Respiratory System

I. Introduction
- A. Internal or true respiration (cellular respiration)
- B. External respiration

II. Anatomy of the Respiratory System
- A. Nose, nasal concha
- B. Pharynx
- C. Epiglottis and glottis
- D. Larynx
  1. Sound production
     - a. Volume
     - b. Pitch (number of vibrations): function of length of cords and tension
     - c. Tone
- E. Tongue, lips, palate - phonation and tonal quality
- F. Trachea:
  1. Extends into the thoracic cavity
  2. Divides into the right and left bronchi
  3. Mucous lining filters incoming air
  4. Cartilaginous rings to dorsal or posterior

  Trachealis muscle: length 4-5 inches
- G. **Bronchial Tree**: trachea and bronchi, branched air passageways that lead to the alveoli: decreasing amounts of cartilage and increasing amounts of muscle as smaller sizes are reached: elastic fibers in the wall aid breathing: epithelium changes from ciliated pseudostratified to cuboidal and simple squamous
  1. Trachea = single structure
  2. Primary bronchi = one to each lung
  3. Secondary (lobar) bronchi = one to each lobe: 3 right lung, 2 left lung
  4. Tertiary (segmental) bronchi = smaller branches
  5. Bronchioles = respiratory branches that lead to alveolar duct
  6. Terminal bronchioles
  7. Respiratory bronchioles
  8. Alveolar ducts
  9. Alveolar sacs and alveoli
- H. **Lungs**
  1. Covered by serous membrane - **Pleural membranes**
     - a. Visceral pleura on lung surface
     - b. Parietal pleura on thoracic wall
     - c. Intra-pleural space = potential space only
     - d. Mediastinum = separates left and right lungs
  2. Right lung = shorter, broader, 3 lobes
  3. Left lung = longer, narrower, 2 lobes
  4. Each lobe is composed of lobules that contain: alveoli, blood vessels and connective tissue

5. **Alveoli**: 300 million, 70 m^2 of surface area
    a. Single layer of squamous epithelium
    b. Plus single layer of squamous endothelium of capillaries
    c. Pulmonary surfactant (phospholipoproteins) made by cells of the alveoli

I. **Diaphragm** and muscles of inspiration (phrenic innervation)
    1. External intercostals = raise, rotate ribs, force sternum forward
    2. Sternocleidomastoid
    3. Pectoralis minor

J. Muscles of expiration
    1. Expiration - is passive and a function of recoil
    2. Forced expiration - upward thrust of diaphragm caused by abdominal muscles, and internal intercostals depressing ribs

K. Inspiration:
    1. Air forced into lung by atmospheric pressure
    2. Results from decrease in intra-alveolar pressure
    3. When the diaphragm moves down, a partial vacuum is created
    4. Thoracic cage at the same time moves up
    5. Atmospheric pressure forces air into bronchial tree
    6. Expansion aided by surface tension between the pleural membranes
    7. Surfactant reduces surface tension to prevent collapse of the alveoli

L. Expiration:
    1. Elastic recoil of tissues and surface tension within the alveoli
    2. Thoracic cage pushed downward, diaphragm upward

M. Terms:
    1. Atmospheric pressure = 760 mm Hg
    2. Collapsing pressure of lungs = 4 mm Hg
    3. Intrapleural pressure
    4. Intrapulmonic pressure
    5. Ventilation of lungs

III. Respiratory Gases

A. Oxygen
    1. Carried as *oxyhemoglobin* (98% within RBCs)
    2. Given up easily due to oxygen tension
    3. Minimal amounts O_2 carried by plasma
    4. 100 mLs of blood carries 20 mLs of O_2

B. Carbon Dioxide
    1. 4% in solution in plasma
    2. 20% carried as carbamine hemoglobin
    3. 72% carried as sodium bicarbonate (see details of chloride shift and role carbonic anhydrase)
    4. 4% carried as potassium bicarbonate

IV. Control of Breathing

A. Efferent control

1. Function of medulla oblongata via spinal cord (phrenic nerve)
2. Voluntary control of cerebrum

B. **Chemical messages**
1. Central chemoreceptors in medulla oblongata
   a. During metabolism O_2 consumed and increased levels of CO_2 and H+
   b. Medulla sensitive to: CO_2 and H+ content of cerebrospinal fluid *and* CO_2 content of blood
   c. High CO_2 or H+ levels is stimulus for increased respiration rates
2. Peripheral chemoreceptors
   a. Aorta and carotid sinuses sensitive to low concentrations of O_2
   b. Afferent message to medulla with efferent result increasing respiration

