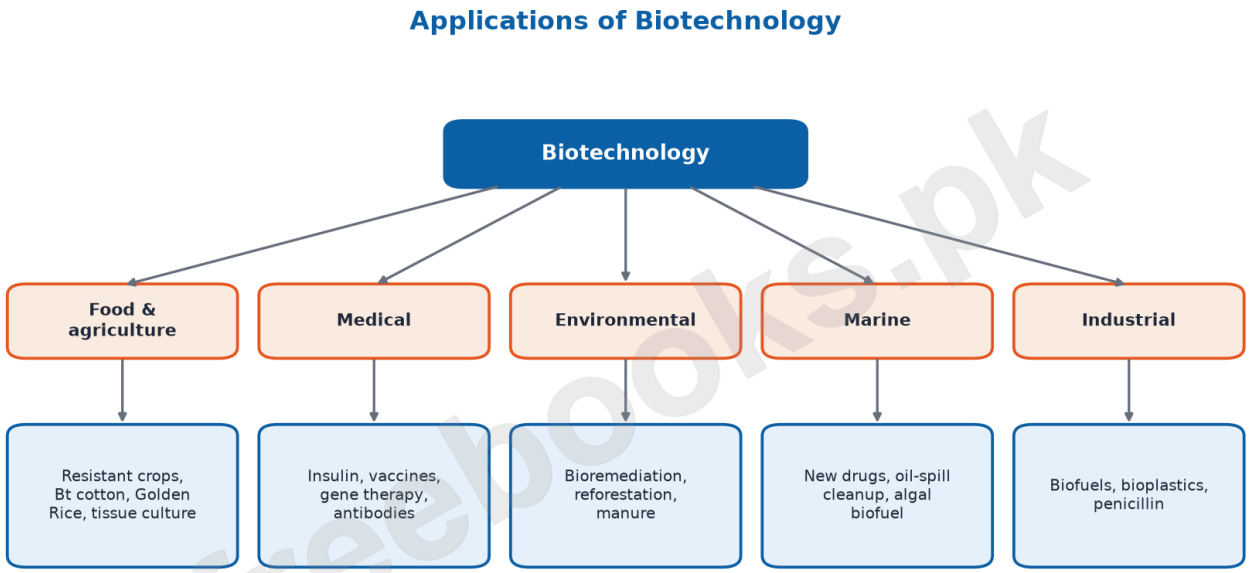
Examples: human insulin, human growth hormone, interferon

Fermentation by yeast: A diagram of sugar fermented by yeast into ethanol and carbon dioxide, with uses in bread and fuel.

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Applications of biotechnology: A chart of the five main fields of biotechnology with examples.



Short Questions and Answers

Define biotechnology.
The use of living cells or organisms to make useful products or processes for specific purposes.

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Why does bread dough rise?
Yeast ferments sugars and releases carbon dioxide, which forms bubbles in the dough.

Why does bread not contain alcohol even though yeast makes ethanol?
The small amount of ethanol evaporates during baking.

Why are bacteria useful in biotechnology?
They are simple, multiply quickly and readily take up new DNA.

Give two useful substances made by bacteria.
Antibiotics such as streptomycin and vitamins such as B12 (also enzymes).

What is bioremediation?
Use of organisms such as bacteria to break down or remove pollutants like oil spills.

What is a plasmid and why is it used?
A small circular DNA loop in bacteria; it can carry a foreign gene into a bacterial cell.

What is recombinant DNA?
DNA made by joining a donor gene into a vector such as a plasmid.

What is gene cloning?
Producing many copies of a gene as bacteria carrying it multiply.

How is human insulin produced by biotechnology?
The human insulin gene is put into bacteria, which make insulin that is collected and purified.

What is a Bt crop?
A crop such as cotton or maize carrying a bacterial gene that makes a toxin harmful to insects but safe for humans.

How does Golden Rice help health?
It makes beta-carotene, which the body converts to vitamin A, helping prevent blindness due to deficiency.

Distinguish gene editing and gene transfer.
Gene editing changes an organism's own DNA; gene transfer moves a gene from one organism into another.

Give two applications of environmental biotechnology.
Bioremediation of pollutants and tissue-cultured saplings for reforestation.

Give two risks of GM crops.
Spread of modified genes to wild plants and evolution of resistant pests (also loss of biodiversity).

Long Questions and Answers

Explain the role of yeast and bacteria in biotechnology.

What is fermentation by yeast?

Breakdown of sugar without oxygen into ethanol and carbon dioxide.

How is yeast used in bread and fuel?

CO_2 makes dough rise; ethanol from sugarcane or maize is purified as biofuel.

Which products do bacteria make?

Antibiotics, enzymes for cheese and detergents, vitamins like B12, and yogurt by Lactobacillus.

How do bacteria help in genetic modification?

Plasmids carry foreign genes into bacteria, which then make products like insulin and growth hormone.

Describe the steps of gene transfer into a bacterium.

What is the first step?

The desired gene is identified and cut out of the donor's DNA.

How is recombinant DNA made?

A plasmid is cut open and the donor gene is joined into it.

How is the gene put into bacteria?

The recombinant plasmid is introduced into a bacterial cell.

What is gene cloning?

The bacterium multiplies into a colony, each cell carrying and expressing the gene.

Describe gene editing and its uses.

What is gene editing?

Adding, deleting or replacing specific parts of an organism's DNA.

How may it help medicine?

It is being researched to correct disorders such as sickle cell anaemia and cystic fibrosis.

How may it help agriculture?

It can produce crops that grow faster and resist pests, diseases and drought.

Why must it be done carefully?

Changes to DNA can have unexpected effects on the organism.

Give examples of products made by gene transfer.

Which hormones are made?

Human insulin for diabetes and human growth hormone for growth disorders, made in bacteria.

Which protective products are made?

Interferon against viruses and hepatitis B vaccine made in yeast.

Which crops are modified?

Bt cotton and maize resist insects; Golden Rice makes beta-carotene.

What is gene therapy?

Introducing working genes into a patient's cells to treat genetic disorders such as thalassaemia.

Describe the applications of biotechnology.

In food and agriculture?

Resistant crop varieties, microbial enzymes, and tissue culture of fruit crops like mango and citrus.

In medicine?

Hormones, vaccines, gene correction, targeted antibodies and early diagnosis.

In the environment and sea?

Bioremediation, reforestation saplings, metal extraction, manure; marine drugs, oil-spill cleanup and algal biofuels.

In industry?

Biofuels, bioplastics and medicines such as penicillin and insulin.

Discuss the potential risks of biotechnology.

What are the health concerns?

Possible allergies or unknown long-term effects of GM foods.

What are the environmental concerns?

Modified genes may spread to wild plants through cross-pollination.

How may biodiversity and pests be affected?

Traditional varieties may be lost, and pests or weeds may become resistant.

