14

The Respiratory System

Lecture Presentation
Anne Gasc
Hawaii Pacific University and
University of Hawaii–Honolulu Community College
The Respiratory System

OUTLINE:

- Structures of the Respiratory System
- Mechanism of Breathing
- Transport of Gases between the Lungs and the Cells
- Respiratory Centers in the Brain
- Respiratory Disorders
Structures of the Respiratory System

- Function
  - Provides the body with essential oxygen and disposes of carbon dioxide
  - Exhaling carbon dioxide, a waste product of cellular respiration, helps regulate the acid–base balance of body fluids
Structures of the Respiratory System

- Four processes play a part in respiration:
  1. Breathing (ventilating)
  2. External respiration
  3. Gas transport
  4. Internal respiration
Figure 14.1 An overview of respiration.
Structures of the Respiratory System

- Regions of the respiratory system
  - Upper
    - Nose and pharynx
  - Lower
    - Larynx, epiglottis, trachea, bronchi, bronchioles, and lungs
Figure 14.2 The respiratory system.

**Upper Respiratory System**
- Filters, warms, and moistens air

**Sinuses**
- Cavities in skull
- Lighten head
- Warm and moisten air

**Nasal Cavity**
- Produces mucus
- Filters, warms, and moistens air
- Olfaction

**Pharynx**
- Passageway for air and food

**Epiglottis**
- Covers larynx during swallowing

**Larynx**
- Air passageway
- Prevents food and drink from entering lower respiratory system
- Produces voice

**Lower Respiratory System**
- Exchanges gases

**Lungs**
- Structures that contain alveoli and air passageways
- Allow exchange of oxygen and carbon dioxide between atmosphere and blood

**Trachea**
- Connects larynx with bronchi leading to each lung
- Conducts air to and from bronchi

**Bronchi**
- Two branches of trachea that conduct air from trachea to each lung

**Bronchioles**
- Narrow passageways to conduct air from bronchi to alveoli

**Alveoli**
- Microscopic chambers for gas exchange

**Respiratory Muscles**
- Cause breathing

**Intercostal Muscles**
- Move ribs during breathing

**Diaphragm**
- Muscle sheet between chest and abdominal cavities with a role in breathing
Figure 14.3 The path of air during inhalation and exhalation.
Nose

- Upper respiratory system
  - Structure
    - Nasal septum divides the inside into two nasal cavities
    - Mucous membrane covers inner surfaces
  - Functions
    - Cleans incoming air
    - Warms and moistens air
    - Provides for the sense of smell
Figure 14.4 Cilia in healthy person (a) vs. cigarette smoker (b).

(a) The cilia are yellow in this color-enhanced electron micrograph. The cells without cilia secrete mucus.

(b) Cigarette smoke first paralyzes and then destroys the cilia. As a result, hazardous materials can accumulate on the surfaces of the air passageways.
Sinuses

- Upper respiratory system
  - Structure
    - Large air-filled spaces in the bones of the face
    - Connect to nasal cavities
  - Functions
    - Lighten head
    - Warm and moisten air
    - Part of the resonating chamber that affects voice
- Sinusitis = inflammation of the mucous membranes of the sinuses
Pharynx and Larynx

- Upper respiratory system (cont’d)
  - Pharynx (throat)
    - Space behind the nose and mouth
    - Passageway for food, drink, and air
    - Connected to the middle ear via auditory (Eustachian) tubes
      - Help equalize pressure
Pharynx and Larynx

- Upper respiratory system (cont’d)
  - Larynx (voice box or Adam’s apple)
    - Boxlike
    - Made primarily of cartilage
    - Serves as a selective entrance to the lower respiratory system
    - Source of the voice
Figure 14.5 The larynx.

(a) The epiglottis is open during breathing but covers the opening to the larynx during swallowing to prevent food or drink from entering the trachea.

(b) The vocal cords are the folds of connective tissue above the opening of the larynx (the glottis) that produce the voice.
Larynx

- The larynx as a selective entrance to the lower respiratory system
  - During swallowing, the larynx rises up and causes the epiglottis (a flap of cartilage) to cover the glottis (opening in the larynx through which air passes)
  - If this mechanism fails and food or drink accidentally enter the trachea, then
    - Coughing may expel material
    - Heimlich maneuver may dislodge material
A person who is choking cannot speak or breathe and needs immediate help. The **Heimlich maneuver** is a procedure intended to force a large burst of air out of the lungs and dislodge the object blocking air flow.

**Step 1:** Stand behind the choking person with arms around the waist.

**Step 2:** Make a fist and place the thumb of the fist beneath the victim’s rib cage about midway between the navel (belly button) and the breastbone.

