

## CHAPTER 19: RESPIRATORY SYSTEM

### OBJECTIVES:

1. Fully explain the process (5 parts of) respiration.
2. Describe the significance of oxygen and carbon dioxide in human cells.
3. Explain the structure and function of mucous membranes that line most of the respiratory tract.
4. Locate the upper respiratory organs on a diagram, describe their structure and any specific functions they may have (both respiratory and other functions, if applicable).
5. Name the four skull bones that contain sinuses.
6. Name the three parts of the pharynx.
7. Explain the significance of the epiglottis and glottis.
8. Give the scientific name for the "Adam's Apple".
9. Describe how and where sound originates and how it is then converted into recognizable speech.
10. Locate the lower respiratory organs on a diagram, describe their structure and any specific functions they may have.
11. Define the terms *C-ring*, *trachealis muscle*, and *carina*.
12. Name the type of cartilage that composes the trachea.
13. Distinguish between a primary, secondary, and tertiary bronchus.
14. Explain what happens to the epithelial lining, cartilage and smooth muscle of the bronchi as they branch deep into the lungs to form terminal bronchioles.
15. Explain the effects that histamine and epinephrine have on terminal bronchioles.
16. Discuss the structure and function of the pleural membranes.
17. Distinguish between a lobe and lobule of the lung.
18. Discuss the microscopic anatomy of the lung.
19. Track a breath of air from the nose to an alveolus, noting what happens to the air as it meets each structure.

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### Objectives (continued)

20. Distinguish between Type I and Type II Alveolar cells, in terms of structure and function.
21. Define the term *surfactant* and describe its important function.
22. Sketch a diagram of the respiratory membrane and then describe its structure in terms of tissue components and thickness. Name the process that occurs through this membrane and explain this process in terms of what is being transported and how, using numerical values.
23. Define the term *pulmonary ventilation*, and describe its two actions in terms of forces, muscles, and membranes involved.
24. Starting with the diaphragm muscle in its relaxed position, describe, in order, the events that occur during inspiration.
25. Explain how Boyle's Law relates to ventilation.
26. Explain why the serous fluid between the pleural membranes has such high surface tension.
27. Define the term *atelectasis*, explain what is usually lacking within the alveoli when it occurs, and name the disease of premature newborns when it occurs.
28. Name the instrument used to measure lung volumes.
29. List, define, give estimate values, and correlate the six different lung volume measurements.
30. Define the term *external respiration*.
31. State Dalton's Law and explain its significance in respiration.
32. List the percentages of N<sub>2</sub>, O<sub>2</sub>, and CO<sub>2</sub> in air.
33. Define what is meant by the partial pressure (pp) of a gas in a mixture and list the pp values of O<sub>2</sub> and CO<sub>2</sub> in air and in the lung capillaries.
34. Discuss the factors that influence the rate at which a gas diffuses.
35. Define the term *internal respiration*.
36. Discuss how oxygen, carbon monoxide and carbon dioxide are transported in the blood.

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### Objectives (continued)

37. Discuss the factors that cause oxygen to be released from the hemoglobin of red blood cells.
38. Define the term *hypoxia*, and describe how it occurs during carbon monoxide poisoning.
39. Write the chemical equation that involves carbon dioxide, water, carbonic acid, a hydrogen ion, and a bicarbonate ion, and explain its significance.
40. Locate the neural respiratory center on a diagram.
41. Distinguish between the rhythmicity area and pneumotaxic area of the neural respiratory center.
42. Explain how respiration is affected by varying chemical ( $\text{CO}_2$  and  $\text{O}_2$ ) concentration in the blood.

## CHAPTER 19: RESPIRATORY SYSTEM

### I. INTRODUCTION

#### A. RESPIRATION: 5 parts:

1. **Pulmonary ventilation\*** = breathing;
2. **External respiration\*** = air into lungs; gas exchange (CO<sub>2</sub> load/O<sub>2</sub> unload); air out;
3. **Transport of respiratory gases** = gases in blood transported from lungs to body cells and back to lungs;
4. **Internal respiration** = exchange of gases at body capillaries (O<sub>2</sub> unload/CO<sub>2</sub> load).
5. **Cellular respiration** = use of oxygen by cells to produce energy (production of CO<sub>2</sub>).

\* Only these two portions are included in the respiratory system.

### II. ORGANS OF THE RESPIRATORY SYSTEM:

See Fig 19.1, page 740 and Summary Table 19.1, pg 752.

