Chapter 15
Lecture and Animation Outline

To run the animations you must be in Slideshow View. Use the buttons on the animation to play, pause, and turn audio/text on or off.

Please Note: Once you have used any of the animation functions (such as Play or Pause), you must first click on the slide's background before you can advance to the next slide.

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes and animations.
Functions

1. Gas exchange
2. Regulation of blood pH
3. Voice Production
4. Olfaction
5. Innate Immunity
6. Ventilation
Upper Respiratory Tract

• External nose

• Nasal cavity

• Pharynx
Nose

- **External nose:**
  composed of mainly of hyaline cartilage

- **Nasal cavity:**
  - extends from nares (nostrils) to choane
  - **choane:** openings to pharynx
  - hard palate is its roof
• **Paranasal sinuses:**
  - air filled spaces within bone
  - open into nasal cavity
  - lined with mucous

• **Conchae:**
  - on each side of nasal cavity
  - increase surface area of nasal cavity
  - help in cleaning, humidifying, warming of air

• **Nasolacrimal ducts:**
  - carry tears from eyes
  - open into nasal cavity
Functions of Nose

- Filters
- Airway for respiration
- Involved in speech
- Olfactory receptors
- Warms air
- Sneezing dislodges materials from nose
Pharynx

- Throat
- Common passageway for resp. and dig. systems
- **Nasopharynx:**
  takes in air
- **Oropharynx:**
  - extends from uvula to epiglottis
  - takes in food, drink, and air
- **Laryngopharynx:**
  - extends from epiglottis to esophagus
  - food and drink pass through
• **Uvula:**
  - “little grape”
  - extension of soft palate

• **Pharyngeal tonsil:**
  aids in defending against infections
Lower Respiratory Tract

- Larynx
- Trachea
- Bronchi
- Lungs
Larynx

- In front of throat
- Consists of cartilage
- **Thyroid cartilage:**
  - largest piece of cartilage
  - called Adam’s apple
- **Epiglottis:**
  - piece of cartilage
  - flap that prevents swallowed materials from entering larynx
• **Vocal folds/cords:**
  - source of voice production
  - air moves past them, they vibrate, and sound is produced
  - force of air determines loudness
  - tension determines pitch

• **Laryngitis:**
  - inflammation of vocal folds
  - caused by overuse, dry air, infection
Figure 15.3  Anatomy of the Larynx
Figure 15.4 Vestibular and Vocal Folds

(Far left) The arrow shows the direction of viewing the vestibular and vocal folds. (a) The relationship of the vestibular folds to the vocal folds and the laryngeal cartilages. (b) Superior view of the vestibular and vocal folds as seen through a laryngoscope.
Trachea

- Windpipe
- Consists of 16-20 C shaped pieces of cartilage
- Contains cilia pseudostratified columnar epi.
- Smoking kills cilia
- Coughing dislodges materials from trachea
- Divides into right and left primary bronchi (lungs)
Bronchi

- Divide from trachea
- Connect to lungs
- Lined with cilia
- Contain C shaped pieces of cartilage
Lungs

- Primary organ of respiration
- Cone shaped
- Rest on diaphragm
- Right lung has 3 lobes
- Left lung has 2 lobes
- Contains many air passageways (divisions)
Air Passageways of Lungs

1. Primary bronchi
2. Lobar (secondary) bronchi
3. Segmental (tertiary) bronchi
4. Bronchioles
5. Terminal bronchioles
6. Respiratory bronchioles
7. Alveolar ducts
8. Alveoli

• Structures become smaller and more numerous from primary bronchi to alveoli
Figure 15.5 Anatomy of the Trachea and Lungs

The trachea and lungs and the branching of the bronchi are shown. Each lung is surrounded by a pleural cavity, formed by the visceral and parietal pleurae.
Lungs Continued

• **Alveoli:**
  - small air sacs
  - where gas exchange occurs
  - surrounded by capillaries
  - 300 million in lungs

