The Respiratory System

- Basic functions of the respiratory system
  - Supplies body with oxygen
  - Disposes of carbon dioxide
- Four processes involved in respiration
  - Pulmonary ventilation
  - External respiration
  - Transport of respiratory gases
  - Internal respiration

Functional Anatomy of the Respiratory System

- Respiratory organs
  - Nose, nasal cavity, and paranasal sinuses
  - Pharynx, larynx, and trachea
  - Bronchi and smaller branches
  - Lungs and alveoli

Organs of the Respiratory System

- Divided into
  - Conducting zone
  - Respiratory zone

The Nose

- Provides an airway for respiration
- Moistens and warms air
- Filters inhaled air
- Resonating chamber for speech
- Houses olfactory receptors
The Nose
- Size variation due to differences in nasal cartilages
- Skin is thin—contains many sebaceous glands

The Nasal Cavity
- External nares—nostrils
- Divided by nasal septum
- Continuous with nasopharynx
  - Posterior nasal apertures—choanae

Nasal Cavity
- Two types of mucous membrane
  - Olfactory mucosa
    - Near roof of nasal cavity
    - Houses olfactory (smell) receptors
  - Respiratory mucosa
    - Lines nasal cavity
    - Epithelium is pseudostratified ciliated columnar

Respiratory Mucosa
- Consists of
  - Pseudostratified ciliated columnar epithelium
  - Goblet cells within epithelium
  - Underlying layer of lamina propria
  - Cilia move contaminated mucus posteriorly

Nasal Conchae
- Superior and middle nasal conchae
  - Part of the ethmoid bone
- Inferior nasal conchae
  - Separate bone
  - Project medially from the lateral wall of the nasal cavity
  - Particulate matter
    - Deflected to mucus-coated surfaces
The Pharynx

- Funnel-shaped passageway
- Connects nasal cavity and mouth
- Divided into three sections by location
  - Nasopharynx
  - Oropharynx
  - Laryngopharynx
- Type of mucosal lining changes along its length

The Nasopharynx

- Superior to the point where food enters
- Only an air passageway
- Closed off during swallowing
- Pharyngeal tonsil (adenoids)
  - Located on posterior wall
  - Destroys entering pathogens
- Contains the opening to the pharyngotympanic tube (auditory tube)
  - Tubal tonsil
    - Provides some protection from infection

The Oropharynx

- Arch-like entranceway—fauces
  - Extends from soft palate to the epiglottis
- Epithelium
  - Stratified squamous epithelium
- Two types of tonsils in the oropharynx
  - Palatine tonsils—in the lateral walls of the fauces
  - Lingual tonsils—covers the posterior surface of the tongue

The Laryngopharynx

- Passageway for both food and air
- Epithelium
  - Stratified squamous epithelium
- Continuous with the esophagus and larynx

The Larynx

- Three functions
  - Voice production
  - Provides an open airway
  - Routes air and food into the proper channels
    - Superior opening is
      - Closed during swallowing
      - Open during breathing

Nine Cartilages of the Larynx

- Thyroid cartilage
  - Shield-shaped, forms laryngeal prominence (Adam's apple)
- Three pairs of small cartilages
  - Arytenoid cartilages
  - Corniculate cartilages
  - Cuneiform cartilages
- Epiglottis
  - Tips inferiorly during swallowing
The Larynx

- Vocal ligaments of the larynx
  - Vocal folds (true vocal cords)
    - Act in sound production
  - Vestibular folds (false vocal cords)
    - No role in sound production
- Epithelium of the larynx
  - Stratified squamous—superior portion
  - Pseudostratified ciliated columnar—inferior portion

Anatomy of the Larynx

The Trachea

- Descends into the mediastinum
- C-shaped cartilage rings keep airway open
- Carina
  - Marks where trachea divides into two primary bronchi
- Epithelium
  - Pseudostratified ciliated columnar

Movements of the Vocal Folds

- Vocal folds in closed position; closed glottis
- Vocal folds in open position; open glottis

Voice production

- Length of the vocal folds changes with pitch
- Loudness depends on the force of air across the vocal folds
- Sphincter function of the larynx
  - Valsalva’s maneuver—straining
- Innervation of the larynx
  - Recurrent laryngeal nerves (branch of vagus)
The Trachea

(a) Cross section of the trachea and esophagus

- Hyaline cartilage
- Submucosa
- Mucosa
- Seromucous gland in submucosa
- Lumen of trachea
- Anterior
- Esophagus
- Trachealis muscle
- Adventitia

(b) Photomicrograph of the tracheal wall (250×)

