15.1 The Respiratory System

- The primary function of the respiratory system is to allow oxygen from the air to enter the blood and carbon dioxide from the blood to exit into the air.

- Ventilation, or breathing, has two parts.
  - Inspiration, or inhaling, conducts air toward the lungs.
  - Expiration, or exhaling, conducts air away from the lungs.

15.1 The Respiratory System

- The respiratory system and the cardiovascular system work together to accomplish
  1. Exchange of gases (O₂ and CO₂) between air and the blood (external respiration).
  2. Transport of gases to and from the lungs and the tissues.
  3. Exchange of gases (O₂ and CO₂) between blood and tissue fluid (internal respiration).
The Respiratory Tract

- As air moves in along the airways, it is:
  - Cleansed by nostril hair and cilia and mucus along nasal cavities and trachea;
  - Warmed by the heat given off by the blood vessels lying close to the surface of airway lining;
  - Moistened by the wet surfaces of the air passages.
- As air moves out, it cools and loses moisture.
The Nose

- **The Nose**
  - Part of upper respiratory tract
  - Includes nasal cavities, pharynx, and larynx
  - Air enters through nostrils (external openings)
  - Contains two nasal cavities
    - Warms and moistens air during inhalation
    - Contains odor receptors
    - Tear glands drain into nasal cavity
  - Separated from mouth by **hard** and **soft palate**

The Pharynx

- **Pharynx** connects nasal and oral cavities to larynx
  - Three parts
    - **Nasopharynx** – where the nasal cavities open posterior to soft palate
    - **Oropharynx** – where the mouth opens
    - **Laryngopharynx** – opens into the larynx
  - **Uvula** – soft extension of soft palate projects into oropharynx
  - **Tonsils** – a protective ring
    - Lymphatic tissue that protects against inhaled microbes
**The Trachea**

- **Trachea (windpipe)**
  - Tube connecting larynx to primary bronchi
  - Held open by C-shaped cartilage rings
  - Cilia sweep mucus toward the pharynx
  - Smoking can destroy cilia

- **Larynx** — cartilaginous structure
  - Passageway for air between pharynx and trachea
- **Vocal cords**
  - Folds of mucosa that vibrate to make sounds
  - **Glottis** - opening between folds
  - **Epiglottis** — Flap preventing food from entering the respiratory tract
The Bronchial Tree

- Trachea divides into right and left primary **bronchi**
  - Lead into right and left lungs
  - Branch to secondary bronchi
    - Eventually lead to **bronchioles**
    - As airways divide and subdivide, the walls become thinner
      - The small rings of cartilage are no longer present
      - Each bronchiole leads into sac called **alveoli**

The Lungs

- The **lungs** are paired, cone-shaped organs.
  - Occupy thoracic cavity
    - **Diaphragm** separates it from abdominal cavity
  - Right lung has 3 lobes
  - Left lung has 2 lobes
    - Allows room for heart
    - Each lobe subdivided into lobules
      - Each lobule has a bronchiole serving many alveoli
The Lungs

- Each lung is covered by very thin serous membranes called **pleura**.
- Another pleura covers the internal chest wall and diaphragm.
- Both pleura produce lubricating serous fluid that helps the pleurae slide freely against each other during inspiration and expiration.
- Surface tension holds the two pleura layers together when the lungs recoil in expiration.

The Lungs

- The alveoli are made up of simple squamous epithelium surrounded by blood capillaries.
  - Gas exchange occurs between the air in the alveolus and the blood in the capillaries.
    - Oxygen diffuses across the walls into blood.
    - Carbon dioxide diffuses into alveoli.
  - Alveoli must stay open to receive air.
    - **Pulmonary surfactant** helps prevent them from closing.
      - **Infant respiratory distress syndrome** – premature infants lack surfactant.
15.2 Mechanisms of Breathing

- During ventilation (breathing), free air flow is vitally important.
- Medical professionals use a device called **spirometer** to record volume.
  - The volume of air exchanged during both normal and deep breathing can be measured.
  - Breathing patterns are a useful way of understanding normal inspiration and expiration.
15.2 Mechanisms of Breathing

- **Spirometer**
  - Records the volume of air exchanged during both normal and deep breathing
- **Spirogram**
  - Shows the measurements recorded when a person breathes as directed by a technician

**Figure 15.6**

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**Respiratory Volumes**

- **Tidal volume**
  - Amount of air inhaled and exhaled with each breath at rest
  - Normally is about 500 ml
- **Vital capacity**
  - Maximum volume moved in and out in a breath
  - Illness can affect vital capacity
Respiratory Volumes

- **Inspiratory reserve volume**
  - Forced inhalation of air moved in above tidal volume
  - Roughly an additional 3.0 liters from tidal volume
- **Expiratory reserve volume**
  - Forced exhalation of air moved out beyond tidal volume
  - Roughly 1.5 liters additional to tidal volume
- These together = **vital capacity**
- All volumes depend on age, gender, physical conditioning