• **Asthma attack:**
  contraction of terminal bronchioles leads to reduced air flow
Figure 15.7 Bronchioles and Alveoli

A terminal bronchiole branches to form respiratory bronchioles, which give rise to alveolar ducts. Alveoli connect to the alveolar ducts and respiratory bronchioles. The alveolar ducts end as two or three alveolar sacs.
Respiratory Membrane

- In lungs where gas exchange between air and blood occurs
- Formed by walls of alveoli and capillaries
- Alveolar ducts and respiratory bronchioles also contribute
- Very thin for diffusion of gases
Layers of Respiratory Membrane

- Thin layer of fluid from alveolus
- Alveolar epithelium (simple squamous)
- Basement membrane of alveolar epithelium
- Thin interstitial space
- Basement membrane of capillary endothelium
- Capillary endothelium (simple squamous)
Figure 15.8 Alveolus and the Respiratory Membrane

(a) Section of an alveolus, showing the air-filled interior and thin walls composed of simple squamous epithelium. The alveolus is surrounded by elastic connective tissue and blood capillaries. (b) $O_2$ and $CO_2$ diffuse across the six thin layers of the respiratory membrane.
Pleural Membranes and Cavities

• **Pleura:**
  double-layered membrane around lungs

• **Parietal pleura:**
  membrane that lines thoracic cavity

• **Visceral pleura:**
  membrane that covers lung’s surface

• **Pleural cavity:**
  space around each lung
Figure 15.9 Pleural Cavities and Membranes

Transverse section of the thorax, showing the relationship of the pleural cavities to the thoracic organs. Each lung is surrounded by a pleural cavity. The parietal pleura lines the wall of each pleural cavity, and the visceral pleura covers the surface of the lungs. The space between the parietal and visceral pleurae is small and filled with pleural fluid.
Ventilation

• What is it?
  - breathing
  - process of moving air in and out of lungs
  - uses **diaphragm**: skeletal muscle that separates thoracic and abdominal cavities
Phases of Ventilation

• Inspiration:
  - breathe in
  - uses external intercostal muscles

• Expiration:
  - breathe out
  - uses internal intercostal muscles
Figure 15.10 Effect of the Muscles of Respiration on Thoracic Volume

(a) Muscles of respiration at the end of expiration. (b) Muscles of respiration at the end of inspiration.
Pressure Changes and Air Flow

- When thoracic cavity volume increases, pressure decreases.

- When thoracic cavity volume decreases, pressure increases.

- Air flows from areas of high to low pressure.
Inspiration

• Diaphragm descends and rib cage expands

• Thoracic cavity volume increases, pressure decreases

• Atmospheric pressure is greater than (high) alveolar pressure (low)

• Air moves into alveoli (lungs)
Expiration

- Diaphragm relaxes and rib cage recoils

- Thoracic cavity volume decreases, pressure increases

- **Alveolar pressure** is greater than (high) atmospheric pressure (low)

- Air moves out of lungs
1. At the end of expiration, alveolar pressure is equal to atmospheric pressure, and there is no air movement.

2. During inspiration, increased thoracic volume results in increased alveolar volume and decreased alveolar pressure. Atmospheric pressure is greater than alveolar pressure, and air moves into the lungs.

3. At the end of inspiration, alveolar pressure is equal to atmospheric pressure, and there is no air movement.

4. During expiration, decreased thoracic volume results in decreased alveolar volume and increased alveolar pressure. Alveolar pressure is greater than atmospheric pressure, and air moves out of the lungs.

PROCESS Figure 15.11 Alveolar Pressure Changes During Inspiration and Expiration

The combined space of all the alveoli is represented by a large “bubble” (blue). The alveoli are actually microscopic and cannot be seen in the illustration.
Lung Recoil

• What is it?
  - tendency for an expanded lung to decrease in size
  - occurs during quiet expiration
  - due to elastic fibers and thin film of fluid lining alveoli
Surfactant

- What is it?
  - mixture of lipoproteins
  - produced by secretory cells of alveoli
  - single layer on surface of thin fluid lining alveoli
  - reduces surface tension
  - keeps lungs from collapsing
Pleural Pressure

• What is it?
  - pressure in pleural cavity
  - less than alveolar pressure
  - keep alveoli from collapsing
Please note that due to differing operating systems, some animations will not appear until the presentation is viewed in Presentation Mode (Slide Show view). You may see blank slides in the “Normal” or “Slide Sorter” views. All animations will appear after viewing in Presentation Mode and playing each animation. Most animations will require the latest version of the Flash Player, which is available at http://get.adobe.com/flashplayer.

