# Basics of Cardiopulmonary Physical Therapy







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JAYPEE

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# 4

# Physiology of Respiratory System

Each day we breathe about 20,000 times. All of this breathing could not happen without help from respiratory system. Although we cannot see it, the air we breathe is made-up of several gases. Oxygen is the most important for keeping us alive because body cells need it for energy and growth. Without oxygen, the body cells would die, whereas, carbon dioxide is the waste gas that is produced when carbon is combined with oxygen as the part of body's energy-making processes. The lungs and respiratory system allow oxygen in the air to be taken into the body, while also enabling the body to get rid of carbon dioxide in the air breathed out.

## COMPOSITION OF AIR

Oxygen is required by cells in the body to allow various metabolic reactions to take place and to produce energy and is, therefore, essential to life **(Table 4.1)**.

## DEFINITION OF RESPIRATION

The respiratory system may be defined as the organs and tissues through which air is passed into and out of the body to allow necessary gaseous exchange to take place the word "Respiration" describes two processes:

1. **Internal or cellular respiration:** It is the means by which glucose or other small molecules are oxidized to produce energy, water and carbon dioxide.

**Table 4.1: Composition of air**

| *Breathed in (%)* | *Gas* | *Breathed out (%)* |
|---|---|---|
| 21 | Oxygen | 17 |
| 78 | Nitrogen | 78 |
| 0 | Carbon dioxide | 04 |
| 01 | Tracer gases | 01 |

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2. **External respiration:** It is the means by which oxygen from the air passes into the blood stream for transportation to the tissue cells and $CO_2$ is collected and transferred back to the lungs and expelled from the body.

Normal rate of inspiration and expiration, the respiratory rate is about 16 times a minute in an adult.

## FUNCTIONS OF RESPIRATORY SYSTEM

- **Protection:** Cilia, both in the upper airways and trachea, beat and move mucus continually towards the mouth. Macrophage alveolar macrophages, phagocytosed inhaled particulate matter and pathogens.
- **Thermoregulation:** Heat loss from the respiratory system helps the body to regulate internal body temperature.

**Functionally**, the respiratory system structures are divided into the conducting zone and respiratory zone.

The conducting zone consists of nose, pharynx, larynx, trachea, bronchi and bronchioles. These structures form a continuous passageway through which air can move in and out of the lungs **(Fig. 4.1)**.

The second functional division of respiratory system is found deep inside the lungs and is called the respiratory zone. It is made-up of respiratory bronchioles, alveolar ducts and alveoli. These thin-walled structures form a region where inhaled oxygen can be exchanged for carbon dioxide in nearby capillaries **(Fig. 4.2)**.

Anatomically, these same structures are often divided into the upper and lower respiratory tracts **(Fig. 4.3)**.

