Chapter 13
The Respiratory System

Slides 13.1 – 13.30
Lecture Slides in PowerPoint by Jerry L. Cook

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Organs of the Respiratory system

- Nose
- Pharynx
- Larynx
- Trachea
- Bronchi
- Lungs – alveoli
Function of the Respiratory System

- Oversees gas exchanges between the blood and external environment
- Exchange of gasses takes place within the lungs in the alveoli
- Passageways to the lungs purify, warm, and humidify the incoming air
The Nose

- The only externally visible part of the respiratory system
- Air enters the nose through the external nares (nostrils)
- The interior of the nose consists of a nasal cavity divided by a nasal septum
Figure 13.2
Anatomy of the Nasal Cavity

- Olfactory receptors are located in the mucosa on the superior surface
- The rest of the cavity is lined with respiratory mucosa
  - Moistens air
  - Traps incoming foreign particles
Anatomy of the Nasal Cavity

- Lateral walls have projections called conchae
  - Increases surface area
  - Increases air turbulence within the nasal cavity
- The nasal cavity is separated from the oral cavity by the palate
  - Anterior hard palate (bone)
  - Posterior soft palate (muscle)
Paranasal Sinuses

- Cavities within bones surrounding the nasal cavity
  - Frontal bone
  - Sphenoid bone
  - Ethmoid bone
  - Maxillary bone
Paranasal Sinuses

- Function of the sinuses
  - Lighten the skull
  - Act as resonance chambers for speech
  - Produce mucus that drains into the nasal cavity
Pharynx (Throat)

- Muscular passage from nasal cavity to larynx

- Three regions of the pharynx
  - Nasopharynx – superior region behind nasal cavity
  - Oropharynx – middle region behind mouth
  - Laryngopharynx – inferior region attached to larynx

- The oropharynx and laryngopharynx are common passageways for air and food
Structures of the Pharynx

- Auditory tubes enter the nasopharynx
- Tonsils of the pharynx
  - Pharyngeal tonsil (adenoids) in the nasopharynx
  - Palatine tonsils in the oropharynx
  - Lingual tonsils at the base of the tongue
Larynx (Voice Box)

- Routes air and food into proper channels
- Plays a role in speech
- Made of eight rigid hyaline cartilages and a spoon-shaped flap of elastic cartilage (epiglottis)
Structures of the Larynx

- **Thyroid cartilage**
  - Largest hyaline cartilage
  - Protrudes anteriorly (Adam’s apple)

- **Epiglottis**
  - Superior opening of the larynx
  - Routes food to the larynx and air toward the trachea
Structures of the Larynx

- Vocal cords (vocal folds)
  - Vibrate with expelled air to create sound (speech)
- Glottis – opening between vocal cords
Trachea (Windpipe)

- Connects larynx with bronchi
- Lined with ciliated mucosa
  - Beat continuously in the opposite direction of incoming air
  - Expel mucus loaded with dust and other debris away from lungs
- Walls are reinforced with C-shaped hyaline cartilage
Primary Bronchi

- Formed by division of the trachea
- Enters the lung at the hilus (medial depression)
- Right bronchus is wider, shorter, and straighter than left
- Bronchi subdivide into smaller and smaller branches
Lungs

- Occupy most of the thoracic cavity
  - Apex is near the clavicle (superior portion)
  - Base rests on the diaphragm (inferior portion)
- Each lung is divided into lobes by fissures
  - Left lung – two lobes
  - Right lung – three lobes
Lungs

Figure 13.4b
Coverings of the Lungs

- Pulmonary (visceral) pleura covers the lung surface
- Parietal pleura lines the walls of the thoracic cavity
- Pleural fluid fills the area between layers of pleura to allow gliding
Respiratory Tree Divisions

- Primary bronchi
- Secondary bronchi
- Tertiary bronchi
- Bronchioli
- Terminal bronchioli
Bronchioles

- Smallest branches of the bronchi

Figure 13.5a
**Bronchioles**

- All but the smallest branches have reinforcing cartilage

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*Figure 13.5a*
Bronchioles

- Terminal bronchioles end in alveoli

Figure 13.5a
Respiratory Zone

- Structures
  - Respiratory bronchioli
  - Alveolar duct
  - Alveoli
- Site of gas exchange
Alveoli

- Structure of alveoli
  - Alveolar duct
  - Alveolar sac
  - Alveolus
- Gas exchange takes place within the alveoli in the respiratory membrane
Respiratory Membrane (Air-Blood Barrier)

- Thin squamous epithelial layer lining alveolar walls
- Pulmonary capillaries cover external surfaces of alveoli
Respiratory Membrane (Air-Blood Barrier)

