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CHAPTER NOTES

Breathing and Exchange of Gases

Class 11 Notes | CBSE Biology

Chapter 14

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Breathing and Exchange of Gases Class 11 Notes | CBSE Biology Chapter 14

Breathing and Exchange of Gases is Chapter 14 of CBSE Class 11 Biology — and one of the highest-yielding chapters for NEET, year after year. It explains how air actually moves in and out of your lungs, how oxygen reaches every cell, and how the carbon dioxide your cells make is carried back out. Master this chapter and a whole cluster of NEET questions on respiratory volumes, the oxygen dissociation curve, and gas transport become near-guaranteed marks.

By the end of these notes you will be able to label the human respiratory system, explain inspiration and expiration in terms of pressure, work out any respiratory volume or capacity, describe how O_2 and CO_2 are transported in blood, read the oxygen dissociation curve, and recall the key respiratory disorders. This is a high-weightage chapter carrying roughly 6–7% of NEET Biology and 5–6 marks in boards, and it links directly to Body Fluids and Circulation.

Table of Contents

- Key Concepts — Respiratory organs, human respiratory system, mechanism of breathing, volumes & capacities, exchange and transport of gases, regulation, disorders
 - Weightage in Board & Entrance Exams
 - Important Definitions
 - Solved & NEET-Style Examples
 - Important Questions for Board Exams
 - Quick Revision Points
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Key Concepts

1. Why We Breathe — Respiration vs Breathing

Breathing (or pulmonary ventilation) is the physical exchange of air between the atmosphere and the lungs. **Cellular respiration** is the chemical breakdown of glucose inside cells to release ATP. Breathing simply supplies the O_2 that respiration needs and removes the CO_2 it produces.

Humans take in O_2 from the air and give out CO_2 . The whole pathway — from nostril to alveolus to blood to cell — exists to keep this two-way gas traffic running smoothly.

2. Respiratory Organs in Animals

Different animals breathe differently depending on their habitat and body organisation.

- **Sponges, coelenterates, flatworms:** simple diffusion across the body surface.
 - **Earthworm:** moist cuticle (skin) is used for gas exchange.
 - **Insects (e.g. cockroach):** a network of **tracheal tubes** carries air directly to tissues.
 - **Aquatic animals (fish, prawns):** **gills** (branchial respiration).
 - **Terrestrial vertebrates:** **lungs** (pulmonary respiration).
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3. Human Respiratory System

The human respiratory system is a single passage that warms, filters, and humidifies air on its way to the lungs.

[DIAGRAM: Air path — external nostrils → nasal chamber → pharynx → larynx → trachea → primary bronchi → bronchioles → alveoli; two lungs enclosed in a double-layered pleura.]

The Conducting Part vs the Exchange Part

- **Conducting part:** external nostrils → nasal cavity → pharynx → larynx → trachea → bronchi → bronchioles up to terminal bronchioles. It transports, clears, humidifies, and warms incoming air — *no gas exchange here*.
- **Respiratory (exchange) part:** alveoli and their ducts — the actual site of O_2 - CO_2 exchange.

Key Structural Points

- The **larynx** is the sound box; the **epiglottis** prevents food entering the trachea during swallowing.
 - The trachea, bronchi and initial bronchioles are supported by **incomplete cartilaginous rings** to prevent collapse.
 - Each **alveolus** is thin-walled and richly supplied with capillaries — together the alveoli give a vast surface area (~70 m²) for diffusion.
 - Lungs are covered by a **double-layered pleura** with pleural fluid in between, reducing friction.
 - The **right lung has 3 lobes**; the **left lung has 2 lobes**.
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4. Mechanism of Breathing

Breathing has two phases — **inspiration** (air in) and **expiration** (air out) — and both are driven by **pressure gradients** created by the diaphragm and intercostal muscles. Air always moves from high to low pressure.

