Chapter 24

The Respiratory System

Lecture Presentation by
Steven Bassett
Southeast Community College
Introduction

- The respiratory system includes:
  - Nose
  - Nasal cavity
  - Sinuses
  - Pharynx
  - Larynx
  - Trachea
  - Bronchi
  - Bronchioles
  - Alveoli
The Upper Respiratory System

- Nose, nasal cavity, sinuses, and pharynx

The Lower Respiratory System

- Larynx, trachea, bronchi, bronchioles, and alveoli
An Overview of the Respiratory System and Respiratory Tract

• Functions of the Respiratory System
  • The following is a partial list of respiratory functions
    • Provides an area for gas exchange between the air and the blood
    • Protects the respiratory surfaces from dehydration (for example)
    • Provides protection against invading pathogens
    • Produces sound involved in verbal communication
    • Assists in the regulation of blood volume, blood pressure, and body fluid pH
An Overview of the Respiratory System and Respiratory Tract

• The Respiratory Epithelium
  • Consists of:
    • **Pseudostratified, ciliated, columnar cells**
      • Except for the pharynx, smaller bronchi, and alveoli
    • **Stratified squamous cells**
      • Found in the pharynx
    • **Mucus-producing cells**
      • Found in the nasal cavity
      • Found in the lower respiratory tract
An Overview of the Respiratory System and Respiratory Tract

• The Respiratory Epithelium
  • Function
    • **Ciliated columnar cells**
      • Move mucus in an upward manner (mucus escalator) so debris can be coughed out
    • **Stratified squamous cells**
      • Provide protection against abrasion
    • **Mucous cells**
      • Produce mucus so inhaled debris will get stuck and not enter the lungs

© 2015 Pearson Education, Inc.
An Overview of the Respiratory System and Respiratory Tract

• Protection of the Respiratory System
  • Hairs in the nose block some of the inhaled debris
    • Called *vibrissae*
  • Nasal cavity produces mucus to trap inhaled debris
    • Sneezing will remove this debris
  • Respiratory epithelium mucus will trap inhaled debris
    • Coughing will remove this debris
The Upper Respiratory System

- The following is the pathway of air
  - Air enters the **external nares**
  - Passes by the **nasal vestibule**
    - Area surrounded by the two pairs of alar cartilage
  - Enters the **nasal cavity**
  - Air flows in and around the **nasal conchae**
    - Inferior, middle, and superior conchae
    - As air swirls around the conchae, debris gets stuck in the mucus
    - As air swirls around the conchae, the air warms a bit before entering the trachea
The Upper Respiratory System

• The following is the pathway of air (continued)
  • Air enters the **internal nares**
  • Air enters the **nasopharynx area**
Figure 24.4a Respiratory Structures in the Head and Neck, Part II

A sagittal section of the head and neck

- Nasal conchae
  - Superior
  - Middle
  - Inferior
- Nasal vestibule
- Nasal cavity
- Superior
- Middle
- Inferior
- Internal nares
- Entrance to auditory tube
- Pharyngeal tonsil
- Pharynx
- Nasopharynx
- Oropharynx
- Laryngopharynx
- Epiglottis
- Aryepiglottic fold
- Glottis
- Vocal fold
- Esophagus
- Frontal sinus
- Trachea
- Cricoid cartilage
- Thyroid cartilage
- Thyroid gland
- Hard palate
- Oral cavity
- Tongue
- Soft palate
- Mandible
- Palatine tonsil
- Lingual tonsil
- Hyoid bone
- External nares
- Nasal vestibułe
The Upper Respiratory System

• The Nose and Nasal Cavity
  • The nose consists of:
    • Nasal bones
    • Nasal septum
      • Vomer and perpendicular plate of the ethmoid
    • Cartilage
    • External nares
    • Alar cartilage
    • Dorsum and apex of the nose
    • Nasal conchae
Figure 24.3 Respiratory Structures in the Head and Neck, Part I

Lateral nasal cartilage

Dorsum of nose

Major alar cartilage

Apex

Minor alar cartilage

External nares

© 2015 Pearson Education, Inc.
The Upper Respiratory System

• The Pharynx
  • The pharynx is a passageway that connects the nose to the mouth to the throat
    • Nasopharynx
      • The back of the nose area
    • Oropharynx
      • The back of the mouth area
      • Consists of pharyngeal arch and uvula
    • Laryngopharynx
      • The area that has the entrance to the trachea and esophagus
A sagittal section of the head and neck
Figure 24.5 Respiratory Structures in the Head and Neck, Part III (2 of 2)
The Lower Respiratory System

