Chapter 14: Breathing and Exchange of Gases

Comprehensive Study Notes

Class 11 Biology - NCERT Based

EXAM SPRINT - Complete Coverage for NEET and Board Examinations

Introduction

Respiration is a vital life process where organisms exchange oxygen (O_2) from the atmosphere with carbon dioxide (CO_2) produced by cells. This process is essential for cellular metabolism and energy production.

Why is Breathing Essential?

- **Energy Production**: O_2 helps break down glucose, amino acids, and fatty acids
- **Waste Removal**: CO_2 (harmful byproduct) must be eliminated
- **Continuous Process**: Cells need constant O_2 supply and CO_2 removal

Definition:

Breathing/Respiration: Process of exchange of O_2 from atmosphere with CO_2 produced by cells.

14.1 RESPIRATORY ORGANS

Respiratory Mechanisms in Different Animals:

Simple Organisms:

- **Lower Invertebrates** (sponges, coelenterates, flatworms): Simple diffusion over entire body surface

- **Earthworms**: Moist cuticle for gas exchange
- **Insects**: Tracheal tubes network for air transport

Complex Organisms:

- **Aquatic Forms**: Gills (branchial respiration) - arthropods, molluscs, fishes
- **Terrestrial Forms**: Lungs (pulmonary respiration) - amphibians, reptiles, birds, mammals
- **Amphibians**: Additional cutaneous respiration through moist skin

14.1.1 Human Respiratory System

Structure and Components:

Conducting Part (Air Transport):

1. **External Nostrils**: Opening above upper lips
2. **Nasal Chamber**: Through nasal passage
3. **Pharynx**: Common passage for food and air
4. **Larynx**: Cartilaginous voice box (sound production)
5. **Epiglottis**: Elastic flap preventing food entry into larynx
6. **Trachea**: Straight tube to mid-thoracic cavity
7. **Bronchi**: Primary → Secondary → Tertiary divisions
8. **Bronchioles**: Terminal bronchioles (very thin)

Respiratory/Exchange Part:

- **Alveoli**: Thin-walled, vascularized sac-like structures
- **Function**: Actual gas diffusion between blood and air

Support Structures:

- **Cartilaginous Rings**: Support trachea, bronchi, and initial bronchioles (incomplete rings)
- **Pleura**: Double-layered membrane covering lungs
- **Pleural Fluid**: Reduces friction between lung surfaces

Thoracic Chamber:

Boundaries:

- **Dorsal**: Vertebral column
- **Ventral**: Sternum
- **Lateral**: Ribs
- **Lower**: Dome-shaped diaphragm

Important Feature: Air-tight chamber where thoracic volume changes reflect in lung volume.

Functions:

Conducting Part:

- Transports atmospheric air to alveoli
- Clears foreign particles
- Humidifies air
- Brings air to body temperature

Exchange Part:

- Site of O_2 and CO_2 diffusion between blood and air

Steps in Respiration Process:

1. **Pulmonary Ventilation**: Breathing (air in/out)
2. **Gas Diffusion**: Across alveolar membrane

3. **Gas Transport**: By blood circulation
4. **Tissue Gas Exchange**: Between blood and tissues
5. **Cellular Respiration**: O_2 utilization and CO_2 production

14.2 MECHANISM OF BREATHING

Two Stages of Breathing:

Inspiration (Inhalation):

Mechanism: Atmospheric air drawn into lungs **Pressure Requirement**: Intra-pulmonary pressure < Atmospheric pressure

Process:

1. **Diaphragm Contraction**: Increases thoracic volume (antero-posterior axis)
2. **External Intercostal Muscle Contraction**: Lifts ribs and sternum (dorso-ventral axis)
3. **Increased Thoracic Volume**: Causes increased pulmonary volume
4. **Decreased Intra-pulmonary Pressure**: Forces air into lungs

Expiration (Exhalation):

Mechanism: Alveolar air released out **Pressure Requirement**: Intra-pulmonary pressure > Atmospheric pressure

Process:

1. **Muscle Relaxation**: Diaphragm and intercostals return to normal
2. **Decreased Thoracic Volume**: Reduces pulmonary volume
3. **Increased Intra-pulmonary Pressure**: Forces air out of lungs