What are the ethical issues?

Some people consider it wrong to alter the genes of living organisms.

Multiple Choice Questions (MCQs)

The term 'biotechnology' was first used by: (A) Mendel (B) Karl Ereky (C) Ian Wilmut (D) Darwin

Correct answer: (B) Karl Ereky. Karl Ereky, 1919.

The oldest form of biotechnology is: (A) Gene editing (B) Fermentation (C) Cloning (D) Gene therapy
Correct answer: (B) Fermentation. Fermentation.

Yeast is a: (A) Bacterium (B) Fungus (C) Virus (D) Alga
Correct answer: (B) Fungus. Single-celled fungus.

The gas that makes bread rise is: (A) Oxygen (B) Nitrogen (C) Carbon dioxide (D) Hydrogen
Correct answer: (C) Carbon dioxide. CO_2.

Streptomycin is obtained from: (A) Penicillium (B) Streptomyces (C) Lactobacillus (D) Yeast
Correct answer: (B) Streptomyces. Streptomyces.

Yogurt is made with the help of: (A) Lactobacillus (B) Streptomyces (C) Bacteriophage (D) Penicillium
Correct answer: (A) Lactobacillus. Lactobacillus.

Small circular DNA in bacteria is called a: (A) Chromatid (B) Plasmid (C) Ribosome (D) Histone
Correct answer: (B) Plasmid. Plasmid.

A virus that infects bacteria is a: (A) Plasmid (B) Bacteriophage (C) Interferon (D) Vector gene
Correct answer: (B) Bacteriophage. Bacteriophage.

DNA formed by joining DNA from two sources is: (A) Recombinant DNA (B) mRNA (C) Chromatin (D) Plasmid only
Correct answer: (A) Recombinant DNA. Recombinant DNA.

Human insulin for diabetics is now mostly made by: (A) Pig pancreas only (B) GM bacteria (C) Plants (D) Viruses
Correct answer: (B) GM bacteria. GM bacteria.

The hepatitis B vaccine is produced in modified: (A) Bacteria (B) Yeast (C) Cotton (D) Rice
Correct answer: (B) Yeast. Yeast.

Bt cotton is resistant to: (A) Drought (B) Insects (C) Herbicides (D) Frost
Correct answer: (B) Insects. Bt toxin kills insects.

Golden Rice provides: (A) Vitamin C (B) Beta-carotene (C) Insulin (D) Iron only
Correct answer: (B) Beta-carotene. Converted to vitamin A.

Use of organisms to clean pollutants is: (A) Bioremediation (B) Fermentation (C) Cloning

(D) Tissue culture
Correct answer: (A) Bioremediation. Bioremediation.

Penicillin is produced by fermentation using: (A) Yeast (B) Penicillium mould (C) Lactobacillus (D) E. coli
Correct answer: (B) Penicillium mould. Penicillium.

Quick Revision Summary

- Biotechnology: living cells/organisms → useful products; term by Karl Ereky (1919).
- Yeast fermentation: sugar → ethanol + CO2; bread rises (CO2), ethanol biofuel.
- Bacteria: antibiotics (Streptomyces), enzymes, vitamin B12, yogurt (Lactobacillus), bioremediation; plasmids carry genes.
- Genetic engineering → GMOs. Gene editing (change own DNA) vs gene transfer (move gene).
- Gene transfer: isolate gene → insert in plasmid (recombinant DNA) → put into bacterium → cloning.
- Products: insulin, growth hormone, interferon, hepatitis B vaccine (yeast), Bt crops, Golden Rice, gene therapy.
- Applications: food, medical, environmental, marine, industrial. Risks: health, gene spread, biodiversity loss, resistant pests, ethics.

Exam Tips

- Learn the three steps of gene transfer in order; draw a simple plasmid diagram.
- Match each product with its source organism (insulin–bacteria, hepatitis B vaccine–yeast, penicillin–Penicillium).
- Remember: fermentation gives both ethanol and CO2; bread uses the CO2, fuel uses the ethanol.
- For 'advantages and risks' questions, give balanced points from both sides.
- Keep a list of the five fields of applications with two examples each.

Note on Facts

The textbook gives virus-resistant tomato and tobacco and herbicide-resistant soybean, maize and cotton as examples of gene editing. These crops were made mainly by gene transfer (adding a foreign gene), not by editing the plant's own DNA; gene-edited crops are a newer development.

The textbook says the first cloned mammal, Dolly, was produced in 1997. Dolly was born in July 1996; the result was announced to the world in February 1997.

The textbook says Golden Rice was made by transferring a gene from a bacterium. Golden Rice actually carries two added genes: one from a soil bacterium and one from a plant (originally daffodil, later maize), which together let the rice grain make beta-carotene.

Chapter 9: Diseases and Immunity

Chapter 9 looks at what makes us ill and how the body protects itself. The WHO defines health as complete physical, mental and social well-being, not just the absence of disease. Diseases may be caused by pathogens (infectious) or by genes, lifestyle, environment or ageing (non-infectious).

These notes cover infectious and non-infectious diseases, zoonotic and vector-borne diseases with examples, allergies and their types, the main kinds of pathogens and how they spread, the three lines of defence of the immune system (innate and acquired immunity), and the steps of blood clotting.

Learning Objectives

- Distinguish infectious and non-infectious diseases with examples.
- Define zoonotic and vector-borne diseases and give examples.
- Describe allergies and their main types.
- Name the types of pathogens, with examples and modes of transmission.
- Describe the first, second and third lines of defence.
- Describe the steps of blood clotting.

Key Concepts

9.1 Disease and Its Basic Types

A disease is a condition that disturbs the normal working of the body or mind, such as an infection, a metabolic disorder or a genetic disorder. Illness is a person's own experience of feeling unwell.

Infectious (communicable) diseases are caused by pathogens and can spread from person to person or from the environment, through contaminated food or water or insect bites. Examples: viral (hepatitis, flu, dengue, measles, HIV, COVID-19); bacterial (typhoid, cholera, tuberculosis, strep throat); fungal (candidiasis); protozoan (malaria, amoebiasis); worms (roundworm, tapeworm). Infections may be localised (one area) or systemic (many organs). Overuse of antibiotics has made many bacteria resistant, a serious health risk.

Non-infectious (non-communicable) diseases do not spread between people. They result from lifestyle (heart disease, hypertension, diabetes, some cancers, stroke), mental health conditions (depression), genetic abnormalities (haemophilia, thalassaemia, muscular dystrophy) or decline of organs with age (Alzheimer's, Parkinson's, arthritis). Diabetes and cancers also have a genetic basis; a healthy lifestyle can delay them.