• The Larynx
  • A cylinder whose cartilaginous walls are stabilized by ligaments or skeletal muscles or both
  • Begins at the level of vertebra C₃ or C₄
  • Ends at the level of vertebra C₇
The Lower Respiratory System

- Unpaired Cartilages of the Larynx
  - **Thyroid cartilage**
    - Contains the laryngeal prominence
  - **Cricoid cartilage**
    - Unpaired cartilage
  - **Epiglottis**
    - Closes over the glottis during swallowing of food
    - Unpaired cartilage
Figure 24.6a Anatomy of the Larynx

- Epiglottis
- Lesser cornu
- Hyoid bone
- Thyrohyoid ligament (extrinsic)
- Laryngeal prominence
- Thyroid cartilage
- Cricoid cartilage
- Cricothyroid ligament (intrinsic)
- Cricotracheal ligament (extrinsic)
- Tracheal cartilages

a Anterior view of the intact larynx
The Lower Respiratory System

• Paired Cartilages of the Larynx
  • **Laryngeal cartilages**
  • Some play a role in the opening and closing of the glottis
  • Consists of:
    • **Arytenoid cartilages**
    • **Corniculate cartilages**
    • **Cuneiform cartilages**
Figure 24.6b Anatomy of the Larynx

- Epiglottis
- Thyroid cartilage
- Cricoid cartilage
- Vestibular ligament
- Vocal ligament
- Arytenoid cartilage
- Tracheal cartilages

**b** Posterior view of the intact larynx
Glottis in the open position.
The Lower Respiratory System

• Laryngeal Ligaments
  • **Intrinsic laryngeal ligaments**
    • Bind the laryngeal cartilages together
  • **Extrinsic laryngeal ligaments**
    • Bind the thyroid cartilage to the hyoid bone and cricoid cartilage
  • **Vestibular and vocal ligaments**
    • Extend between the thyroid cartilage and the arytenoids.
The Lower Respiratory System

• Sound Production by the Vocal Cords
  • Air passing between the vocal cords creates sound
    • Pitch depends on the diameter, length, and tension in the vocal cords
      • Children have slender, short vocal folds thus creating a high-pitched sound
      • At puberty, the vocal cords of males become thicker and longer thus producing a deeper voice than females
    • Amplification of sound occurs in the sinus cavities
  • Production of definite sounds depends on movement of the lips, tongue, and cheeks
Figure 24.7ab The Vocal Cords

(a) Glottis in the open position.

(b) Glottis in the closed position.

Coriniculate cartilage
Cuneiform cartilage
Vestibular fold
Vocal fold
Epiglottis
Root of tongue

Glottis (open)
Aryepiglottic fold

Glottis (closed)
Vocal fold
Vestibular fold
Epiglottis

© 2015 Pearson Education, Inc.
The Lower Respiratory System

• Laryngeal Musculature
  • **Intrinsic muscles**
    • Regulate tension of the vocal cords
    • Open and close the glottis
  • **Extrinsic muscles**
    • Position and stabilize the larynx
Figure 24.8 Movements of the Larynx during Swallowing

1. Tongue forces compacted bolus into oropharynx

2. Laryngeal movement folds epiglottis; pharyngeal muscles push bolus into esophagus

3. Bolus moves along esophagus; larynx returns to normal position
The Trachea

• Characteristics of the Trachea
  • Size
    • 11 cm long and 2.5 cm diameter
  • Bifurcates at the carina into the right and left bronchi at T₅
  • Contains 15–20 tracheal cartilages
    • Each cartilage ring is actually C-shaped, not a complete ring
    • Connecting one cartilage ring to another are annular ligaments
Figure 24.9a Anatomy of the Trachea and Primary Bronchi

- Hyoid bone
- Larynx
- Trachea
- Annular ligaments
- Tracheal cartilages
- Location of carina (internal ridge)
- Root of right lung
- Superior lobar bronchus
- Lung tissue
- Middle lobar bronchus
- Primary bronchi
- Secondary bronchi
- Inferior lobar bronchi
- Superior lobar bronchus

Anterior view showing the plane of section for part (b)
The Trachea

• Characteristics of the Trachea (continued)
  • The lining consists of:
    • Respiratory epithelia
    • Lamina propria
    • Submucosa
  • The posterior side of the cartilage ring is the trachealis muscle
    • This muscle allows for constriction and dilation of the trachea
Histological cross-sectional view of the trachea showing its relationship to surrounding structures.
The Primary Bronchi

