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CUET · BIOLOGY · CLASS XI · CODE 304

Breathing and Exchange of Gases

CUET unit: Human Physiology → Breathing and Exchange of Gases

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- Establishes that breathing (pulmonary ventilation) is the atmospheric leg of respiration — exchange of O2 in for CO2 out — distinct from cellular respiration.
- Compares respiratory strategies across animal groups (diffusion across body surface, moist cuticle, tracheal tubes, gills, lungs) and details the human pulmonary apparatus.
- Quantifies the breathing cycle through respiratory volumes, capacities and partial-pressure gradients — the source of nearly every numerical MCQ on this chapter.
- Explains gas transport by haemoglobin (O2 dissociation curve, Bohr-style factors) and the three CO2 transport routes, plus neural regulation by medullary rhythm + pontine pneumotaxic centres.
- High-yield for CUET because every sub-section is dense with named structures, fixed values and definitions — easy to convert into single-best-answer MCQs.

📖 Detailed Notes

2.1 Core concepts

- Breathing (commonly called respiration) is the exchange of O2 from the atmosphere with CO2 produced by cells; O2 is needed to break down glucose, amino acids and fatty acids, while CO2 released is harmful and must be expelled (NCERT §14 intro, p. 183).
- Respiratory strategies vary by habitat and organisation: sponges, coelenterates and flatworms exchange gases by simple diffusion over the entire body surface; earthworms use moist cuticle; insects use tracheal tubes; aquatic arthropods and molluscs use gills (branchial respiration); terrestrial forms use lungs (pulmonary respiration). Fishes use gills; amphibians, reptiles, birds and mammals respire through lungs; frogs additionally use cutaneous respiration through moist skin (NCERT §14.1, p. 183).
- Human respiratory passage: external nostrils → nasal chamber → pharynx (common food–air passage) → larynx (sound box; glottis covered by epiglottis during swallowing) → trachea → primary bronchi (trachea divides at the 5th thoracic

vertebra) → secondary and tertiary bronchi → bronchioles → terminal bronchioles → alveoli. Trachea, primary, secondary and tertiary bronchi and initial bronchioles are supported by incomplete cartilaginous rings (NCERT §14.1.1, p. 184).

- Lungs are paired and enclosed in a double-layered pleura with pleural fluid between the layers to reduce friction; the outer pleural membrane contacts the thoracic lining and the inner contacts the lung surface (NCERT §14.1.1, p. 184).
- The conducting part (external nostrils → terminal bronchioles) transports, cleans, humidifies and warms air; the respiratory/exchange part (alveoli + ducts) is the site of actual O2/CO2 diffusion (NCERT §14.1.1, p. 185).
- Thoracic chamber boundaries: dorsally the vertebral column, ventrally the sternum, laterally the ribs, and below the dome-shaped diaphragm; the chamber is air-tight so changes in its volume are mirrored in pulmonary volume (NCERT §14.1.1, p. 185).
- Respiration involves five steps: (i) pulmonary ventilation, (ii) diffusion across alveolar membrane, (iii) transport of gases by blood, (iv) diffusion between blood and tissues, (v) cellular utilisation of O2 (NCERT §14.1.1, p. 185).
- Inspiration: diaphragm contracts → thoracic volume increases on antero-posterior axis; external intercostals contract → ribs and sternum lift up → thoracic volume increases on dorso-ventral axis; pulmonary volume rises, intra-pulmonary pressure falls below atmospheric, air rushes in. Expiration: diaphragm and intercostals relax → thoracic and pulmonary volumes decrease → intra-pulmonary pressure rises slightly above atmospheric → air is expelled. Healthy human breathes 12–16 times/minute; a spirometer measures volumes for clinical assessment (NCERT §14.2, pp. 185–186).
- Respiratory volumes: Tidal Volume (TV) ≈ 500 mL (a healthy man inspires/expires ~6000–8000 mL per minute); Inspiratory Reserve Volume (IRV) 2500–3000 mL; Expiratory Reserve Volume (ERV) 1000–1100 mL; Residual Volume (RV) 1100–1200 mL (NCERT §14.2.1, pp. 186–187).
- Respiratory capacities: Inspiratory Capacity (IC) = TV + IRV; Expiratory Capacity (EC) = TV + ERV; Functional Residual Capacity (FRC) = ERV + RV; Vital Capacity (VC) = ERV + TV + IRV; Total Lung Capacity (TLC) = RV + ERV + TV + IRV = VC + RV (NCERT §14.2.1, p. 187).
- Gas exchange at alveoli (and at tissues) is by simple diffusion driven by pressure/concentration gradients; solubility of gases and thickness of the diffusion membrane also affect the rate. Partial pressures (mm Hg) — O2: atmospheric 159, alveoli 104, deoxygenated blood 40, oxygenated blood 95, tissues 40; CO2: atmospheric 0.3, alveoli 40, deoxygenated blood 45, oxygenated blood 40, tissues 45. CO2 solubility is 20–25 times higher than O2, so CO2 diffuses more per unit pressure difference (NCERT §14.3, Table 14.1, pp. 187–188).
- Diffusion membrane has three layers: thin squamous epithelium of alveoli, endothelium of alveolar capillaries, and the basement substance between them; total thickness less than a millimetre (NCERT §14.3, p. 188).