#### A. UPPER RESPIRATORY ORGANS: See Fig 19.2, page 741.

0. Most of the UROs are lined with **mucous membranes**:  
See Fig 19.3, page 741.
  - a. ET with many goblet cells (mucus);
  - b. Specifically, pseudostratified columnar ET in the trachea,
    - m The mucus functions to trap debris.
    - o The cilia beats the debris to the pharynx to be swallowed and destroyed by digestive enzymes.
    - m This tissue also serves to warm and moisten incoming air.
1. **Nose** (external nares or nostrils)
  - a. bone & cartilage with internal hairs;
  - b. traps large particles (i.e. filters air).
2. **Nasal cavity** (separated by nasal septum)
  - a. bone & cartilage lined with mucous membranes;
  - b. warms and moistens incoming air;
  - c. olfactory reception;
  - d. resonating chambers for speech.

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### II. ORGANS OF THE RESPIRATORY SYSTEM

#### A. UROs (continued)

3. **Nasal conchae** (within nasal cavity)
  - a. superior, middle & inferior;
  - b. divide nasal cavity into a series of groove-like passageways;
  - c. lined by mucous membranes;
  - d. increases turbulence of incoming air to better warm, moisten and filter).
  
4. **Paranasal sinuses: See Fig 19.4, page 744.**
  - a. within 4 skull bones (frontal, ethmoid, sphenoid, maxillary);
  - b. drain into nasal cavity;
  - c. lined with mucous membranes;
  - d. reduce weight of skull;
  - e. resonating chambers for speech.
  
5. **Pharynx** (or throat)
  - a. wall of skeletal muscle lines with mucous membranes;
  - b. passageway for air and food;
  - c. resonant chamber for speech sounds;
  - d. three parts:
    - m nasopharynx (uppermost);
    - m oropharynx (middle);
    - m laryngopharynx (lowest).
  
6. **Larynx** (or voice box) **See Fig 19.5, 19.6, & 19.7, pages 744 & 745.**
  - a. Anatomy (9 pieces of cartilage)
    - m **thyroid cartilage** (Adam's apple);
    - m **epiglottis** closes off the airway during swallowing;
    - m two pairs of vocal folds (false over true vocal cords);
    - m glottis = triangular slit; opening between two pairs of vocal cords.
    - m **cricoid cartilage** = ring of hyaline cartilage attached to first ring of trachea; site of tracheostomy
    - m arytenoid cartilages;
    - m corniculate cartilages;
    - m cuneiform cartilages.

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### II. ORGANS OF THE RESPIRATORY SYSTEM

#### A. UROs (continued)

#### 6. Larynx (or voice box) See Fig 19.7, page 745.

##### b. Voice production

Mucous membranes form 2 pairs of folds:

- m upper ventricular folds (false vocal cords);
- m lower vocal folds (true vocal cords);
- m space between them = glottis.

Sound originates from vibration of the vocal folds, but other structures (pharynx, mouth, nasal cavity, and paranasal sinuses) convert that sound into recognizable speech.

#### B. Lower Respiratory Organs:

#### 1. Trachea (windpipe) See Fig 19.8, page 746.

- a. Location = mediastinum; anterior to esophagus; extends from larynx to T5;
- b. Structure:
  - m 16-20 incomplete rings of hyaline cartilage = **C-rings**;
  - m Rings are completed by trachealis muscle and elastic CT facing esophagus;  
See Fig 19.9, page 746.
  - m lined by mucous membranes;  
See Fig 19.10, page 746.
  - m Carina = point where trachea divides into right & left bronchus;
- c. Function = **support against collapse**; continue to warm, moisten & filter air.

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### II. ORGANS OF THE RESPIRATORY SYSTEM

#### B. Lower Respiratory Organs:

##### 2. Bronchial tree within lungs: See Fig 19.12, pg 748.

- a. a **primary (1<sup>o</sup>) bronchus** leads into each lung and then branches into...
- b. **secondary (2<sup>o</sup>) bronchi** which branch to each lobe and then branch into ...
- c. **tertiary (3<sup>o</sup>) bronchi** that divide into...
- d. **bronchioles** which branch into tubes called...
- e. **terminal bronchioles.**

\* With this extensive branching:

m Epithelium changes from ciliated pseudostratified columnar epithelium to non-ciliated simple columnar epithelium in terminal bronchioles;

m Cartilage decreases;

m Smooth muscle increases (innervated by ANS and hormones:

1. Parasympathetic and histamine constrict bronchioles;
2. Sympathetic and epinephrine dilate bronchioles.

f. Further branching is microscopic and will be discussed in greater detail later:

m respiratory bronchioles;

m alveolar ducts;

m alveolar sacs;

m alveoli.