- The trachea branches at the carina
  - The branching forms the left and right primary bronchi
  - The primary bronchi enter into each lung
  - The right primary bronchus is steeper and larger in diameter than the left
    - Hence, a person can aspirate foreign objects into the right lung easier than the left lung
Figure 24.12a The Bronchial Tree and Divisions of the Lungs

Gross anatomy of the lungs showing the bronchial tree and its divisions.
The Primary Bronchi

- Each primary bronchus enters the lung at the point called the **hilum**
  - The hilum is also the point of entrance and exit of the pulmonary blood vessels
- The combination of the bronchus, artery, and vein is called the **root**
Anterior view of the opened chest showing the relative positions of the left and right lungs and heart.
Diagrammatic views of the lateral surfaces of the isolated right and left lungs

**RIGHT LUNG**
- Apex
- Superior lobe
- Middle lobe
- Oblique fissure
- Inferior lobe
- Base

**LEFT LUNG**
- Apex
- Superior lobe
- Cardiac notch
- Oblique fissure
- Inferior lobe
- Base
Diagrammatic views of the medial surfaces of the isolated right and left lungs

- Apex
- Superior lobar bronchus
- Pulmonary arteries
- Middle lobar bronchus
- Superior lobar bronchus
- Inferior lobar bronchus
- Pulmonary veins
- Horizontal fissure
- Oblique fissure
- Groove for esophagus
- Superior lobe
- Middle lobe
- Inferior lobe
- Hilum
- Groove for aorta
- Oblique fissure
- Diaphragmatic surface
- Right Lung
- Left Lung

© 2015 Pearson Education, Inc.
The Lungs

• Structure of the Lungs
  • The apex points superiorly and the base inferiorly
  • The right lung has three lobes
    • Superior, middle, and inferior lobes
    • Consists of a horizontal fissure and an oblique fissure
  • The left lung has two lobes
    • Superior and inferior lobes
    • Contains the oblique fissure
    • Left lung has a cardiac notch
Diagrammatic views of the lateral surfaces of the isolated right and left lungs.
The Lungs

• Structure of the Lungs
  • Lung surfaces
    • Costal surface
    • Mediastinal surface
    • Diaphragmatic surface
The Lungs

• The Pulmonary Bronchi
  • The primary bronchi branch numerous times once inside the lungs (outside the lungs they are called *extrapulmonary bronchi* while inside the lungs they are called *intrapulmonary bronchi*)
  • Each primary bronchus divides to form:
    • *Secondary bronchi* and *tertiary bronchi*
    • Each tertiary bronchus goes to a specific lung area called a *bronchopulmonary segment*
Figure 24.11 Bronchi and Bronchioles

- Primary bronchus
- Cartilage ring
- Root of lung
- Secondary (or inferior lobar) bronchus
- Cartilage plates
- Visceral pleura
- Tertiary (or segmental) bronchi
- Bronchioles

**BRONCHIOLE**

- Respiratory epithelium
- Smooth muscle

© 2015 Pearson Education, Inc.
The Lungs

• Branches of the Right Primary Bronchus
  • Divides into three secondary bronchi
    • Superior lobar bronchus
    • Middle lobar bronchus
    • Inferior lobar bronchus
Figure 24.9a Anatomy of the Trachea and Primary Bronchi

- Hyoid bone
- Larynx
- Annular ligaments
- Tracheal cartilages
- Location of carina (internal ridge)
- Root of right lung
- Superior lobar bronchus
- Lung tissue
- Root of left lung
- Secondary bronchi
- Middle lobar bronchus
- Inferior lobar bronchi
- Superior lobar bronchus

RIGHT LUNG

LEFT LUNG

Anterior view showing the plane of section for part (b)
Figure 24.9b Anatomy of the Trachea and Primary Bronchi

Histological cross-sectional view of the trachea showing its relationship to surrounding structures

© 2015 Pearson Education, Inc.
The Lungs

• Branches of the Left Primary Bronchus
  • Divides into two secondary bronchi
    • Superior lobar bronchus
    • Inferior lobar bronchus
Figure 24.9a Anatomy of the Trachea and Primary Bronchi

- Hyoid bone
- Larynx
- Trachea
- Annular ligaments
- Tracheal cartilages
- Location of carina (internal ridge)
- Root of right lung
- Superior lobar bronchus
- Lung tissue
- Middle lobar bronchus
- Primary bronchi
- Secondary bronchi
- Inferior lobar bronchus
- Root of left lung
- Superior lobar bronchus

Anterior view showing the plane of section for part (b)
Figure 24.9b Anatomy of the Trachea and Primary Bronchi