Inspiration (active)

- The **diaphragm contracts** and flattens; the **external intercostal muscles contract** and lift the ribs and sternum.
- Thoracic volume increases → **intra-pulmonary pressure falls below atmospheric pressure** → air rushes in.

Expiration (normally passive)

- The diaphragm and external intercostals **relax**; ribs and diaphragm return to their resting position.
- Thoracic volume decreases → **intra-pulmonary pressure rises above atmospheric pressure** → air is pushed out.

Key idea: A healthy person breathes **12–16 times per minute**. Breathing rate can be measured with a **spirometer**, which also gives clinical data on lung volumes.

5. Respiratory Volumes and Capacities

A capacity is simply the sum of two or more volumes. These exact values are extremely high-yield for NEET.

Respiratory Volumes

Volume	Meaning	Value
Tidal Volume (TV)	Air inspired or expired in one normal breath	~500 mL
Inspiratory Reserve Volume (IRV)	Extra air inspired by forcible inspiration	2500–3000 mL
Expiratory Reserve Volume (ERV)	Extra air expired by forcible expiration	1000–1100 mL
Residual Volume (RV)	Air remaining in lungs after forcible expiration	1100–1200 mL

Respiratory Capacities

Capacity	Formula	Value
Inspiratory Capacity (IC)	TV + IRV	~3500 mL
Expiratory Capacity (EC)	TV + ERV	~1500 mL
Functional Residual Capacity (FRC)	ERV + RV	~2300 mL
Vital Capacity (VC)	ERV + TV + IRV	~3500–4500 mL
Total Lung Capacity (TLC)	VC + RV (= RV + ERV + TV + IRV)	~5800–6000 mL

Note: Vital Capacity (VC) is the maximum air a person can breathe out after a maximum inspiration — a key indicator of lung health.

6. Exchange of Gases — at the Alveoli

Gas exchange happens at the **respiratory membrane** (alveolar wall + capillary wall) purely by **diffusion**, driven by partial pressure differences. No energy is spent here.

Partial pressure (p) is the pressure exerted by an individual gas in a mixture. Each gas diffuses from where its partial pressure is high to where it is low.

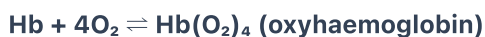
Site	pO ₂ (mm Hg)	pCO ₂ (mm Hg)
Atmospheric air	159	0.3
Alveoli	104	40
Deoxygenated blood (entering alveoli)	40	45
Oxygenated blood (leaving alveoli)	95	40
Tissues	40	45

Direction of diffusion: At the alveoli, O₂ moves from alveolar air (104) into blood (40), and CO₂ moves from blood (45) into alveolar air (40). At the tissues, the gradients reverse.

Why CO₂ keeps up despite a small gradient: CO₂ is about **20–25 times more soluble** than O₂, so even a small pressure difference moves large amounts of it.

7. Transport of Oxygen

About **97% of O₂** is carried bound to **haemoglobin** as **oxyhaemoglobin**; only about **3%** is dissolved in plasma.



Each haemoglobin molecule can bind a maximum of **four O₂ molecules**. Binding is reversible and depends mainly on the partial pressure of O₂.

Oxygen Dissociation Curve

A graph of percentage saturation of haemoglobin against pO₂ is **sigmoid (S-shaped)**.

[DIAGRAM: Sigmoid oxygen dissociation curve — % saturation of Hb on the y-axis vs pO₂ on the x-axis; a right shift marked at high CO₂, high H⁺, high temperature.]

- **In the alveoli** (high pO₂, low pCO₂, lower temperature): conditions favour the **formation** of oxyhaemoglobin.
- **In the tissues** (low pO₂, high pCO₂, high H⁺, higher temperature): conditions favour the **dissociation** of O₂ from haemoglobin.

Bohr effect: a rise in CO₂, H⁺, or temperature shifts the curve to the **right**, so haemoglobin releases more O₂ exactly where active tissues need it.

8. Transport of Carbon Dioxide

CO₂ is carried in blood in **three forms**.