Additional Features:

- **Additional Muscles**: Abdominal muscles can increase breathing strength
- **Normal Rate**: 12-16 breaths per minute (healthy human)
- **Assessment Tool**: Spirometer for measuring air volumes

14.2.1 Respiratory Volumes and Capacities

Primary Volumes:

1. Tidal Volume (TV):

- **Definition**: Air inspired/expired during normal respiration
- **Value**: ~500 mL
- **Per Minute**: 6000-8000 mL

2. Inspiratory Reserve Volume (IRV):

- **Definition**: Maximum air inspired after normal inspiration
- **Value**: 2500-3000 mL

3. Expiratory Reserve Volume (ERV):

- **Definition**: Maximum air expired after normal expiration
- **Value**: 1000-1100 mL

4. Residual Volume (RV):

- **Definition**: Air remaining after forcible expiration
- **Value**: 1100-1200 mL

Pulmonary Capacities:

1. Inspiratory Capacity (IC):

- **Formula**: TV + IRV
- **Definition**: Total air inspired after normal expiration

2. Expiratory Capacity (EC):

- **Formula**: TV + ERV
- **Definition**: Total air expired after normal inspiration

3. Functional Residual Capacity (FRC):

- **Formula**: ERV + RV
- **Definition**: Air remaining after normal expiration

4. Vital Capacity (VC):

- **Formula**: TV + IRV + ERV
- **Definition**: Maximum air breathed in after forced expiration

5. Total Lung Capacity (TLC):

- **Formula**: VC + RV = TV + IRV + ERV + RV
- **Definition**: Total air accommodated after forced inspiration

14.3 EXCHANGE OF GASES

Sites of Gas Exchange:

1. **Primary Site**: Alveoli (blood ↔ atmospheric air)
2. **Secondary Site**: Tissues (blood ↔ tissue cells)

Mechanism: Simple Diffusion

Driving Force: Pressure/concentration gradients

Factors Affecting Diffusion Rate:

1. **Pressure Gradients**: Difference in partial pressures
2. **Gas Solubility**: CO_2 is 20-25 times more soluble than O_2
3. **Membrane Thickness**: Thinner membranes favor diffusion

Partial Pressures:

Definition: Pressure contributed by individual gas in mixture

- **Oxygen**: pO_2
- **Carbon Dioxide**: pCO_2

Partial Pressure Values (mm Hg):

Location	pO_2	pCO_2
Atmospheric Air	159	0.3
Alveoli	104	40
Deoxygenated Blood	40	45
Oxygenated Blood	95	40
Tissues	40	45

Gradients for Diffusion:

- **Oxygen**: Alveoli → Blood → Tissues (159 → 104 → 40)
- **Carbon Dioxide**: Tissues → Blood → Alveoli (45 → 40 → 0.3)

Diffusion Membrane Structure:

Three Layers:

1. **Thin Squamous Epithelium**: Alveolar lining
2. **Endothelium**: Alveolar capillaries
3. **Basement Substance**: Between epithelium and endothelium

Total Thickness: Less than 1 millimeter (optimal for diffusion)

14.4 TRANSPORT OF GASES

14.4.1 Transport of Oxygen

Transport Methods:

- **97%**: By RBCs (as oxyhaemoglobin)
- **3%**: Dissolved in plasma

Haemoglobin Characteristics:

- **Color**: Red
- **Component**: Iron-containing pigment
- **Location**: RBCs
- **Binding Capacity**: 4 oxygen molecules per haemoglobin

Oxygen-Haemoglobin Binding:

Reversible Reaction: $Hb + 4O_2 \rightleftharpoons HbO_8$ (Oxyhaemoglobin)

Factors Affecting Binding:

Primary Factor: Partial pressure of O_2 (pO_2) **Secondary Factors**:

- Partial pressure of CO_2 (pCO_2)
- Hydrogen ion concentration (pH)

- Temperature

Oxygen Dissociation Curve:

Shape: Sigmoid (S-shaped) **Plot**: % Hb saturation vs pO_2 **Significance**: Shows binding/release patterns

Binding Conditions:

Favorable for Binding (Alveoli):