C. Physical control
1. Temperature: increases = respiration increases
   decreases = respiration decreases
2. Blood pressure: increases with respirations decreasing
   decreases with respirations increasing
3. Irritation: cough or a sneeze
4. Incidental

V. Pulmonary Terminology
A. Respiration rate
1. 14-18 cycles/minute in an adult
2. 40 cycles in a newborn
3. 30 in an infant, 25 in a 5 year old

B. Tidal volume = the amount of air moved in and out of the lungs with each cycle, at rest about 500 mLs or 1/2 liter
C. Inspiratory reserve = volume of air in excess of tidal volume which can be inhaled
D. Expiratory reserve = volume of air in excess of tidal volume which can be exhaled
E. Vital capacity = 4.5 liters, the greatest quantity of air one has after the greatest possible inhalation followed by the deepest exhalation
F. Residual air = what is left in lungs after deepest exhalation, ~1.5 liters (only removed if total collapse of lungs)
G. Total lung capacity is (vital + residual)
H. Dead air space = air in bronchial tree, ~150 mLs
I. Minimal air = air trapped in alveoli even if lung collapses, proof of live birth in autopsy

VI. Alveolar Ventilation
A. **Minute respiratory volume**: (tidal volume X breathing rate)
B. **Alveolar ventilation rate**: [(tidal volume - dead air space) X rate]
C. Alveolar ventilation rate is important in the gas exchange between alveolar air and blood

VII. Control of Breathing
A. **Respiratory Center** - medulla oblongata and pons
1. Located in the brainstem

2. Respiratory rhythm area includes two neuron groups
   a. Dorsal - basic breathing rhythm
   b. Ventral - forceful breathing
3. Pneumotaxic area regulates the breathing rate

VIII. Regulation of blood flow
- A. Chemoreceptors: aortic and carotid arteries (sensitive to O_2 and CO_2 levels)
  1. Normal O_2 levels:
     a. High O_2 levels = fewer afferent impulses, medulla sends message to slow heart
     b. Low O_2 levels = more afferent impulses, medulla via efferent outflow increases heart rate
- B. Pressure receptors
  1. Arterial pressure receptors in aortic and carotid sinus:
     Pressure increases → increased stimulation → medulla (cardio-regulatory area) → Vagus nerve to heart (inhibitory) → decreased heart rate
  2. Venous pressure receptors in right atria and caval veins
     Pressure increases → stimulation to brain → heart (stimulatory)

IX. Factors that Affect Breathing
- A. Chemical, stretching of lungs, emotional state
- B. Chemosensitive areas are connected to the respiratory center
  1. CO2 and H2O create carbonic acid
  2. This releases H+ ions
  3. Chemosensitive areas influenced by H+
  4. Stimulation increases breathing rate
- C. Inflation reflex and hyperventilation

X. Alveolar Gas Exchange
- A. Alveoli:
  1. Air sacs at the distal end of the alveolar duct
  2. Alveoli may have alternate passageways into other alveoli
- B. Respiratory membrane:
  1. Alveolar and capillary walls
  2. Gas exchange takes place through this area

XI. Transport of Gases
- A. O2 combines with hemoglobin
- B. Results in oxyhemoglobin - unstable, releases O2 in low oxygen areas
- C. More oxygen released when:
  1. Higher temperature
  2. Blood becomes more acidic
  3. CO2 level increases
- D. Carbon monoxide (CO)
  1. CO forms as a result of fuel combustion
  2. Combines with hemoglobin easily - more stable

3. Toxic - hemoglobin can't transport O2

E. Carbon dioxide (CO_2)
   1. Carried either with hemoglobin or as bicarbonate ion
   2. Most transported as bicarbonate ion
   3. Carbonic anhydrase (enzyme) speeds reactions of water and Co_2 to form carbonic acid
   4. Carbonic acid releases H^+ and bicarbonate ions

C. Oxygen (O_2)
   1. Used for cellular respiration in the mitochondria, essential in the Kreb's cycle and E.T.S.