ANATOMY AND PHYSIOLOGY OF THE PULMONARY SYSTEM
Section 1 Part B
Reading Assignment: Des Jardins - Chapter 1, pp.

THE LOWER AIRWAY

I. Cartilaginous Airways
   A. Trachea
      1. extends from the cricoid cartilage at C6 to carina at T5 (second costal cartilage) and the angle of Louis
      2. trachea is 11 to 13 cm in length, 1.5 to 2.5 cm in diameter
         a. infant - trachea is approximately 6-8 cm long
      3. epithelium - pseudostratified ciliated columnar epithelium
         a. approximately 200 cilia per cell, length of cilia is 5-7 µ
         b. cilia beat about 1500 x per minute
         c. goblet cells -
            d. extends from trachea to respiratory bronchioles
      4. contains 16 to 20 C-shaped cartilaginous rings -
      5. posterior aspect of ring is open -
      6. a fibroelastic membrane separates the trachea from the anterior wall of the esophagus
      7. divides the right and left main stem bronchi at the carina
   B. Mainstem bronchi (2)
      1. represents the first generation of airway
      2. histologically is similar to the trachea
      3. the mainstem bronchi are surrounded by C-shaped cartilaginous rings
      4. right main stem bronchus
         a. wider and shorter than the left mainstem bronchus
         b. forms a 20 to 30 degree angle with the vertical axis
      5. left mainstem bronchus
         a. forms a 45 to 55 degree angle with vertical axis
         b. due to greater angle of deviation, aspirate is less likely to enter left mainstem bronchus than right
      6. in the infant the mainstem bronchi bifurcate at equal angle of about 55 degrees to midline
   C. Lobar bronchi (5)
      1. represent the second generation of airways
      2. histologically similar to trachea and mainstem bronchi
      3. cartilage assumes the shape of irregular plates and diminish in size and number as they progress into the lung
      4. right mainstem bronchi divides into three lobar bronchi
         a. upper
         b. middle
         c. lower
      5. left mainstem bronchi divides into two lobar bronchi
         a. upper and lower
   D. Segmental bronchi (18)
      1. third generation of airways, branch from lobar bronchi
      2. right lung has 10 segments
         a. upper lobe (3) segments - 1) apical segment (s.), 2) posteriors., 3) anterior s.
         b. middle lobe (2) segments - 4) lateral s., 5) medial s.
         c. lower lobe (5) segments - 6) superior basal s., 7) medial basal s., 8) anterior basal s., 9) lateral basal s., 10) posterior basal s.
3. the left lung has 8 segments  
   a. upper lobe (4) segments - 1) apical posterior s., 3) anterior s., 4) superior lingula, 5) inferior lingula  
   b. lower lobe (4) segments - 6) superior basal s., 8) anterio-medial basal s., 9) lateral basal s., 10) posterior basal s  
   c. epithelium - pseudostratified ciliated columnar  

E. Subsegmental bronchi  
   1. comprise airway generations 4 to 9  
   2. airway diameter decreases from 4 to 1 mm  
   3. peribronchiolar connective tissue containing bronchial arteries, nerves, and lymphatics surrounds the bronchi  
   4. only small plates of cartilage remain and disappear by the 9th generation  

II. Noncartilaginous Airways  
A. Bronchioles - diameter is less than 1 mm, no longer surrounded by connective tissue sheaths  
   1. nonrespiratory bronchioles - generation 10-19  
      a. conduct gas to area of gas exchange  
      b. epithelium  
         i) pseudostratified ciliated columnar  
         ii) goblet cells disappear by 16th generation  
      c. cartilage is absent, lamina propria is directly connected to lung paryenchyma  
      d. terminal bronchioles - generation 16-19  
         i) cilia ends at 16  
         ii) epithelium changes to cuboidal cells  
      e. terminal bronchioles mark the end of conducting airways the cross sectional area of the airways increases markedly at the 16 generation  
   2. respiratory bronchioles  
      a. consist of three to four generations - (20-23)  
      b. epithelium is low cuboidal that flattens to simple squamous epithelium at the alveolar level  
      c. gas exchange begins in this area where squamous cells begin  
      d. alveoli appear  
      e. the portion of the airway distal to a terminal bronchiole forms the "terminal respiratory unit" or acinus  

B. Alveolar ducts  
   1. arise from respiratory bronchioles  
   2. consists of three to four generations - (24-27)  
   3. composed of simple squamous epithelium  
   4. each duct ends in a cluster of alveolar sacs and alveoli  
   5. smooth muscles continues as small fibers in the openings of the alveolar ducts  
   6. about one half of the total number of alveoli arise from alveolar ducts  

C. Alveolar sacs  
   1. final generation  
   2. exist in cluster of 15 to 20 units with common walls  
   3. represent the remaining one half of alveoli  

D. Alveoli  
   1. alveolar epithelium is composed of Type I or squamous pneumocytes and Type II or granular pneumocytes  
      a. Type I cells are flat, thin and comprise 95% of the alveolar surface  
      b. Type II comprise only 5% to total surface but are equal to or exceed the number
of Type I cells.
i) cells are cuboidal
ii) responsible for the production, storage and release of surfactant
c. Type III cells are the pulmonary macrophages
   i) move with ameboid motion
   ii) rid the lung of any foreign substance by phagocytosis
2. there are approximately 300 million alveoli in the two lungs -
3. pores of Kohn (alveolar septal pores)
a. holes located in inter alveolar septa
b. lined with alveolar epithelial cells
c. thought to contribute to collateral ventilation -
4. canals of Lambert
   a. pathways connecting terminal and respiratory bronchioles to other airways of other terminal respiratory airways
   b. provide collateral ventilation