- High pO_2
- Low pCO_2
- Low H^+ concentration
- Lower temperature

Favorable for Release (Tissues):

- Low pO_2
- High pCO_2
- High H^+ concentration
- Higher temperature

Oxygen Delivery:

Normal Conditions: 100 mL oxygenated blood delivers ~5 mL O_2 to tissues

14.4.2 Transport of Carbon Dioxide

Transport Methods:

- **70%**: As bicarbonate (HCO_3^-)

- **20-25%**: By haemoglobin (carbamino-haemoglobin)
- **7%**: Dissolved in plasma

Carbamino-Haemoglobin Formation:

Binding: CO_2 + Hb ⇌ $HbCO_2$ (Carbamino-haemoglobin) **Factors**:

- **High pCO_2, Low pO_2**: Promotes binding (tissues)
- **Low pCO_2, High pO_2**: Promotes release (alveoli)

Bicarbonate Transport:

Key Enzyme: Carbonic Anhydrase (high concentration in RBCs)

Chemical Reactions:

$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$
(Carbonic Anhydrase catalyzed)

At Tissues (High pCO_2):

- $CO_2 \rightarrow HCO_3^- + H^+$ (forward reaction)
- CO_2 trapped as bicarbonate

At Alveoli (Low pCO_2):

- $HCO_3^- + H^+ \rightarrow CO_2 + H_2O$ (reverse reaction)
- CO_2 released for exhalation

CO_2 Delivery:

Normal Conditions: 100 mL deoxygenated blood delivers ~4 mL CO_2 to alveoli

14.5 REGULATION OF RESPIRATION

Neural Control System:

Primary Center:

Respiratory Rhythm Centre:

- **Location**: Medulla region of brain
- **Function**: Primary regulation of breathing rhythm
- **Control**: Maintains basic respiratory pattern

Modulating Center:

Pneumotaxic Centre:

- **Location**: Pons region of brain
- **Function**: Modulates respiratory rhythm centre
- **Effect**: Reduces inspiration duration, alters respiratory rate

Chemosensitive Control:

Chemosensitive Area:

- **Location**: Adjacent to rhythm centre
- **Sensitivity**: Highly sensitive to CO_2 and H^+ ions
- **Response**: Activates rhythm centre when CO_2/H^+ increases
- **Result**: Adjustments in respiration to eliminate excess substances

Peripheral Receptors:

Location: Aortic arch and carotid artery **Function**: Detect CO_2 and H^+ changes **Action**: Send signals to rhythm centre for corrections

Role of Oxygen:

Significance: Quite insignificant in respiratory rhythm regulation **Note**: CO_2 and H^+ are primary regulatory factors

14.6 DISORDERS OF RESPIRATORY SYSTEM

Common Respiratory Disorders:

1. Asthma:

Symptoms: Difficulty breathing, wheezing **Cause**: Inflammation of bronchi and bronchioles **Effect**: Narrowed airways, breathing difficulty

2. Emphysema:

Type: Chronic disorder **Pathology**: Alveolar wall damage **Consequence**: Decreased respiratory surface area **Major Cause**: Cigarette smoking

3. Occupational Respiratory Disorders:

Industries Affected: Grinding, stone-breaking **Problem**: Excessive dust exposure **Consequence**: Inflammation → Fibrosis → Lung damage **Prevention**: Protective masks for workers

Health Impacts:

- **Reduced Gas Exchange**: Damaged alveolar surfaces
- **Breathing Difficulties**: Narrowed or blocked airways
- **Long-term Damage**: Progressive tissue damage

NEET-Specific Important Points

High-Yield Topics for NEET:

1. **Respiratory System Anatomy**:
   - Conducting vs respiratory parts
   - Pleural membranes and function
   - Thoracic chamber boundaries
2. **Breathing Mechanism**:
   - Inspiration/expiration process
   - Role of diaphragm and intercostal muscles
   - Pressure gradients
3. **Respiratory Volumes**:
   - Definitions and values
   - Pulmonary capacity calculations
   - Clinical significance
4. **Gas Exchange**:
   - Partial pressure gradients
   - Diffusion factors
   - Membrane structure
5. **Gas Transport**:
   - Oxygen transport mechanisms
   - CO_2 transport pathways
   - Haemoglobin binding factors
6. **Regulation**:
   - Neural control centers