Respiratory Volumes

- During normal breathing, only about 70% of the tidal volume reaches the alveoli.
  - 30% remains in the airways
  - Even after deep exhalation air remains in the lungs
- **Residual volume**
  - Amount of air always remaining in lungs
  - Typically about 1000ml of air

Inspiration and Expiration

- **Understanding Ventilation**
  1. There is a continuous column of air from pharynx to alveoli.
  2. The lungs lie in the sealed-off thoracic cavity.
     - Rib cage forms top and sides
     - Intercostal muscles lie between the ribs
     - Diaphragm forms the floor
  3. The lungs adhere to the thoracic wall by way of the pleura.
Inspiration

- The active phase
  - Diaphragm contracts
    - Becomes flattened
  - Internal intercostals contract
    - Raises rib cage up and out
  - Volume of thoracic cavity increases
  - Air pressure inside alveoli lowers
  - Air rushes in due to negative pressure

Expiration

- The passive phase
  - Diaphragm and internal intercostals relax
  - Recoil returns them to original shape
  - Volume of thoracic cavity decreases
  - Air pressure inside alveoli increases
  - Air rushes out

Control of Breathing

- Normally, adults have resting breathing rate of 12 to 20 ventilations per minute.
- The respiratory center located in the medulla oblongata of the brain controls the ventilation rhythm.
- This center stimulates inspiration by sending signals to certain muscles.
- When the center temporarily stops, signals are not sent to the muscles.
Control of Breathing

- Inspiration begins when respiratory center sends out nerve impulses to the diaphragm and external intercostals, causing contraction.
- Expiration begins when respiratory center ceases to send out nerve impulses to diaphragm and external intercostals; relaxation occurs.
- The respiratory center is also influenced by chemical and neural input.

Control of Breathing

- **Chemical input** to respiratory center
  - Directly sensitive to the levels of CO₂ and H⁺
    - When levels rise, respiratory center increases rate and depth of breathing
  - Indirectly responsive to O₂
    - Chemoreceptors in the **carotid** and **aortic bodies** sensitive to oxygen levels in blood
      - When levels decrease, impulses are sent to respiratory center.
      - Respiratory center then increases rate and depth of breathing.
15.3 Gas Exchanges in the Body

- Respiration includes the exchange of gases in the lungs (external respiration) and the exchange of gases in the tissues (internal respiration).
- Most of the O₂ carried in the blood is attached to the iron-containing heme portion of the protein hemoglobin.

External Respiration

- Exchange of gas between air in alveoli and blood
  - Partial pressure refers to the amount of pressure each gas in a mixture exerts.
  - Symbolized by $P_{CO_2}$ and $P_{O_2}$
  - Blood in pulmonary capillaries has a higher $P_{CO_2}$ than atmospheric air.
  - $CO_2$ diffuses from blood into alveoli

External Respiration

- Most $CO_2$ is carried as bicarbonate ions ($HCO_3^-$).
- Carbonic anhydrase catalyzes the breakdown of carbonic acid ($H_2CO_3$).
**External Respiration**

- The pressure gradient for O\(_2\) is the reverse of CO\(_2\).
- P\(_{O2}\) is low in pulmonary capillaries and high in alveoli.
- O\(_2\) diffuses into blood.
- Hemoglobin picks up O\(_2\) and becomes oxyhemoglobin.

\[
\text{Hb} + \text{O}_2 \rightarrow \text{HbO}_2
\]

**Internal Respiration**

- Internal Respiration
  - Exchange of gas between systemic capillaries and tissues
  - Partial pressure of O\(_2\) is greater in capillaries than tissues
  - Oxyhemoglobin gives up O\(_2\) which diffuses out of the blood into tissues

\[
\text{HbO}_2 \rightarrow \text{Hb} + \text{O}_2
\]

**Internal Respiration**

- CO\(_2\) diffuses into the blood.
  - A small amount combines with hemoglobin.
- Most CO\(_2\) combines with H\(_2\)O.
- Carbonic anhydrase speeds up the reaction.
15.4 Disorders of the Respiratory System

- The respiratory tract is constantly exposed to the air in our environment and thus susceptible to:
  - Various infectious agents
  - Pollution
  - In some individuals, tobacco smoke
Disorders of the Upper Respiratory Tract

- Upper respiratory tract
  - Includes nasal cavities, the pharynx, and the larynx
  - Susceptible to a variety of viral and bacterial infections due to its air filtering function
  - Upper respiratory infections can also spread from these areas to the middle ear or the sinuses

The Common Cold

- Most are caused by relatively mild viruses
  - Most common are rhinoviruses
  - Symptoms include sneezing, runny nose, and mild fever
  - Last a few days to a week for individuals with a healthy immune system
  - Antibiotics are ineffective against viral infections
  - Medications may be use to treat symptoms