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### II. ORGANS OF THE RESPIRATORY SYSTEM

#### B. Lower Respiratory Organs:

##### 3. LUNGS: See Fig 19.12, page 748.

a. Location = thoracic cavity;

b. Description:

m paired, cone-shape organs;

m covered by **pleural (serous) membranes**:

1. visceral pleura;
2. parietal pleura;
3. pleural cavity filled with serous fluid.

\* In contrast to the lubrication function we attributed to serous fluid in the past, the **pleural fluid has a very high surface tension** that allows the two membranes to act as one (i.e. when the lungs inflate, the rib cage enlarges ...).

c. Gross Anatomy:

m **Each lung is divided into lobes** by fissures:

1. Right lung has 3 lobes;
2. Left lung has 2 lobes.

m Each lobe:

1. receives a secondary bronchus;
2. is divided into lobules.

m **Each lobule**: See Fig 19.14, page 749.

1. is wrapped in elastic CT;
2. contains a lymphatic vessel, an arteriole, a venule, and a branch from a terminal bronchiole.

d. Microscopic anatomy: Fig 19.14, page 749.

m Each **terminal bronchiole** subdivides into microscopic branches called...

m **respiratory bronchioles** (lined by simple squamous epithelium) which subdivide into several (2-11) ...

m **alveolar ducts** which terminate into numerous

m **alveoli** and alveolar sacs (2-3 alveoli that share a common opening).

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### II. ORGANS OF THE RESPIRATORY SYSTEM

#### B. Lower Respiratory Organs:

#### 3. LUNGS

##### e. ALVEOLI (microscopic air sacs)

See Fig 19.15, page 750 & Fig 19.32, page 766.

m wall consist of two types of epithelial cells and macrophages;

1. **Type I Alveolar cells** form a continuous simple squamous lining of the alveolar wall;
2. **Type II Alveolar cells** interrupt above lining and **secrete surfactant:**

- a. complex mixture = detergent;
- b. lowers surface tension and prevents alveolar collapse.

3. **Alveolar Macrophages** remove dust particles and other debris from alveolar spaces.

##### f. Alveolar-Capillary (Respiratory) Membrane

See Fig 19.32, page 766.

m Composition:

1. simple squamous epithelium of alveolus;
2. basement membrane of alveolus;
3. endothelium of the lung capillary;
4. basement membrane of lung cap.

m Structure = **thin** (0.5  $\mu\text{m}$  in thickness).

m Function = allows for **rapid diffusion of gases** (from [high] to [low]).

\* The lungs contain more than 300 million alveoli = SA of  $70\text{m}^2$  for gas exchange **at one time!**

##### g. Blood Supply to Lungs (two fold):

m pulmonary circuit (deoxygenated blood);

m Oxygenated blood is delivered through bronchial arteries (off thoracic aorta).

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### III. PHYSIOLOGY OF RESPIRATION

Recall that the function of the respiratory system is supply cells with oxygen and remove carbon dioxide. The three basic processes are pulmonary ventilation, external respiration and internal respiration.

#### A. Pulmonary Ventilation (Breathing):

Breathing involves two actions, inspiration & expiration.

##### 1. **Inspiration** (inhalation) = breathing air in.

###### a. Force necessary is **atmospheric pressure**:

m When the diaphragm is at rest (curved upward):

1. The air pressure outside the lungs is equal to the air pressure inside the lungs (1 atm or 760 mm Hg)
2. The thoracic cavity has a given size and volume.

Fig 19.20, page 754.

Fig 19.21, page 754.

m **During inspiration:**

See Fig 19.22, page 755.

(Boyles' Law)

1. The diaphragm muscle pushes downward;
2. The size of thoracic cavity increases;
3. The pressure in the thoracic cavity decreases (758 mm Hg);
4. The air pressure inside the thoracic cavity (lungs) is less than the atmospheric pressure and therefore **air rushes into lungs** to equalize the pressure gradient.

m **Pleural Membranes** aid in inspiration:

1. Serous fluid between membranes primarily contains water;
2. The water in the serous fluid has great **surface tension** and therefore,
3. Membranes move together:
  - a. thoracic cage expands;
  - a. parietal pleura expands;
  - b. visceral pleura expands;
  - c. lungs expand.

m Contraction of the external **intercostal muscles** also aid inspiration.