**Histological cross-sectional view of the trachea showing its relationship to surrounding structures**
The Lungs

• Branches of the Secondary Bronchi
  • The secondary bronchi divides to form tertiary bronchi
    • The right lung has 10 tertiary bronchi and therefore 10 bronchopulmonary segments
    • The left lung has 9 tertiary bronchi and therefore 9 bronchopulmonary segments
Gross anatomy of the lungs showing the bronchial tree and its divisions.
Isolated left and right lungs have been colored to show the distribution of the bronchopulmonary segments.
The Lungs

• The Bronchioles
  • Tertiary bronchi give rise to bronchioles
    • Bronchioles have a diameter of 0.3–0.5 mm
    • They are self-supporting and therefore do not require cartilage plates
    • Consist of smooth muscle for bronchodilation (sympathetic stimulation) and bronchoconstriction (parasympathetic stimulation)
  • Bronchioles terminate with clusters of alveolar sacs
Figure 24.11 Bronchi and Bronchioles

- Primary bronchus
- Cartilage ring
- Root of lung
- Secondary (or inferior lobar) bronchus
- Cartilage plates
- Visceral pleura
- Secondary (or superior lobar) bronchus
- Respiratory bronchioles
- Terminal bronchiole
- Lobule
- Bronchioles

© 2015 Pearson Education, Inc.
The Lungs

• Alveolar Ducts and Alveoli
  • Each lung has about 150 million alveoli
  • Extensive network of capillaries surrounds each alveolus
    • Capillaries drop off carbon dioxide and pick up oxygen
  • Elastic tissue surrounds each alveolus
    • Maintains the shape and position of each alveolus during inhalation and exhalation
The structure of one portion of a single pulmonary lobule

- Bronchopulmonary segment
- Trachea
- Left primary bronchus
- Visceral pleura
- Secondary bronchus
- Tertiary bronchi
- Smaller bronchi
- Bronchioles
- Bronchiole
- Respiratory bronchiole
- Terminal bronchiole
- Respiratory epithelium
- Bronchiolus
- Bronchial artery (red), vein (blue), and nerve (yellow)
- Elastic fibers
- Branch of pulmonary artery
- Smooth muscle around terminal bronchiole
- Capillary beds
- Arteriole
- Lymphatic vessel
- Alveolar duct
- Alveolar sac
- Interlobular septum
- Alveoli
- Pleural cavity
- Visceral pleura
- Parietal pleura
The Lungs

• The Alveolus and the Respiratory Membrane
  • The cells associated with alveoli
    • The lining consists of a single layer of **squamous cells**
      • These are called **type I pneumocytes**
    • **Type II pneumocytes** are scattered among the type I pneumocytes
      • Type II pneumocytes secrete surfactant
    • Surfactant prevents alveolar collapse
    • **Alveolar macrophages** wander around phagocytizing particulate matter
Basic structure of a lobule, cut to reveal the arrangement between the alveolar ducts and alveoli. A network of capillaries surrounds each alveolus. These capillaries are surrounded by elastic fibers.
b SEM of lung tissue showing the appearance and organization of the alveoli.
The Lungs

• The Alveolus and the Respiratory Membrane
  • Gas exchange at the alveoli
    • *Pulmonary arteries* transport carbon dioxide to the alveolar capillaries
    • Carbon dioxide leaves the capillaries and enters the alveolar sacs
    • Oxygen leaves the alveolar sacs and enters the capillaries
    • Oxygen enters the *pulmonary veins* and returns to the heart to be pumped to all parts of the body
The structure of one portion of a single pulmonary lobule
The respiratory membrane.
The Pleural Cavities and Pleural Membranes

- The right and left pleural cavities are separated by the mediastinum.
- Each lung is lined by a serous membrane.
  - The membrane is made of two continuous layers.
    - **Visceral pleura** portion covers the outer surface of the lung.
    - **Parietal pleura** portion covers the inside lining of the thoracic wall.
  - The space created between the visceral and parietal is the **pleural cavity**.
The Pleural Cavities and Pleural Membranes

• The pleural cavity between the visceral and parietal membranes consists of:
  • **Pleural fluid**
    • Reduces friction when the lungs move upon inhalation and exhalation
  • **Pleurisy**
    • A condition in which the membranes produce too much pleural fluid or the membranes adhere to the thoracic wall thereby resulting in pain upon inhalation and exhalation
Figure 24.15 Anatomical Relationships in the Thoracic Cavity

