

Physiology

Sample Paper – 8

Questions:	25	Duration:	45 min
Total Marks:	100	Marking:	+4 / –1

Topics: Respiratory · Cardiovascular · Endocrine · Renal · Haematology · Nutrition · Nervous



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Quick Reference**Instructions**

- This paper has **25 questions** carrying **100 marks**.
- Each correct answer: **+4 marks**. Each wrong answer: **–1 mark**. Unattempted: **0**.
- Suggested time: **45 minutes**. All questions are single-correct MCQs.
- Covers: Respiratory, Cardiovascular, Endocrine, Renal, Haematology, Nutrition, Nervous systems.
- Click a question number in the answer key to jump to its solution.

Q1. The volume of air that remains in the lungs after a maximal forced exhalation — which cannot be expelled even by the most forceful expiration — is called the residual volume. Its approximate value in a healthy adult is:

- (A) 500 mL
- (B) 1200 mL
- (C) 3000 mL
- (D) 4800 mL

Q2. Angiotensin I is converted to the active vasoconstrictor angiotensin II by an enzyme located primarily in the pulmonary capillary endothelium. This enzyme is:

- (A) Angiotensin-converting enzyme (ACE)
- (B) Renin
- (C) Aldosterone synthase
- (D) Aminopeptidase N

Q3. The oxygen–haemoglobin dissociation curve shifts to the right (decreased O_2 affinity) under which of the following conditions?

- (A) Decreased body temperature
- (B) Alkalosis (raised blood pH)
- (C) Low altitude with reduced 2,3-DPG
- (D) Increased CO_2 , increased H^+ , and raised temperature (Bohr effect)

Q4. Graves' disease is the most common cause of hyperthyroidism. Its underlying mechanism involves:

- (A) Iodine deficiency leading to thyroid enlargement
- (B) Excessive TSH secretion from the anterior pituitary
- (C) Stimulating autoantibodies (TSI) that bind and activate TSH receptors on the thyroid
- (D) Autonomous thyroid nodules secreting excess thyroxine independently of TSH

Q5. The menstrual cycle in a woman with regular cycles is measured from the first day of menstruation to the first day of the next period. The normal cycle length is approximately:

- (A) 14 days
- (B) 28 days
- (C) 35 days
- (D) 42 days

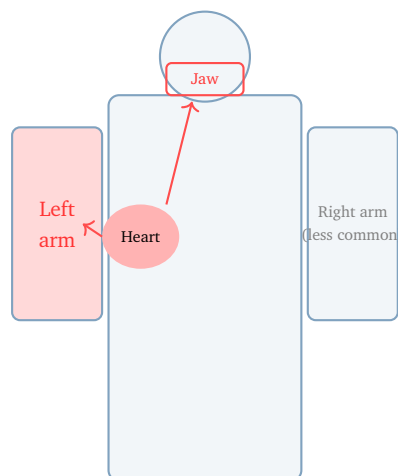
Q6. Among the major blood cell types, which has the shortest lifespan in the circulation?

- (A) Erythrocyte (red blood cell) – approximately 120 days
- (B) Monocyte – approximately 1–3 days in blood then migrates to tissues
- (C) Lymphocyte – long-lived memory cells survive for years
- (D) Neutrophil (granulocyte) – approximately 5–10 hours in blood

Q7. Erythrocytes maintain their characteristic biconcave disc shape through a cytoskeletal network attached to the inner surface of the plasma membrane. The principal structural protein of this cytoskeleton is:

- (A) Spectrin
- (B) Actin alone
- (C) Myosin
- (D) Ankyrin

Q8. During an acute myocardial infarction (heart attack), pain is often referred to sites distant from the heart. The diagram below illustrates referred pain pathways. In which locations is cardiac referred pain most typically felt?