- Transport of gases: ~97% of O_2 carried by RBCs (as oxyhaemoglobin), ~3% dissolved in plasma; ~20–25% of CO_2 carried by RBCs as carbamino-haemoglobin, ~70% as bicarbonate, ~7% dissolved in plasma (NCERT §14.4, p. 189).
- Each haemoglobin molecule binds a maximum of four O_2 molecules; binding is mainly governed by pO_2 and modulated by pCO_2, H^+ concentration and temperature. The plot of % saturation versus pO_2 is the sigmoid oxygen dissociation curve; alveolar conditions (high pO_2, low pCO_2, low H^+, low temperature) favour oxyhaemoglobin formation, while tissue conditions (low pO_2, high pCO_2, high H^+, high temperature) favour dissociation. Every 100 mL of oxygenated blood delivers ~5 mL O_2 to tissues (NCERT §14.4.1, p. 189; Figure 14.5).
- CO_2 transport by bicarbonate route uses the enzyme carbonic anhydrase (concentrated in RBCs, traces in plasma) catalysing $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$; reaction proceeds forward at tissues (high pCO_2) and reverses at alveoli (low pCO_2). Every 100 mL of deoxygenated blood delivers ~4 mL CO_2 to the alveoli (NCERT §14.4.2, p. 190).
- Regulation: respiratory rhythm centre in the medulla oblongata maintains rhythm; pneumotaxic centre in the pons can reduce the duration of inspiration and thus alter respiratory rate; a chemosensitive area adjacent to the rhythm centre senses CO_2 and H^+ (not O_2 primarily); receptors in the aortic arch and carotid artery also sense CO_2 and H^+ and signal the rhythm centre. Role of O_2 in respiratory regulation is insignificant (NCERT §14.5, p. 190).
- Disorders: Asthma — difficulty in breathing with wheezing due to inflammation of bronchi and bronchioles; Emphysema — chronic damage to alveolar walls reducing respiratory surface, major cause cigarette smoking; Occupational respiratory disorders — long exposure to dust in industries (grinding, stone-breaking) causes inflammation, fibrosis and serious lung damage; protective masks advised (NCERT §14.6, pp. 190–191).