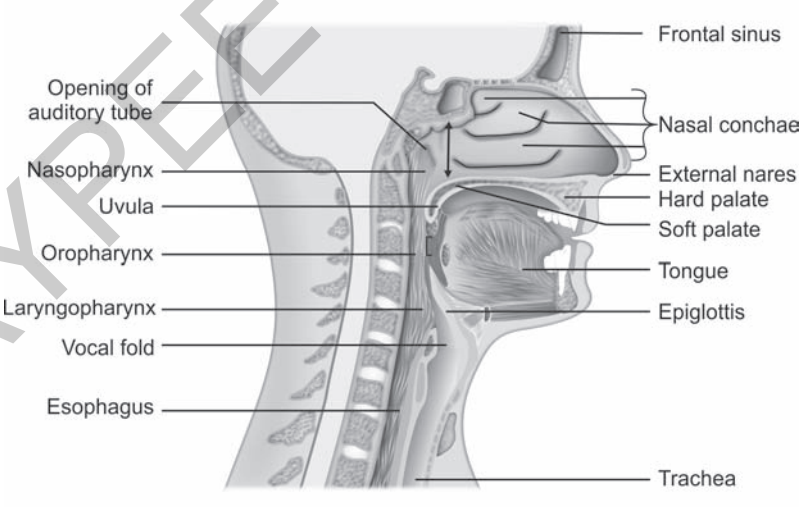


**Fig. 4.1:** Conducting zone of respiratory system

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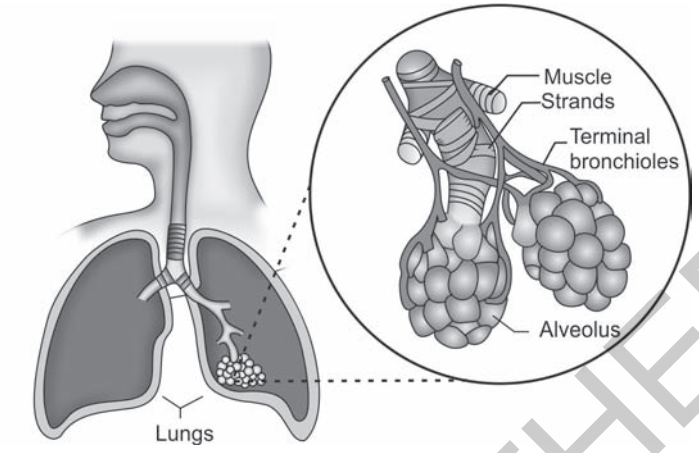


**Fig. 4.2:** Respiratory zone of respiratory system

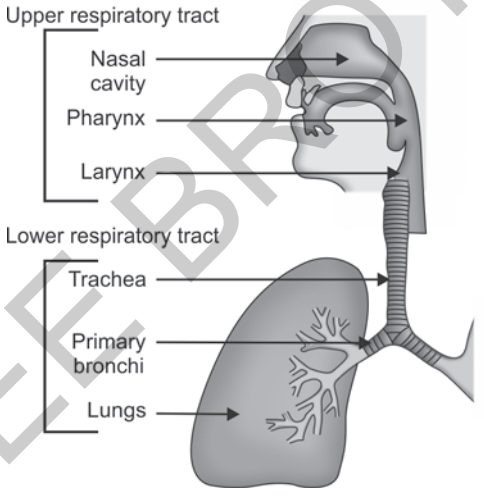


**Fig. 4.3:** Upper and lower respiratory track

- **Upper respiratory tract:** It is formed by nose, pharynx and larynx, which are located in head and neck.
- **Lower respiratory tract:** It is formed by trachea, bronchi and lungs which are located in the thorax.

## STRUCTURE OF RESPIRATORY TRACT (FIG. 4.4)

- **Nasal cavity and sinuses:** Proper breathing involves drawing air in through the nose. The nasal cavity warms and moistens the air and filters it of impurities.

  Tiny hairs and sticky mucous membranes trap foreign materials before they enter the delicate tissues of the lungs. Structures in the nasal cavity

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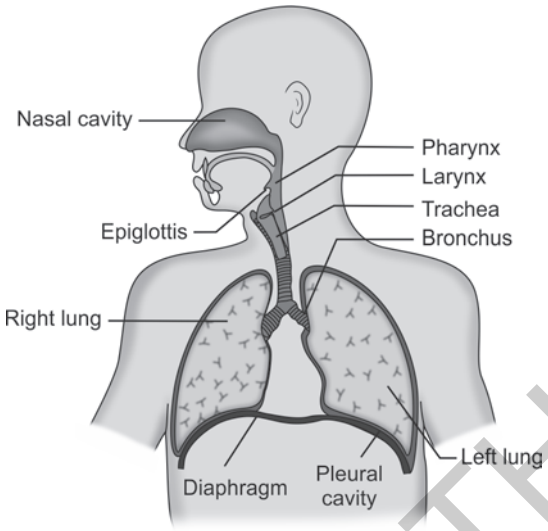


**Fig. 4.4:** Structure of respiratory tract

called concha increase the surface area allowing maximum efficiency. The sinuses provide resonance for voice.

- **Pharynx:** Pharynx refers to the part of respiratory tract behind the nasal cavity and mouth, i.e. throat. The nasal cavity warms, humidifies (moistens), and filter the air, we breathe.
- **Larynx:** Moving down further the respiratory tract, there is larynx or "voice box" which contains vocal cords. The voice is produced by controlled vibrations of the vocal cords as air is pushed out of the lungs and through the larynx.
- **Lobes of the lungs:** The right lung is divided into three lobes while the left lung is divided into two. The left lung is smaller than the right.

Firstly, the trachea or windpipe, divides into two principal bronchi as it enters the lungs. The principal bronchi are further divided into smaller and smaller bronchi. Further, divisions of the bronchi eventually lead to tiny tubes, called bronchioles which led to tiny air sacs known as alveoli. The alveoli are richly supplied with capillaries where the exchange of gases takes place between red blood cells and the air.