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### III. PHYSIOLOGY OF RESPIRATION

#### A. Pulmonary Ventilation (Breathing):

2. **Expiration** = breathing out depends on two factors:  
See Fig 19.24, page 757.

- a. the **elastic recoil of tissues** that were stretched during inspiration (i.e. tissues bouncing back to shape).
- b. the inward pull of surface tension due to the alveolar fluid.

\* See Summary of inspiration and expiration in Table 19.2, page 755 and Table 19.3, page 757.

3. **Atelectasis** (Collapsed Lung)

- a. At the end of an expiration, the alveoli tend to recoil inward and collapse on themselves;
- b. **Surfactant** (mixture of phospholipid & proteins) produced by Type II Alveolar cells decreases the surface tension in the lungs;
- c. As the alveoli become smaller during expiration, the surfactant overcomes the pressure differential and allows the alveoli to remain inflated.

\* **Respiratory Distress Syndrome (RDS)** in newborns (collapsed lungs) occurs due to the lack of surfactant in the alveoli.

See page 755.

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### III. PHYSIOLOGY OF RESPIRATION

#### A. Pulmonary Ventilation (Breathing):

#### 4. Respiratory Air Volumes: See Fig 19.25, page 758.

- a. are measured by a **spirometer**;
- b. include the following:
  - m **Tidal Volume** = amount (volume) of air that enters the lungs during normal inspiration and leaves the lungs during normal expiration; approximately 500 ml;
  - m **Inspiratory Reserve Volume (IRV)** = the amount of air the can be forcibly inhaled after a normal tidal expiration; approximately 3000 ml;
  - m **Expiratory Reserve Volume (ERV)** = the amount of air that can be forcibly exhaled after a normal tidal expiration; approximately 1100 ml;
  - m **Vital Capacity (VC)** = the maximum amount of air that can be exhaled after a maximum inhalation;  
**VC = TV + IRV + ERV = 4600 ml.**
  - m **Residual Volume** = amount of air that always remains in lungs; 1200 ml;
  - m Total Lung Capacity = VC + RV; approximately 6 L.

**See Summary Table 19.4, page 759.**

#### 5. Modified Respiratory Movements (Table 19.5, page 760)

Modified respiratory movements occur in addition to normal breathing; usually the result of reflexes.

- a. Cough = sends blast of air through and clears upper respiratory tract;
- b. Sneeze = forcefully expels air through nose & mouth;
- c. Laugh = a deep breath released in a series of short convulsive expirations;
- d. Hiccup = spasmodic contraction of diaphragm;
- e. Yawn = deep inspiration through open mouth; (ventilates alveoli?).

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### IV. Control of Breathing

- A. Normal breathing = rhythmic; involuntary.
- B. Nervous Control = **Respiratory Center**:  
See Fig 19.27, page 760.
  - 1. located in pons & medulla of brain stem;
  - 2. **Rhythmicity area** = medulla:
    - a. composed of **dorsal respiratory group** which controls the basic rhythm of breathing;
    - b. **ventral respiratory group** which controls forceful breathing.
  - 3. **Pneumotaxic area** = pons:
    - a. controls rate of breathing.

\* See Fig 19.28, page 762 for Summary of Nervous Control of Breathing
- C. Chemical Regulation: See Fig 19.29, page 763.
  - 1. **Chemoreceptors** in carotid & aortic bodies of some arteries are sensitive to:
    - a. Low levels of oxygen;
    - b. High levels of CO<sub>2</sub> ;
      - m affect chemosensitive areas of respiratory center and breathing rate increases.
    - c. Effector Sites:
      - m diaphragm/intercostals
      - m smooth muscle of terminal bronchioles
    - d. **Hyperventilation**
      - m rapid, shallow breathing increases O<sub>2</sub> level;
      - m breathing into paper bag rich in CO<sub>2</sub> normalizes gas concentrations

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### IV. Control of Breathing

#### D. **Factors that influence breathing:**

See Table 19.6, page 765.

1. Stretch of Tissues;
2. Low blood oxygen;
3. High Blood carbon dioxide;
4. Low pH;
5. Others: temperature, pain, irritation of airways.

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### V. EXTERNAL RESPIRATION: See Fig 19.34, page 767.