Figure 13.6
Gas Exchange

- Gas crosses the respiratory membrane by diffusion
  - Oxygen enters the blood
  - Carbon dioxide enters the alveoli
- Macrophages add protection
- Surfactant coats gas-exposed alveolar surfaces
Events of Respiration

- Pulmonary ventilation – moving air in and out of the lungs
- External respiration – gas exchange between pulmonary blood and alveoli
Events of Respiration

- Respiratory gas transport – transport of oxygen and carbon dioxide via the bloodstream
- Internal respiration – gas exchange between blood and tissue cells in systemic capillaries
Mechanics of Breathing (Pulmonary Ventilation)

- Completely mechanical process
- Depends on volume changes in the thoracic cavity
- Volume changes lead to pressure changes, which lead to the flow of gases to equalize pressure
Mechanics of Breathing (Pulmonary Ventilation)

- Two phases
  - Inspiration – flow of air into lung
  - Expiration – air leaving lung
Inspiration

- Diaphragm and intercostal muscles contract
- The size of the thoracic cavity increases
- External air is pulled into the lungs due to an increase in intrapulmonary volume
Inspiration

Changes in anterior-posterior and superior-inferior dimensions

- Ribs elevated as external intercostals contract
- Diaphragm moves inferiorly during contraction

Changes in lateral dimensions

Full inspiration

Figure 13.7a
Exhalation

- Largely a passive process which depends on natural lung elasticity
- As muscles relax, air is pushed out of the lungs
- Forced expiration can occur mostly by contracting internal intercostal muscles to depress the rib cage
Exhalation

Figure 13.7b
Pressure Differences in the Thoracic Cavity

- Normal pressure within the pleural space is always negative (intrapleural pressure)
- Differences in lung and pleural space pressures keep lungs from collapsing
Nonrespiratory Air Movements

- Can be caused by reflexes or voluntary actions

- Examples
  - Cough and sneeze – clears lungs of debris
  - Laughing
  - Crying
  - Yawn
  - Hiccup
Respiratory Volumes and Capacities

- Normal breathing moves about 500 ml of air with each breath (tidal volume [TV])
- Many factors that affect respiratory capacity
  - A person’s size
  - Sex
  - Age
  - Physical condition
- Residual volume of air – after exhalation, about 1200 ml of air remains in the lungs
Respiratory Volumes and Capacities

- Inspiratory reserve volume (IRV)
  - Amount of air that can be taken in forcibly over the tidal volume
  - Usually between 2100 and 3200 ml

- Expiratory reserve volume (ERV)
  - Amount of air that can be forcibly exhaled
  - Approximately 1200 ml
Respiratory Volumes and Capacities

- Residual volume
  - Air remaining in lung after expiration
  - About 1200 ml
Respiratory Volumes and Capacities

- Vital capacity
  - The total amount of exchangeable air
  - Vital capacity = TV + IRV + ERV
- Dead space volume
  - Air that remains in conducting zone and never reaches alveoli
  - About 150 ml
Respiratory Volumes and Capacities

- Functional volume
  - Air that actually reaches the respiratory zone
  - Usually about 350 ml
- Respiratory capacities are measured with a spirometer
Respiratory Capacities

Figure 13.9

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Respiratory Sounds

- Sounds are monitored with a stethoscope.
- Bronchial sounds – produced by air rushing through trachea and bronchi.
- Vesicular breathing sounds – soft sounds of air filling alveoli.
External Respiration

- Oxygen movement into the blood
  - The alveoli always has more oxygen than the blood
  - Oxygen moves by diffusion towards the area of lower concentration
  - Pulmonary capillary blood gains oxygen
External Respiration

- Carbon dioxide movement out of the blood
  - Blood returning from tissues has higher concentrations of carbon dioxide than air in the alveoli
  - Pulmonary capillary blood gives up carbon dioxide
- Blood leaving the lungs is oxygen-rich and carbon dioxide-poor
Gas Transport in the Blood

- Oxygen transport in the blood
  - Inside red blood cells attached to hemoglobin (oxyhemoglobin [HbO$_2$])
  - A small amount is carried dissolved in the plasma
Gas Transport in the Blood

- Carbon dioxide transport in the blood
  - Most is transported in the plasma as bicarbonate ion ($\text{HCO}_3^-$)
  - A small amount is carried inside red blood cells on hemoglobin, but at different binding sites than those of oxygen
Internal Respiration

- Exchange of gases between blood and body cells
- An opposite reaction to what occurs in the lungs
  - Carbon dioxide diffuses out of tissue to blood
  - Oxygen diffuses from blood into tissue
Internal Respiration

(a) Loading of O₂
Hb + O₂ → HbO₂ (Oxyhemoglobin is formed)