- When the bronchi become inflamed, a condition results which is referred to as bronchitis.
- When the alveoli become inflamed due to an infection, a condition results which is referred to as pneumonia.

## CONTROL OF RESPIRATION

**Sympathetic division:** The bronchiole branches contain smooth muscle which is under the control of the autonomic nervous system. Stimulation from sympathetic division of autonomic nervous system causes these

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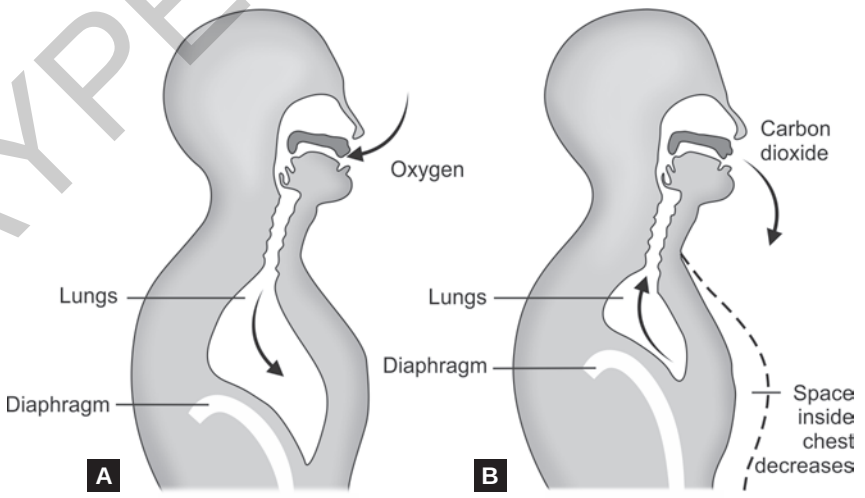
smooth muscles to relax, dilating the bronchial branches allowing more air to pass through the lungs. This is what happens during the "fight or flight" response. When danger is perceived, the sympathetic nervous system is stimulated to prepare the body for immediate action. In the case of lungs, this means allowing more air through so that more oxygen will be available for muscle contraction (to either fight or run away from the danger).

**Parasympathetic division:** When this system is stimulated, the smooth muscles of bronchial branches contract, causing constriction of the bronchial branches allowing less air through the lungs. Normally, the two divisions of autonomic nervous system are in balance, but imbalance can occur. Overstimulation of the parasympathetic nervous system can cause such constriction of the airways that makes breathing difficult, resulting in asthma.

## MECHANICS OF BREATHING (FIGS 4.5A AND B)

The bony thorax and respiratory muscles function as a pump with variable frequency and variable volume displacement to deliver atmospheric air to the alveolo-capillary surface. The components of bony thorax consist of thoracic spine, ribs, scapulae, clavicles, and sternum. The respiratory muscles consist of internal and external intercostals, scaleni, sternocleidomastoid, trapezi, and rhomboids. The primary respiratory muscle of inspiration during tidal breathing is the diaphragm.

The act of breathing is performed primarily by the diaphragm; a large muscle that separates the thoracic cavity from the abdominal cavity. The diaphragm is a dome-shaped fibromuscular separation between the chest and abdomen. The central portion of the diaphragm is made-up of tendinous tissue and at the periphery consists of skeletal muscle, which attaches to the chest wall. The diaphragm receives nerve innervation from the phrenic nerve, which made-up from branches from 3rd, 4th, 5th cervical nerve roots. The diaphragm may




**Figs 4.5A and B:** Mechanics of breathing. (A) Inhalation; (B) Exhalation

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function voluntarily when one takes a deep inspiration, or it may function involuntarily during normal breathing at rest or during sleep.

### Inspiration

Inspiration and expiration work on the basic principle that a change in volume brings about a change in pressure, which causes movement of air. During inspiration, the diaphragm contracts and flattens. It enlarges the thoracic cavity mainly in a longitudinal direction, but also anteriorly and laterally. This movement increases the transverse dimension of the thorax and is called the "bucket handle" motion.

The sternum moves outward from the spine and this movement increases anterior to posterior dimension and is called the "pump handle" motion. With exercise and in disease states associated with increased work of breathing, the accessory muscles of breathing, including the intercostals, scaleni, sternocleidomastoid, trapezi, and rhomboids become involved in inspiration **(Fig. 4.6)**.

### Expiration

Exhalation during resting breathing is the result of passive recoil of the lung and chest wall with some modulation by the diaphragm. The abdominal muscles are the major muscle group active during exhalation **(Figs 4.7A and B)**.

