

# Respiratory System

## I. Functions of the Respiratory System

- A. gas exchange
- B. prevent dehydration
- C. sound
- D. olfaction
- E. pH regulation

## II. Anatomy of the Respiratory System

### A. Nose

- 1. external nares – vestibule – nasal cavity – internal nares (choanae)
- 2. paranasal sinuses – frontal, sphenoidal, maxillary, ethmoidal
- 3. nasal conchae – turbinates – and meatuses – warm, moisten and trap
- 4. nasal mucosa – cilia – smoker's cough
- 5. cystic fibrosis – thick mucous secretions that block airways – genetic

### B. Pharynx

- 1. muscular tube lined by mucous membrane
- 2. throat
- 3. nasopharynx, oropharynx, laryngopharynx

### C. Larynx

- 1. voice box
- 2. connects pharynx to trachea
- 3. thyroid cartilage – Adam's apple – hyaline – thyrohyoid membrane
- 4. cricoid cartilage – landmark for tracheostomy
- 5. epiglottis
- 6. arytenoids, cuneiform, and corniculate cartilages – important in supporting and moving the vocal chords
- 7. voice production – elastic ligaments deep to membrane of vocal folds
  - a. contraction causes vocal folds to stretch into airways
  - b. air pushes against them and vibrates – strings of a guitar
  - c. pitch controlled by tension on vocal chords – males thicker and longer, lower pitch
  - d. volume controlled by air pressure
  - e. whispers almost close rima glottides – vocal folds do not vibrate, no pitch
- 8. laryngitis – inflammation of the larynx – interferes with contraction of vocal cords or can't vibrate freely

### D. Trachea

- 1. windpipe
- 2. connects larynx to primary bronchi
- 3. tracheal cartilage – rings, keeps airway open
- 4. tracheostomy – hole
- 5. intubation – tube

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## E. Bronchi

1. right and left pulmonary bronchi
2. bronchial tree
  - a. trachea, primary bronchi, secondary bronchi, tertiary bronchi, bronchioles, terminal bronchioles
  - b. walls of bronchi contain rings of cartilage
  - c. walls of bronchioles contain smooth muscle tissue
3. compare tissues as look at tree
4. bronchoscopy – illuminated tube, culture, biopsy, meds, clear

## F. Lungs

1. pleural membrane
  - a. parietal – attached to wall of thoracic cavity
  - b. visceral – covers lungs
  - c. pleural cavity
2. right lung has three lobes, left has two
3. within lobules of lobes, terminal bronchioles subdivide into respiratory bronchioles which subdivide into alveolar ducts which divide into alveoli arranged in alveolar sacs
4. surfactant – in alveolar fluid – surface tension at all water air interferes; polar molecules more strongly attracted to each other than to air molecules – like keeping a soap bubble from collapsing, keeps alveoli from collapsing
  - a. phospholipids and lipoproteins that keeps alveoli from collapsing after each exhalation
5. pneumonia – inflammation of lobules of lung
6. pulmonary embolism – clot that blocks that obstructs circulation to the lung tissue
7. pleurisy – inflammation of pleural membrane

## III. Respiratory Physiology

### A. Pulmonary Ventilation – breathing

1. compliance – measure of the ease with which the lungs and thoracic wall can be expanded – balloon (thin or thick)
2. inspiration – inhalation
  - a. Boyle's law – pressure is inversely related to volume of gas assuming the temperature is constant – jar demo
3. muscles used in respiration
  - a. diaphragm – contraction lowers
  - b. external intercostals – contraction pulls ribs and sternum up and out
  - c. internal intercostals – contraction pulls ribs and sternum down and in
4. pressure
  - a. atmospheric pressure = 760 mm Hg
  - b. intrapleural pressure
    - i. subatmospheric – 4.6 mm Hg less than atmospheric – causes parietal and visceral pleurae to adhere strongly to each other – surfaces moist helps also

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- c. alveolar pressure (intrapulmonic)
    - i. lung volume increases causing alveolar pressure to drop about 2 mm Hg – allows alveoli to fill with air
  - 5. expiration – exhalation
    - a. inspiratory muscles relax – decrease volume
    - b. alveolar pressure increases to 762 mm Hg
    - c. air moves out of lungs
  - 6. breathing patterns
    - a. normal quiet breathing – eupnea
      - i. passive – no muscle contractions used
      - ii. elastic recoil of chest wall and lungs
    - b. apnea
      - i. temporary cessation of breathing
    - c. dyspnea – labored heavy breathing
    - d. tachypnea – rapid breathing
    - e. costal breathing – shallow, chest breathing – external intercostals
    - f. diaphragmatic breathing – diaphragm + accessory inspiratory muscles
  - 7. atelectasis – collapsed lung or incomplete expansion of a lung
- B. Lung Volumes and Capacities
- 1. respiration – one inspiration + one exhalation
  - 2. spirometer – used to measure volume of air in a breath and rate of ventilation
  - 3. tidal volume – 500 ml – volume of one breath
  - 4. minute ventilation – amount of air inhaled and exhaled in 1 minute
  - 5. anatomic dead space – 150 ml of the 500 ml tidal volume remain in air spaces of the respiratory system – about the same as ideal weight in pounds
  - 6. inspiratory reserve volume – inspired air above and beyond tidal volume – 3100 ml
  - 7. expiratory reserve volume – exhaled air above and beyond tidal volume – 1200 ml
  - 8. residual volume – 1200 ml that cannot be expired due to incompressible structures in the respiratory system
  - 9. vital capacity – 4800 ml – inspiratory reserve + tidal volume + expiratory reserve
  - 10. total lung capacity – sum of all volumes – 6000 ml – including residual volume
- C. Exchange of Oxygen and Carbon Dioxide
- 1. Gas Laws
    - a. Dalton's Law
      - i. each gas in a mixture exerts pressure as if all other gases not present – partial pressure
      - ii. gas diffuses from an area where partial pressure is higher to where its partial pressure is lower

