Pulmonary A & P
Advanced Pathophysiology

Starting points

- Upper and lower airways, chest wall, circulation
- Primary function to exchange gases between blood and environmental air
- 3 steps in this process
    - ventilation
    - diffusion
    - perfusion

Structure/function

- nasopharynx: The upper part of the pharynx that connects the nasal cavity to the throat

- tonsils: Masses of lymphoid tissue found in the pharynx that play a small role in immune system function
-
- laryngopharynx: The lower part of the pharynx above the larynx and below the oropharynx

- oropharynx: The middle part of the pharynx that connects to the oral cavity and the other two chambers of the pharynx

- Lungs: principal function is to transport oxygen from the atmosphere into the bloodstream, and to release carbon dioxide from the bloodstream into the atmosphere. Air travels through the mouth or nose into the pharynx, larynx, trachea, and bronchi and bronchioles in order to reach the lungs

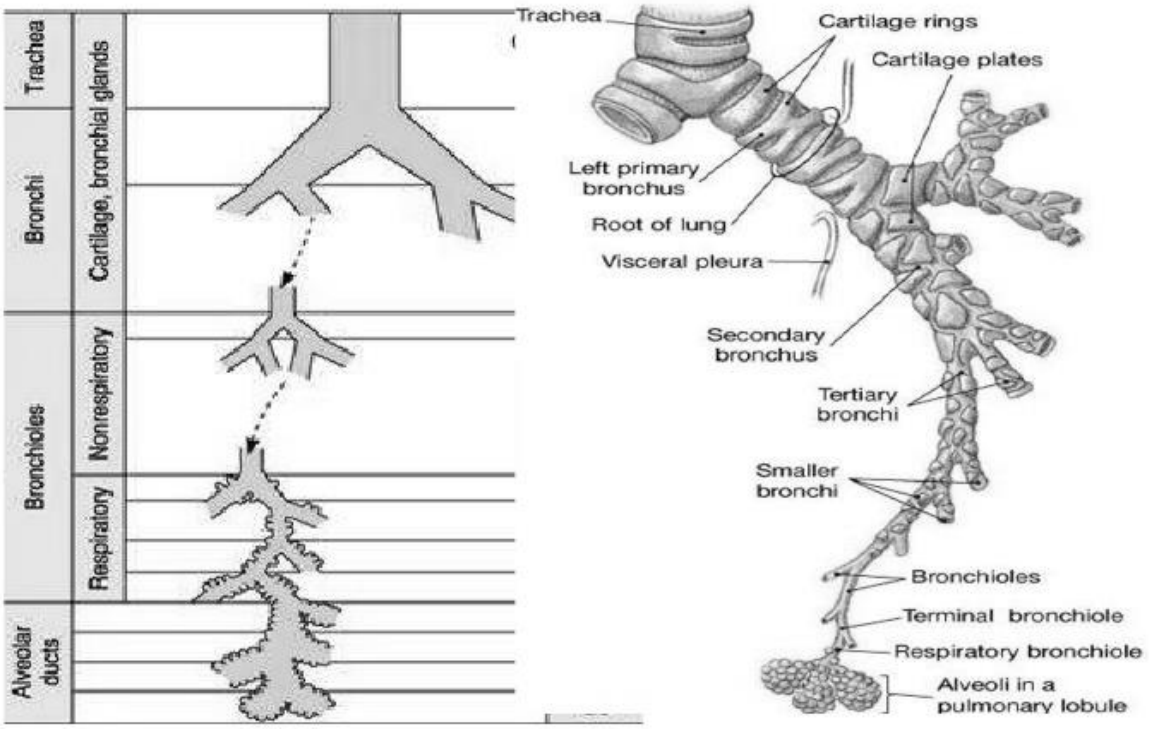
- Alveoli: the functional units of the lungs, exchange of gases here

- pleura: The double-layered membranous lining of the thoracic cavity that covers the lungs

- bronchus: Either of the two airways that are the primary branches of the trachea, leading directly into the lungs

- bronchopulmonary segment: A distinct functional region of the lung that is separated from the rest of the lung by connective tissue