9.1 Zoonotic and Vector-Borne Diseases

A zoonotic disease is an infection naturally passed from animals to humans, through direct contact, food, water or the environment. Anthrax is caused by the bacterium Bacillus anthracis and spreads from contaminated hides, wool or meat, entering through wounds, food or inhaled spores. Bird flu (avian influenza) is caused by influenza A virus and spreads by close contact with infected birds.

Ebola, caused by the Ebola virus, spreads through blood and body fluids of infected people or animals and contaminated objects. Some diseases such as AIDS began as zoonoses and later spread only among humans.

Vector-borne diseases are spread by vectors, living organisms that carry pathogens from one host to another. Malaria (protozoan Plasmodium) is spread by the female Anopheles mosquito and affects the liver and red blood cells. Dengue fever (dengue virus) is spread by the Aedes mosquito. Lyme disease (bacterium Borrelia burgdorferi) is spread by ticks and affects skin, joints and nerves. Yellow fever (yellow fever virus) is spread by Aedes or Haemagogus mosquitoes and attacks the liver and then other organs.

9.1 Allergies

An allergy is an abnormal immune response to a substance that is normally harmless, called an allergen (pollen, dust mites, some foods, insect stings, some medicines). The body releases chemicals such as histamine, causing symptoms in the skin, airways, gut or circulation.

Types: respiratory allergies (allergic rhinitis or hay fever with sneezing and runny nose; asthma with narrowed airways); skin allergies (eczema with itchy inflamed patches; contact dermatitis from nickel, latex or plants); food allergies (peanuts, nuts, shellfish, milk, eggs, wheat); insect sting allergies (bee, wasp, ant venom); drug allergies (some antibiotics, aspirin, NSAIDs).

Anaphylaxis (anaphylactic shock) is a severe, sudden, life-threatening allergic reaction with difficulty breathing and a sharp fall in blood pressure; it needs emergency treatment.

9.2 Pathogens

A pathogen is a microorganism or agent that causes disease in its host: viruses, bacteria, fungi, protists and parasitic worms. Pathogens spread mainly through air, food, water, person-to-person contact and animal bites.

Examples: influenza virus (flu, airborne droplets), HIV (AIDS, sexual contact, blood, needles), SARS-CoV-2 (COVID-19, droplets and surfaces); Streptococcus pyogenes (strep throat), Mycobacterium tuberculosis (TB, airborne droplets), Escherichia coli (food poisoning, contaminated food or water); Candida albicans (candidiasis), athlete's foot fungi (contaminated surfaces), Aspergillus (aspergillosis, inhaled spores); Plasmodium falciparum (malaria, mosquito), Giardia (giardiasis) and Entamoeba histolytica (amoebiasis) from contaminated food or water. Tapeworms and roundworms live in the intestine as parasites.

9.3 Immunity: First and Second Lines of Defence

Immunity is the body's ability to defend itself against pathogens. Innate immunity is present from birth and includes the first and second lines of defence; acquired immunity develops during life and forms the third line.

First line (non-specific barriers): the skin is a physical barrier and its oil and sweat secretions slow microbial growth; mucous membranes lining the airways, gut and urethra secrete mucus that traps pathogens.

Second line (non-specific internal defences): phagocytes such as neutrophils and macrophages (from monocytes) engulf and destroy microbes, and neutrophils also release killing chemicals and

fibre nets; natural killer cells destroy virus-infected cells and cancer cells. Protective proteins include complement proteins that punch holes in the membranes of target cells and interferon, released by virus-infected cells, which helps neighbouring cells resist the virus.

Inflammation: damaged cells release histamine, which widens local blood vessels, causing heat, redness and swelling and bringing more defence cells. Fever: macrophages release pyrogens that act on the brain's temperature centre, raising body temperature above 37 °C; this boosts phagocytes and slows microbial growth.

9.3 Third Line of Defence and Blood Clotting

The third line is acquired, specific immunity. In active immunity, B-lymphocytes make antibodies against a particular pathogen; it may be natural (after infection) or artificial (after vaccination) and is long-lasting. In passive immunity, ready-made antibodies are given to a person (or pass from mother to baby); it acts at once but is short-lived.

Blood clotting (coagulation) stops bleeding: (1) exposed collagen in an injured vessel activates platelets, which stick to it and form a temporary platelet plug; (2) clotting factors released by platelets convert the plasma protein prothrombin into thrombin; (3) thrombin converts soluble fibrinogen into insoluble fibrin threads, which weave through the plug and trap blood cells to form a clot; (4) platelets in the clot contract, pulling the wound edges together. After healing, the clot is dissolved by a plasma protein and normal flow returns.

Important Definitions

Health
A state of complete physical, mental and social well-being, not merely absence of disease.

Disease
A condition that disturbs normal functioning of the body or mind.

Pathogen
A microorganism or agent that causes disease.

Infectious disease
A disease caused by a pathogen that can spread.

Non-infectious disease
A disease that does not spread from person to person.

Zoonotic disease
An infection naturally transmitted from animals to humans.

Vector
A living organism that carries a pathogen from one host to another.

Allergy
An abnormal immune response to a normally harmless substance.

Allergen
A substance that triggers an allergy.

Histamine
A chemical released in allergy and inflammation that widens blood vessels.

Anaphylaxis
A severe, life-threatening allergic reaction.

Immunity
The body's ability to resist disease-causing organisms.

Phagocytosis
Engulfing and digesting of microbes by cells such as neutrophils.

Interferon
A protein released by virus-infected cells that protects nearby cells.

Inflammation
Local heat, redness and swelling caused by histamine after injury or infection.

Pyrogens
Chemicals from macrophages that cause fever.

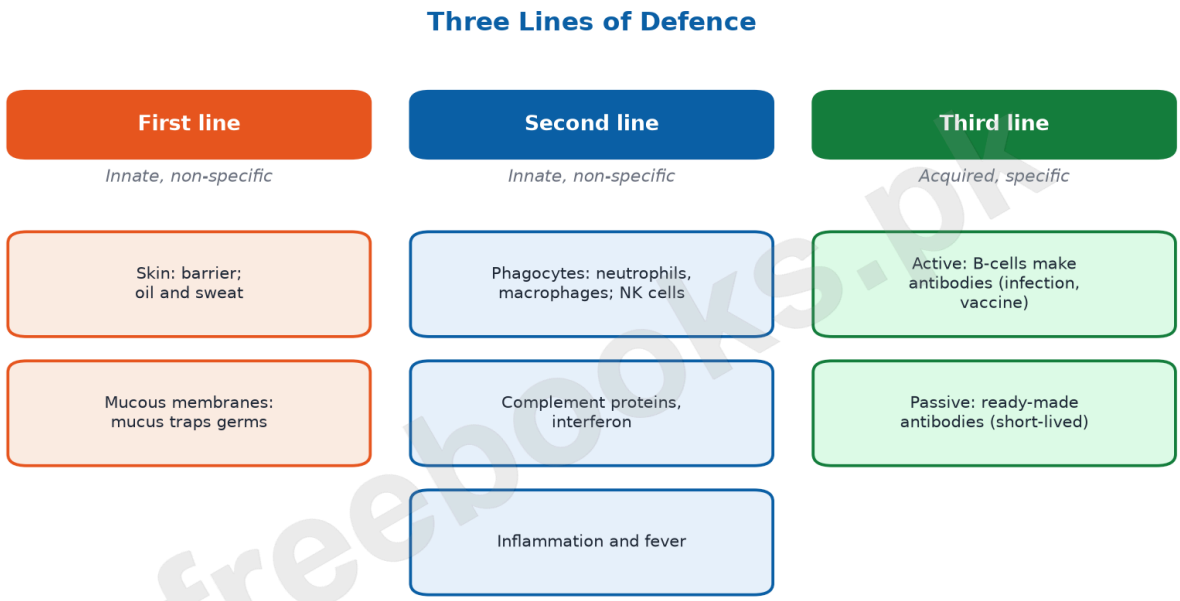
Active immunity
Immunity in which the body makes its own antibodies.