- Hyaline cartilage
- Lamina propria (connective tissue)
- Submucosa
- Mucosa
- Seromucous gland
- Pseudostratified ciliated columnar epithelium

Bronchi in the Conducting Zone

- Bronchial tree
  - Extensively branching respiratory passageways
    - Primary bronchi (main bronchi)
      - Largest bronchi
      - Right main bronchi
      - Wider and shorter than the left

Bronchi in the Conducting Zone

- Secondary (lobar) bronchi
  - Three on the right
  - Two on the left

- Tertiary (segmental) bronchi
  - Branch into each lung segment

- Bronchioles
  - Little bronchi, less than 1 mm in diameter

- Terminal bronchioles
  - Less than 0.5 mm in diameter

 Bronchi in the Conducting Zone

- Superior lobe of right lung
- Middle lobe of right lung
- Inferior lobe of right lung
- Superior lobe of left lung
- Left main (primary) bronchus
- Lobar (secondary) bronchus
- Segmental (tertiary) bronchus
- Inferior lobe of left lung

(a) The branching of the bronchial tree

(b) Photomicrograph of a bronchus (13×)

- Mucosa
- Pseudostratified epithelium
- Lamina propria
- Fibromusculo-cartilaginous layer
- Cartilage plate
- Smooth muscle

Bronchi in the Conducting Zone

- Changes in Tissue Composition along Conducting Pathways
  - Supportive connective tissues change
  - C-shaped rings replaced by cartilage plates
  - Epithelium changes
    - First, pseudostratified ciliated columnar
    - Replaced by simple columnar, then simple cuboidal epithelium
  - Smooth muscle becomes important
  - Airways widen with sympathetic stimulation
  - Airways constrict under parasympathetic direction
Structures of the Respiratory Zone

- Consists of air-exchanging structures
- **Respiratory bronchioles**—branch from terminal bronchioles
  - Lead to **alveolar ducts**
  - Lead to **alveolar sacs**

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Figure 22.9a

- **Alveolar duct**
- **Alveoli**
- **Respiratory bronchioles**
- **Terminal bronchiole**

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Figure 22.9b

- **Alveolar pores**
- **Alveolar duct**
- **Respiratory bronchiole**
- **Alveoli**

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Structures of the Respiratory Zone

- **Alveoli**
  - ~300 million alveoli account for tremendous surface area of the lungs
  - Surface area of alveoli is ~140 square meters

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Structures of the Respiratory Zone

- Structure of alveoli
  - **Type I cells**—single layer of simple squamous epithelial cells
  - Surrounded by basal lamina
  - Alveolar and capillary walls plus their basal lamina form the ...
  - **Respiratory membrane**

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Structures of the Respiratory Zone

- Structures of alveoli (continued)
  - **Type II cells**—scattered among type I cells
    - Are cuboidal epithelial cells
    - Secrete **surfactant**
      - Reduces surface tension within alveoli—keeps alveoli from collapsing when we exhale
  - **Alveolar macrophages**
Anatomy of Alveoli and the Respiratory Membrane

- Elastic fibers
- Smooth muscle
- Alveolus
- Capillaries

(c) Detailed anatomy of the respiratory membrane

The Respiratory Zone

- Features of alveoli
  - Surrounded by elastic fibers
  - Interconnect by way of alveolar pores
  - Internal surfaces
    - A site for free movement of alveolar macrophages

Gross Anatomy of the Lungs

- Major landmarks of the lungs
  - Apex, base, hilum, and root
  - Left lung
    - Superior and inferior lobes
    - Fissures—oblique
  - Right lung
    - Superior, middle, and inferior lobes
    - Fissures—oblique and horizontal

Gross Anatomy of the Lungs

Anterior View of Thoracic Structures

Bronchopulmonary Segments

Right lung
- Right superior lobe (3 segments)
- Right middle lobe (2 segments)
- Right inferior lobe (5 segments)

Left lung
- Left superior lobe (5 segments)
- Left inferior lobe (5 segments)
Blood Supply and Innervation of the Lungs

- **Pulmonary arteries**
  - Deliver oxygen-poor blood to the lungs
- **Pulmonary veins**
  - Carry oxygenated blood to the heart
- **Bronchial arteries (2 on left, 1 on right)**
  - Supply systemic (oxygenated) blood to the lung structures (enter lung’s medial surface along with the large pulmonary vessels)
- **Innervation**
  - Sympathetic, parasympathetic, and visceral sensory fibers
  - Parasympathetic—constrict airways
  - Sympathetic—dilate airways