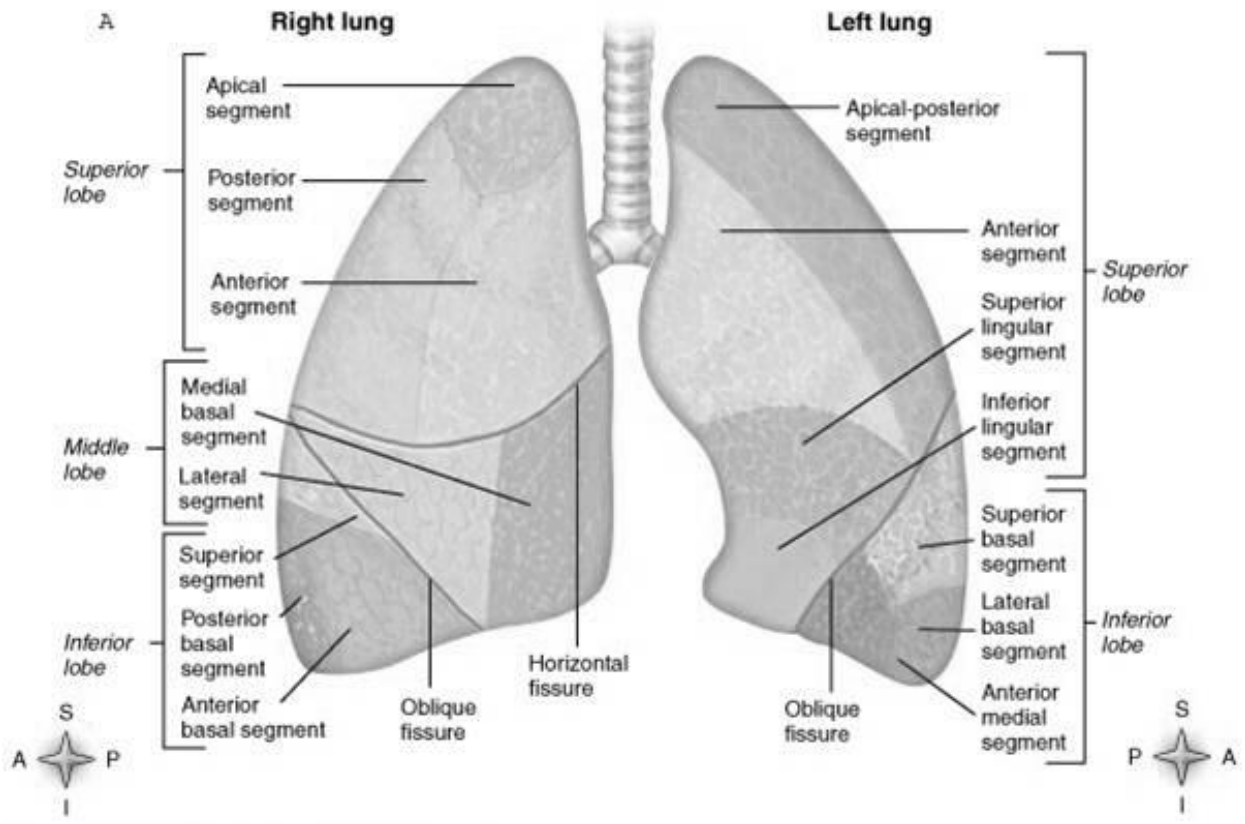
Conducting & Respiratory Zones



- Alveoli: primary gas exchange units
- 480 mil by adulthood

- dead space: Alveolar space that can no longer contribute to gas exchange
- due to damage or scarring
- Physiological dead space

- extracellular matrix: A fluid space secreted by cells (including alveolar cells) for structural and functional support



Pulmonary circulation

- Extensive surface area for gas exchange
    - >>> dissolved oxygen enters the capillaries, while carbon dioxide leaves pulmonary circulation
    - >>>The oxygenated blood then leaves the lungs through pulmonary veins (also contained in the hilum)
    - >>> then return the blood to the left side of the heart, completing the cycle of pulmonary circulation