Passive immunity
Short-lived immunity from antibodies received ready-made.

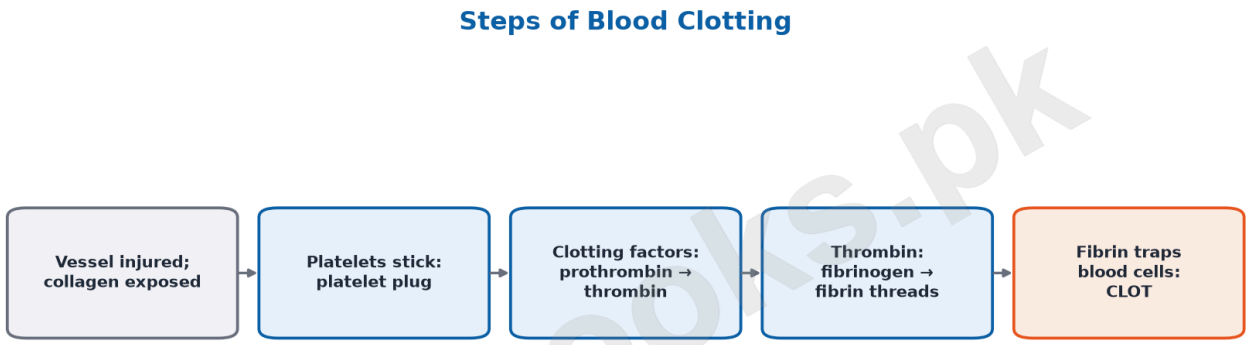
Thrombin
An enzyme that converts fibrinogen into fibrin.

Key Facts at a Glance

Disease / item	Cause / fact
Malaria	Plasmodium; Anopheles mosquito
Dengue fever	Dengue virus; Aedes mosquito
Lyme disease	Borrelia burgdorferi; ticks



Steps of blood clotting: A flow chart of the steps from vessel injury to clot formation.



Platelets then contract to close the wound; after healing the clot is dissolved.

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Short Questions and Answers

Distinguish disease and illness.

A disease is a condition disturbing body function; illness is the person's own experience of feeling unwell.

Distinguish infectious and non-infectious diseases.

Infectious diseases are caused by pathogens and can spread; non-infectious ones arise from

genes, lifestyle, environment or ageing and do not spread.

Why is overuse of antibiotics dangerous?
It allows resistant bacteria to survive and multiply, so antibiotics stop working.

What is a zoonotic disease? Give two examples.
An infection passed from animals to humans, e.g., anthrax and bird flu.

What is a vector? Name the vectors of malaria and dengue.
An organism carrying a pathogen between hosts; Anopheles mosquito (malaria) and Aedes mosquito (dengue).

Why is removing standing water important in preventing dengue?
Aedes mosquitoes breed in standing water, so removing it reduces the vector population.

What is an allergen? Give three examples.
A normally harmless substance that triggers allergy, e.g., pollen, dust mites and peanuts.

What is anaphylaxis?
A severe sudden allergic reaction with breathing difficulty and a drop in blood pressure that needs emergency treatment.

How does the skin protect against pathogens?
It is a physical barrier and its oil and sweat secretions inhibit microbial growth.

How do neutrophils and macrophages defend the body?
They engulf and destroy microbes by phagocytosis.

What is the role of interferon?
Released by virus-infected cells, it makes nearby cells produce proteins that resist the virus.

Why is inflammation useful?
Widened blood vessels bring more blood and defence cells to the site, helping stop the spread of microbes.

How does fever help fight infection?
Higher temperature increases phagocyte activity and slows the growth of bacteria and viruses.

Distinguish active and passive immunity.
In active immunity the body makes its own antibodies (long-lasting); in passive immunity antibodies are given ready-made (short-lived).

What is the role of thrombin in clotting?
It converts soluble fibrinogen into insoluble fibrin threads that form the clot.

Long Questions and Answers

Describe infectious and non-infectious diseases.

What are infectious diseases?

Communicable diseases caused by pathogens that spread by contact, food, water or bites.

Give examples of infectious diseases by pathogen.

Viral (flu, dengue, HIV), bacterial (TB, typhoid, cholera), fungal (candidiasis), protozoan (malaria), worms (tapeworm).

What are non-infectious diseases?

Non-communicable diseases due to lifestyle, genes, environment or ageing.

Give examples of non-infectious diseases.

Heart disease, diabetes, cancer (lifestyle/genetic); haemophilia, thalassaemia (genetic); Alzheimer's, arthritis (degenerative).

Describe zoonotic and vector-borne diseases.

What are zoonotic diseases?

Infections naturally passed from animals to humans through contact, food, water or the environment.

Describe anthrax, bird flu and Ebola.

Anthrax (Bacillus anthracis, from hides, wool, meat); bird flu (influenza A, from birds); Ebola (virus, from body fluids).

What are vector-borne diseases?

Infections carried from host to host by vectors such as mosquitoes and ticks.

Give examples.

Malaria (Anopheles), dengue and yellow fever (Aedes), Lyme disease (ticks).

Describe allergies and their types.

What is an allergy?

An abnormal immune reaction to a harmless allergen, releasing histamine.

What are respiratory and skin allergies?

Hay fever and asthma; eczema and contact dermatitis.

What are food, sting and drug allergies?

Reactions to foods like peanuts and eggs, to bee or wasp venom, and to some antibiotics, aspirin or NSAIDs.

What is anaphylaxis?

A severe, life-threatening reaction with breathing difficulty and low blood pressure needing urgent treatment.

Describe the first and second lines of defence.

What is the first line?

Skin and mucous membranes that physically block and trap pathogens.

Which cells act in the second line?