- Pericardial cavity
- Right lung, middle lobe
- Oblique fissure
- Right pleural cavity
- Atria
- Esophagus
- Aorta
- Right lung, inferior lobe
- Spinal cord
- Body of sternum
- Ventricles
- Rib
- Left lung, superior lobe
- Visceral pleura
- Left pleural cavity
- Parietal pleura
- Bronchi
- Posterior mediastinum
- Left lung, inferior lobe
Respiratory Muscles and Pulmonary Ventilation

• Respiratory Muscles
  • The muscles involved in pulmonary ventilation (breathing) are:
    • Diaphragm
    • External intercostals
    • Internal intercostals
Respiratory Muscles and Pulmonary Ventilation

• Diaphragm
  • Contracts (lowers) to cause inhalation
  • Relaxes (raises) to cause exhalation

• External intercostals
  • Elevate the ribs to aid in inhalation

• Internal intercostals
  • Depress the ribs to aid in exhalation
The Respiratory Muscles

**Accessory Respiratory Muscles (Inhalation)**
- Sternocleidomastoid muscle
- Scalene muscles
- Pectoralis minor muscle
- Serratus anterior muscle

**Primary Respiratory Muscles (Inhalation)**
- Diaphragm

**Accessory Respiratory Muscles (Exhalation)**
- External intercostal muscles
- Serratus anterior muscle
- Diaphragm
- Transversus thoracis muscle
- External oblique muscle
- Rectus abdominis
- Internal oblique muscle
The Mechanics of Breathing

Ribs and sternum elevate

Diaphragm contracts
Inhalation
Inhalation is an active process. It primarily involves the diaphragm and the external intercostal muscles, with assistance from the accessory respiratory muscles as needed.

**KEY**

- = Movement of rib cage
- = Movement of diaphragm
- = Muscle contraction

**Accessory Respiratory Muscles (Inhalation)**
- Sternocleidomastoid muscle
- Scalene muscles
- Pectoralis minor muscle
- Serratus anterior muscle

**Primary Respiratory Muscles (Inhalation)**
- External intercostal muscles
- Diaphragm
Respiratory Muscles and Pulmonary Ventilation

• Respiratory Movements
  • Respiratory movements can be classified two ways: eupnea or hyperpnea

  • **Eupnea**: quiet breathing
    • May involve diaphragmatic breathing or costal breathing or both
    • During pregnancy, due to the uterus pushing upward on the diaphragm, women typically use costal breathing

  • **Hyperpnea**: forced breathing
    • Generally requires the use of accessory breathing muscles
Respiratory Changes at Birth

• Prior to Birth
  • Pulmonary arterial resistance is high
    • Pulmonary vessels are collapsed
  • Rib cage is compressed
  • Lungs and passageways contain no air but do contain small amounts of fluid

• At Birth
  • Air enters and forces the fluid out
  • Closure of:
    • Foramen ovale and ductus arteriosus
Respiratory Centers of the Brain

- There are three pairs of nuclei in the pons and medulla oblongata that regulate the respiratory muscles
  - The **respiratory rhythmicity center** sets the respiratory pace
  - The **apneustic center** adjusts the respiratory pace
  - The **pneumotaxic center** adjusts the respiratory pace
Figure 24.17 Respiratory Centers and Reflex Controls

- **Higher centers**: Cerebral cortex, Limbic system, Hypothalamus
- **Respiratory Rhythmicity Centers**: Dorsal respiratory group (DRG), Ventral respiratory group (VRG)
- **Chemoreceptors and baroreceptors**: Carotid and aortic sinuses
- **Stretch receptors of lungs**: Diaphragm
- **Motor neurons**: Controlling diaphragm, other respiratory muscles
- **CSF Chemoreceptors**: Pons
- **Phrenic nerve**: Medulla oblongata

KEY:
- = Stimulation
- = Inhibition
Respiratory Muscles and Pulmonary Ventilation

- There are three different reflexes involved in respiration:
  - **Mechanoreceptor reflexes**
    - Respond to changes in lung volume or changes in blood pressure
  - **Chemoreceptor reflexes**
    - Respond to changes in partial pressures of carbon dioxide and oxygen
    - Respond to changes in pH
  - **Protective reflexes**
    - Respond to physical injury or irritation
Aging and the Respiratory System

• The respiratory system becomes less efficient as we age

• Noteworthy changes include:
  • Elastic tissue begins to deteriorate
    • Lungs cannot expand or constrict as much as they used to
  • Movements of the ribs are restricted due to arthritis
  • Some degree of emphysema, which hinders breathing
  • With age, roughly 1 square foot of respiratory membrane is lost each year after age 30