Inspiration

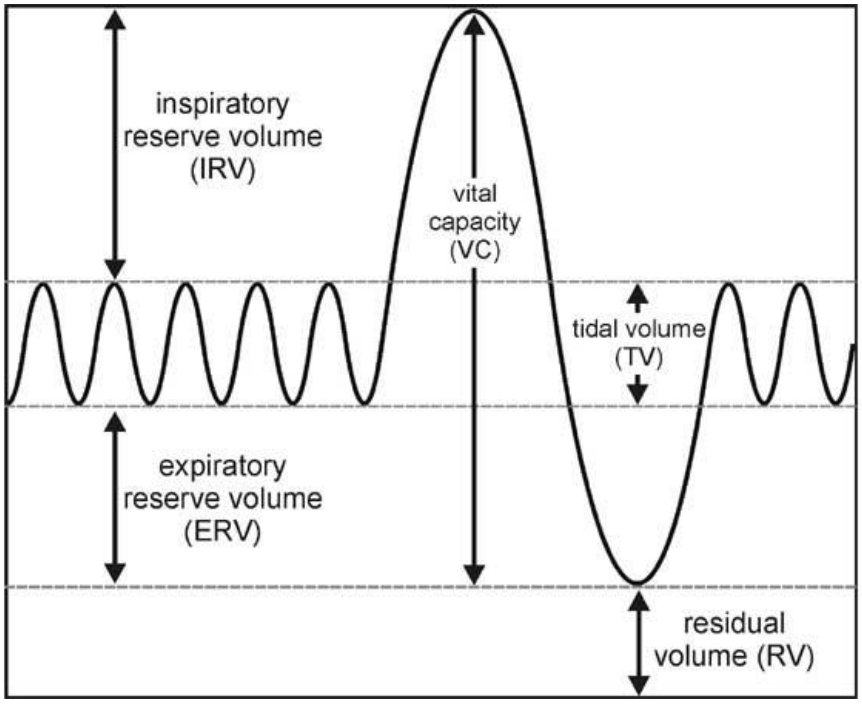
- begins with the contraction of the diaphragm, which results in expansion of the thoracic cavity and the pleural cavity
- The pleural cavity normally has a lower pressure compared to ambient air (–3 mmHg normally and typically –6 mmHg during inspiration), so when it expands, the pressure inside the lungs drops
- Pressure and volume are inversely related to each other, so the drop in pressure inside the lung increases the volume of air inside the lung by drawing outside air into the lung

Expiration

- voluntary or involuntary = serve different purposes for the body
- 2 types of expiration are controlled by different centers within the body.
- Voluntary expiration is actively controlled. It is generally defined by holding air in the lungs and releasing it at a fixed rate
    - The nervous system component that controls voluntary expiration is the motor cortex (the ascending respiratory pathway), because it controls muscle movements, but this pathway isn't fully understood, and there are many other possible sites in the brain that may also be involved
- Involuntary expiration is not under conscious control, and is an important component for metabolic function.
    - Examples include breathing during sleep or meditation. Changes in breathing patterns may also occur for metabolic reasons, such as through increased breathing rate in people with acidosis from negative feedback
    - principle neural control center for involuntary expiration consists of the medulla oblongata and the pons, which are located in the brainstem directly beneath the brain.

Respiratory rate

- time period is variable (usually expressed in breaths per minute)because it that time period allows for estimation of minute ventilation
- During normal breathing, the volume of air cycled through inhalation and exhalation is called tidal volume (VT), and is the amount of air exchanged in a single breath
- Tidal volume x respiratory rate = minute ventilation, which is one of the most important indicators of lung function
- In an average human adult, the average respiratory rate is 12 breaths per minute, with a tidal volume of .5 liters and a minute ventilation of 6 liters per minute, though these numbers vary from person to person
- Infants and children have considerably higher respiratory rates than adults



Respiratory Center

- Respiratory centers contain chemoreceptors that detect pH levels in the blood
- ventral respiratory group controls voluntary forced exhalation and acts to increase the force of inspiration

- dorsal respiratory group (nucleus tractus solitarius) controls mostly inspiratory movements and their timing