- Chemical regulation
- Feedback mechanisms

Common NEET Question Patterns:

1. **Numerical Problems**:
   - Respiratory volume calculations
   - Partial pressure comparisons
   - Gas transport percentages
2. **Mechanism Questions**:
   - Breathing process steps
   - Gas exchange mechanisms
   - Transport pathways
3. **Comparison Questions**:
   - Different respiratory volumes
   - Gas transport methods
   - Control mechanisms
4. **Disorder-Related Questions**:
   - Symptoms and causes
   - Effects on gas exchange
   - Preventive measures

Memory Aids and Mnemonics

Respiratory Volumes:

"Tigers In Every Room"

- **T**idal Volume
- **I**nspiratory Reserve Volume
- **E**xpiratory Reserve Volume
- **R**esidual Volume

Pulmonary Capacities:

"I Eat Five Vegetables To Live"

- **I**nspiratory Capacity
- **E**xpiratory Capacity
- **F**unctional Residual Capacity
- **V**ital Capacity
- **T**otal Lung Capacity

Gas Transport:

"Please Deliver Bicarbonate"

- **P**lasma (dissolved)
- **D**irect binding (carbamino-Hb)
- **B**icarbonate (major CO_2 transport)

Breathing Control Centers:

"Respiratory Pneumonia Chemo"

- **R**espiratory rhythm centre (medulla)
- **P**neumotaxic centre (pons)
- **C**hemosensitive area (medulla)

Practice Questions for NEET

Multiple Choice Questions:

1. What percentage of CO_2 is transported as bicarbonate? a) 20-25% b) 70% c) 7% d) 97%
2. The respiratory rhythm centre is located in: a) Pons b) Cerebrum c) Medulla d) Cerebellum
3. Vital capacity includes: a) TV + IRV + ERV b) TV + IRV c) ERV + RV d) All lung volumes

Numerical Problems:

1. If tidal volume is 500 mL and breathing rate is 15/min, calculate air moved per minute.
2. Calculate vital capacity if TV = 500 mL, IRV = 3000 mL, ERV = 1100 mL.

Short Answer Questions:

1. Explain the mechanism of inspiration.
2. Why is CO_2 more efficiently transported than O_2?
3. What is the significance of the oxygen dissociation curve?

Long Answer Questions:

1. Describe the complete pathway of oxygen from atmosphere to tissues.
2. Explain the neural regulation of respiration.
3. Compare the transport mechanisms of oxygen and carbon dioxide.

Application-Based Questions:

Scenario-Based Problems:

Q1: A person climbs to high altitude. What changes occur in:

- Partial pressure of gases

- Breathing rate
- Oxygen transport

Q2: During exercise, how does the body adjust:

- Breathing pattern
- Gas exchange
- Transport mechanisms

Q3: In emphysema patients:

- What structural changes occur
- How is gas exchange affected
- What compensatory mechanisms operate

Summary Table: Gas Transport Overview

Gas	Transport Method	Percentage	Location	Mechanism
O_2	Oxyhaemoglobin	97%	RBCs	Hb-O_2 binding
O_2	Dissolved	3%	Plasma	Simple solution
CO_2	Bicarbonate	70%	Plasma/RBCs	Carbonic anhydrase
CO_2	Carbamino-Hb	20-25%	RBCs	Hb-CO_2 binding
CO_2	Dissolved	7%	Plasma	Simple solution

Key Values to Remember:

Respiratory Volumes (mL):

- **TV**: 500
- **IRV**: 2500-3000

- **ERV**: 1000-1100
- **RV**: 1100-1200

Partial Pressures (mm Hg):

- **Atmospheric pO_2**: 159
- **Alveolar pO_2**: 104
- **Tissue pO_2**: 40

Gas Delivery (per 100 mL blood):

- **O_2 delivery**: ~5 mL
- **CO_2 pickup**: ~4 mL

EXAM SPRINT - Master Breathing and Gas Exchange with focused study on mechanisms, transport pathways, and regulatory systems. Understanding numerical values and their significance is crucial for NEET success.

Source: NCERT Biology Class 11, Chapter 14 - Comprehensive coverage for NEET preparation