Lab Activity 27

Anatomy of the Respiratory System

Portland Community College
BI 233
Terminology

- **Pulmonary Ventilation**: aka breathing, is the movement of air into and out of the lungs

- **External Respiration**: The gas exchange between the blood and alveoli

- **Internal Respiration**: Exchange of gases between systemic blood and tissue cells

- **Cellular Respiration**: Happens in Mitochondria. Metabolic reactions that consume O2 and release CO2 during ATP production
Upper & Lower Respiratory System

- Upper Respiratory System
  - Nose
  - Pharynx

- Lower Respiratory System
  - Larynx
  - Trachea
  - Bronchi
  - Lungs
Nasal Cavity

Nose and Nasal Cavities

- Frontal sinus
- Middle nasal concha
- Nasal concha
- Sphenoid sinus
- Internal naris
- Inferior nasal concha
- Nasopharynx
- External naris
Nasal Cavity

Opening of Auditory Tube

Superior Middle & Inferior Turbinates

External Nares
Nasal Cavity

- The nasal epithelium covering the conchae serves to cleanse, warm and humidify the air
- Nasal conchae increase the surface areas for the mucus epithelium
- The olfactory epithelium in the upper medial part of the nasal cavity is involved in the sense of smell.
- The nasal cavity serves as a resonating chamber as well as an avenue for escaping air.
Nasal Turbinates or Conchae

- Ciliated pseudostratified columnar epithelium with goblet cells pushes trapped dust toward the back of the throat to be swallowed.
Sinuses
Tonsils

Pharyngeal Tonsils (Adenoids)

Palatine Tonsils

Lingual Tonsils
Tonsils

- Tonsils: lymphoid tissue.
Pharynx

- Connects the nasal and oral cavities to the larynx and esophagus
- Anatomically divided into 3 sections:
  - Nasopharynx
  - Oropharynx
  - Laryngopharynx
Nasopharynx
(pseudostratified epithelium)

Oropharynx
(stratified squamous epithelium)

Laryngopharynx
(stratified squamous epithelium)
Larynx: aka Voice Box

• Made of 9 pieces of cartilage, the most important are:
  • Thyroid cartilage (Adam’s Apple)
    • Thyrohyoid membrane
  • Cricoid Cartilage
    • Cricothyroid ligament
• Epiglottis
Larynx

- Thyroid Cartilage
- Cricoid Cartilage
- Tracheal Cartilage
- Epiglottis
- Thyrohyoid Membrane
- Hyoid Bone
- Cricothyroid Ligament
Inside the Larynx

- **Vestibular Folds**: folds of mucous membranes
  - Upper folds: false vocal cords
  - Lower folds: true vocal cords
- **These** attach to the arytenoid cartilages by the vocal ligaments
- **Glottis**: The vocal cords and the space between the folds
- **Rima glottis**: the space between the vocal folds
Inside the Larynx

• Vestibular Folds:
  • Also called false vocal cords, ventricular band of larynx, ventricular folds, and upper folds

• Vocal Cords, or vocal folds
  • Lower, “true” vocal cords
  • Attach to the arytenoid cartilages by the vocal ligaments (internal)

• Glottis: The vocal cords and the space (rima glottidis) between them.
Inside the Larynx

(a) Anterior view
(b) Posterior view
(c) Sagittal section

Epiglottis
Hyoid bone
Laryngeal prominence
Thyroid cartilage
Cricoid cartilage
Arytenoid cartilages
Tracheal cartilages
Vocal ligament
Cuneiform cartilage
Vestibular ligament
Arytenoid cartilage
Coracoid cartilage
Trachea
Hyoid bone
Thyroid cartilage
Cricoid cartilage
Inside the Larynx

- Rima Glottis
- True Vocal Cords
- Glottis
- Epiglottis
- Tongue
- Corniculate cartilage
- Cuneiform cartilage
Glottis: True cords plus opening
Rima Glottis: The opening
Airways

- Larynx
- Trachea
- Right Mainstem Bronchi
- Left Mainstem Bronchi
- Secondary Bronchi
- Carina
- Secondary Bronchi
Respiratory Tree

Bronchi, Bronchial Tree, and Lungs

- Larynx
- Primary bronchi
- Secondary bronchi
- Tertiary bronchi
- Bronchioles
- Cardiac notch
- Pulmonary artery
- Pulmonary vein
- Alveolar duct
- Alveoli
Bronchi

- The **carina** of the last tracheal cartilage marks the end of the trachea and the beginning of the right and left bronchi
  - Left main stem bronchus
  - Right main stem bronchus
- Bronchi subdivide into secondary bronchi, each supplying a lobe of the lungs
Branching of Bronchial Tree