- (A) Right arm and right shoulder only
- (B) Left arm and jaw
- (C) Epigastric region and right iliac fossa
- (D) Right leg and lower back

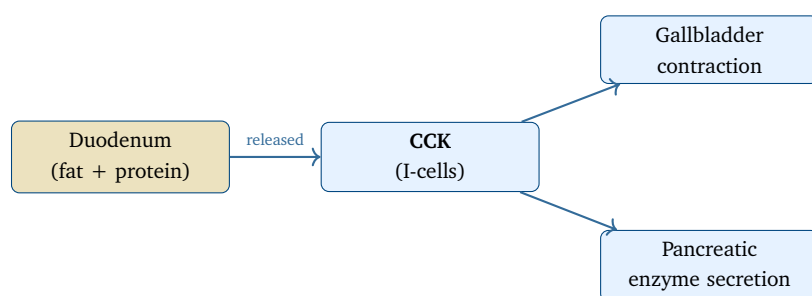
Q9. Which pituitary gonadotrophin stimulates follicle development and oestrogen secretion in females, while stimulating Sertoli cells and spermatogenesis in males?

- (A) Luteinising hormone (LH)
- (B) Prolactin
- (C) Growth hormone (GH)
- (D) Follicle-stimulating hormone (FSH)

Q10. Vitamin A (retinol) deficiency is the leading cause of preventable childhood blindness worldwide. The earliest and most characteristic symptom of vitamin A deficiency is:

- (A) Night blindness (nyctalopia) due to impaired rhodopsin synthesis
- (B) Scurvy (bleeding gums and poor wound healing)
- (C) Pellagra (dermatitis, diarrhoea, dementia)
- (D) Rickets (soft and deformed bones)

Q11. Cholecystokinin (CCK) is a gastrointestinal hormone released by I-cells of the duodenum and jejunum. The diagram below shows its release triggers and targets. CCK primarily stimulates:



- (A) Gastric acid secretion from parietal cells
- (B) Secretion of bicarbonate from the pancreatic ducts
- (C) Gallbladder contraction and pancreatic enzyme secretion
- (D) Increased gastric motility and gastrin release

Q12. Cardiac troponin I (cTnI) and troponin T (cTnT) are released into the bloodstream when cardiac muscle cells are damaged. They are used clinically as diagnostic biomarkers of:

- (A) Pulmonary embolism (blood clot in lungs)
- (B) Myocardial infarction (heart attack)
- (C) Liver cirrhosis and hepatocellular damage
- (D) Acute pancreatitis

Q13. Sickle cell disease is an autosomal recessive haemoglobinopathy. The underlying molecular defect is:

- (A) Deletion of alpha-globin genes on chromosome 16
- (B) An abnormal iron-loading disorder causing haemosiderin deposition

- (C) A point mutation in the beta-globin gene substituting glutamate with valine at position 6 (HbS)
- (D) Deficiency of glucose-6-phosphate dehydrogenase (G6PD) in erythrocytes

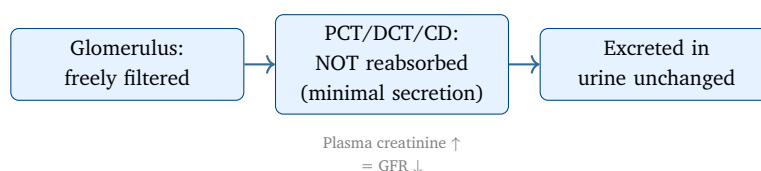
Q14. Aquaporins are integral membrane proteins that form water channels in cell membranes. In the kidney, aquaporin-2 (AQP2) channels in the collecting duct are regulated by ADH. Their primary function is to allow:

- (A) Rapid water reabsorption across tubular epithelial cell membranes
- (B) Active sodium transport against the electrochemical gradient
- (C) Urea secretion into the tubular lumen
- (D) Potassium diffusion along its concentration gradient

Q15. Bile acids secreted into the small intestine are predominantly reabsorbed and returned to the liver via the portal circulation for re-secretion (enterohepatic circulation). The major site of active bile acid reabsorption is the:

- (A) Duodenum
- (B) Jejunum
- (C) Terminal ileum
- (D) Proximal colon

Q16. Creatinine is used clinically to estimate the glomerular filtration rate (GFR). The diagram below shows its handling by the nephron. Creatinine is a reliable GFR marker because:



- (A) It is actively secreted by the proximal tubule in large amounts
- (B) It is completely reabsorbed by the distal convoluted tubule
- (C) It is freely filtered at the glomerulus and neither significantly secreted nor reabsorbed
- (D) It binds to plasma proteins and is therefore not filtered at all

Q17. Nitric oxide (NO) is a gaseous signalling molecule synthesised from L-arginine by nitric oxide synthase (NOS) in endothelial cells. Its principal cardiovascular action is:

- (A) Vasoconstriction through activation of Rho-kinase in smooth muscle
- (B) Platelet activation and promotion of thrombus formation
- (C) Increased cardiac contractility via cAMP-mediated pathways
- (D) Vasodilation through activation of soluble guanylyl cyclase, raising cGMP in vascular smooth muscle

Q18. The majority of coagulation factors (including fibrinogen, prothrombin, Factors V, VII, VIII, IX, X, and XIII) are synthesised by which organ?

- (A) The liver
- (B) The spleen
- (C) Bone marrow megakaryocytes
- (D) Vascular endothelial cells

Q19. Central cyanosis — a bluish discolouration of the lips, tongue, and mucous membranes — occurs when the oxygen saturation of arterial haemoglobin falls below approximately:

- (A) 85% (approximately 5 g/dL deoxyhaemoglobin in arterial blood)
- (B) 95% (the lower limit of the normal range)
- (C) 70% (seen only in advanced respiratory failure)
- (D) 99% (any drop below the normal maximum)

Q20. Thiamine (vitamin B₁) is an essential cofactor for several key enzymes including pyruvate dehydrogenase and alpha-ketoglutarate dehydrogenase. Deficiency of vitamin B₁ causes:

- (A) Pellagra (the three Ds: dermatitis, diarrhoea, dementia)
- (B) Beriberi (peripheral neuropathy, cardiac failure) or Wernicke–Korsakoff syndrome
- (C) Scurvy (bleeding gums, poor wound healing, perifollicular haemorrhages)
- (D) Megaloblastic anaemia and subacute combined degeneration of the spinal cord

Q21. Serotonin (5-hydroxytryptamine, 5-HT) is a monoamine neurotransmitter and paracrine signalling molecule. The vast majority ($\approx 95\%$) of the body's serotonin is found in:

- (A) The raphe nuclei of the brainstem
- (B) Adrenal chromaffin cells alongside adrenaline
- (C) Hypothalamic nuclei controlling appetite and mood
- (D) Enterochromaffin cells of the gastrointestinal mucosa

Q22. Spirometry measures various lung volumes and capacities. Forced vital capacity (FVC) is defined as:

- (A) The volume of air inhaled during a normal quiet breath at rest (tidal volume)
- (B) The additional volume of air that can be inhaled beyond a normal tidal breath (inspiratory reserve volume)
- (C) The volume of air remaining in the lungs after a normal quiet exhalation (functional residual capacity)
- (D) The maximum volume of air forcefully exhaled after a maximum inhalation

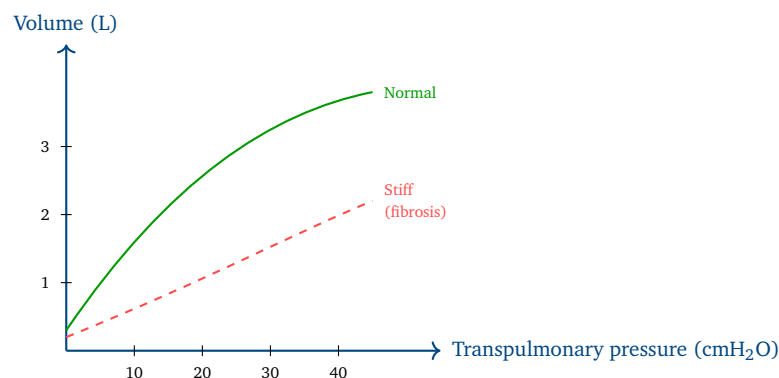
Q23. In the kidney tubule, sodium reabsorption is coupled to hydrogen ion secretion by an antiport mechanism. This process of Na^+/H^+ exchange in the proximal tubule primarily functions to:

- (A) Secrete potassium into the tubular lumen
- (B) Reabsorb filtered chloride ions via a co-transporter
- (C) Reabsorb filtered bicarbonate and regulate acid-base balance
- (D) Concentrate urea in the medullary interstitium

Q24. Parkinson's disease is characterised by progressive degeneration of dopaminergic neurons in the substantia nigra pars compacta. The neurotransmitter that is deficient in Parkinson's disease is:

- (A) Dopamine
- (B) Acetylcholine
- (C) Serotonin (5-HT)
- (D) Gamma-aminobutyric acid (GABA)

Q25. Lung compliance is a measure of the distensibility of the lung (volume change per unit pressure change). The pressure–volume diagram below compares normal lungs with a pathological condition. In which condition is lung compliance markedly *reduced* (stiffer lungs)?



- (A) Emphysema (destruction of alveolar walls, hyperinflation)
- (B) Pulmonary fibrosis (excess collagen deposition, stiff lungs)
- (C) Asthma (bronchospasm, normal compliance between attacks)
- (D) Pneumothorax (air in the pleural space)

Answer Key — Physiology Sample Paper 8

1	B	2	A	3	D	4	C	5	B
6	D	7	A	8	B	9	D	10	A
11	C	12	B	13	C	14	A	15	C
16	C	17	D	18	A	19	A	20	B
21	D	22	D	23	C	24	A	25	B

Detailed Solutions

Solution

Q1. (B) 1200 mL

The **residual volume (RV)** is the air remaining after maximal exhalation (≈ 1200 mL in adults). It cannot be measured by spirometry alone (requires body plethysmography or gas dilution). It serves to keep alveoli partially open between breaths and prevents atelectasis. Total lung capacity = vital capacity + residual volume ($\approx 4800 + 1200 = 6000$ mL). Tidal volume (TV) = 500 mL; inspiratory reserve = 3000 mL; expiratory reserve ≈ 1100 mL.

Solution

Q2. (A) Angiotensin-converting enzyme (ACE)

ACE (a zinc-metalloprotease, kininase II) is expressed abundantly on pulmonary capillary endothelial cells. It cleaves the C-terminal dipeptide from angiotensin I (10 aa) to produce angiotensin II (8 aa), a potent vasoconstrictor. ACE also inactivates bradykinin (a vasodilator) — hence ACE inhibitors cause bradykinin accumulation and the characteristic dry cough. ACE inhibitors (e.g., ramipril, enalapril) are used for hypertension and heart failure.

Solution

Q3. (D) Increased CO_2 , H^+ , and temperature (Bohr effect)

The **Bohr effect** describes the right shift of the oxyhaemoglobin dissociation curve under conditions of increased CO_2 , decreased pH (increased H^+), raised temperature, and elevated 2,3-DPG. A right shift means *lower O_2 affinity* — haemoglobin releases O_2 more readily to metabolically active tissues. Conversely, alkalosis, hypothermia, and low CO_2 shift the curve left (higher affinity, less O_2 delivery).

Solution**Q4. (C) Stimulating autoantibodies (TSI) binding TSH receptors**

Graves' disease is an autoimmune disorder in which thyroid-stimulating immunoglobulins (TSI/TRAb) mimic TSH and *constitutively* activate TSH receptors on thyroid follicular cells. This leads to excessive T3/T4 production (hyperthyroidism), diffuse goitre, exophthalmos (proptosis), and pretibial myxoedema. TSH levels are suppressed by negative feedback. It affects women predominantly (7:1 ratio). Treatment: antithyroid drugs (carbimazole), radioiodine, or thyroidectomy.