(b) Unloading of CO₂
CO₂ + H₂O → H₂CO₃ → H⁺ + HCO₃⁻

Alveoli (air sacs)
O₂ → CO₂

Tissue cells
CO₂ → HCO₃⁻

Red blood cell
HbO₂ → Hb + O₂

Pulmonary capillary
Plasma

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Figure 13.11
External Respiration, Gas Transport, and Internal Respiration Summary

Figure 13.10
Neural Regulation of Respiration

- Activity of respiratory muscles is transmitted to the brain by the phrenic and intercostal nerves
- Neural centers that control rate and depth are located in the medulla
- The pons appears to smooth out respiratory rate
- Normal respiratory rate (eupnea) is 12–15 respirations per minute
- Hypernia is increased respiratory rate often due to extra oxygen needs
Neural Regulation of Respiration

Figure 13.12

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Factors Influencing Respiratory Rate and Depth

- Physical factors
  - Increased body temperature
  - Exercise
  - Talking
  - Coughing
- Volition (conscious control)
- Emotional factors
Factors Influencing Respiratory Rate and Depth

- Chemical factors
  - Carbon dioxide levels
    - Level of carbon dioxide in the blood is the main regulatory chemical for respiration
    - Increased carbon dioxide increases respiration
    - Changes in carbon dioxide act directly on the medulla oblongata
Factors Influencing Respiratory Rate and Depth

- Chemical factors (continued)
  - Oxygen levels
    - Changes in oxygen concentration in the blood are detected by chemoreceptors in the aorta and carotid artery
    - Information is sent to the medulla oblongata
Respiratory Disorders: Chronic Obstructive Pulmonary Disease (COPD)

- Exemplified by chronic bronchitis and emphysema
- Major causes of death and disability in the United States
Features of these diseases

- Patients almost always have a history of smoking
- Labored breathing (dyspnea) becomes progressively more severe
- Coughing and frequent pulmonary infections are common
Respiratory Disorders: Chronic Obstructive Pulmonary Disease (COPD)

- Features of these diseases (continued)
  - Most victims retain carbon dioxide, are hypoxic and have respiratory acidosis
  - Those infected will ultimately develop respiratory failure
Emphysema

- Alveoli enlarge as adjacent chambers break through
- Chronic inflammation promotes lung fibrosis
- Airways collapse during expiration
- Patients use a large amount of energy to exhale
- Overinflation of the lungs leads to a permanently expanded barrel chest
- Cyanosis appears late in the disease
Chronic Bronchitis

- Mucosa of the lower respiratory passages becomes severely inflamed
- Mucus production increases
- Pooled mucus impairs ventilation and gas exchange
- Risk of lung infection increases
- Pneumonia is common
- Hypoxia and cyanosis occur early
Chronic Obstructive Pulmonary Disease (COPD)

- Tobacco smoke
- Air pollution

Continual bronchial irritation and inflammation

Chronic bronchitis
- Excessive mucus produced
- Chronic productive cough
- Bronchospasm

Breakdown of elastin in connective tissue of lungs

Emphysema
- Destruction of alveolar walls
- Lung fibrosis
- Air trapping

- Airway obstruction or air trapping
- Dyspnea
- Frequent infections

Respiratory failure

Figure 13.13
Lung Cancer

- Accounts for 1/3 of all cancer deaths in the United States
- Increased incidence associated with smoking
- Three common types
  - Squamous cell carcinoma
  - Adenocarcinoma
  - Small cell carcinoma
Sudden Infant Death syndrome (SIDS)

- Apparently healthy infant stops breathing and dies during sleep
- Some cases are thought to be a problem of the neural respiratory control center
- One third of cases appear to be due to heart rhythm abnormalities
Asthma

- Chronic inflamed hypersensitive bronchiole passages
- Response to irritants with dyspnea, coughing, and wheezing
Developmental Aspects of the Respiratory System

- Lungs are filled with fluid in the fetus
- Lungs are not fully inflated with air until two weeks after birth
- Surfactant that lowers alveolar surface tension is not present until late in fetal development and may not be present in premature babies
Developmental Aspects of the Respiratory System

- Important birth defects
  - Cystic fibrosis – oversecretion of thick mucus clogs the respiratory system
  - Cleft palate
Aging Effects

- Elasticity of lungs decreases
- Vital capacity decreases
- Blood oxygen levels decrease
- Stimulating effects of carbon dioxide decreases
- More risks of respiratory tract infection
Respiratory Rate Changes Throughout Life

- Newborns – 40 to 80 respirations per minute
- Infants – 30 respirations per minute
- Age 5 – 25 respirations per minute
- Adults – 12 to 18 respirations per minute
- Rate often increases somewhat with old age