**Step 3:** Grasp the fist with your other hand and deliver a rapid “bear hug” up and under the rib cage with the clenched fist. Be careful not to press on the ribs or the breastbone because doing so could cause serious injury.

**Step 4:** Repeat until the object is dislodged.
Larynx

- The larynx as the source of the voice
  - Vocal cords (two thick stands of tissue stretched over the glottis) vibrate and produce the voice
    - Tension of vocal cords determines pitch
      - Stretched and thin cords = higher pitch
  - Laryngitis
    - Inflammation of the larynx
    - Vocal cords become swollen and thick, causing voice to deepen
Trachea (Windpipe) and Bronchial Tree

- Lower respiratory system
  - Trachea
    - Tube held open by C-shaped rings of cartilage
    - Conducts air between environment and lungs
Trachea (Windpipe) and Bronchial Tree

- Lower respiratory system (cont’d)
  - Bronchial tree
    - Network of progressively smaller air tubes
      - Trachea divides into two air tubes called primary bronchi, each of which leads to a lung
      - Bronchi branch repeatedly within each lung, eventually forming bronchioles
        - Bronchioles terminate in alveoli (air sacs)
    - Bronchi are held open by cartilage; the amount of cartilage decreases as tubes get smaller
      - Bronchioles lack cartilage and have smooth muscle
Figure 14.7 *A resin cast of the bronchial tree of the lungs.*
Asthma

- Spasms of the bronchial muscles that severely restrict air flow
- Characterized by recurring attacks of wheezing and difficult breathing and persistent inflammation of the airways
- Inhalants
  - Relax bronchial muscles
  - Reduce inflammation of air tubules
Alveoli

- Lower respiratory system
  - Minute sacs where
    - Oxygen diffuses from the inhaled air into the blood
    - Carbon dioxide diffuses from the blood into the alveolar air to be exhaled

- Surfactant
  - Phospholipid molecules that coat alveoli and keep them open
  - Respiratory distress syndrome (RDS) occurs in some premature babies due to insufficient production of surfactant
Figure 14.8 Alveoli in the lungs.

(a) Each alveolus is a small air-filled sac. In this section, some of the alveoli have been cut open and you can see into them.

(b) Much of the surface of each alveolus is covered with capillaries. The interface provides a vast surface area for the exchange of gases between the alveoli and the blood.
Table 14.1 Review of Structures of the Respiratory System

<table>
<thead>
<tr>
<th>Structure</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper respiratory system</strong></td>
<td></td>
<td></td>
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<tr>
<td>Nasal cavity</td>
<td>Cavity within the nose, divided into right and left halves by nasal septum; has three shelflike bones</td>
<td>Filters and conditions (moistens and warms incoming air); olfaction (sense of smell)</td>
</tr>
<tr>
<td>Sinuses</td>
<td>Large, air-filled spaces in the bones of the face</td>
<td>Lessen the weight of the head; warm and moisten inhaled air</td>
</tr>
<tr>
<td>Pharynx (throat)</td>
<td>Chamber connecting nasal cavities to esophagus and larynx</td>
<td>Common passageway for air, food, and drink</td>
</tr>
<tr>
<td>Epiglottis</td>
<td>Flap of tissue reinforced with cartilage</td>
<td>Covers the glottis during swallowing</td>
</tr>
<tr>
<td>Larynx</td>
<td>Cartilaginous, boxlike structure between the pharynx and trachea that contains the vocal cords and the glottis</td>
<td>Allows air but not other materials to pass to the lower respiratory system; source of the voice</td>
</tr>
<tr>
<td><strong>Lower respiratory system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trachea</td>
<td>Tube reinforced with C-shaped rings of cartilage that leads from the larynx to the bronchi</td>
<td>The main airway; conducts air from larynx to bronchi</td>
</tr>
<tr>
<td>Bronchi (primary)</td>
<td>Two large branches of the trachea reinforced with cartilage</td>
<td>Conduct air from trachea to each lung</td>
</tr>
<tr>
<td>Bronchioles</td>
<td>Narrow passageways leading from bronchi to alveoli</td>
<td>Conduct air to alveoli; adjust airflow in lungs</td>
</tr>
<tr>
<td>Lungs</td>
<td>A pair of elastic structures within the thoracic (chest) cavity containing surfaces for gas exchange</td>
<td>Exchange oxygen and carbon dioxide between blood and air</td>
</tr>
<tr>
<td>Alveoli</td>
<td>Microscopic sacs within lungs, bordered by extensive capillary network</td>
<td>Provide immense, internal surface area for gas exchange</td>
</tr>
</tbody>
</table>
Mechanism of Breathing