- Trachea
- Primary Bronchi
- Secondary Bronchi
- Tertiary Bronchi
- Bronchioles
- Terminal/Respiratory Bronchioles
Lungs

• **Apex**: the part under the clavicle
• **Base**: the part touching the diaphragm
• **Costal Surface**: the part touching the ribs
• **Hilus**: indentation containing pulmonary and systemic blood vessels
• Left Lung has 2 lobes and a cardiac notch
  • Left upper lobe
  • Left lower lobe
• Right Lung has 3 lobes
  • Right upper lobe, middle lobe, lower lobe
Lungs: Medial View
Lung Lobes

- RUL (Right Upper Lobe)
- LUL (Left Upper Lobe)
- RML (Right Middle Lobe)
- LLL (Left Lower Lobe)
- RLL (Right Lower Lobe)
Pleura

- Pleura is the double-layered sac of serous membrane
  - Parietal Pleura is the outer layer and is attached to the thoracic walls
  - Visceral Pleura is the inner layer covering the lung tissue
- The layers are only touching, they are not fused together
  - The potential space is called the pleural cavity
  - There is serous fluid between the layers which allows them to slide against each other during breathing
Pleural cavity is in between the two layers.
Mediastinum

- The area between the lungs.
- Posterior to the sternum
- Anterior to the vertebrae
- Contains the heart, great vessels, esophagus and thymus
Inspiration/Expiration

- **Inspiration**: Increase in thoracic cavity size
- **Inspiratory muscles**
  - External intercostals (lift the rib cage)
  - Diaphragm (Becomes flat)
- **Expiration**: Decrease in thoracic cavity size
- **Expiratory muscles**
  - For the most part it is just the relaxation of the inspiratory muscles (passive process)
  - Internal intercostals & abdominal muscles used only for forced expiration
Muscles of Respiration

- Sternocleidomastoid muscle
- Scalene muscles
- Pectoralis minor muscle (cut)
- Transversus thoracis muscle
- Serratus anterior muscle
- Diaphragm
- External intercostal muscles
- Internal intercostal muscles
Muscles: Inspiration
Muscles: Expiration
Trachea Histology

- Composed of three layers
  - Mucosa: made up of goblet cells and ciliated pseudostratified columnar epithelium
  - Submucosa: connective tissue deep to the mucosa
  - Adventitia: outermost layer, has C-shaped rings of hyaline cartilage
Trachea

- Pseudostratified ciliated columnar epithelium
- Seromucous glands in submucosa
- Lumen of trachea
- Hyaline cartilage ring
- Mucous membrane
- Submucosa
- Adventitia
- Esophagus
- Trachealis muscle
- Posterior
- Anterior
Trachea Histology
Trachea H&E

- pseudostratified columnar epithelium
- goblet cell
- cilia
- basement membrane
- capillary
Seromucous Glands (Trachea)
Trachea

Pseudostratified Columnar Epithelium

Submucosa with seromucous glands

Hyaline Cartilage
Bronchi ➔ Bronchioles

- Tissue walls of bronchi mimic that of the trachea
- As conducting tubes become smaller, structural changes occur and eventually they become bronchioles
  - Cartilage support structures change
    - Bronchioles differ from bronchi in that they lack cartilage
  - Epithelium types change
  - Amount of smooth muscle increases
Bronchi Histology

- Respiratory epithelium
- SM
- Serous glands
- Hyaline cartilage
• Respiratory Bronchioles: Continued branching leads to the area where gas exchange occurs by simple diffusion.
Notice the lack of cartilage

Simple columnar epithelium
Respiratory Bronchioles → Alveolar Ducts → Alveolar sacs
Alveolar sacs look like clusters of grapes.
The “individual grapes” are Alveoli.
Type I Pneumocytes are flattened for gas exchange

Type II Pneumocytes are cuboidal and produce surfactant
Respiratory Membrane

- The area where gas exchange between air and blood occurs
- It is the fused alveolar and capillary walls (3 layers)
  1. Alveolar epithelium
  2. Fused basal laminae
  3. Capillary epithelium
Respiratory Membrane

- Type II (surfactant-secreting) cell
- Type I cell of alveolar wall
- Alveoli (gas-filled airspaces)
- Red blood cell
- Alveolar pores in capillary
- Macrophage
- Respiratory membrane

(d) Alveolar epithelium
- Fused basal laminae of the alveolar epithelium and the capillary endothelium
- Capillary endothelium

O₂ and CO₂ exchange between alveoli and capillary blood
Lab Activity 28

Respiratory System Physiology
Buffers
Spirometry

- Measures the volume of air inspired or expired
- Spirometry cannot access information about absolute lung volumes
- It cannot measure the amount of air in the lung, only the amount entering or leaving.
Respiratory Volumes

- **Tidal Volume** \( TV \)
  - Volume of air moved in or out of the lungs during quiet breathing about 500 mL.