Solution**Q5. (B) 28 days**

The normal menstrual cycle averages **28 days** (range 21–35 days). It has two phases relative to ovulation: the *follicular phase* (days 1–14, FSH-driven follicle growth, oestrogen rise) and the *luteal phase* (days 14–28, LH surge triggers ovulation on day 14, corpus luteum secretes progesterone). If fertilisation does not occur, the corpus luteum degenerates, progesterone falls, and menstruation begins.

Solution**Q6. (D) Neutrophil – approximately 5–10 hours in blood**

Neutrophils have the shortest circulating lifespan of the major blood cells (≈ 5 –10 hours in blood, then 1–2 days in tissues). They are the most abundant white blood cells (≈ 60 –70% of WBCs) and the first responders to bacterial infection. Erythrocytes live ≈ 120 days; monocytes ≈ 1 –3 days in blood; lymphocyte memory cells may persist for decades. The high neutrophil turnover ($\approx 10^{11}$ /day from bone marrow) matches their rapid consumption in infection.

Solution**Q7. (A) Spectrin**

Spectrin is the principal cytoskeletal protein of the erythrocyte membrane, forming a flexible meshwork beneath the lipid bilayer. It exists as alpha-spectrin/beta-spectrin heterodimers that link together into tetramers and are anchored to the membrane via ankyrin and band 3 protein (ion exchanger). This spectrin scaffold gives the RBC its deformability (to squeeze through capillaries 3–4 μm wide) and resilience. Hereditary spherocytosis results from spectrin or ankyrin mutations, causing fragile, spherical RBCs.

Solution**Q8. (B) Left arm and jaw**

Referred pain in myocardial infarction is felt in the **left arm** (especially the ulnar surface), **jaw**, left shoulder, and sometimes the epigastrium. This occurs because cardiac afferent pain fibres (sympathetic T1–T5) converge on the same dorsal horn neurons receiving somatic sensation from the left arm and jaw (convergence-projection theory). The left arm referral is most classic; jaw/neck pain is also common. Right-sided MI may occasionally refer to the right arm.

Solution**Q9. (D) Follicle-stimulating hormone (FSH)**

FSH, secreted by gonadotroph cells of the anterior pituitary under GnRH stimulation, acts on: (females) granulosa cells of ovarian follicles → stimulates follicle growth and aromatase activity (oestrogen synthesis); (males) Sertoli cells of the testes → supports spermatogenesis and produces inhibin B (which inhibits FSH by negative feedback). LH (Option A) triggers ovulation and stimulates Leydig cells (testosterone). FSH and LH levels are used to distinguish primary from secondary gonadal failure.

Solution**Q10. (A) Night blindness (nyctalopia)**

Vitamin A (retinol) is converted to 11-*cis*-retinal, which combines with opsin to form **rhodopsin** in rod photoreceptors (used for low-light vision). The earliest symptom of deficiency is **night blindness (nyctalopia)**. Progressive deficiency causes xerophthalmia (dry eye), Bitot's spots, corneal ulceration, and ultimately keratomalacia (corneal melting) and irreversible blindness. Vitamin A is also essential for epithelial integrity and immune function.

Solution**Q11. (C) Gallbladder contraction and pancreatic enzyme secretion**

CCK (cholecystokinin) is released by I-cells of the duodenum and proximal jejunum when fat and protein enter the small intestine. Its two main actions are: (1) contraction of the gallbladder → bile release into duodenum for fat emulsification; (2) stimulation of pancreatic acinar cells → secretion of lipase, protease, and amylase. CCK also slows gastric emptying (satiety) and potentiates secretin's stimulation of pancreatic bicarbonate secretion.

Solution**Q12. (B) Myocardial infarction**

Cardiac troponins (cTnI and cTnT) are regulatory proteins of the cardiac muscle contractile apparatus. They are highly specific for cardiac muscle and are released into the bloodstream when cardiomyocytes are irreversibly injured. Troponin levels rise 3–6 hours post-infarction, peak at 12–24 hours, and remain elevated for 7–14 days (high-sensitivity assays detect even minor injury). They have replaced CK-MB as the gold standard biomarker for diagnosing acute myocardial infarction (AMI).

