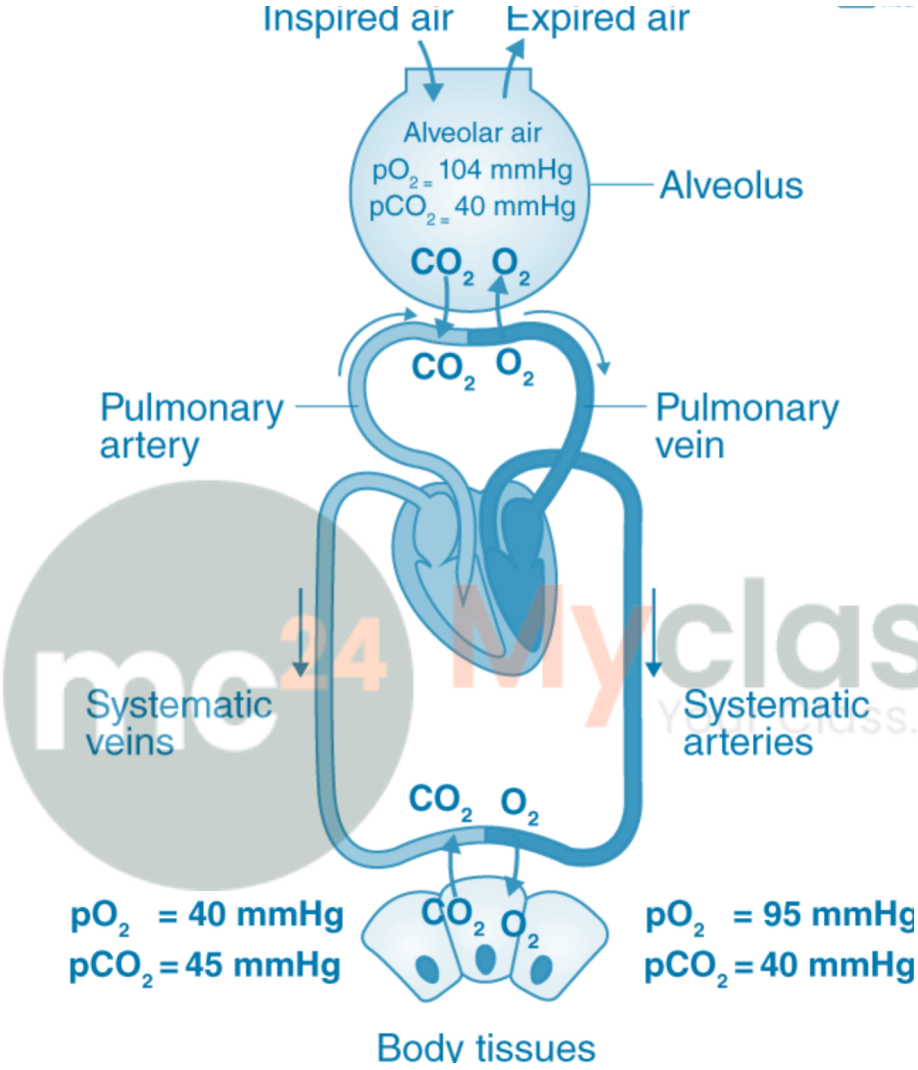
NCERT Exemplar Solutions of Class 11 Biology – Chapter 17: Breathing and Exchange of Gases

LONG ANSWER TYPE QUESTIONS

1. Explain the transport of O_2 and CO_2 between alveoli and tissue with a diagram.

Solution:

OXYGEN TRANSPORT MECHANISM:



1. Alveolar Oxygen Uptake:

- Inhaled oxygen reaches alveoli (pO_2 = 104 mmHg)
- Higher partial pressure gradient drives diffusion from alveoli to pulmonary capillaries
- O_2 crosses respiratory membrane (0.5 µm thick)

2. Oxygen-Hemoglobin Binding:

- O_2 binds to hemoglobin in RBCs forming oxyhemoglobin (HbO_2)
- Cooperative binding: 1 Hb molecule binds 4 O_2 molecules
- 97% transported as HbO_2, 3% dissolved in plasma