- Air moves between the atmosphere and the lungs in response to pressure gradients
  - Air moves into lungs when pressure in atmosphere is greater than pressure in lungs
  - Air moves out of lungs when pressure in lungs is greater than pressure in atmosphere
- Pressure changes within the lungs, caused by changes in the size of the thoracic cavity, move air into and out of the lungs
Inhalation

- Also called inspiration
- Air moves into the lungs when the thoracic cavity increases in volume due to contraction of the diaphragm and intercostal muscles
- Air rushes in because pressure in lungs is less than pressure in atmosphere
- Active process involving muscle contraction
Exhalation

- Also called expiration
- Air moves out of the lungs when the diaphragm and intercostal muscles relax and the thoracic cavity decreases in volume
- Air moves out of the lungs because pressure in the lungs is greater than pressure in the atmosphere
- Typically a passive process without muscle contraction
Figure 14.9 Volume of the thoracic cavity during inhalation and exhalation.

Inhalation

- Rib cage moves up and out
- Intercostal muscles contract
- Diaphragm contracts and flattens

The chest cavity increases in size, and pressure within the lungs decreases.

The lungs expand, and air moves in.

Exhalation

- Rib cage moves down and inward
- Intercostal muscles relax
- Diaphragm relaxes and moves upward

The chest cavity decreases in size, and pressure within the lungs increases.

The lungs recoil, and air moves out.
The Volume of Air Moved Into or Out of the Lungs during Breathing

- Tidal volume
  - Volume of air inhaled or exhaled during a normal breath

- Inspiratory reserve volume
  - Volume of air that can be inhaled in addition to a normal breath

- Expiratory reserve volume
  - Volume of air that can be exhaled in addition to a normal breath
The Volume of Air Moved Into or Out of the Lungs during Breathing

- Vital capacity
  - Maximum volume of air that can be inhaled or exhaled in a single forced breath
  - Tidal volume + inspiratory reserve volume + expiratory reserve volume
- Residual volume
  - Volume of air remaining in lungs after maximum exhalation
- Total lung capacity
  - Total volume of air in lungs after maximal inhalation
  - Vital capacity + residual volume
Figure 14.10 A spirometer is used to measure the volumes of air in the lungs.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (~500 ml)</td>
<td>Amount of air inhaled or exhaled during an ordinary breath</td>
</tr>
<tr>
<td>Inspiratory reserve volume (~1900–3300 ml)</td>
<td>Amount of air that can be inhaled in addition to a normal breath</td>
</tr>
<tr>
<td>Expiratory reserve volume (~1000 ml)</td>
<td>Amount of air that can be exhaled in addition to a normal breath</td>
</tr>
<tr>
<td>Vital capacity (~3400–4800 ml)</td>
<td>Maximum amount of air that can be inhaled or exhaled in a single forced breath</td>
</tr>
<tr>
<td>Residual volume (~1100–1200 ml)</td>
<td>Amount of air remaining in the lungs after maximum exhalation</td>
</tr>
<tr>
<td>Total lung capacity (4500–6000 ml)</td>
<td>Total amount of air in the lungs after maximal inhalation (vital capacity + residual volume)</td>
</tr>
</tbody>
</table>
Transport of Gases between the Lungs and the Cells

- Three processes (review)
  - External respiration
    - Occurs in alveoli
    - Oxygen diffuses into blood and carbon dioxide diffuses from blood
  - Gas transport by the blood
  - Internal respiration
    - Occurs in tissues
    - Oxygen diffuses out of blood and into cells, and carbon dioxide diffuses out of cells and into blood
Figure 14.11 *Internal and external respiration.*

**O₂ = oxygen**

**CO₂ = carbon dioxide**

- **Internal respiration:** Gas exchange in capillary beds throughout body tissues
- **External respiration:** Gas exchange in lungs

Blood flow through the capillary network on the surface of the alveolus.

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Transport of Gases between the Lungs and the Cells

- Most oxygen carried in the blood is bound to hemoglobin, a protein in RBCs
  - Hemoglobin bound to oxygen is called oxyhemoglobin
- Carbon dioxide is removed by the blood in one of three ways
  1. Dissolved in blood plasma
  2. Carried by hemoglobin (carbaminohemoglobin)
  3. As a bicarbonate ion (most of carbon dioxide transport). Bicarbonate ions are an important part of the body’s acid-base buffering system
Respiratory Centers in the Brain

- Basic breathing pattern
  - Controlled by a breathing center located in the medulla
    - Within the breathing center is an inspiratory area and an expiratory area
  - Pattern of breathing can be voluntarily altered through impulses originating in the cerebral cortex
Figure 14.12 Neural and chemical controls of breathing.