Pharyngitis, Tonsillitis, and Laryngitis

- **Pharyngitis**
  - Inflammation of the throat due to infection
  - *Streptococcus pyogenes* causes “strep throat”
  - Symptoms are sore throat, fever, and white patches
  - Treated by antibiotics
Pharyngitis, Tonsillitis, and Laryngitis

• **Tonsillitis**
  – Tonsils (lymphoid tissue) become inflamed and enlarged
  – Frequent inflammation can lead to surgical removal by tonsillectomy

• **Laryngitis**
  – Inflammation of the larynx
  – Causes hoarseness with difficulty in speaking
    • Benign polyps can develop on vocal cords, especially individuals that use them excessively.

Sinusitis

– Inflammation of the cranial sinuses within the facial skeleton that drain into the nasal cavities
– Develops when nasal congestion blocks sinus openings
– Symptoms include postnasal discharge, headache, and facial pain
– Up to 10% of upper respiratory infections are accompanied by sinusitis

Otitis Media

• Inflammation of the middle ear
  – Nasal infections spread to the ear by way of the auditory (eustachian) tubes.
  – Tympanostomy tubes are helpful in children with chronic otitis media.
Disorders of the Lower Respiratory Tract

- Several disorders of the lower respiratory tract cause problems by obstructing normal airflow.
- Causes
  - Foreign objects lodged in the trachea
  - Excessive mucus in bronchi or bronchioles
  - Conditions that tend to restrict normal elasticity

Disorders of the Trachea and Bronchi

- **Choking**
  - Obstruction of the trachea
  - Heimlich maneuver - a physical technique to expel blockage
  - Tracheotomy - insertion of a breathing tube into the trachea (tracheostomy)
    - Individuals whose larynx or trachea has been damaged or destroyed may require a permanent tracheostomy tube.

- **Acute bronchitis**
  - Inflammation of the primary and secondary bronchi
  - Usually preceded by a viral infection that leads to a secondary bacterial infection

- **Chronic bronchitis**
  - Airways are inflamed and filled with mucus
  - Bronchi have undergone degenerative change including the loss of cilia
  - Smoking is the most common cause
Disorders of the Trachea and Bronchi

• **Asthma**
  – A disease of the bronchi and bronchioles
  – Marked by wheezing, breathlessness
    • Sometimes coughing and expectoration of mucus
  – Triggered by specific irritants
    • Smooth muscle in bronchioles spasms
  – Incurable but can be treated with medicines

Diseases of the Lungs

• **Pneumonia**
  – Infection in which bronchi or alveoli fill with thick fluid
  – Symptoms include high fever, chest pain, and headache
  – Caused by bacteria, viruses, and other infectious agents

• **Pulmonary tuberculosis**
  – Caused by the bacterium *Mycobacterium tuberculosis*
  – Lung cells build a protective capsule (tubercle) around invading bacteria
  – If resistance is low, bacteria escape and spread
  – TB skin test – checks for exposure to *M. tuberculosis*

Diseases of the Lungs

• **Emphysema**
  – A chronic and incurable disease
  – Damages the walls of the alveoli
  – Reduces surface area for gas exchange
  – COPD usually associated with smoking

• **Cystic fibrosis (CF)**
  – Recessive genetic condition
  – Caused by defective protein needed for Cl- transport
  – Mucus in the lungs becomes very thick and sticky
  – Interferes with breathing
Diseases of the Lungs

- **Pulmonary fibrosis**
  - Fibrous connective tissue builds up in the lungs, causing a lack of elasticity.
  - Vital capacity is consequently reduced.

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Acute Bronchitis
Airways are inflamed due to infection (acute) or due to an irritant (chronic). Coughing brings up mucus and pus.

Figure 15.12a

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b. Asthma
Airways are inflamed due to irritation, and bronchioles constrict due to muscle spasms.

Figure 15.12b
c. **Pneumonia**
Alveoli fill with pus and fluid, making gas exchange difficult.

Figure 15.12c

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d. **Pulmonary Tuberculosis**
Tubercles encapsulate bacteria, and elasticity of lungs is reduced.

Figure 15.12d

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e. **Emphysema**
Alveoli burst and fuse into enlarged air spaces. Surface area for gas exchange is reduced.

Figure 15.12e
Diseases of the Lungs

- **Lung Cancer**
  - Leading cause of cancer death in men and women
  - 87% of cases associated with cigarette smoking
  - Series of progressive steps
    - Thickening of cells lining bronchi
    - Loss of cilia
    - Appearance of cells with atypical nuclei
    - Tumor formation – disordered cells with atypical nuclei
    - Metastasis – cancerous cells spread to other parts of the body
Normal Lung versus Cancerous Lung

Figure 15.13

a. Normal lung  b. Lung cancer

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