Basic functions of the respiratory system:

- **Gas exchange** – supply oxygen to aerobic tissues in the body and remove carbon dioxide as a waste product.

- **Pulmonary ventilation** - the physics of getting air in- to and out- of the lungs.

- **External respiration** - gas exchange between the lungs and blood (oxygen loading and CO₂ unloading).

- **Transport of respiratory gases** - movement of gases) from the lungs to the cell.

- **Internal respiration** – gas exchange between the capillaries and the tissues (oxygen and CO₂ loading).
Functional anatomy of the respiratory system:

**Conducting Zone**
- Rigid conduits for air to reach site of gas exchange
  - nose
  - nasal cavity
  - pharynx
  - larynx
  - trachea
  - bronchi

**Respiratory Zone**
- Site of gas exchange
  - respiratory bronchioles
  - alveolar ducts
Conducting Zone:

Nose
- airway
- moistens and warms air
- filters inspired air
- resonating chamber for speech
- olfaction

-paranasal sinuses
- frontal, sphenoid, ethmoid and maxillary bones
- warm and moisten air
Conducting Zone:

Pharynx

- connects the nasal cavity and mouth to the larynx and esophagus
- common pathway for food and air (throat)
- nasopharynx
- oropharynx
- laryngopharynx
Conducting Zone:

Laryngopharynx – common passage way for food and air
Larynx – voice box
**Conducting Zone:**

**Trachea**
- Windpipe
- Larynx at division forming two primary bronchi at midthorax

- Mucosa – pseudostratified epithelium (goblet cells)
- Submucosa – connective tissue
  - Seromucous glands – mucous
- Adventitia – CT hyaline cartilage
Conducting Zone:

Bronchi
Bronchial tree
- left and right primary bronchi
  - formed by divisions of the trachea
- secondary bronchi (lobar)
  - inside the lungs
  - 3 on the right
  - 2 on the left
- tertiary bronchi (segmental)
- fourth-order
- fifth-order
- 23 orders of branching air ways
- bronchioles (under 1 mm in diameter)
Conducting Zone:

Bronchioles
- bronchioles (under 1 mm in diameter)
- terminal bronchioles (less than 0.5 mm)
Conducting Zone:

Cartilage:
- rings
- irregular plates
- no cartilage in bronchioles
- replaced by elastic fibers

Epithelium:
- pseudostratified (ciliated)
- columnar (ciliated)
- cuboidal in terminal bronchioles (no cilia)

Smooth Muscle:
- increases as tubes get smaller
Human Anatomy and Physiology

The respiratory zone

**Respiratory Zone:**
- Respiratory bronchioles
- Alveoli (300 million)
- Alveolar ducts
- Alveolar sacs

**Gas Exchange:**
- Respiratory membrane

![Diagram of respiratory zone with labels: Smooth muscle, Capillaries, Elastic fibers, Alveolus, Alveolar duct, Alveoli, Terminal bronchiole, Respiratory bronchioles, Alveolar sacs.]
**Respiratory Zone:**
Respiratory membrane (air-blood barrier) or (Alveolar-capillary membrane) is composed of:
- simple squamous epithelial cells (Type I cells)
- cobweb of pulmonary capillaries

*Primary function is gas exchange*

- Type II cells (cuboidal) surfactant
- elastic fibers
- alveolar pores allow for pressure equalization between alveoli
- alveolar macrophages (dust cells)
Pleural Coverings:
- double layered serosa
- parietal pleura lines the thoracic wall
- pulmonary or visceral pleura which covers the lung surface
- pleural cavity is the space between the two layers
- pleural fluid fills the cavity
**Blood supply:**
- Pulmonary circulation
- Bronchial circulation

Pulmonary arteries from the right side of the heart supply blood to the lungs.
- Pulmonary arteries branch profusely along with the bronchi
- Pulmonary capillary networks surrounding alveoli