- **Inspiratory Reserve Volume** \( IRV \)
  - Volume that can be inhaled during forced breathing in addition to tidal volume 3100mL.

- **Expiratory Reserve Volume** \( ERV \)
  - Volume that can be exhaled during forced breathing after a normal tidal volume 1200 mL.
Respiratory Volumes

- **Minute Respiratory Volume** (MRV)
  - The volume of air breathed during 1 min.
  
  \[ \text{MRV (ml/min)} = \text{TV} \times \text{Respirations/min} \]

- **Residual Volume** (RV)
  - *Can not be measured using spirometry*
  - Volume that remains in the lungs at all times 1200 mL.
Respiratory Capacity

- **Vital Capacity** \( VC \)
  - Maximum volume that can be exhaled after taking the deepest breath possible
  \[ VC = TV + IRV + ERV \]

- **Inspiratory Capacity** \( IC \)
  - Maximum volume that can be inhaled after a normal exhalation
  \[ IC = TV + IRV \]
Respiratory Capacity

• **Functional Residual Capacity** \( FRC \)
  - The amount of air left in the lungs after a normal exhalation
  \[
  FRC = ERV + RV
  \]

• **Total Lung Capacity** \( TLC \)
  - *can not be measured using spirometry*
  - Total volume of air that the lungs can hold.
  \[
  TLC = VC + RV
  \]
Pulmonary Function Tests

- Pulmonary function tests help distinguish between obstructive and restrictive pulmonary diseases
- Forced Vital Capacity \( \text{FVC} \)
  - Amount expelled after taking the deepest breath possible then exhaling forcefully and rapidly
- Forced expiratory volume \( \text{FEV}_T \)
  - The percentage of vital capacity exhaled during a specific time
- \( \text{FEV}_1 \) is during the first second (normally 75% to 85% of FVC)
  - \( \text{FEV}_1 \) is low in obstructive disease
Pulmonary Function Test

- **Time (sec)**
  - Inspiration: 0, 1, 2
  - Expiration: 0, 1, 2, 3

- **Inspiratory Capacity**
- **Forced Vital Capacity (FVC)**
- **FEV₁**

- **Total Lung Capacity**
- **Residual Volume**

- **Tidal Vol.**
Pulmonary Function Tests

• Typical values for a patient with COPD
  • FEV1 61% (normal is 75-85%)
  • Shows air trapping
    (values shown as % of expected value)
  • Vital Capacity 73%
  • FEV1/VC 0.61 (normally >0.72)
  • Residual volume 175%
  • Total lung capacity 105%
Buffers

- Buffers are chemicals that can regulate or stabilize pH change by removing $\text{H}^+$
- Buffers convert strong acids to weak acids
  - Weak acids contribute fewer $\text{H}^+$ ions & have less effect on pH
Acid Base Balance in Blood

- In the RBC and minimally in the plasma, this reaction takes place
- \[ \text{CO}_2 + \text{H}_2\text{O} \; \leftrightarrow \; \text{H}_2\text{CO}_3 \; \leftrightarrow \; \text{HCO}_3^- + \text{H}^+ \]

- The bicarbonate ions (\(\text{HCO}_3^-\)) help buffer the blood by combining with extra \(\text{H}^+\) in the blood.
- Carbonic acid (\(\text{H}_2\text{CO}_3\)) releases \(\text{H}^+\) when the blood becomes too basic.
- This way, the balance of \(\text{H}^+\) remains steady and the pH is doesn’t fluctuate.
Carbonic Acid Buffer System: Dealing with Acids

- \( \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+ \) (Add an acid) + \( \text{H}^+ \)

- The \( \text{H}^+ \) will combine with \( \text{HCO}_3^- \) to create \( \text{H}_2\text{CO}_3 \)
- \( \text{H}_2\text{CO}_3 \) will then dissociate into \( \text{CO}_2 + \text{H}_2\text{O} \)
- Breathing will increase to rid the body of the extra \( \text{CO}_2 \)
Carbonic Acid Buffer System: Dealing with Bases

• \( \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+ \) (Add a base) + OH⁻

• The OH⁻ will combine with H⁺ to create H₂O

• \( \text{H}_2\text{CO}_3 \) will dissociate into \( \text{HCO}_3^- + \text{H}^+ \) to restore the H⁺ concentration
The End