III. Specialized Cells and Tissues of the Pulmonary System
A. Alveolar-capillary membrane
1. structure
   a. alveolar epithelium
   b. alveolar basement membrane
   c. ground substance
   d. endothelial basement membrane
   e. endothelium
2. pathway for oxygen to move from the alveolus to the hemoglobin molecule
   a. surfactant layer
   b. alveolar epithelium and basement membrane
   c. ground substance
   d. endothelium basement membrane and endothelium
   e. plasma
   f. red blood cell membrane
   g. red blood cell cytoplasm to hemoglobin molecule

B. Specialized cells in the respiratory system
1. alveolar macrophages
   a. phagocytic cells located in the luminal space of the alveolus -
   b. originate in the bone marrow as monocytes and migrate to the lung through the blood stream
   c. help to remove bacteria and other particles in the terminal airways
   d. in addition to defending the lung, macrophages synthesize interferon and tumor-inhibiting factors
2. basal cells
   a. located in the epithelium along the basement membrane -
   b. replenish surface layers of ciliated and mucous cells
3. Clara cells
   a. function as secretory cells in respiratory bronchioles
   b. secretions contribute to extracellular liquid lining of he bronchioles
   c. contain enzymes that help detoxify inhaled toxic substances
   d. may also produce and release surfactant
4. mast cells
   a. found in respiratory mucosa, connective tissue, and the lung parenchyma
   b. when stimulated by the antigen-antibody reaction these cells release chemical mediators - histamine, serotonin, ECF, heparin
5. goblet cells  
   a. synthesize mucus and secrete contents to the epithelial surface  
   b. stimulated by irritation that results in increased mucus production  

C. Histology of the tracheobronchial tree  
1. epithelium ranges from pseudostratified ciliated columnar epithelium to low cuboidal to simple squamous epithelium.  
2. tunica muscularis  
   a. muscle bands are wrapped around airway  
   b. extend distally to alveolar ducts  
   c. stimulation causes bronconstriction and increases airway resistance  
3. lamina propria  
   a. contains loose fibrous tissue  
   b. blood vessels  
   c. branches of vagus nerve  
   d. mast cells  
   i) located near blood vessels, scattered throughout smooth muscles  
   ii) release chemical mediators causing bronchoconstriction  
   e. the amount of cartilage present is usually inversely proportional to the amount of smooth muscle present  

D. Mucus  
1. submucosal glands in the epithelium and goblet cells store and release mucus  
   a. submucosal glands extend deep into the lamina propria  
   b. innervated by the vagal parasympathetic nerve  
   c. produces approx. 100 ml of mucus per day  
   d. found from trachea to terminal bronchioles  
2. composition of mucus  
   a. water 95%  
   b. glycoprotein 1%  
   c. carbohydrates  
   d. lipids  
   e. DNA  
   f. cellular debris  
   g. foreign particles  
3. function of mucus and ciliated epithelium  
   a. clearance mechanism for foreign particles and debris  
   b. humidification of inspired air  
4. mucus is divided into two layers  
   a. sol layer  
   i) fluid layer adjacent to the mucosal surface  
   ii) layer in which ciliary activity takes place  
   b. gel layer  
   i) more viscous layer than sol  
   ii) propelled on top of sol layer  
5. increased mucus production occurs in chronic bronchitis due to hyperplasia of the goblet cells and the submucosal glands  
6. factors that slow down mucus travel  
   a. cigarette smoke  
   b. dehydration  
   c. positive pressure ventilation
IV. Circulatory Systems in the Lung

A. Bronchial circulation
1. bronchial arteries nourish the tracheobronchial tree -
   a. arise from the aorta
   b. extend into the lung next to airways -
   c. provide arterial blood to -
2. airways are nourished by pulmonary arteries at the terminal airways and down to the alveolar sacs
3. venous return
   a. one third of the blood returns to the right atrium via the azygos, hemiazygous, and intercostal veins
   b. two-thirds of the blood returns through pulmonary circulation via bronchopulmonary anastomosis -

B. Pulmonary vascular system
1. pulmonary cardiac output originates from the right ventricle -
   a. pulmonary circulation moves through arteries, arterioles, capillaries, venules, and veins before returning to the left atrium
   b. primary function is to circulate blood by the alveoli in order for blood to load oxygen and unload carbon dioxide
   c. pulmonary circulation also provides nutritional support for lung paryenchyma beginning with the terminal bronchioles and extending to the alveolar sacs
2. arteries
   a. pulmonary arteries enter through the hilar region of the lung -
   b. follow airways in a posterior lateral position
   c. arteries branch as airways branch
   d. an artery has three distinct layers:
      i) tunica intima -
      ii) tunica media -
      iii) tunica adventitia -
3. arterioles
   a. walls of arterioles consist of three layers
      i) endothelial layer
      ii) elastic layer -
      iii) smooth muscle fibers -
   b. supply nutrients to respiratory bronchioles
   c. regulate pulmonary blood flow -
4. capillaries -
   a. composed of thin endothelium -
   b. endothelium has selective permeability -
   c. primary function -
   d. also provide sites where biologically active substances can be degraded -
5. venules and veins
   a. provide a route for blood to return to the left heart
   b. veins have thinner walls and contain less smooth muscles
   c. do not have one-way valves as seen in systemic circulation
   d. provide reservoirs for circulation
   e. veins return to the hilar region via independent routes