- A. Definition = the exchange of oxygen and carbon dioxide between the alveoli and lung blood capillaries.
- B. The pressure of gas determines the rate at which it will diffuse from region to region (Dalton's Law).
- C. Air is a mixture of gases:
1. 78% Nitrogen
  2. 21% Oxygen
  3. .04% Carbon Dioxide
- D. In a mixture of gases, the amount of pressure that each gas creates = partial pressure.  
In air:  $O_2 = 21\%$ ;  $P_{O_2} = 104$  mm Hg  
 $CO_2 = .04\%$ ;  $P_{CO_2} = 40$  mm Hg
- E. The partial pressure of a gas is directly related to the concentration of that gas in a mixture.
- F. Diffusion of gases through the respiratory membrane proceeds from where a gas is at high pp -----> low pp.

#### Alveolus

$$P_{CO_2} = 40 \text{ mm Hg}$$

$$P_{O_2} = 104 \text{ mm Hg}$$

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$$P_{CO_2} = 45 \text{ mm Hg}$$

$$P_{O_2} = 40 \text{ mm Hg}$$

#### Capillary

**Therefore,  $CO_2$  will flow from lung capillary -----> alveolus &  $O_2$  will flow from alveolus -----> lung capillary.**

- G. The **rate of diffusion of gases** also depends on a number of factors, including the following:
1. gas exchange surface area;
  2. diffusion distance;
  3. breathing rate and depth.

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### VI. Internal Respiration

- A. Definition = the exchange of oxygen and carbon dioxide between tissue blood capillaries and tissue cells.
- B. In tissue cell:  $p\text{CO}_2 = 45$ ;  $p\text{O}_2 = 40$ ;  
In tissue cap:  $p\text{CO}_2 = 40$ ;  $p\text{O}_2 = 105$ .
- C. Therefore, oxygen moves from the tissue cap into the tissue cell and carbon dioxide moves from the tissue cell into the tissue cap.

### VII. Transport of Gases (in Blood)

- A. Oxygen
  - 1. binds with hemoglobin (Hb) in red blood cells to form oxyhemoglobin;
  - 2. A weak bond is formed so oxygen can be delivered (released into) to tissues when needed.
  - 3. The release of oxygen from hemoglobin depends on many factors:
    - a. high blood  $[\text{CO}_2]$ ;
    - b. low blood pH (acidity);
    - c. high blood temperature.
    - \* To remember these conditions, think of what happens in a skeletal muscle during exercise, when oxygen is required.
  - 4. Carbon Monoxide (CO) binds to hemoglobin more efficiently than oxygen.
    - a. If the hemoglobin (that is suppose to bind with oxygen) is bound to CO, much less Hb is available to bind and transport oxygen to the tissues; **Hypoxia** results.  
See introduction on page 739.

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### VII. Transport of Gases (in Blood)

#### B. Carbon Dioxide (CO<sub>2</sub>)

1. CO<sub>2</sub> is transported in 3 forms:

- a. dissolved CO<sub>2</sub>= 7%
- b. carbaminohemoglobin= 23%
- c. bicarbonate ions= 70%

2. In tissues, CO<sub>2</sub> is produced by cellular respiration.

- a. This CO<sub>2</sub> combines with H<sub>2</sub>O to form H<sub>2</sub>CO<sub>3</sub> (Carbonic acid) which then
- b. dissociates under the influence of carbonic anhydrase to release
- c. H<sup>+</sup> and bicarbonate ion(HCO<sub>3</sub><sup>-</sup>):



\* RXN is reversed in lungs & CO<sub>2</sub> is expelled during expiration.

## **CHAPTER 19: RESPIRATORY SYSTEM**

### **VIII. Homeostatic Imbalances: Disorders of the Respiratory System**

- A. Deviated Septum (page 740)
- B. Effects of Cigarette Smoking (CA 19.1, pages 742-743)
- C. Cystic Fibrosis (page 749)
- D. Respiratory Distress Syndrome (page 755)
- E. Pneumothorax (page 756)
- F. Sleep Apnea (page 762)
- G. Altitude Sickness (page 767)
- H. Disorders Impairing Gas Exchange (CA 19.5, page 768-769)

### **IX. Other Interesting Topics Concerning the Respiratory System**

- A. Tracheostomy (page 746 and Fig 19.11, page 747).
- B. Bronchoscopy (page 748)
- C. Artificial Respiration (page 750)
- 4. Lung Irritants (CA 19.2, page 753)
- 5. Respiratory Disorders that Decrease Ventilation (CA 19.3, page 761)
- 6. Exercise and Breathing (CA 19.4, page 765)

### **X. Innerconnections of the Respiratory System**

See page 773.