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- b. Henry's Law
    - i. the quantity of a gas that will dissolve in a liquid is proportional to the partial pressure of the gas and its solubility coefficient (physical or chemical attraction for water)
    - ii. decompression sickness – nitrogen comes out of solution in tissues
  - 2. Respiration
    - a. external respiration
      - i. exchange of oxygen and carbon dioxide at the alveoli
      - ii. high altitude sickness – total air pressure drops, percentage of oxygen is same, but less abundant due to drop in pressure
    - b. rate depends on
      - i. partial pressure difference of gases
      - ii. surface area for gas exchange
      - iii. diffusion distance
      - iv. solubility and molecular weight of the gases
    - c. internal respiration
      - i. systemic circulation
- D. Transport of Oxygen and Carbon Dioxide
- 1. Oxygen
    - a. 98.5% of oxygen transported by hemoglobin
    - b. only dissolved oxygen gets sent to tissue cells, bond with hemoglobin must break
    - c. hemoglobin and oxygen partial pressure
      - i.  $PO_2$  determines how much oxygen binds to hemoglobin – greater  $PO_2$  = higher saturation of hemoglobin
    - d. other factors that affect the saturation of hemoglobin
      - i. pH – Bohr effect – as pH decreases, affinity for  $O_2$  decreases,  $O_2$  dissociates – due to hydrogen ions binding to amino acids and altering structure
      - ii. partial pressure of  $CO_2$  – high  $CO_2$  causes low pH due to formation of carbonic acid (skeletal muscle has lactic acid production that lowers pH and decreases affinity for oxygen)
      - iii. temperature – T increases,  $O_2$  released from hemoglobin
      - iv. 2, 3 – bisphosphoglycerate – BPG – formed during glycolysis – decreases affinity for oxygen – binds to hemoglobin
    - e. fetal hemoglobin
      - i. greater affinity for oxygen
      - ii. binds BPG less strongly
      - iii. important because maternal blood oxygen levels are very low in placenta
    - f. carbon monoxide poisoning
      - i. binds more strongly than oxygen
      - ii. even small concentrations of CO will reduce oxygen carrying ability

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2. Carbon Dioxide Transport
  - a. 3 forms of carbon dioxide
    - i. dissolved CO<sub>2</sub> in plasma – 7%
    - ii. bound to hemoglobin – 23%
    - iii. bicarbonate ions in plasma – 70% - H<sub>2</sub>CO<sub>3</sub> – H<sup>+</sup> + HCO<sub>3</sub><sup>-</sup>, H<sup>+</sup> combines with hemoglobin, oxygen dissociates, HCO<sub>3</sub><sup>-</sup> accumulates in RBC and diffuses down concentration gradient to plasma – Cl<sup>-</sup> ions replace as they diffuse into RBC – maintains electrical balance between plasma and RBC – chloride shift
3. Haldane Effect
  - a. the more oxygen bound, the less carbon dioxide
  - b. deoxyhemoglobin buffers more hydrogen ions, thereby removing hydrogen ions from solution and promoting the conversion of carbon dioxide to bicarbonate ions

## E. Control of Respiration

1. Neural Control
  - a. Respiratory center – medulla oblongata and pons
    - i. Medullary rhythmicity center – autorhythmic neurons begin inspirations and inspiratory area becomes active after 3 sec due to impulses from autorhythmic neurons – expiratory area normally not active unless forceful ventilation occurs
    - ii. Pneumotaxic area – inhibits inspiratory area – limits duration of inspiration
    - iii. Apneustic area – stimulates inspiratory area – prolong inspiration – pneumotaxic overrides
2. Chemical Regulation
  - a. chemoreceptors respond to pCO<sub>2</sub> and H<sup>+</sup> changes – if these chemicals increase, inspiratory area is stimulated
    - i. hypercapnia – increase in blood pCO<sub>2</sub> level
    - ii. hypocapnia – decrease in blood pCO<sub>2</sub> level
3. Inflation Reflex – Hering – Breuer reflex
  - a. baroreceptors in bronchi and bronchioles
  - b. when stretched, inhibit inspiratory and apneustic areas – prevents excessive inflation

## F. Disease Conditions

1. Emphysema – COPD (chronic obstructive pulmonary disease)
  - a. alveolar walls degenerate
2. Asthma – COPD
  - a. chronic inflammatory disorder
  - b. airways hyperreactive to stimuli
3. Tuberculosis
  - a. bacteria destroy lung tissue – replace by fibrous connective tissue