- Ventilatory rate (minute volume) is tightly controlled and determined primarily by blood levels of carbon dioxide as determined by metabolic rate
- Chemoreceptors can detect changes in blood pH that require changes in involuntary respiration to correct
- The apneustic (stimulating) and pneumotaxic (limiting) centers of the pons work together to control rate of breathing

Ventilation

- Ventilation occurs under the control of the autonomic nervous system from parts of the brain stem—the medulla oblongata and the pons —that together form the respiration regulatory center
- Minute Ventilation (VE): The amount of air entering the lungs per minute
- It can be defined as tidal volume (the volume of air inhaled in a single breath) times the amount of breaths in a minute
- Alveolar Ventilation (VA): amount of gas per unit of time that reaches the alveoli

- It is defined as tidal volume minus dead space (the space in the lungs where gas exchange does not occur) times the respiratory rate
- Dead Space Ventilation (VD): The amount of air per unit of time that doesn't reach the alveoli
    - It is defined as volume of dead space times the respiratory rate

Pulmonary ventilation

- rate at which gas enters or leaves the lung
- alveolar ventilation rate changes according to the frequency of breath, tidal volume, and amount of dead space
- PA refers to alveolar partial pressure of a gas
- Pa refers to the partial pressure of that gas in arterial blood
- Gas exchange occurs from passive diffusion
- because PAO2 >PaO2 in deoxygenated blood

Oxygen transport

- 98.5% of the oxygen in a sample of arterial blood in a healthy human breathing air at sea-level pressure is bound to the hemoglobin in blood
- Approx 1.5% of oxygen is physically dissolved in the other blood liquids and not connected to Hgb
- function of Hgb is to provide a binding site for oxygen to carry oxygen throughout the bloodstream to the systemic tissues for cellular respiration

Oxyhemoglobin Dissociation Curve

- percentage of oxygen that is saturated in the Hgb of blood is generally represented by a curve that shows the relationship between PaO2 and O2 saturation

- Saturation of O2 in hemoglobin is an indicator for how much O2 is able to reach the tissues of the body
- Carbon Dioxide Transport
- Carbon dioxide is transported through the bloodstream either dissolved in blood, bound the hemoglobin, or converted to bicarbonate ions
- Haldane effect = decreased binding of carbon dioxide in hemoglobin due to increased oxygen levels and increased binding of carbon dioxide to hemoglobin from decreased oxygen levels

- Increased carbon dioxide= decreased blood pH = acidosis
- Decreased carbon dioxide = increased blood pH = alkalosis

V/Q ratio

- Ventilation (V) perfusion (Q) ratio
- Normal 0.8
- Effective gas exchange requires an approximately even distribution of gas (ventilation) and blood (perfusion)

Maintaining blood pH

- An increase in carbon dioxide concentration leads to a decrease in the pH of blood due to the production of H+ ions from carbonic acid
- In response to a decrease in blood pH, the respiratory center (in the medulla) sends nervous impulses to the external intercostal muscles and the diaphragm, to increase the breathing rate and the volume of the lungs during inhalation
- Hyperventilation causes alkalosis, which causes a feedback response of decreased ventilation (to increase carbon dioxide), while hypoventilation causes acidosis, which causes a feedback response of increased ventilation (to remove carbon dioxide)
- Any situation with hypoxia (too low oxygen levels) will cause a feedback response that increases ventilation to increase oxygen intake
- Vomiting causes alkalosis
- diarrhea causes acidosis

Surface tension/surfactant

- force exerted by water molecules on the surface of the lung tissue as those water molecules pull together
- Water (H_2O) is a highly polar molecule, so it forms strong covalent bonds with other water molecules
- Surfactant = lipoprotein which lowers the surface tension, uses a “soap like” effect that separates the water molecules thereby decreasing the tension
- Produced by type II alveoli cells
- Allow alveoli to inflate much easier

Compliance and Elastic recoil of the Lung

- Compliance =based on elasticity and surface tension of the lungs
- Compliance inversely related to the elastic recoil of the lungs, so thickening of lung tissue will decrease lung compliance
- lungs must also be able to overcome the force of surface tension from water on lung tissue during inflation in order to be compliant, and greater surface tension causes lower lung compliance