2.2 Definitions to memorise

Term	Definition	Page
Breathing (respiration)	Exchange of O_2 from atmosphere with CO_2 produced by cells	183
Branchial respiration	Gas exchange through vascularised gills (aquatic arthropods, molluscs, fishes)	183
Pulmonary respiration	Gas exchange through vascularised lungs (terrestrial vertebrates)	183
Cutaneous respiration	Gas exchange through moist skin (e.g., frog)	183
Alveoli	Thin, irregular-walled, vascularised bag-like structures arising from terminal bronchioles; primary site of gas exchange	184, 187

Term	Definition	Page
Pleura	Double-layered membrane around lungs with pleural fluid that reduces friction	184
Conducting part	External nostrils to terminal bronchioles — transports, cleans, humidifies and warms air	185
Respiratory/exchange part	Alveoli and their ducts — site of actual O2/CO2 diffusion	185
Tidal Volume (TV)	Volume of air inspired or expired during normal respiration (~500 mL)	186
Inspiratory Reserve Volume (IRV)	Additional air a person can inspire by forcible inspiration (2500–3000 mL)	186
Expiratory Reserve Volume (ERV)	Additional air a person can expire by forcible expiration (1000–1100 mL)	186
Residual Volume (RV)	Volume of air remaining in lungs after a forcible expiration (1100–1200 mL)	187
Vital Capacity (VC)	Maximum air a person can breathe in after a forced expiration = ERV + TV + IRV	187
Total Lung Capacity (TLC)	Total air in lungs at end of forced inspiration = RV + ERV + TV + IRV (= VC + RV)	187
Functional Residual Capacity (FRC)	Air remaining in lungs after a normal expiration = ERV + RV	187
Partial pressure	Pressure contributed by an individual gas in a mixture (pO2, pCO2)	187
Oxygen dissociation curve	Sigmoid curve of % saturation of haemoglobin with O2 versus pO2	189
Carbamino-haemoglobin	Compound formed when CO2 binds reversibly with haemoglobin	189
Carbonic anhydrase	RBC enzyme catalysing $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$ in both directions	190
Respiratory rhythm centre	Specialised centre in medulla regulating respiratory rhythm	190
Pneumotaxic centre	Centre in the pons that can reduce duration of inspiration	190
Asthma	Difficulty in breathing with wheezing due to inflammation of bronchi and bronchioles	190
Emphysema	Chronic disorder where alveolar walls are damaged; major cause cigarette smoking	190

2.3 Diagrams / processes to remember

- Figure 14.1 (p. 184) — Human respiratory system with sectional view of the left lung, showing epiglottis, larynx, trachea, bronchus, bronchiole, alveoli, pleural membranes, pleural fluid and diaphragm.
- Figure 14.2 (p. 186) — (a) Inspiration: diaphragm contracted, ribs and sternum raised, thoracic volume increased; (b) Expiration: diaphragm relaxed and arched upward, ribs and sternum returned to original position, thoracic volume decreased.
- Figure 14.3 (p. 188) — Exchange of gases at alveolus and at body tissues, showing pO2 and pCO2 values in pulmonary artery (deoxygenated, 40/45) and pulmonary vein/systemic arteries (oxygenated, 95/40).
- Figure 14.4 (p. 188) — Section of an alveolus with pulmonary capillary; three-layered diffusion membrane: squamous epithelium of alveolar wall, basement substance, endothelium of blood capillary.
- Figure 14.5 (p. 189) — Sigmoid oxygen dissociation curve (% saturation of Hb with O2 vs pO2 in mm Hg).
- Table 14.1 (p. 187) — Partial pressures (mm Hg) of O2 and CO2 in atmospheric air, alveoli, deoxygenated blood, oxygenated blood and tissues.