Neutrophils and macrophages (phagocytosis) and natural killer cells (destroy infected and cancer cells).

Which proteins help?

Complement proteins that puncture target cells and interferon that protects neighbouring cells against viruses.

How do inflammation and fever help?

Histamine widens vessels to bring defence cells; pyrogens raise temperature to boost phagocytes and slow microbes.

Describe the third line of defence.

Why is it called acquired immunity?

It develops during life after exposure to a pathogen or vaccine.

What is active immunity?

B-lymphocytes produce antibodies against a specific pathogen; long-lasting.

How can active immunity be natural or artificial?

Natural after recovering from infection; artificial after vaccination.

What is passive immunity?

Ready-made antibodies are received, giving immediate but short-lived protection.

Describe the process of blood clotting.

How is the platelet plug formed?

Exposed collagen activates platelets, which stick to the injured wall.

How is thrombin formed?

Clotting factors from platelets convert prothrombin into thrombin.

How is the clot formed?

Thrombin converts fibrinogen into fibrin threads that trap blood cells.

What happens afterwards?

Platelets contract to close the wound; after repair the clot is dissolved.

Multiple Choice Questions (MCQs)

A disease that spreads from person to person is: (A) Diabetes (B) Tuberculosis (C) Haemophilia (D) Arthritis
Correct answer: (B) Tuberculosis. TB is infectious.

Thalassaemia is an example of a: (A) Viral disease (B) Genetic disease (C) Zoonotic disease (D) Vector-borne disease
Correct answer: (B) Genetic disease. Genetic disorder.

A disease naturally passed from animals to humans is: (A) Allergic (B) Zoonotic (C) Degenerative (D) Genetic
Correct answer: (B) Zoonotic. Zoonotic.

Anthrax is caused by a: (A) Virus (B) Bacterium (C) Protozoan (D) Fungus
Correct answer: (B) Bacterium. Bacillus anthracis.

The vector of malaria is the: (A) Aedes mosquito (B) Anopheles mosquito (C) Tick (D) Housefly
Correct answer: (B) Anopheles mosquito. Anopheles.

Lyme disease is spread by: (A) Mosquitoes (B) Ticks (C) Water (D) Air
Correct answer: (B) Ticks. Ticks.

The chemical released in allergic reactions is: (A) Insulin (B) Histamine (C) Thrombin (D) Interferon
Correct answer: (B) Histamine. Histamine.

Candidiasis is caused by a: (A) Fungus (B) Bacterium (C) Virus (D) Worm
Correct answer: (A) Fungus. Candida albicans.

Tuberculosis is mainly transmitted by: (A) Mosquito bite (B) Airborne droplets (C) Contaminated water (D) Ticks
Correct answer: (B) Airborne droplets. Airborne droplets.

The first line of defence includes: (A) Antibodies (B) Skin and mucous membranes (C) Macrophages (D) Fever
Correct answer: (B) Skin and mucous membranes. Physical barriers.

Macrophages develop from: (A) Lymphocytes (B) Monocytes (C) Platelets (D) RBCs
Correct answer: (B) Monocytes. Monocytes.

Interferon is released by cells infected with: (A) Bacteria (B) Viruses (C) Fungi (D) Worms
Correct answer: (B) Viruses. Viruses.

Fever is triggered by chemicals called: (A) Histamines (B) Pyrogens (C) Antibodies (D) Allergens
Correct answer: (B) Pyrogens. Pyrogens.

Immunity after vaccination is: (A) Natural passive (B) Artificial active (C) Innate (D) Artificial passive
Correct answer: (B) Artificial active. Body makes its own antibodies.

Fibrinogen is converted into fibrin by: (A) Prothrombin (B) Thrombin (C) Collagen (D) Histamine
Correct answer: (B) Thrombin. Thrombin.

Quick Revision Summary

- Health (WHO): physical, mental and social well-being.
- Infectious: viruses, bacteria, fungi, protozoa, worms. Non-infectious: lifestyle, genetic, degenerative.
- Zoonotic: anthrax, bird flu, Ebola. Vector-borne: malaria (Anopheles), dengue (Aedes), Lyme (ticks), yellow fever.
- Allergy: allergen → histamine; respiratory, skin, food, sting, drug; anaphylaxis is an emergency.
- Pathogens spread by air, food, water, contact, bites.
- Innate: 1st line (skin, mucus), 2nd line (phagocytes, NK cells, complement, interferon, inflammation, fever).
- Acquired (3rd line): active (B-cells make antibodies; natural or vaccine) vs passive (given antibodies, short-lived).
- Clotting: platelet plug → prothrombin → thrombin → fibrinogen → fibrin → clot.

Exam Tips

- Make a table of disease, pathogen, type and vector; it covers many MCQs.
- Learn the three lines of defence with one or two examples each.
- Remember: vaccines give active artificial immunity; ready-made antibodies give passive immunity.
- Learn the clotting sequence prothrombin → thrombin, fibrinogen → fibrin in order.
- Do not confuse vector-borne (carried by an organism) with zoonotic (from animals).

Note on Facts

The textbook calls natural killer cells a type of T-lymphocyte. Natural killer cells are lymphocytes, but they are a separate group from T-cells and belong to innate (non-specific) immunity, as the chapter itself places them in the second line of defence.

The textbook's pathogen table lists 'Tinea pedis' as the fungus that causes athlete's foot. Tinea

pedis is the medical name of the disease itself; it is caused by fungi such as Trichophyton.

Chapter 10: Evolution

Chapter 10 explains evolution: the change in the inherited traits of a population over many generations. Small changes that help organisms survive in their environment build up over time and can lead to new species. Charles Darwin explained how this happens through natural selection.

These notes cover Darwin's voyage on HMS Beagle and his observations, the theory of evolution by natural selection with the beetle, giraffe and peppered moth examples, the definition of species, allopatric and sympatric speciation, the sources of variation, and the evidence for evolution from fossils, comparative anatomy and selective breeding.

Learning Objectives

- Describe Darwin's main observations on the voyage of HMS Beagle.
- Explain the theory of evolution by natural selection with examples.
- Define species and explain allopatric and sympatric speciation.
- Describe mutation, recombination, gene flow and random fertilisation as sources of variation.
- Describe fossil evidence, homologous and vestigial structures as evidence of evolution.
- Explain how selective breeding supports the idea of evolution.

Key Concepts

10.1 Darwin's Observations

Charles Darwin (1809–1882), an English naturalist, travelled around the world for five years on HMS Beagle and collected many observations.

Unique species: different regions and islands had their own distinct plants and animals. Variation within species: members of the same species living in different places differed in ways that suited their environments (adaptations).

Finches: on the Galápagos Islands, finches on different islands had beaks of different size and shape, each suited to the food available there, such as seeds, cactus or insects. Fossils: fossils of extinct animals resembled living species, suggesting species change over time.