- Pulmonary veins form post alveoli to carry oxygenated blood back to the heart

Bronchial arteries come from the aorta and enter the lung at the hilus
- The bronchial arteries run along the branching bronchi and supply lung tissue except the alveoli
- Bronchial veins drain the bronchi but most moves into the pulmonary circulation
Human Anatomy and Physiology
Blood Supply and Innervation of the Lungs

**Innervation:**
- parasympathetic motor fibers (some sympathetic fibers)
- visceral sensory fibers

Enter the lung through the pulmonary plexus on the lung root

parasympathetic fibers – constrict the air tubes
sympathetic fibers – dilate air tubes
**Breathing:**

Simply pressure changes driven by diaphragm and external intercostal muscle contractions

<table>
<thead>
<tr>
<th>Sequence of events</th>
<th>Changes in anterior-posterior and superior-inferior dimensions</th>
<th>Changes in lateral dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inspiratory muscles contract (diaphragm descends; rib cage rises)</td>
<td>Ribs elevated and sternum flares as external intercostals contract</td>
<td>External intercostals contract</td>
</tr>
<tr>
<td>2. Thoracic cavity volume increases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Lungs stretched; intrapulmonary volume increases</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Intrapulmonary pressure drops (to (-1) mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Air (gases) flows into lungs down its pressure gradient until intrapulmonary pressure is 0 (equal to atmospheric pressure)</td>
<td>Diaphragm moves inferiorly during contraction</td>
<td></td>
</tr>
</tbody>
</table>
Breathing:

yellow is the increase in volume during inspiration

Volume during Inspiration

Volume At rest

Lungs
Breathing:

Increased volume causes a drop in pressure if the system is closed. Where is the system closed to the outside?

Boyle’s law – $P_1V_1 = P_2V_2$
Breathing:

Increased volume causes a drop in pressure if the system is closed. Where is the system closed to the outside? **The pleural cavity!**

The decrease in intrapleural cavity pressure is translated to the lungs via the inner visceral pleural membrane because it is attached to the outer surface of the lung. Thus, an increase in volume causes a decrease in intrapleural pressure because it is a closed system.
Breathing:

The lungs are an open system via the trachea and as such as intrapleural pressure drops lung volume increases and lung pressure also decreases. However, because the lungs are open to the outside, air rushes into the lungs to equalize the pressure. Thus, the drop in pulmonary pressure is transient.

Pulmonary pressure returns to zero as air moves into the lungs to take up the volume change (drop in pressure).
Human Anatomy and Physiology
Respiratory Mechanics

![Graph showing respiratory mechanics with volume of breath, pressure relative to atmospheric pressure, and intrapulmonary pressure.](image)
Breathing:

Airway Resistance -
-friction or drag along the respiratory passageway

\[
\text{Flow} = \frac{\Delta P}{R}
\]

-maximum resistance in medium size bronchi then drops as cross sectional area increases

-bronchiole smooth muscle very sensitive to parasymp stimulation
Lung volumes

dead space – volume of air filling the conducting zone and never contributes to gas exchange (anatomical dead space 150 ml).
-if some of the alveoli collapse or are obstructed (alveolar dead space). Total dead space = AnoDS + AlvDS
Human Anatomy and Physiology
Respiratory Mechanics