Form	Approx. %
As bicarbonate (HCO_3^-) in plasma	~70%
Bound to haemoglobin as carbamino-haemoglobin	~20–23%
Dissolved in plasma	~7%

The enzyme **carbonic anhydrase**, present in high concentration in RBCs, speeds up the reaction:



- **At the tissues** (high pCO_2): CO_2 diffuses into blood and is converted to bicarbonate.
- **At the alveoli** (low pCO_2): the reaction reverses, releasing CO_2 to be breathed out.

Every 100 mL of deoxygenated blood delivers about **4 mL of CO_2** to the alveoli for removal.

9. Regulation of Respiration

The body finely adjusts breathing to match its needs, mostly involuntarily.

- **Respiratory rhythm centre** in the **medulla oblongata** controls the basic rhythm of breathing.
- **Pneumotaxic centre** in the **pons** can moderate the rhythm centre and reduce the duration of inspiration.
- **Chemosensitive area** near the rhythm centre is sensitive to **CO_2 and H^+** ; a rise in these signals the centre to increase the rate and depth of breathing.
- Receptors in the **aortic arch and carotid artery** also detect changes in CO_2 and H^+ and send signals to the rhythm centre.

Key idea: Oxygen plays only a minor role in the moment-to-moment regulation of breathing — **CO_2 is the main stimulus.**

10. Disorders of the Respiratory System

Disorder	Cause / Description
Asthma	Difficulty in breathing due to inflammation of bronchi and bronchioles, causing wheezing.
Emphysema	Alveolar walls are damaged and lose elasticity, reducing the surface area for gas exchange; major cause is cigarette smoking.
Occupational respiratory disorders	Long-term exposure to dust in industries (e.g. grinding, stone-breaking) causes inflammation and fibrosis; silicosis and asbestosis are examples.

Note: In occupational settings, protective masks and proper ventilation are the front-line defence against these disorders.

Weightage in Board & Entrance Exams

Exam	Typical Weightage	Most-Tested Areas
CBSE Board (Class 11)	5–6 marks	Mechanism of breathing, volumes & capacities, gas exchange
NEET	1–2 questions (high-yield)	Respiratory volumes/capacities, O ₂ dissociation curve, CO ₂ transport, partial pressures
AIIMS-pattern / Olympiads	1–2 questions	Bohr effect, regulation of respiration, disorders

[TABLE: Question-type split — VSA (1 mark): definitions & values; SA (2–3 marks): mechanism of breathing, gas transport; LA (5 marks): respiratory volumes/capacities with calculations, oxygen dissociation curve.]

Important Definitions

Term	Definition
Breathing	Physical exchange of air between the atmosphere and the lungs (pulmonary ventilation)
Tidal Volume (TV)	Volume of air inspired or expired in one normal breath (~500 mL)
Vital Capacity (VC)	Maximum air a person can expire after a maximum inspiration = ERV + TV + IRV
Residual Volume (RV)	Air remaining in the lungs after the most forcible expiration (~1100–1200 mL)
Partial pressure	Pressure contributed by an individual gas in a mixture of gases
Oxyhaemoglobin	Reversible compound formed when O ₂ binds to haemoglobin: $\text{Hb} + 4\text{O}_2 \rightleftharpoons \text{Hb}(\text{O}_2)_4$
Bohr effect	Rightward shift of the O ₂ dissociation curve due to high CO ₂ , H ⁺ or temperature, promoting O ₂ release
Carbonic anhydrase	Enzyme in RBCs that catalyses $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$
Emphysema	Disorder where alveolar walls are damaged, reducing gas-exchange surface; chiefly caused by smoking

Solved & NEET-Style Examples

Example 1

Calculate the Vital Capacity of a person with TV = 500 mL, IRV = 3000 mL, ERV = 1100 mL, RV = 1200 mL.

Answer: $VC = ERV + TV + IRV = 1100 + 500 + 3000 = \mathbf{4600\text{ mL}}$.