The Pleurae

- A double-layered sac surrounding each lung
  - Parietal pleura
  - Visceral pleura
- **Pleural cavity**
  - Potential space between the visceral and parietal pleurae
- **Pleurae help divide the thoracic cavity**
  - Central mediastinum
  - Two lateral pleural compartments

Location of Lungs in Thoracic Cavity

- Two phases of **pulmonary ventilation**
  - Inspiration—inhalaion
  - Expiration—exhalation

The Mechanisms of Ventilation
**Inspiration**

- Volume of thoracic cavity increases
  - Decreases internal gas pressure
  - Action of the diaphragm
    - Diaphragm flattens
  - Action of intercostal muscles
  - Contraction raises the ribs

**Expiration**

- Quiet expiration—chiefly a passive process
  - Inspiratory muscles relax
  - Diaphragm moves superiority
  - Volume of thoracic cavity decreases
  - Forced expiration—an active process
    - Produced by contraction of
      - Internal and external oblique muscles
      - Transverse abdominis muscles

**Changes in Thoracic Volume**

- **At rest**, air pressure in the thoracic cavity is equal to atmospheric (air) pressure. Pressure in the pleural cavity is less than atmospheric; the difference keeps the lungs inflated.
- **Inspiration**: Inspiratory muscles contract and increase the volume of the thoracic and pleural cavities. Pleural fluid in the pleural cavity allows the parietal and visceral pleura to slide over each other, increasing the volume and allowing the lungs to expand. As the volume increases, the pressure decreases, and air flows into the lungs.
- **Expiration**: Inspiratory muscles relax, reducing thoracic and pleural cavity volumes. The pleural cavity and the lungs decrease, causing pressure to increase. As the pressure increases, air flows out. Resting state is reestablished.

**Neural Control of Ventilation**

- Most important respiratory center
  - VRG—ventral respiratory group
    - Located in reticular formation in the medulla oblongata
    - Neurons generate respiratory rhythm
Respiratory Centers in the Brain Stem

Ventral respiratory group (VRG) contains rhythm generators whose output drives respiration.

Pontine respiratory centers interact with the medullary respiratory centers to smooth the respiratory pattern.

Dorsal respiratory group (DRG) integrates peripheral sensory input and modifies the rhythms generated by the VRG.

Neural Control of Ventilation

- Respiratory center
  - Generates baseline respiration rate
  - In the reticular formation of the medulla oblongata
- Chemoreceptors
  - Sensitive to rising and falling oxygen levels
  - Central chemoreceptors—located in medulla
  - Peripheral chemoreceptors
    - Aortic bodies
    - Carotid bodies

Location of Peripheral Chemoreceptors

Disorders of Lower Respiratory Structures

- Bronchial asthma
  - A type of allergic inflammation
  - Hypersensitivity to irritants in the air or to stress
  - Asthma attacks characterized by
    - Contraction of bronchiole smooth muscle
    - Secretion of mucus in airways
- Cystic fibrosis (CF)—inherited disease
  - Exocrine gland function is disrupted
  - Respiratory system affected by
    - Oversecretion of viscous mucus
- Chronic obstructive pulmonary disease (COPD)
  - Airflow into and out of the lungs is difficult
    - Obstructive emphysema
    - Chronic bronchitis
    - History of smoking
Disorders of Lower Respiratory Structures

- Tobacco smoke
- Air pollution
- Chronic bronchitis
- Bronchial asthma
- Connective tissue breakdown
- Emphysema
- Destruction of alveolar walls
- Loss of lung elasticity
- Air trapping
- Alveolar destruction

Figure 22.18

Alveolar Changes in Emphysema

(a) Scanning electron micrograph of alveoli from a normal lung
(b) Scanning electron micrograph of alveoli from a patient with emphysema

Figure 22.19

Disorders of Upper Respiratory Structures

- Epistaxis—nosebleed

The Respiratory System Throughout Life

- By week 4 of development
  - Olfactory placodes appear
  - Invaginate to form olfactory pits
  - Laryngotracheal bud
    - Forms trachea, bronchi, and bronchi subdivisions
    - Reaches functional maturity late in development
  - At birth, only one-sixth of alveoli are present
  - Those who begin smoking as teenagers
    - Lungs never fully develop
    - Additional alveoli never form

The Respiratory System Throughout Life

- Number of glands in the nasal mucosa declines
- Nose dries
  - Produces thickened mucus
  - Thoracic wall becomes more rigid
- Lungs lose elasticity
- Oxygen levels in the blood may fall

Aging of the Respiratory System