After years of further study, Darwin published 'On the Origin of Species' in 1859, setting out the theory of evolution by natural selection.

10.2 Evolution by Natural Selection

The theory states that living things change over time: individuals with helpful variations survive and reproduce more, passing these variations to their young, so over many generations the helpful traits become common and new species can arise.

Steps: (1) Variation: individuals of a species differ, for example some beetles are green and some brown. (2) Struggle for survival: resources are limited and there are predators and diseases; birds

eat beetles. (3) Survival of the fittest: those best suited survive; brown beetles blend with soil and are eaten less. 'Fittest' means best suited, not strongest. (4) Reproduction: survivors pass on their useful traits, so more brown beetles are born. (5) Gradual change: over many generations the whole population may become brown.

Giraffe example: giraffes with slightly longer necks reached leaves on tall trees in dry seasons, survived and reproduced more, so long necks became common. Peppered moth example: in industrial England, soot darkened tree bark; dark moths were better hidden from birds than light moths, so the dark form became more common.

10.3 Species and Speciation

A species is a group of organisms that can interbreed under natural conditions and produce fertile offspring, and is reproductively isolated from other groups. Lions (Panthera leo) and tigers (Panthera tigris) are separate species because they do not interbreed in nature.

Speciation is the formation of new species. In allopatric speciation, a population is split by a geographical barrier such as a mountain range, river or sea; the separated groups evolve differently and become distinct species, as with the Galápagos finches. In sympatric speciation, groups in the same area become reproductively isolated because of differences in habitat, diet or mate choice, for example fish groups in one lake that stop interbreeding.

10.4 Sources of Variation

Mutation: a permanent change in DNA, arising spontaneously or due to radiation or chemicals, that can be inherited. Most mutations are neutral or harmful but some are useful; for example a mutation giving antibiotic resistance helps bacteria survive when antibiotics are used.

Genetic recombination: during meiosis, genes are shuffled into new combinations in gametes, so offspring of sexually reproducing parents get new mixtures of traits; this is why siblings differ.

Gene flow (migration): individuals or pollen moving from one population to another bring in new alleles, such as drought-resistance genes. Random fertilisation: any sperm can fuse with any egg, so each child of the same parents gets a unique combination of genes.

10.5 Evidence of Evolution

Palaeontology (fossil record): fossils are remains, impressions or traces of past organisms, mostly in sedimentary rocks. They show a sequence of change; the earliest vertebrate fossils are fishes, followed by amphibians and reptiles, then mammals and birds. Archaeopteryx, with both reptile and bird features, links birds to reptile (dinosaur) ancestors.

Comparative anatomy: homologous structures have the same basic structure but different functions, such as the forelimbs of humans, cats, whales and bats, pointing to a common ancestor. Analogous structures have the same function but different structure, such as wings of insects and birds. Vestigial structures have little or no use now but were functional in ancestors: the human appendix, human ear muscles, pelvic bones in whales and wings of flightless birds such as ostriches.

Selective breeding: humans choose plants or animals with desired traits and breed them, producing breeds of animals (hens, cows, goats, sheep) and varieties or cultivars of plants (wheat,

rice, potato, apple). It shows how much natural variation exists and how selection can change a population over generations, just as natural selection does.

Important Definitions

Evolution
Change in the inherited traits of a population over successive generations.

Adaptation
A feature of body or behaviour that helps an organism survive in its environment.

Natural selection
Process by which better-suited individuals survive and reproduce more.

Survival of the fittest
Survival of individuals best suited to their environment.

Species
Organisms that interbreed naturally to produce fertile offspring.

Speciation
Formation of new species by evolution.

Allopatric speciation
Speciation after populations are separated by a geographical barrier.

Sympatric speciation
Speciation within the same area due to reproductive isolation.

Variation
Inheritable differences among individuals of a population.

Mutation
A permanent, heritable change in DNA.

Genetic recombination
New combinations of genes formed during meiosis.

Gene flow
Movement of genes between populations by migration.

Fossil
Remains, impression or trace of an organism from the past.

Homologous structures

Similar structures with different functions, from a common ancestor.

Analogous structures
Structures with similar function but different structure.

Vestigial structures
Reduced parts with little or no function now.

Selective breeding
Breeding chosen organisms to obtain desired traits.

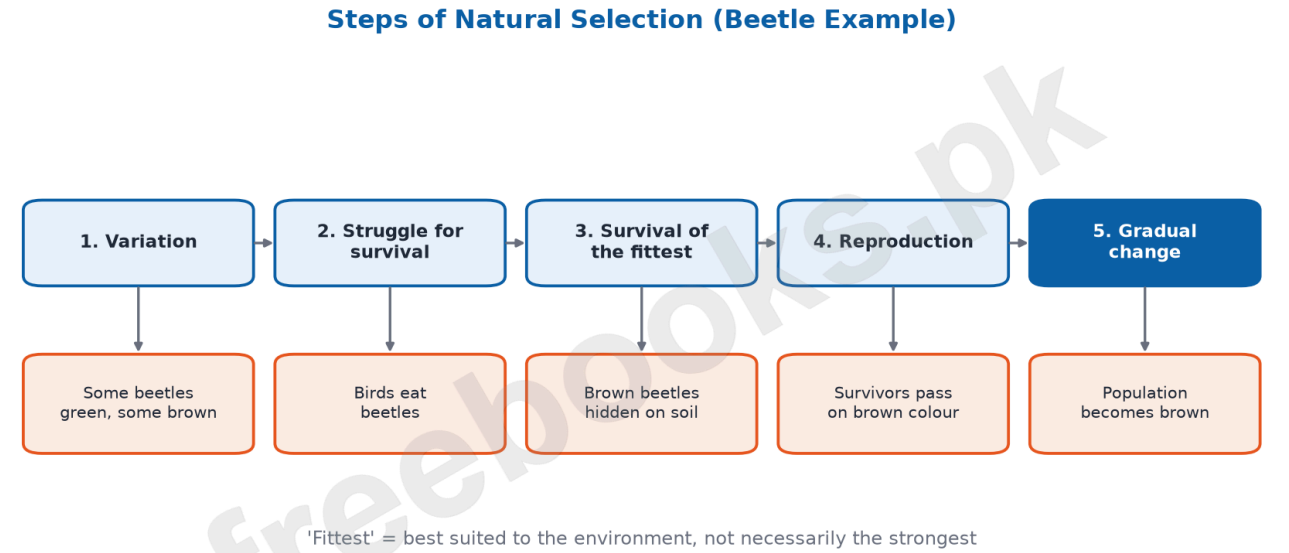
Cultivar
A plant variety produced by selective breeding.