Solution**Q13. (C) Point mutation in beta-globin gene (glutamate → valine at position 6)**

Sickle cell disease (HbSS) results from a single nucleotide change (GAG → GTG) in codon 6 of the *HBB* gene, substituting **glutamate** (hydrophilic) with **valine** (hydrophobic). This causes HbS to polymerise under deoxygenated conditions, deforming erythrocytes into rigid sickle shapes. Consequences: vaso-occlusive crises, haemolytic anaemia, and organ damage. The sickle trait (HbAS) provides partial protection against *Plasmodium falciparum* malaria.

Solution**Q14. (A) Rapid water reabsorption across tubular cell membranes**

Aquaporins (AQPs) are membrane channel proteins that greatly increase osmotic water permeability. AQP1 is constitutively expressed in the proximal tubule and thin descending limb; **AQP2** in the collecting duct principal cells is regulated by ADH (vasopressin). ADH binds V2 receptors → cAMP → protein kinase A → insertion of AQP2 into the luminal membrane → increased water reabsorption → concentrated urine. Diabetes insipidus results from ADH deficiency (central) or AQP2 dysfunction (nephrogenic).

Solution**Q15. (C) Terminal ileum**

Bile acids (primary: cholic and chenodeoxycholic; secondary: deoxycholic and lithocholic) are actively reabsorbed in the **terminal ileum** via the apical sodium-dependent bile acid transporter (ASBT/SLC10A2). Approximately 95% of secreted bile acids are recirculated via the portal vein to the liver for re-secretion (enterohepatic circulation). The pool circulates 6–10 times per day. Ileal resection (e.g., Crohn's disease) disrupts reabsorption, causing bile acid diarrhoea and reduced fat-soluble vitamin absorption.

Solution**Q16. (C) Freely filtered, not significantly secreted or reabsorbed**

Creatinine is a breakdown product of creatine phosphate in muscle. It has a relatively constant production rate (proportional to muscle mass), is freely filtered at the glomerulus, and is neither significantly reabsorbed nor secreted (there is minor tubular secretion, causing slight overestimation of GFR by $\approx 10\text{--}15\%$). Therefore, urinary creatinine excretion $\approx$ filtered load, and GFR can be estimated from serum creatinine using the CKD-EPI or MDRD formula. A doubling of serum creatinine indicates $\approx 50\%$ reduction in GFR.

Solution**Q17. (D) Vasodilation via soluble guanylyl cyclase and cGMP**

Nitric oxide (NO), synthesised by endothelial NOS (eNOS) from L-arginine + O_2 , diffuses into adjacent vascular smooth muscle cells and activates **soluble guanylyl cyclase** $\rightarrow$ converts GTP to cGMP $\rightarrow$ activates protein kinase G $\rightarrow$ phosphorylates myosin light chain phosphatase and potassium channels $\rightarrow$ **smooth muscle relaxation and vasodilation**. NO also inhibits platelet aggregation. Glyceryl trinitrate (GTN, used for angina) releases NO exogenously. Endothelial dysfunction (reduced NO) contributes to hypertension and atherosclerosis.

Solution**Q18. (A) The liver**

The **liver** is the principal site of synthesis for virtually all coagulation factors: fibrinogen (Factor I), prothrombin (II), and Factors V, VII, VIII (partial), IX, X, XI, XII, and XIII. Factors II, VII, IX, and X require vitamin K for their activation (gamma-carboxylation of glutamate residues). Severe liver disease (cirrhosis) or vitamin K deficiency causes coagulopathy with prolonged prothrombin time (PT/INR). Platelets are produced by megakaryocytes in bone marrow, not the liver.

Solution**Q19. (A) Below $\approx 85\%$ oxygen saturation**

Central cyanosis becomes visible when there is ≥ 5 g/dL of deoxyhaemoglobin in arterial blood, which corresponds to $\text{SpO}_2 \approx 85\%$ in a person with normal haemoglobin (≈ 15 g/dL). It is best detected in highly vascular areas (tongue, lips, conjunctiva). Causes include respiratory failure, cyanotic congenital heart disease, and methaemoglobinaemia. *Peripheral* cyanosis (cold, blue fingers/toes with warm core) suggests vasoconstriction or poor perfusion rather than low arterial O_2 .