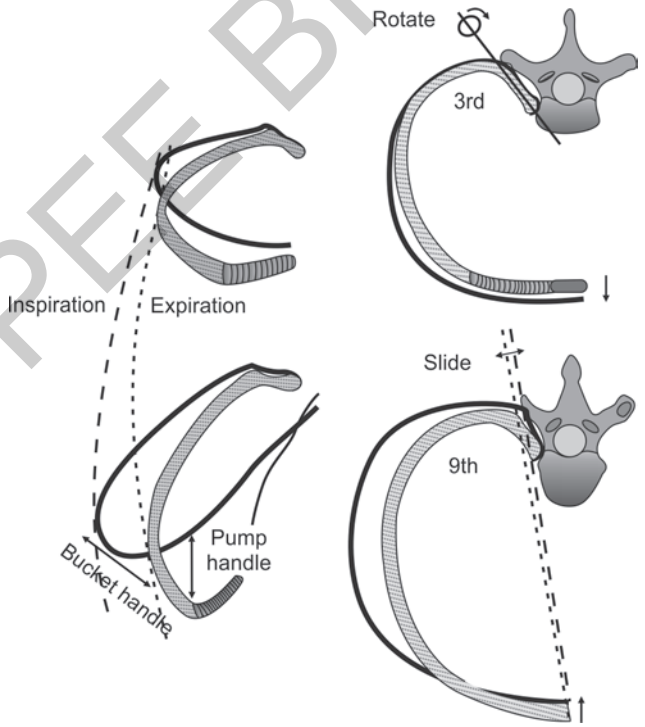


**Fig. 4.6:** Bucket handle and pump handle motion of ribs

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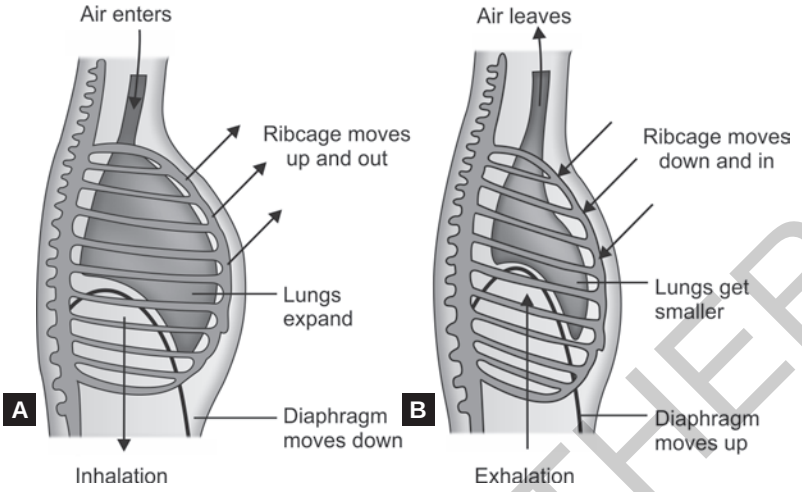


**Figs 4.7A and B:** Process of inhalation and exhalation

### Motions of Ribs

When airway resistance is abnormally high, during exercise or forceful expiratory maneuvers (cough or sneezing), the abdominal musculature and internal intercostals muscles contract and depress and lower the thoracic cage, causing positive intra-abdominal and intrapleural pressure; ultimately resulting in decrease in the volume of thoracic cavity.

## LUNG VOLUMES AND CAPACITIES

The mechanical ability of "pumping air" into the lung can be measured as part of assessment of the lung. Physiologically, the lung can be divided into four lung volumes and four capacities; a capacity is the sum of two or more lung import. The lung volumes and capacities that are most important for gas exchange are the functional residual capacity, tidal volume, and inspiratory reserve volume **(Table 4.2)**.

