Respiration
(c) External anatomy of lungs

- Superior lobe
- Middle lobe
- Inferior lobe

- Apex
- Base
- Cardiac notch

- Right lung is divided into three lobes.
- Left lung is divided into two lobes.

(d) Sectional view of chest
Each lung is enclosed in two pleural membranes. The esophagus and aorta pass through the thorax between the pleural sacs.

- Esophagus
- Aorta
- Right lung
- Left lung
- Right pleural cavity
- Pericardial cavity
- Left pleural cavity
- Heart

Superior view

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(e) Branching of airways

The trachea branches into two primary bronchi.

The primary bronchus divides 22 more times terminating in a cluster of alveoli.

(f) Structure of lung lobule

Each cluster of alveoli is surrounded by elastic fibers and a network of capillaries.

- Bronchial artery, vein and nerve
- Branch of pulmonary artery
- Smoother muscle
- Elastic fibers
- Branch of pulmonary vein
- Capillary beds
- Lymphatic vessel
- Alveoli
(g) Alveolar structure

- Type I cell for gas exchange.
- Type II cell (surfactant cell) synthesizes surfactant.
- Endothelial cell of capillary
- Alveolar macrophage ingests foreign material.

Capillary
Elastic fibers

(h) Exchange surface of alveoli

Alveolar epithelium
Nucleus of endothelial cell
RBC
Endothelium
Plasma
Alveolar air space
Surfactant
Fused basement membranes

Blue arrow represents gas exchange between alveolar air space and the plasma.
Ciliated epithelium of the trachea

- Cilia move mucus to pharynx
- Dust particle
- Mucus layer traps inhaled particles.
- Watery saline layer allows cilia to push mucus toward pharynx.
- Cilia
- Goblet cell secretes mucus.
- Nucleus of columnar epithelial cell
- Basement membrane
(a) At rest, diaphragm is relaxed.

(b) Diaphragm contracts, thoracic volume increases.

(c) Diaphragm relaxes, thoracic volume decreases.
(a) Normal lung at rest

- **P = -3 mm Hg**
- Intrapleural pressure is subatmospheric.

- Ribs
- Intrapleural space
- Pleural membranes
- Diaphragm

- Elastic recoil of the chest wall tries to pull the chest wall outward.
- Elastic recoil of lung creates an inward pull.

(b) Pneumothorax

- **P = P\text{$_{atm}$}**

- Lung collapses to unstretched size
- Pleural membranes

- The rib cage expands slightly.
- If the sealed pleural cavity is opened to the atmosphere, air flows in.
When the subject inhales, air moves into the lungs. The volume of the bell decreases, and the pen rises on the tracing.
The four lung volumes:

- **RV** = Residual volume
- **ERV** = Expiratory reserve volume
- **Vₜ** = Tidal volume
- **IRV** = Inspiratory reserve volume

**Pulmonary volumes (mL):**

<table>
<thead>
<tr>
<th>Volume Type</th>
<th>Males</th>
<th>Females</th>
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<tbody>
<tr>
<td>IRV</td>
<td>3000</td>
<td>1900</td>
</tr>
<tr>
<td>Vₜ</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>ERV</td>
<td>1100</td>
<td>700</td>
</tr>
<tr>
<td>Residual volume</td>
<td>1200</td>
<td>1100</td>
</tr>
</tbody>
</table>

End of normal inspiration:
- Tidal volume $500 \text{ mL}$
- Inspiratory reserve volume $3000 \text{ mL}$
- Inspiratory capacity $4600 \text{ mL}$

End of normal expiration:
- Expiratory reserve volume $1100 \text{ mL}$
- Total lung capacity

Residual volume $1200 \text{ mL}$

Functional residual capacity $4200 \text{ mL}$

A spirometer tracing showing lung volumes and capacities.

Capacities are sums of 2 or more volumes.
Inhalation of 500 mL (tidal volume) followed by 150 mL of fresh air reaching alveoli.

Dead space is filled with fresh air.

At the end of expiration, the dead space is filled with "stale" air from alveoli.

Respiratory cycle in an adult:

1. End of inspiration
2. Exhale 500 mL (tidal volume)
3. Inhale 500 mL of fresh air
4. Dead space filled with fresh air

The first exhaled air comes out of the dead space. Only 350 mL leaves the alveoli.
O₂ dissolved in plasma (≈ Pₒ₂) < 2%

O₂ + Hb → Hb•O₂
Red blood cell

Hb•O₂ → Hb + O₂

Transport to cells

O₂ used in cellular respiration
(a) Oxygen transport in blood without hemoglobin. Alveolar $P_O_2 = \text{arterial } P_O_2$

$P_O_2 = 100 \text{ mm Hg}$

Oxygen dissolves in plasma.

(b) Oxygen transport at normal $P_O_2$ in blood with hemoglobin

$P_O_2 = 100 \text{ mm Hg}$

Red blood cells with hemoglobin are carrying 98% of their maximum load of oxygen.

(c) Oxygen transport at reduced $P_O_2$ in blood with hemoglobin

$P_O_2 = 28 \text{ mm Hg}$

Red blood cells carrying 50% of their maximum load of oxygen.

<table>
<thead>
<tr>
<th></th>
<th>$O_2$ content of plasma</th>
<th>$O_2$ content of red blood cells</th>
<th>Total $O_2$ carrying capacity</th>
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</thead>
<tbody>
<tr>
<td>a</td>
<td>$3 \text{ mL } O_2/\text{L blood}$</td>
<td>0</td>
<td>$3 \text{ mL } O_2/\text{L blood}$</td>
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<tr>
<td>b</td>
<td>$3 \text{ mL } O_2/\text{L blood}$</td>
<td>197 mL $O_2/\text{L blood}$</td>
<td>$200 \text{ mL } O_2/\text{L blood}$</td>
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<tr>
<td>c</td>
<td>$0.8 \text{ mL } O_2/\text{L blood}$</td>
<td>99.5 mL $O_2/\text{L blood}$</td>
<td>$100.3 \text{ mL } O_2/\text{L blood}$</td>
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