3. Systemic Oxygen Delivery:

- Oxygenated blood reaches tissue capillaries (pO_2 = 40 mmHg)
- Lower pO_2 in tissues causes O_2 dissociation from Hb
- O_2 diffuses from capillaries into tissue cells
- Facilitated by Bohr effect (high CO_2, low pH, high temperature)

CARBON DIOXIDE TRANSPORT MECHANISM:

1. Cellular CO_2 Production:

- Metabolic processes produce CO_2 in tissue cells
- CO_2 diffuses from cells into tissue capillaries (pCO_2 = 45 mmHg in tissues)

2. CO_2 Transport Forms:

- **70% as HCO_3^-**: $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ (carbonic anhydrase catalyzed)
- **23% as carbaminohaemoglobin**: CO_2 binds to amino groups of Hb
- **7% dissolved in plasma**: Physical dissolution

3. Pulmonary CO_2 Elimination:

- Venous blood reaches lung capillaries (pCO_2 = 45 mmHg)
- CO_2 dissociates from transport forms due to lower alveolar pCO_2 (40 mmHg)
- CO_2 diffuses across respiratory membrane into alveoli
- Eliminated during expiration

KEY PHYSIOLOGICAL FEATURES:

- **Bohr Effect**: O_2 and CO_2 binding inversely related
- **Chloride Shift**: HCO_3^-/Cl^- exchange maintains ionic balance
- **Carbonic Anhydrase**: Essential enzyme in RBCs for CO_2 transport
- **Pressure Gradients**: Drive diffusion at both alveolar and tissue levels

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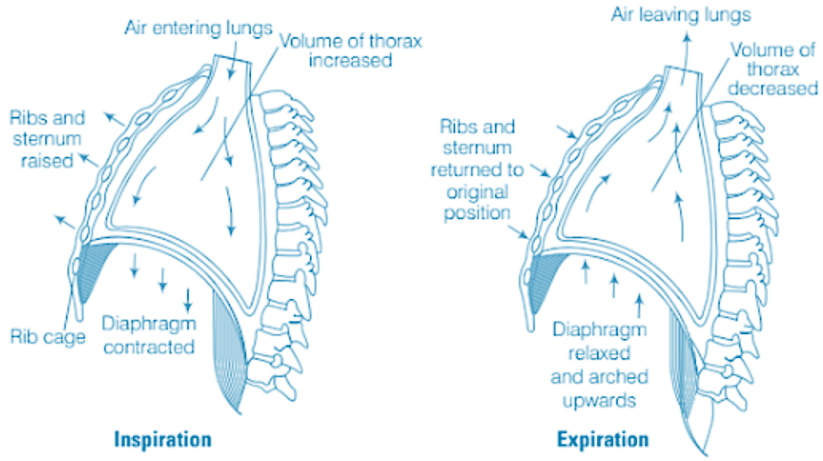
2. Explain the mechanism of breathing with neat labelled sketches.

Solution:

BREATHING MECHANISM involves two main processes:



A. INSPIRATION (INHALATION)

Process:

1. **Diaphragm Contraction**
    - Diaphragm contracts and moves downward (~1-3 cm)
    - Increases vertical dimension of thoracic cavity
2. **Intercostal Muscle Contraction**
    - External intercostal muscles contract
    - Ribs move upward and outward
    - Sternum moves forward
    - Increases anteroposterior and lateral dimensions
3. **Thoracic Cavity Expansion**
    - Combined muscle actions increase thoracic volume
    - Lungs expand passively due to pleural linkage
    - Intrapulmonary pressure decreases below atmospheric pressure (-1 to -3 mmHg)
4. **Air Inflow**
    - Pressure gradient drives atmospheric air into lungs
    - Air flows from high pressure (atmosphere) to low pressure (lungs)
    - Continues until pressure equilibrium is reached

B. EXPIRATION (EXHALATION)

Process:

1. **Muscle Relaxation**
    - Diaphragm relaxes and moves upward
    - External intercostal muscles relax
    - Ribs move downward and inward
2. **Thoracic Cavity Reduction**
    - Thoracic volume decreases
    - Lungs recoil due to elastic properties
    - Intrapulmonary pressure increases above atmospheric pressure (+1 to +3 mmHg)
3. **Air Outflow**
    - Pressure gradient drives air out of lungs
    - Air flows from high pressure (lungs) to low pressure (atmosphere)
    - Continues until pressure equilibrium is reached

PRESSURE RELATIONSHIPS:

- **Atmospheric Pressure**: 760 mmHg (reference)
- **Intrapulmonary Pressure**: Varies with breathing cycle
- **Intrapleural Pressure**: Always negative (-4 to -8 mmHg)
- **Transpulmonary Pressure**: Difference between intrapulmonary and intrapleural pressure

FORCED BREATHING:

- **Forced Inspiration**: Accessory muscles (sternocleidomastoid, scalenes) assist

- **Forced Expiration**: Internal intercostals and abdominal muscles contract actively

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3. Explain the role of neural system in regulation of respiration.

Solution:

NEURAL CONTROL OF RESPIRATION involves multiple brain centers working in coordination:

RESPIRATORY CONTROL CENTERS:

1. PNEUMOTAXIC CENTRE

- **Location**: Dorsal part of pons varolii
- **Function**:
  - **Inhibits inspiration**, reducing its duration
  - Regulates breathing rate and pattern
  - Prevents overinflation of lungs
  - Controls transition from inspiration to expiration
- **Effect**: Increases respiratory frequency by shortening inspiratory phase

2. RESPIRATORY RHYTHM CENTRE (MEDULLARY INSPIRATORY CENTRE)

- **Location**: Medulla oblongata
- **Function**:
  - **Primary pacemaker** for respiratory rhythm
  - Generates basic respiratory pattern
  - Controls automatic breathing during rest
  - Integrates inputs from other centers
- **Components**:
  - Inspiratory neurons (I-neurons)
  - Expiratory neurons (E-neurons)

3. APNEUSTIC CENTRE

- **Location**: Lower part of pons varolii
- **Function**:
  - **Prolongs inspiration** by stimulating inspiratory center
  - Increases duration and depth of inspiration
  - Normally inhibited by pneumotaxic center
- **Effect**: Results in deeper, slower breathing pattern

4. CHEMOSENSITIVE CENTRE

- **Location**: Medulla oblongata and pons region
- **Function**:
  - **Detects changes** in CO_2, H^+, and O_2 levels
  - **Primary stimulus**: CO_2 levels (via H^+ concentration)
  - **Secondary stimulus**: O_2 levels (when severely low)
- **Mechanism**:

- ↑CO_2 → ↑H_2CO_3 → ↑H^+ → stimulates center → ↑ventilation
- ↓O_2 (< 60 mmHg) → stimulates peripheral chemoreceptors → ↑ventilation

PERIPHERAL CHEMORECEPTORS:

- **Location**: Carotid and aortic bodies
- **Function**:
  - Monitor arterial pO_2, pCO_2, and pH
  - Become active when pO_2 < 60 mmHg
  - Send signals via glossopharyngeal and vagus nerves

INTEGRATION AND CONTROL:

1. **Normal Breathing**: Medullary center generates basic rhythm
2. **Modified Breathing**: Pneumotaxic and apneustic centers fine-tune pattern
3. **Chemical Control**: Chemosensitive centers adjust rate based on blood chemistry
4. **Emergency Response**: Rapid adjustments during exercise, stress, or pathological conditions

FEEDBACK MECHANISMS:

- **Negative feedback** maintains homeostasis
- **CO_2 increase** → **ventilation increase** → **CO_2 decrease**
- **O_2 decrease** → **ventilation increase** → **O_2 increase**

CLINICAL SIGNIFICANCE:

- **Respiratory failure**: Dysfunction of control centers
- **Sleep apnea**: Disrupted neural control during sleep
- **Drug effects**: Opioids depress respiratory centers
- **Altitude adaptation**: Chemoreceptor adaptation to low O_2