Key Facts at a Glance

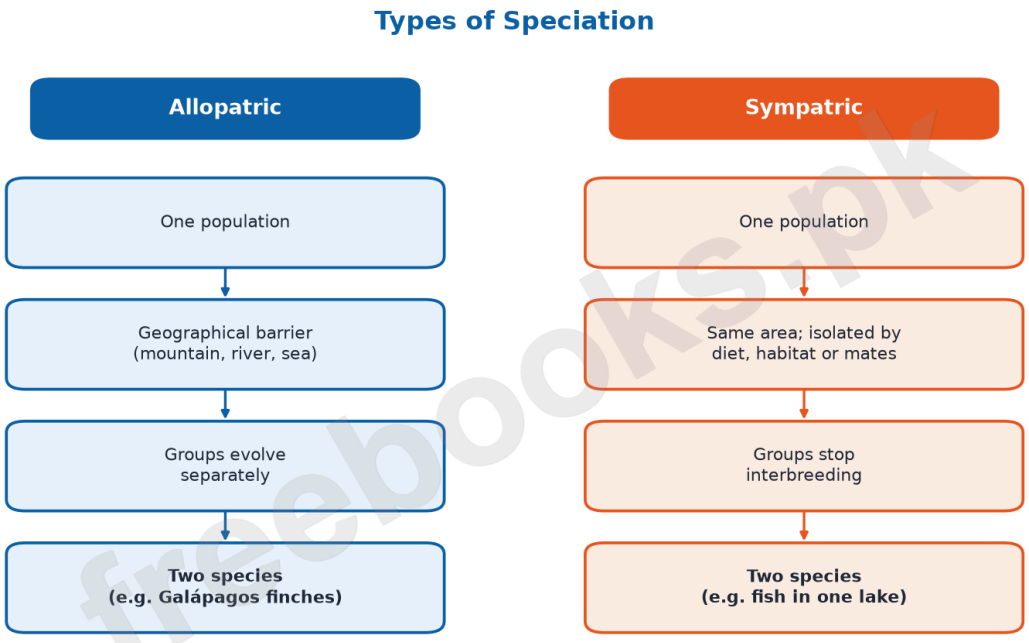
Item	Fact
Charles Darwin	1809–1882, English naturalist
Darwin's ship	HMS Beagle; five-year voyage
'On the Origin of Species'	Published 1859
Finches studied on	Galápagos Islands
Industrial example	Peppered moth
Lion and tiger	Panthera leo and Panthera tigris
Speciation by barrier	Allopatric
Speciation in same area	Sympatric
Earliest vertebrate fossils	Fishes
Bird–reptile link fossil	Archaeopteryx
Example of homologous organs	Forelimbs of human, cat, whale, bat
Vestigial in humans	Appendix, ear muscles

Diagrams

Steps of natural selection: A flow chart of the five steps of natural selection using the beetle example.

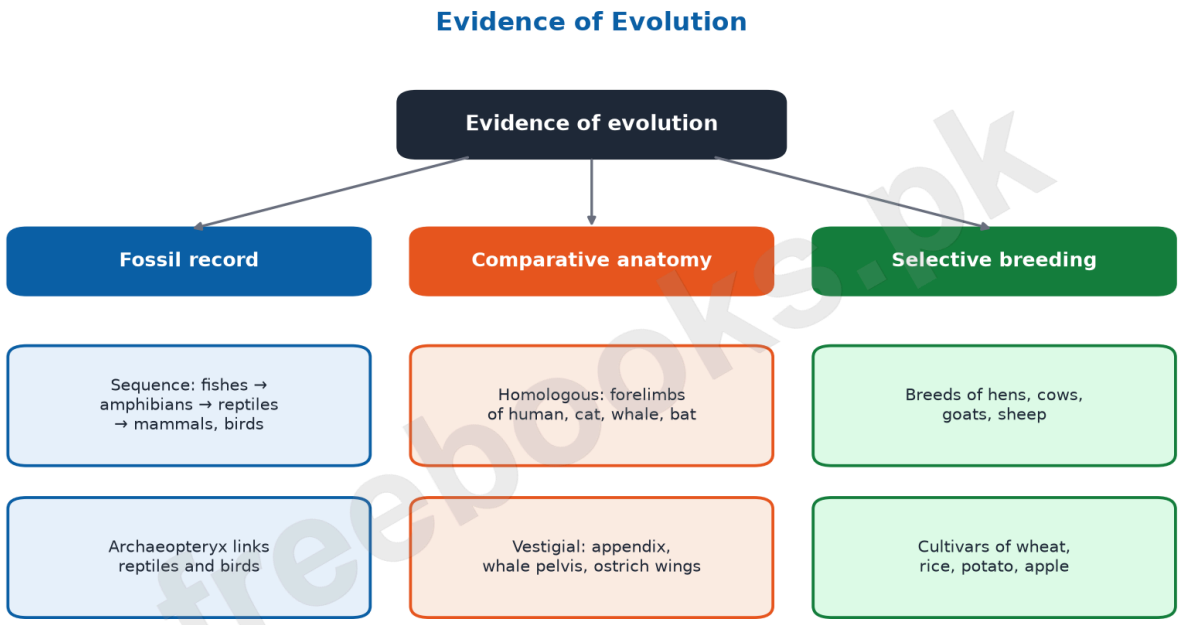


Types of speciation: A comparison of allopatric and sympatric speciation.



Evidence of evolution: A chart of the main evidence of evolution with examples.

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Short Questions and Answers

What is evolution?
A change in the inherited characteristics of a population over many generations.

What did the Galápagos finches show Darwin?
Their beaks differed in shape and size to suit the food on each island, showing adaptation.

How did fossils influence Darwin?
Fossils of extinct animals resembled living ones, suggesting species change over time.

What does 'fittest' mean in natural selection?
Best suited to the environment, not necessarily the strongest.

Why must there be variation for natural selection to act?
Selection can only favour some individuals over others if they differ in inherited traits.

Explain the peppered moth example in one or two lines.
Soot darkened tree bark; dark moths were hidden from birds and survived more, so they became common.

Define species.
A group of organisms that interbreed in nature and produce fertile offspring.

Why are lions and tigers separate species?

They do not interbreed under natural conditions; they are reproductively isolated.

Distinguish allopatric and sympatric speciation.
Allopatric happens after a geographical barrier separates populations; sympatric happens within the same area through reproductive isolation.

How can mutation be useful? Give an example.
A mutation may give a survival advantage, such as antibiotic resistance in bacteria.

Why are siblings different from one another?
Genetic recombination during meiosis and random fertilisation give each child a unique gene combination.

What is gene flow?
Movement of genes into a population when individuals or pollen migrate from another population.

Why is Archaeopteryx important?
It has features of both reptiles and birds, supporting the evolution of birds from reptile ancestors.

Distinguish homologous and analogous organs.
Homologous organs share structure but differ in function; analogous organs share function but differ in structure.

