Respiratory System

- Nasal cavity
- Nostril
- Oral cavity
- Larynx
- Right primary bronchus
- Right lung
- Pharynx
- Trachea
- Site of carina
- Left primary bronchus
- Left lung
- Diaphragm
Respiratory System

(a) Frontalis muscle deep to skin
Root and bridge of nose
Dorsum nasi
Ala of nose
Apex of nose
Philtrum
External naris (nostril)

(b) Frontal bone
Nasal bone
Septal cartilage
Maxillary bone (frontal process)
Lateral cartilage
Lesser alar cartilages
Greater alar cartilages
Dense fibrous connective tissue

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Respiratory System

- Sphenoidal sinus
- Superior meatus
- Middle meatus
- Pharyngeal tonsil
- Opening of pharyngotympanic (auditory) tube
- Nasopharynx
- Posterior nasal aperture
- Uvula
- Palatine tonsil
- Fauces
- Oropharynx
- Laryngopharynx
- Vestibular fold
- Vocal fold
- Esophagus

- Frontal sinus
- Cribiform plate of ethmoid bone
- Superior concha
- Middle concha
- Inferior concha
- Vestibule
- Inferior meatus
- Nostril
- Hard palate
- Soft palate
- Tongue
- Lingual tonsil
- Epiglottis
- Hyoid bone
- Thyroid cartilage of larynx
- Cricoid cartilage
- Laryngeal cartilages
- Thyroid gland
- Trachea

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Respiratory System

- Body of hyoid bone
- Thyrohyoid membrane
- Cuneiform cartilage
- Corniculate cartilage
- Arytenoid cartilage
- Arytenoid muscle
- Cricoid cartilage
- Tracheal cartilages
- Body of hyoid bone
- Thyrohyoid membrane
- Fatty pad
- Vestibular fold (false vocal cord)
- Thyroid cartilage
- Vocal fold (true vocal cord)
- Cricothyroid ligament
- Cricotracheal ligament

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Respiratory System

Base of tongue
Epiglottis
False vocal cord
True vocal cord
Glottis
Inner lining of trachea
Corniculate cartilage

(a) (b)

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Respiratory System

(a) Diagram of the trachea showing:
- Posterior and anterior views
- Esophagus
- Trachealis muscle
- Hyaline cartilage ring
- Mucous membrane
- Submucosa
- Adventitia

(b) Close-up image of pseudostratified ciliated columnar epithelium in the submucosa.

(c) Image of ciliated cells.
Respiratory System
Respiratory System

Type II (surfactant-secreting) cell
Type I cell of alveolar wall
Epithelial cell nucleus
Endothelial cell nucleus
Capillary
Macrophage
Respiratory membrane
Alveoli (gas-filled airspaces)
Red blood cell in capillary
Alveolar pores in capillary
Alveolar epithelium
Fused basal laminae of the alveolar epithelium and the capillary endothelium
Capillary endothelium

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Respiratory System

- Pulmonary Ventilation

- Atmospheric pressure
- Intrapleural pressure 756 mm Hg (~4 mm Hg)
- Collapsing force of lungs 4 mm Hg
- Intrapulmonary pressure 760 mm Hg (0 mm Hg)

Lung
Thoracic wall
Parietal pleura
Pleural cavity
Visceral pleura
Diaphragm
## Respiratory System

<table>
<thead>
<tr>
<th>Inspiration</th>
<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>
<td></td>
</tr>
<tr>
<td>② Thoracic cavity volume increases</td>
<td>Diaphragm moves inferiorly during contraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>③ Lungs stretched; intrapulmonary volume increases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>④ Intrapulmonary pressure drops (to (-1 \text{ mm Hg}))</td>
<td></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>
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<tr>
<td>① Inspiratory muscles relax (diaphragm rises; rib cage descends due to recoil of costal cartilages)</td>
<td>Ribs and sternum depressed as external intercostals relax</td>
<td>External intercostals relax</td>
<td></td>
</tr>
<tr>
<td>② Thoracic cavity volume decreases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>③ Elastic lungs recoil passively; intrapulmonary volume decreases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>④ Intrapulmonary pressure rises (to (+1 \text{ mm Hg}))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>⑤ Air (gases) flows out of lungs down its pressure gradient until intrapulmonary pressure is 0</td>
<td>Diaphragm moves superiorly as it relaxes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Respiratory System

Volume of breath

4 seconds elapsed

Inspiration
Expiration

Intrapulmonary pressure
Trans-pulmonary pressure
Intrapleural pressure

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Respiratory System

• Measuring of Lung Function

  – Compliance – the ease at which the lungs and thoracic wall can be expanded – if reduced it is more difficult to inflate the lungs – causes:

    • Damaged lung tissue

    • Fluid within lung tissue

    • Decrease in pulmonary surfactant

    • Anything that impedes lung expansion or contraction

  – Respiratory Volumes and Capacities will be covered in Lab –
Respiratory System

• Exchange of Oxygen and Carbon Dioxide

  - Charles’ Law – the volume of a gas is directly proportional to the absolute temperature, assuming the pressure remains constant

    As gases enter the lung they warm and expand, increasing lung volume

  - Dalton’s Law – each gas of a mixture of gases exerts its own pressure as if all the other gases were not present

  - Henry’s Law – the quantity of a gas that will dissolve in a liquid is proportional to the partial pressure of the gas and its solubility coefficient, when the temperature remains constant
• External and Internal Respiration
Respiratory System

• Transport of Oxygen and Carbon Dioxide by the Blood

- Oxygen Transport

  • 1.5% dissolved in plasma

  • 98.5% carried with Hb inside of RBC’s as oxyhemoglobin

    - Hb – made up of protein portion called the globin portion and the heme portion which is pigmented and contains 4 atoms of Fe, each Fe can bind with 1 molecule of oxygen

    - Association of Hb with oxygen is affected by four factors

      » pO₂ – the greater the pO₂ the more oxygen will combine with Hb, until the Hb becomes saturated

      » Acidity pH – in a lower (more acidic) pH oxygen will dissociate from Hb and be released (frequently related to high carbon dioxide)

      » Temperature – as temperature increases, so does the the amount of oxygen released from Hb

      » BPG (2,3 biphosphoglycerate) – a chemical formed inside RBC’s during glycolysis – the higher the levels of BPG the more oxygen is released by Hb
Respiratory System

![Graph showing percent saturation of hemoglobin at different temperatures.]

- **10°C**
- **20°C**
- **38°C**
- **43°C**

- **Normal body temperature**

![Graph showing percent saturation of hemoglobin vs. PO2 (mm Hg).]

- **Decreased carbon dioxide** (PCO2 20 mm Hg) or H⁺ (pH 7.6)
- **Normal arterial carbon dioxide** (PCO2 40 mm Hg) or H⁺ (pH 7.4)
- **Increased carbon dioxide** (PCO2 80 mm Hg) or H⁺ (pH 7.2)
Respiratory System

- Carbon Dioxide Transport
  - 9% dissolved in plasma
  - 13% carried by Hb as carbaminohemoglobin
  - 78% converted to bicarbonate (HCO\textsuperscript{-}) ions
Respiratory System

(a) Oxygen release and carbon dioxide pickup at the tissues

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Respiratory System

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

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Respiratory System

- Carbon Monoxide Poisoning

- Control of Respiration
  - Respiratory Center
    - Medullary Rhythmicity Area – controls the basic rhythm of breathing
      - Inspiratory Area – autorhythmic neurons, set normal breathing rhythm
      - Expiratory Area – usually inactive, only active during high levels of ventilation
    - Pontine (Pons) Areas – coordinate the switching between inspiration and expiration
      - Pneumotaxic Area – limits inspiration, facilitates expiration (prevents over expansion of the lungs, the shorter the time the faster the respiration rate
      - Apneustic Area – sends info to the inspiratory area, prolonging inspiration and inhibiting expiration
Respiratory System
Respiratory System

(a) During normal quiet breathing

INSPIRATORY AREA
ACTIVE
2 seconds
Diaphragm actively contracts
Normal quiet inspiration

INACTIVE
3 seconds
Diaphragm relaxes followed by elastic recoil of chest wall and lungs
Normal quiet expiration

(b) During labored breathing

EXPIRATORY AREA

INTERNAL INTERCOstral and abdominal muscles contract

INSPIRATORY AREA
ACTIVE

Diaphragm, external intercostal, sternocleidomastoid, pectoralis minor, and scalene muscles contract
Forceful inspiration

Activates
Respiratory System

- Regulation of Respiratory Center Activity

Other receptors (e.g., pain) and emotional stimuli acting through the hypothalamus

Higher brain centers (cerebral cortex—voluntary control over breathing)

Peripheral chemoreceptors

\[ O_2 \downarrow, CO_2 \uparrow, H^+ \uparrow \]

Central chemoreceptors

\[ CO_2 \uparrow, H^+ \uparrow \]

Respiratory centers (medulla and pons)

Stretch receptors in lungs

Irritant receptors

Receptors in muscles and joints
Increased arterial $P_{CO_2}$

Increased $P_{CO_2}$, 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 $CO_2$ exhaled)

Arterial $P_{CO_2}$ and pH return to normal

Key:
- Initial stimulus
- Physiological response
- Result
Respiratory System
Respiratory System

(a) Spirographic record for a male

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Respiratory System

<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>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Respiratory capacities</th>
<th></th>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<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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