Solution**Q20. (B) Beriberi or Wernicke–Korsakoff syndrome**

Thiamine (B₁) is a cofactor for pyruvate dehydrogenase (PDH), alpha-ketoglutarate dehydrogenase, and transketolase. Deficiency impairs aerobic glucose metabolism, especially in high-energy-demand tissues. **Beriberi** presents as: *wet* (high-output cardiac failure, oedema) or *dry* (peripheral neuropathy, wasting). **Wernicke's encephalopathy** (confusion, ophthalmoplegia, ataxia) and Korsakoff's psychosis (anterograde amnesia, confabulation) occur with chronic alcoholism + thiamine deficiency. Treatment: IV thiamine.

Solution**Q21. (D) Enterochromaffin cells of the GI tract (≈95%)**

Despite being known as a brain neurotransmitter, ≈95% of the body's serotonin is stored in **enterochromaffin (EC) cells** of the intestinal mucosa, where it regulates GI motility and secretion. About 5% is in platelets (taken up from portal blood). Only ≈1–2% is in the CNS raphe nuclei, where it modulates mood, appetite, and sleep. This is why SSRIs (which block serotonin reuptake) cause GI side effects such as nausea. Carcinoid tumours of EC cells hypersecrete serotonin, causing carcinoid syndrome (flushing, diarrhoea, bronchoconstriction).

Solution**Q22. (D) Maximum volume forcefully exhaled after a maximum inhalation**

Forced vital capacity (FVC) = the total volume of air expelled as fast and completely as possible starting from maximal inspiration. In healthy adults: FVC ≈ 4.5–5.0 L (male), 3.0–3.5 L (female). The FEV₁/FVC ratio (>0.7 normal) distinguishes obstructive (ratio <0.7: asthma, COPD) from restrictive (ratio normal/raised, both reduced: fibrosis) lung disease. Spirometry is the gold-standard for diagnosing and monitoring chronic lung conditions.

Solution**Q23. (C) Reabsorb filtered bicarbonate and regulate acid-base balance**

In the **proximal tubule**, the apical Na⁺/H⁺ exchanger (NHE3) secretes H⁺ into the lumen in exchange for Na⁺ reabsorption. The secreted H⁺ combines with filtered HCO₃[−] → H₂CO₃ → CO₂ + H₂O (catalysed by luminal carbonic anhydrase IV) → CO₂ diffuses into the cell → regenerated as HCO₃[−] (via intracellular CA II) → exits basolaterally. This reabsorbs ≈85% of filtered bicarbonate and is critical for maintaining arterial pH.

Solution**Q24. (A) Dopamine**

Parkinson's disease results from progressive loss of **dopaminergic neurons** in the *substantia nigra pars compacta* (SNpc), depleting dopamine in the *striatum* (caudate + putamen). This disrupts the basal ganglia circuitry controlling smooth, voluntary movement. Clinical features: resting tremor (4–6 Hz, pill-rolling), bradykinesia, rigidity (cogwheel), and postural instability. Diagnosis: clinical. Treatment: levodopa/carbidopa (dopamine precursor), dopamine agonists (pramipexole, ropinirole), MAO-B inhibitors (selegiline). Lewy bodies (alpha-synuclein aggregates) are the pathological hallmark.

Solution**Q25. (B) Pulmonary fibrosis**

Lung compliance = $\Delta V / \Delta P$ (volume change per unit transpulmonary pressure change). **Pulmonary fibrosis** (idiopathic or secondary) causes excess collagen deposition → stiff, non-compliant lungs → *reduced compliance*. On spirometry: restrictive pattern (reduced FVC and TLC, FEV_1/FVC normal or raised). *Emphysema* (Option A) *increases* compliance (lung over-distensible, loss of elastic recoil). *Surfactant deficiency* also reduces compliance (neonatal respiratory distress syndrome). Clinical measurement: oesophageal balloon manometry.