Give two vestigial structures.
The human appendix and pelvic bones in whales (also human ear muscles, ostrich wings).

Long Questions and Answers

Describe Darwin's observations during the voyage of HMS Beagle.

What was the voyage?

A five-year journey around the world on HMS Beagle by the naturalist Charles Darwin.

What did he notice about species and variation?

Different regions had unique species, and members of a species varied in ways suited to their environment.

What did the finches show?

Beak size and shape on each Galápagos island matched the available food.

What did fossils suggest?

Extinct animals resembled living ones, suggesting gradual change; he published 'On the Origin of Species' in 1859.

Explain the theory of evolution by natural selection.

What is variation?

Individuals of a species differ in colour, size, speed and other traits.

What is the struggle for survival?

Limited food and space, predators and diseases mean not all individuals survive.

What is survival of the fittest?

Individuals best suited to the environment survive and reproduce more.

How does this lead to evolution?

Useful traits are inherited and become common over many generations, which may produce new species.

Explain natural selection using the giraffe and peppered moth.

How did long necks become common in giraffes?

Longer-necked giraffes reached high leaves in dry seasons, survived and passed on long necks.

What happened to peppered moths?

Pollution darkened tree bark, so dark moths were camouflaged and survived better than light ones.

What was the result?

The population came to have more of the favoured form over generations.

What do both examples show?

The environment selects the variation that improves survival, changing the population.

Describe species and speciation.

What is a species?

Organisms that interbreed naturally and produce fertile offspring, isolated from other groups.

What is speciation?

The formation of new species by evolution.

Describe allopatric speciation.

A barrier like a mountain or sea separates populations, which evolve differently, as in Galápagos finches.

Describe sympatric speciation.

Groups in the same area stop interbreeding due to diet, habitat or mate choice, e.g., fish in a lake.

Describe the sources of variation.

What is mutation?

A permanent change in DNA that may produce new traits, e.g., antibiotic resistance.

What is genetic recombination?

Shuffling of genes during meiosis giving new combinations in gametes.

What is gene flow?

Migration of individuals or pollen bringing new alleles into a population.

What is random fertilisation?

Any sperm can fuse with any egg, giving unique combinations in each offspring.

Describe the evidence of evolution.

How does the fossil record support evolution?

Fossils show a sequence of change through time, and Archaeopteryx links reptiles and birds.

What are homologous structures?

Forelimbs of human, cat, whale and bat share structure but differ in function, indicating common ancestry.

What are vestigial structures?

Reduced organs like the human appendix and whale pelvic bones that were functional in ancestors.

How does selective breeding support evolution?

It shows natural variation exists and that selection over generations changes a population.

Multiple Choice Questions (MCQs)

Darwin travelled around the world on: (A) HMS Victory (B) HMS Beagle (C) Titanic (D) Endeavour
Correct answer: (B) HMS Beagle. HMS Beagle.

'On the Origin of Species' was published in: (A) 1809 (B) 1859 (C) 1882 (D) 1900
Correct answer: (B) 1859. 1859.

Darwin studied finches on the: (A) Canary Islands (B) Galápagos Islands (C) Maldives (D) Hawaii
Correct answer: (B) Galápagos Islands. Galápagos.

In natural selection, 'fittest' means: (A) Strongest (B) Largest (C) Best suited (D) Fastest
Correct answer: (C) Best suited. Best suited.

Dark peppered moths increased because they were: (A) Stronger (B) Better camouflaged (C) Larger (D) Faster
Correct answer: (B) Better camouflaged. Hidden on dark bark.

Organisms that interbreed naturally and give fertile offspring form a: (A) Genus (B) Species (C) Population only (D) Family
Correct answer: (B) Species. Species.

Speciation caused by a mountain range separating populations is: (A) Sympatric (B) Allopatric (C) Artificial (D) Random
Correct answer: (B) Allopatric. Allopatric.

A permanent change in DNA is a: (A) Fossil (B) Mutation (C) Breed (D) Cultivar
Correct answer: (B) Mutation. Mutation.

New gene combinations formed during meiosis are due to: (A) Gene flow (B) Recombination (C) Mutation only (D) Selection
Correct answer: (B) Recombination. Recombination.

Migration of pollen bringing new genes is: (A) Gene flow (B) Speciation (C) Mutation (D) Analogy
Correct answer: (A) Gene flow. Gene flow.

The earliest vertebrates in the fossil record are: (A) Reptiles (B) Fishes (C) Birds (D) Mammals
Correct answer: (B) Fishes. Fishes.

Archaeopteryx links birds with: (A) Fishes (B) Reptiles (C) Mammals (D) Amphibians
Correct answer: (B) Reptiles. Reptile (dinosaur) ancestors.

Forelimbs of human and bat are: (A) Analogous (B) Homologous (C) Vestigial (D) Unrelated
Correct answer: (B) Homologous. Same structure, different function.

Wings of an insect and a bird are: (A) Homologous (B) Analogous (C) Vestigial (D) Fossils
Correct answer: (B) Analogous. Same function, different structure.

Plant varieties produced by selective breeding are called: (A) Breeds (B) Cultivars (C) Mutants (D) Fossils
Correct answer: (B) Cultivars. Cultivars.

Quick Revision Summary

- Evolution: change in heritable traits of a population over generations.
- Darwin (1809–1882), HMS Beagle; unique species, variation, Galápagos finches, fossils; 'On the Origin of Species' (1859).
- Natural selection: variation → struggle for survival → survival of the fittest → reproduction → gradual change.

- Examples: beetles, giraffe neck, peppered moth.
- Species: interbreed, fertile offspring. Speciation: allopatric (barrier) vs sympatric (same area).
- Variation: mutation, recombination, gene flow, random fertilisation.
- Evidence: fossils (Archaeopteryx), homologous vs analogous, vestigial (appendix, whale pelvis), selective breeding.

Exam Tips

- Learn the five steps of natural selection and practise applying them to any example.
- Do not confuse homologous (same structure) with analogous (same function).
- Remember allopatric = 'other place' (barrier) and sympatric = 'same place'.
- Give one example for each source of variation and each type of evidence.
- Learn key dates: Darwin 1809–1882, Origin of Species 1859.

Note on Facts

The textbook lists the order of vertebrate fossils as fishes, amphibians, reptiles, then birds and mammals. Early mammals actually appear in the fossil record before the first birds (about 200 million years ago versus about 150 million years ago); both came after reptiles.

The textbook describes the human appendix as vestigial. It is reduced compared with the large caecum of plant-eating mammals, but scientists now know it contains lymphoid tissue and may help the immune system and gut bacteria, so it is not entirely without function.

The textbook says natural selection works in three steps but then describes five. The five-step description (variation, struggle, survival of the fittest, reproduction, gradual change) is the complete one to learn.

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