At the end of expiration, barometric air pressure ($P_B$) and alveolar air pressure ($P_{alv}$) are equal. Therefore, no movement of air into or out of the lungs takes place.
Factors that Influence Pulmonary Ventilation

• Lung elasticity:
  - lungs need to recoil between ventilations
  - decreased by emphysema

• Lung compliance:
  - expansion of thoracic cavity
  - affected if rib cage is damaged

• Respiratory passageway resistance:
  occurs during an asthma attack, infection, tumor
Pulmonary Volumes

• **Spirometer:**
  device that measures pulmonary volumes

• **Tidal volume (TV):**
  volume of air inspired and expired during quiet breathing

• **Inspiratory reserve volume (IRV):**
  volume of air that can be inspired forcefully after a normal inspiration
• **Expiratory reserve volume (ERV):**
  volume of air that can be expired forcefully after a normal expiration

• **Residual volume (RV):**
  volume of air remaining in lungs after a max. expiration (can’t be measured with spirometer)
• Vital Capacity (VC):
  - max. amount of air a person can expire after a max. inspiration
  \[ VC = IRV + ERV + TV \]

• Total lung capacity (TLC):
  \[ TLC = VC + RV \]
Factors that Influence Pulmonary Volumes

- Gender
- Age
- Height
- Weight
Gas Exchange

- **Respiratory membrane:**
  - where gas exchange between blood and air occurs
  - primarily alveoli
  - some in respiratory bronchioles and alveolar ducts
  - does NOT occur in bronchioles, bronchi, trachea
  - influenced by thickness of membrane, total area of membrane, partial pressure of gases
Respiratory Membrane Thickness

- Increased thickness decreases rate of diffusion
- Pulmonary edema decreases diffusion
- Rate of gas exchange is decreased
- $O_2$ exchange is affected before $CO_2$ because $CO_2$ diffuse more easily than $O_2$
Surface Area

• Total surface area is 70 square meters (basketball court)

• Decreased due to removal of lung tissue, destruction from cancer, emphysema
Partial Pressure

• What is it?
  - pressure exerted by a specific gas in a mixture of gases
  - Ex. Total pressure of all gases is 760 (mm Hg) and 21% of mixture is O\textsubscript{2} then partial pressure for O\textsubscript{2} is 160 mm Hg
  - symbol is P and gas (Po\textsubscript{2})
Diffusion of Gases in Lungs

- Cells in body use $O_2$ and produce $CO_2$.
- Blood returning from tissues and entering lungs has a decreased $Po_2$ and increased $Pco_2$.
- $O_2$ diffuses from alveoli into pulmonary capillaries (blood).
- $CO_2$ diffuses from capillaries into alveoli.
Please note that due to differing operating systems, some animations will not appear until the presentation is viewed in Presentation Mode (Slide Show view). You may see blank slides in the “Normal” or “Slide Sorter” views. All animations will appear after viewing in Presentation Mode and playing each animation. Most animations will require the latest version of the Flash Player, which is available at http://get.adobe.com/flashplayer.

Fresh air entering the lungs carries oxygen to the alveoli. The amount of gas in air or of gas dissolved in a fluid can be expressed as partial pressure, which is measured in millimeters of mercury.
1. Oxygen diffuses into the arterial ends of pulmonary capillaries, and CO₂ diffuses into the alveoli because of differences in partial pressures.