**NEURAL CONTROLS**
- Cerebral cortex: Conscious control of breathing
- Medulla oblongata: Breathing center

**CHEMICAL CONTROLS**
- Medulla oblongata: Chemoreceptors respond to rising blood level of carbon dioxide (increased acidity, \( \text{H}^+ \)) and lowered blood level of oxygen
- Carotid bodies: Chemoreceptors respond to rising blood level of carbon dioxide and lowered blood level of oxygen
- Aortic bodies: Chemoreceptors respond to rising blood level of carbon dioxide and lowered blood level of oxygen

- Lungs
- Intercostal muscles
- Heart
- Diaphragm
Carbon Dioxide and Oxygen

- Carbon dioxide
  - Most important chemical influencing breathing rate
  - Chemoreceptors located in the medulla, aortic bodies, and carotid bodies
  - Increased carbon dioxide prompts increased breathing rate

- Oxygen
  - Does not influence breathing rate unless its blood levels fall dangerously low
  - Chemoreceptors located in the medulla, aortic bodies, and carotid bodies
Carbon Dioxide and Oxygen

The Human Respiratory System

When we inhale, oxygen enters the lungs, diffuses into the bloodstream, and is carried to tissues throughout the body. When we exhale, the bloodstream carries carbon dioxide from the tissues back to the lungs, where it is expelled. This tutorial illustrates the breathing mechanism and the processes of gas exchange in the lungs and in the body tissues.

Press "PLAY" to begin Animation.
Figure 14.13 The role of carbon dioxide in controlling the breathing rate.

Increased blood level of carbon dioxide (increased acidity, $H^+$)

Increased carbon dioxide level (increased acidity, $H^+$) in cerebrospinal fluid

Sensed by chemoreceptors in medulla

Sensed by peripheral chemoreceptors in aortic and carotid bodies

Breathing control center in medulla stimulated

Breathing rate increased (more carbon dioxide exhaled)

Carbon dioxide level in blood returns to normal
Respiratory Disorders

- Common cold
  - Caused by more than 200 different viruses
  - Typically lasts 1 to 2 weeks
  - Usually transmitted when a person handles an object that is contaminated with a virus and then touches mucous membranes
Respiratory Disorders

- Flu (influenza)
  - In humans, caused by three major types of viruses (A, B, and C), each with many variants
  - Symptoms more severe than those of a cold
  - Can be complicated by secondary infections such as pneumonia, bronchitis, and sinusitis
  - Vaccines are 60% to 70% effective
    - New strains constantly appear
Respiratory Disorders

- Pneumonia
  - An inflammation of the lungs
    - Fluid accumulates in the alveoli, reducing gas exchange
    - Bronchioles swell and narrow, making breathing difficult
  - Most commonly caused by a bacterial or viral infection
Respiratory Disorders

- Strep throat
  - Caused by *Streptococcus* bacteria
  - Soreness accompanied by swollen glands and fever
  - Can have serious consequences
    - Rheumatic fever
    - Kidney disease (glomerulonephritis)
  - If you have a sore throat, get a “strep test”
Respiratory Disorders

- Tuberculosis
  - Infection caused by the bacterium *Mycobacterium tuberculosis*
  - Transmitted through respiratory droplets
  - Results in fibrous tissue (tubercles) in the lungs
  - Can be fatal
Respiratory Disorders

- Bronchitis
  - Inflammation of the mucous membrane of the bronchi
  - Caused by viruses, bacteria, or chemical irritation
  - Inflammation results in the production of excess mucus, which triggers a deep cough
  - Can be acute or chronic
Respiratory Disorders

- Emphysema
  - Caused by the destruction of alveoli, usually by smoking
  - Results in:
    - Reduction in the surface area available for gas exchange
    - Increase in dead air space in lungs
  - Main symptom is shortness of breath
  - Can be treated but not cured
Figure 14.14 Comparison of (a) normal alveoli and (b) alveoli in an individual with emphysema.

(a) Normal alveoli

(b) Emphysema causes breakdown of alveolar walls.
Respiratory Disorders

- Lung cancer
  - 85% to 90% of cases are caused by smoking, and are therefore preventable
- Typical progression
  - Chronic inflammation of the lungs
  - Changes in the cells of the airway linings
  - Uncontrolled cell division forms a tumor
  - Cancer cells spread to other parts of the lung and rest of the body
Respiratory Disorders
Figure 14.15 *Lung cancer.*
You Should Now Be Able To:

- Know the detailed structures of the respiratory system
- Know and understand the mechanism of breathing and the transport of gases between the lungs and the cells and the volume of air moved into or out of the lungs during breathing
- Understand the roles of the respiratory centers in the brain
- Know the main respiratory disorders: common cold, flu, pneumonia, strep throat, bronchitis, chronic bronchitis, emphysema, lung cancer, and what is second hand smoke