2.4 Common confusions / NTA trap points

- Trachea divides at the level of the **5th thoracic vertebra** — students often misremember this as the 4th or 6th.
- Volumes vs capacities: a capacity is always a sum of two or more volumes. VC = IRV + TV + ERV (does NOT include RV); TLC = VC + RV; FRC = ERV + RV (does NOT include TV).
- O2 transport split is **97% bound + 3% dissolved**, whereas CO2 transport split is **70% bicarbonate + 20–25% carbamino-Hb + 7% dissolved** — distractors swap these numbers.
- The chemosensitive area and aortic/carotid receptors respond to **CO2 and H+**, not to O2; the role of O2 in regulation is described as insignificant.
- Inflammation of **bronchi and bronchioles** is asthma; damage to **alveolar walls** is emphysema — examiners often swap the targets.
- pCO2 in atmospheric air is **0.3 mm Hg** (very low), but in alveoli it is 40 — atmospheric pCO2 is not zero.
- Solubility of CO2 is **20–25 times higher** than O2 (not the diffusion coefficient or the partial pressure).
- **Hering-Breuer reflex** is mediated by stretch receptors in alveoli, not by chemoreceptors (NCERT §14.5, p. 271).
- **Hb is a tetramer** of 4 polypeptide chains; each iron-containing haem binds one O2 molecule, so one Hb binds 4 O2 (p. 269).

- **Diffusion membrane thickness** is less than a millimetre — examiners ask for "thin" not exact figure (p. 268).
- **Inspiration vs expiration drivers** — Inspiration is active (diaphragm contracts and flattens, external intercostals lift ribs and sternum, intra-pulmonary pressure falls below atmospheric); normal expiration is passive (elastic recoil), but forced expiration uses internal intercostals and abdominal muscles (NCERT §14.3, p. 267).
- **Smoking and emphysema** — Long-term smoking damages alveolar walls, reducing the gas-exchange surface; pulmonary fibrosis (from silica/asbestos) leads to a stiff, non-compliant lung (p. 271).

2.5 Quick comparison table — respiratory system at a glance

#	Item	Value / Detail	Page
1	Tidal Volume (TV)	500 mL	268
2	Inspiratory Reserve Volume (IRV)	2500–3000 mL	268
3	Expiratory Reserve Volume (ERV)	1000–1100 mL	268
4	Residual Volume (RV)	1100–1200 mL	268
5	Inspiratory Capacity (IC)	TV + IRV	268
6	Expiratory Capacity (EC)	TV + ERV	268
7	Functional Residual Capacity (FRC)	ERV + RV	268
8	Vital Capacity (VC)	ERV + TV + IRV	268
9	Total Lung Capacity (TLC)	RV + ERV + TV + IRV	268
10	pO2 alveoli / blood / tissue	104 / 95 / 40 mm Hg	269
11	pCO2 alveoli / blood / tissue	40 / 40 / 45 mm Hg	269
12	O2 transport — bound : dissolved	97% : 3%	269
13	CO2 transport split	70% HCO3-, 20–25% carbamino-Hb, 7% dissolved	270
14	Carbonic anhydrase site	RBC	270
15	Respiratory rhythm centre	Medulla; pneumotaxic centre in pons	271

🎯 Practice MCQs

Q1. Which type of respiration is shown by aquatic arthropods and molluscs?

A. Cutaneous respiration through moist skin

B. Tracheal respiration through a network of tubes

C. Branchial respiration through vascularised gills

D. Pulmonary respiration through vascularised lungs

Q2. At what level does the trachea divide into the right and left primary bronchi?

A. 3rd thoracic vertebra

B. 4th thoracic vertebra

C. 5th thoracic vertebra

D. 6th thoracic vertebra

Q3. Which of the following statements about pulmonary volumes is correct?

A. Tidal Volume averages 1100–1200 mL

B. Inspiratory Reserve Volume averages 2500–3000 mL

C. Expiratory Reserve Volume averages 2500–3000 mL

D. Residual Volume averages 500 mL

📊 PYQ Alignment

In CUET (UG) past papers (2022–2025) this chapter is a perennial favourite — typically yielding eight to ten MCQs across the 50-question Biology section, with a strong preference for numerical recall (tidal/residual volumes, capacity sums, partial-pressure values from Table 14.1, transport percentages) and direct definitional questions on the

oxygen dissociation curve, carbonic anhydrase reaction, pneumotaxic centre, and the asthma/emphysema distinction.