**Table 4.2: Lung capacities and volumes**

| | | | |
|---|---|---|---|
| Total lung capacity (TLC) 6000 mL | Vital capacity (VC) 4800 mL | Inspiratory reserve volume (IRV) 3600 mL | Inspiratory capacity (IC) 3600 mL |
| | | Tidal volume (Vt) 500 mL | |
| | Residual volume (RV) 1200 mL | Expiratory reserve volume (ERV) 1200 mL | Functional residual capacity (FRC) 2400 mL |
| | | Residual volume (RV) 1200 mL | |

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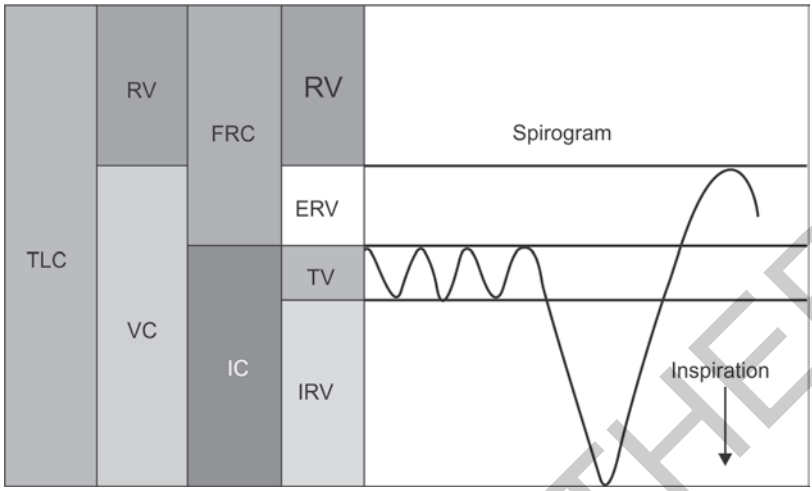


**Fig. 4.8:** Lung volume subdivisions

### Terms, Abbreviations, and Normal (Adult) Values of Lung Volumes and Capacities (Fig. 4.8)

*Tidal Volume*

The amount of air inspired and expired during normal resting ventilation is termed tidal volume (Vt).
**Normal value:** 500 mL.

*Inspiratory Reserve Volume*

When only a tidal breath occupies the lungs, there is "room" for additional air that can be inhaled. This volume in excess of that used in tidal breathing is the inspiratory reserve volume (IRV).
**Normal value:** 3600 mL.

*Expiratory Reserve Volume*

There is quantity of air that can potentially be exhaled beyond the end of a tidal exhalation.
**Normal value:** 1200 mL.

*Residual Volume*

The lungs are not completely emptied of air even after maximally exhaling the expiratory volume. The volume of air remaining within lungs when expiratory reserve volume (ERV) has been exhaled is called residual volume (RV).
**Normal value:** 1200 mL.

*Inspiratory Capacity*

The sum of tidal volume plus inspiratory reserve volume is known as inspiratory capacity (IC).
**Normal value:** 3600 mL.

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*Functional Residual Capacity*

The combination of residual volume and expiratory reserve volume is known as functional residual capacity (FRC).
**Normal value:** 2400 mL.

*Vital Capacity*

The sum of inspiratory reserve volume, tidal volume, and expiratory reserve volume is called the vital capacity (Vt).
**Normal value:** 4800 mL.

*Total Lung Capacity*

The sum of vital capacity and residual volume is called the total lung capacity (TLC).
**Normal value:** 6000 mL.

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# Basics of Cardiopulmonary Physical Therapy

***Salient Features***

- Continues to be one of the standard medical textbooks consulted throughout the world
- Provides fundamental treatment about many practical and theoretical concepts that form the basis of cardiopulmonary physical therapy and has been designed for easy but thorough treatment of vital material
- Consists of detailed and comprehensive text
- *Section 1* provides an introduction to cardiopulmonary physical therapy, and explains the physiology of cardiopulmonary and respiratory system
- *Section 2* introduces cardiac and pulmonary rehabilitation, its goals, benefits and our response to exercise
- *Section 3* provides extensive coverage of the most common respiratory disease and their assessments. It also explains the care of patients in intensive care unit
- *Section 4* provides assessment of cardiovascular disease and also explains the most common disease related to cardiovascular system.
  - *Chapter 12* provides the basics of mechanical ventilation, how to use, its types and what is the role of physiotherapist when patient is on the ventilator.
  - *Chapter 13* provides the use of humidifiers and aerosol therapy in patients with respiratory disease.
  - *Chapter 14* provides details of gas therapy, that is oxygen delivery to patient, the devices we can use.
  - *Chapter 15* provides knowledge about how we can take care of patients with natural or artificial airway by the means of physiotherapy and explains the various airway clearance techniques
- Useful for undergraduates and postgraduates, practicing in clinic and hospital setting and initiates the newcomer to cardiopulmonary physical therapy, one of the fastest growing fields in the physiotherapy.




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Shelving Recommendation
**PHYSIOTHERAPY**

ISBN 978-93-5090-944-7

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