The Respiratory System

ESSENTIALS OF HUMAN ANATOMY & PHYSIOLOGY
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 gases 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
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
- 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

- 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
- 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
- Differences in lung and pleural space pressures keep lungs from collapsing
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
- All but the smallest branches have reinforcing cartilage
- 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
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
- 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
- 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
Expiration

- 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
Non-respiratory Air Movements

- Can be caused by reflexes or voluntary actions

- Examples
  - Cough and sneeze – clears lungs of debris
  - Laughing
  - Crying – causes hyperventilation
  - Yawn
  - Hiccup – caused by spasms of diaphragm
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
  - Air remaining in lung after expiration
  - About 1200 ml
- **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
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
Functional volume

- Air that actually reaches the respiratory zone
  - Usually about 350 ml

- Respiratory capacities are measured with a spirometer
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
- 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

- Carbon dioxide transport in the blood
  - Most is transported in the plasma as bicarbonate ion (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
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.
- Hyperpnea is increased respiratory rate often due to extra oxygen needs.
Factors Influencing Respiratory Rate and Depth

- Physical factors
  - Increased body temperature
  - Exercise
  - Talking
  - Coughing
- Volition (conscious control)
- Emotional factors
- Chemical factors
  - Carbon dioxide levels
    - Increased carbon dioxide increases respiration
    - Changes in carbon dioxide act directly on the medulla oblongata
  - 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 US 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
  - 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
- Over inflation 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
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
Lungs are filled with fluid in the fetus

Lungs are not fully inflated with air until two weeks after birth

**Surfactant** – lowers alveolar surface tension

- There isn’t a sufficient amount until the 28th week in fetal development
- Premature babies often have trouble breathing
Important birth defects

- Cystic fibrosis – over secretion 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