**Breathing:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Adult male average value</th>
<th>Adult female average value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (TV)</td>
<td>500 ml</td>
<td>500 ml</td>
<td>Amount of air inhaled or exhaled with each breath under resting conditions</td>
</tr>
<tr>
<td>Inspiratory reserve volume (IRV)</td>
<td>3100 ml</td>
<td>1900 ml</td>
<td>Amount of air that can be forcefully inhaled after a normal tidal volume inhalation</td>
</tr>
<tr>
<td>Expiratory reserve volume (ERV)</td>
<td>1200 ml</td>
<td>700 ml</td>
<td>Amount of air that can be forcefully exhaled after a normal tidal volume exhalation</td>
</tr>
<tr>
<td>Residual volume (RV)</td>
<td>1200 ml</td>
<td>1100 ml</td>
<td>Amount of air remaining in the lungs after a forced exhalation</td>
</tr>
<tr>
<td>Total lung capacity (TLC)</td>
<td>6000 ml</td>
<td>4200 ml</td>
<td>Maximum amount of air contained in lungs after a maximum inspiratory effort: TLC = TV + IRV + ERV + RV</td>
</tr>
<tr>
<td>Vital capacity (VC)</td>
<td>4800 ml</td>
<td>3100 ml</td>
<td>Maximum amount of air that can be expired after a maximum inspiratory effort: VC = TV + IRV + ERV (should be 80% TLC)</td>
</tr>
<tr>
<td>Inspiratory capacity (IC)</td>
<td>3600 ml</td>
<td>2400 ml</td>
<td>Maximum amount of air that can be inspired after a normal expiration: IC = TV + IRV</td>
</tr>
<tr>
<td>Functional residual capacity (FRC)</td>
<td>2400 ml</td>
<td>1800 ml</td>
<td>Volume of air remaining in the lungs after a normal tidal volume expiration: FRC = ERV + RV</td>
</tr>
</tbody>
</table>

(b) Summary of respiratory volumes and capacities for males and females

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Gas exchange:

- Inspired air: $P_{O_2} = 160$ mm Hg, $P_{CO_2} = 0.3$ mm Hg
- Alveoli of lungs: $P_{O_2} = 104$ mm Hg, $P_{CO_2} = 40$ mm Hg
- Expired air: $P_{O_2} = 120$ mm Hg, $P_{CO_2} = 27$ mm Hg
- Blood entering alveolar capillaries: $P_{O_2} = 40$ mm Hg, $P_{CO_2} = 45$ mm Hg
- Blood leaving tissue capillaries: $P_{O_2} = 40$ mm Hg, $P_{CO_2} = 45$ mm Hg
- Tissues: $P_{O_2}$ less than 40 mm Hg, $P_{CO_2}$ greater than 45 mm Hg

Diagram showing the process of gas exchange with labels for oxygen ($O_2$) and carbon dioxide ($CO_2$) pressures in different parts of the respiratory system.
Reduced alveolar ventilation; excessive perfusion

Pulmonary arterioles serving these alveoli constrict

Reduced alveolar ventilation; reduced perfusion

Enhanced alveolar ventilation; inadequate perfusion

Pulmonary arterioles serving these alveoli dilate

Enhanced alveolar ventilation; enhanced perfusion
Decreased carbon dioxide \( (P_{CO_2} \ 20 \text{ mm Hg}) \) or \( H^+ \) (pH 7.6)

Normal arterial carbon dioxide \( (P_{CO_2} \ 40 \text{ mm Hg}) \) or \( H^+ \) (pH 7.4)

Increased carbon dioxide \( (P_{CO_2} \ 80 \text{ mm Hg}) \) or \( H^+ \) (pH 7.2)
(a) Oxygen release and carbon dioxide pickup at the tissues

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(b) Oxygen pickup and carbon dioxide release in the lungs

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Increased arterial PCO₂

Increased PCO₂, decreased pH in cerebrospinal fluid

Central chemoreceptors in medulla (mediate 70% of the response)

Peripheral chemoreceptors (carotid and aortic bodies) (mediate 30% of the response)

Afferent impulses

Medullary respiratory centers

Efferent impulses

Respiratory muscles

Increased ventilation (more CO₂ exhaled)

Arterial PCO₂ and pH return to normal

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Chronic bronchitis
Bronchial edema, chronic productive cough, bronchospasm

Emphysema
Destruction of alveolar walls, lung fibrosis, air trapping

Continual bronchial irritation and inflammation

Breakdown of elastin in connective tissue of lungs

Tobacco smoke
Air pollution

α-1 antitrypsin deficiency

Airway obstruction or air trapping
Dyspnea
Frequent infections

Abnormal ventilation-perfusion ratio
Hypoxemia
Hypoventilation
(b) 5 weeks

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