Example 2

For the same person, find the Total Lung Capacity (TLC).

Answer: $TLC = VC + RV = 4600 + 1200 = \mathbf{5800\text{ mL}}$.

Example 3

At the alveoli, in which direction do O_2 and CO_2 diffuse, and why?

Answer: O_2 diffuses from alveolar air (pO_2 104) into deoxygenated blood (pO_2 40); CO_2 diffuses from blood (pCO_2 45) into alveolar air (pCO_2 40). Diffusion always follows the partial-pressure gradient (high $\rightarrow$ low).

Example 4

Why is the O_2 dissociation curve sigmoid, and what happens when it shifts right?

Answer: Binding of one O_2 increases haemoglobin's affinity for the next (cooperative binding), giving the S-shape. A right shift (high CO_2 , H^+ , temperature — the Bohr effect) lowers Hb's O_2 affinity, so more O_2 is unloaded to active tissues.

Example 5

In what form is most CO_2 transported in blood, and which enzyme is responsible?

Answer: About 70% of CO_2 is transported as **bicarbonate (HCO_3^-)**; the enzyme **carbonic anhydrase** in RBCs catalyses its formation.

Example 6

A patient's alveolar walls are damaged and have lost elasticity after years of smoking. Name the disorder and its main effect.

Answer: Emphysema. The reduced alveolar surface area impairs gas exchange, causing breathlessness.

Important Questions for Board Exams

1-Mark Questions (VSA)

1. Define tidal volume and give its approximate value.
2. Name the enzyme that catalyses the conversion of CO_2 into bicarbonate in RBCs.
3. What is the main stimulus that regulates the rate of breathing?
4. Name the structure that prevents food from entering the trachea while swallowing.
5. In which form is the maximum amount of oxygen transported in blood?

2–3-Mark Questions (SA)

1. Explain the mechanism of inspiration in terms of pressure changes in the thoracic cavity.
2. Distinguish between Vital Capacity and Total Lung Capacity, giving the formula for each.
3. Describe how carbon dioxide is transported from the tissues to the lungs.
4. What is the Bohr effect? State the factors that shift the oxygen dissociation curve to the right.

5-Mark Questions (LA)

1. With the help of a labelled diagram, describe the human respiratory system and distinguish the conducting part from the exchange part.
 2. Explain the exchange of gases at the alveoli and the tissues using partial pressure values, and state why CO_2 diffusion is efficient despite a small gradient.
 3. Describe the role of the medulla, pons, and chemosensitive area in the regulation of respiration.
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Quick Revision Points

- Breathing = ventilation; respiration = ATP release in cells
- Air path: nostrils → nasal cavity → pharynx → larynx → trachea → bronchi → bronchioles → alveoli
- Right lung = 3 lobes, left lung = 2 lobes; lungs covered by double-layered pleura
- Inspiration: diaphragm + external intercostals contract → thoracic volume up → pressure down → air in
- Normal breathing rate = 12–16/min; measured by a spirometer
- TV ~500 mL; VC = ERV + TV + IRV; TLC = VC + RV (~5800–6000 mL)
- Gas exchange = diffusion along partial-pressure gradients; CO_2 is ~20–25× more soluble than O_2
- O_2 transport: 97% as oxyhaemoglobin (Hb binds 4 O_2), 3% dissolved; curve is sigmoid
- Bohr effect: high CO_2 /H⁺/temperature → right shift → more O_2 released to tissues
- CO_2 transport: ~70% bicarbonate, ~20–23% carbamino-Hb, ~7% dissolved; enzyme = carbonic anhydrase

- Regulation: rhythm centre (medulla), pneumotaxic centre (pons); CO_2/H^+ are main stimuli
 - Disorders: asthma (bronchial inflammation), emphysema (smoking, alveolar damage), occupational (silicosis, asbestosis)
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Next Chapter: Chapter 15 — Body Fluids and Circulation



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