2. As a result of diffusion at the venous ends of pulmonary capillaries, the \( P_{O_2} \) in the blood is equal to the \( P_{O_2} \) in the alveoli, and the \( P_{CO_2} \) in the blood is equal to the \( P_{CO_2} \) in the alveoli.

3. The \( P_{O_2} \) of blood in the pulmonary veins is less than in the pulmonary capillaries because of mixing with deoxygenated blood from veins draining the bronchi and bronchioles.

4. Oxygen diffuses out of the arterial ends of tissue capillaries, and CO₂ diffuses out of the tissue because of differences in partial pressures.

5. As a result of diffusion at the venous ends of tissue capillaries, the \( P_{O_2} \) in the blood is equal to the \( P_{O_2} \) in the tissue, and the \( P_{CO_2} \) in the blood is equal to the \( P_{CO_2} \) in the tissue.

PROCESS Figure 15.13  Gas Exchange

Differences in partial pressure are responsible for the exchange of oxygen and carbon dioxide that occurs between the alveoli and the pulmonary capillaries and between the tissues and the tissue capillaries.
Diffusion of Gases in Tissues

- Blood flow from lungs through left side of heart to tissue capillaries
- Oxygen diffuses from capillaries into interstitial fluid because $P_{o2}$ in interstitial fluid is lower than capillary
- Oxygen diffuses from interstitial fluid into cells ($P_{o2}$) is less
Figure 15.14 Gas Exchange in the Tissues and in the Lungs

(a) In the tissues, CO₂ diffuses into red blood cells, where the enzyme carbonic anhydrase (CA) is located. CA catalyzes the reaction of CO₂ with H₂O to form carbonic acid (H₂CO₃). H₂CO₃ dissociates to form bicarbonate ions (HCO₃⁻) and hydrogen ions (H⁺). Oxygen is released from hemoglobin (Hb) and diffuses into tissue cells.

(b) In the lungs, CO₂ diffuses from red blood cells into the alveoli. CA catalyzes the formation of CO₂ and H₂O from H₂CO₃, H⁺ and HCO₃⁻ combine to replace H₂CO₃. Oxygen diffuses into red blood cells and binds to hemoglobin.
Carbon Dioxide Transport and Blood pH

- CO$_2$ diffuses from cells into capillaries
- CO$_2$ enters blood and is transported in plasma, comb. with blood proteins, bicarbonate ions
- CO$_2$ reacts with water to form carbonic acid when forms H$^+$ + bicarbonate ions
- Carbonic anhydrase (RBC) increases rate of CO$_2$ reacting with water
- CO$_2$ levels increase blood pH decreases
Rhythmic Ventilation

- Normal respiration rate is 12-20 resp. per minute (adults)
- Controlled by neurons in medulla oblongata
- Rate is determined by number of times resp. muscles are stimulated
Figure 15.15 Respiratory Structures in the Brainstem

Specific structures in the brainstem correlate with the nerves that innervate the muscles of respiration.
Nervous Control of Breathing

• Higher brain centers allow voluntary breathing

• Emotions and speech affect breathing

• Hering-Breuer Reflex:
  inhibits respiratory center when lungs are stretched during inspiration
Several regulatory mechanisms affect the rate and depth of breathing. A plus sign indicates that the mechanism increases breathing and a minus sign indicates that it results in a decrease in breathing.
Chemical Control of Breathing

- Chemoreceptors in medulla oblongata respond to changes in blood pH.
- Blood pH are produced by changes in blood CO₂ levels.
- An increase in CO₂ causes decreased pH, result is increased breathing.
- Low blood levels of O₂ stimulate chemoreceptors in carotid and aortic bodies, increased breathing.
Medullary chemoreceptors detect an increase in blood pH (often caused by a decrease in blood CO₂), causing a decrease in breathing. Decreased breathing increases blood CO₂.

Blood pH increases: Homeostasis Disturbed

Blood pressure (normal range)

Blood pH decreases: Homeostasis Disturbed

Blood pH increases: Homeostasis Restored

Increased breathing decreases blood CO₂.

Blood pH decreases: Homeostasis Restored