- low lung compliance =lungs are “stiff” and have a higher than normal level of elastic recoil.
- would need a greater-than-average change in pleural pressure to change the volume of the lungs, and breathing becomes more difficult as a result

Lung Capacity

- Lung capacity = total amount of air inside the lungs at certain phases of the respiratory cycle
- It is usually measured as the amount of air that is exhaled after inhalation with a device called a spirometer
- Vital capacity (VC) =maximum amount of air that a person can exhale after inhaling as much air as possible
- It is also the sum of tidal volume and the inspiratory and expiratory reserve volumes, which capture the differences between normal breathing and maximal breathing.

FEV1/FVC Ratio

- forced expiratory volume (FEV1) and forced vital capacity (FVC)
- The most widely used diagnostic application for lung capacities
- FEV1: The volume of air exhaled in one second of forced expiration
- FVC: The total volume exhaled air during a forced expiration
- FEV1/FVC ratio is an important indicator of lung health and is the standard approach for diagnosing COPD
- includes emphysema and bronchitis, both caused by smoking

Metabolic Functions

- lungs secrete many enzymes and proteins that serve non-respiratory metabolic functions
- ACE (angiotensin converting enzyme) secreted by the endothelial cells of the capillaries
- Immunoglobin A (IgA) antibody that can attack pathogens and mark them for phagocytosis from macrophages and neutrophils.
- Protease Secreted from lung macrophages and neutrophils during inflammatory response to damage pathogens. A fibrinolytic that can break up thrombosis (blood clots) in the lungs
- Reactive oxygen species (ROS) Free radicals, which are any substance with an unpaired electron in the valence shell, can cause oxidative stress (damage) in cells.

- Anti-microbial peptides: Various chemokines and proteins that are secreted by the mucus membranes of the airways

Pulmonary function

- Testing and Common Complaints
- Spirometry
  - test works by measuring airflow into and out of your lungs
  - breathe into a small machine called a spirometer (a medical device records the amount of air you breathe in and out and the speed of your breath)
  - Spirometry tests are used to diagnose these conditions:
    - COPD
    - asthma
    - restrictive lung disease (such as interstitial pulmonary fibrosis)
    - other disorders affecting lung function

Diffusing Capacity

- Lung diffusion testing measures how well the lungs exchange gases
- important part of lung testing because the major function of the lungs is to allow oxygen to "diffuse" or pass into the blood from the lungs, and to allow carbon dioxide to "diffuse" from the blood into the lung
- Inhale air containing a very small amount of CO and a tracer gas, such as methane or helium. You hold your breath for 10 seconds, then rapidly blow it out (exhale)
- The exhaled gas is tested to determine how much of the tracer gas was absorbed during the breath

ABG

- sampling provides valuable information on the acid-base balance at a specific point in the course of a patient's illness
- It is the only reliable determination of ventilation success as evidenced by CO_2 content
- It constitutes a more precise measure of successful gas exchange and oxygenation
- ABG sampling is the only way of accurately determining the alveolar-arterial oxygen gradient

Chest Xray

uses a very small dose of ionizing radiation to produce pictures of the inside of the chest
used to evaluate the lungs, heart and chest wall and may be used to help diagnose shortness of breath, persistent cough, fever, chest pain or injury

may be used to help diagnose and monitor treatment for a variety of lung conditions such as pneumonia, emphysema and cancer
chest x-ray is fast and easy, it is particularly useful in emergency diagnosis and treatment

Signs and symptoms In pulmonary dysfunction

Dyspnea

- Dyspnea = SOB
- Symptom can be present in the absence of disease, or be the net result of multiple disease processes
- extremely common symptom
- Approx. 25% of patients seen by the provider in the ambulatory setting present with dyspnea
- This number can be as high as 50% in the tertiary care setting
- Multiple systems
- Lung, heart, GI, hematological, neuromuscular

cough

- action the body takes to get rid of substances that are irritating to the air passages
- occurs when cells along the air passages get irritated and trigger a chain of events air in the lungs is forced out under high pressure
- a voluntary process or the body may cough on its own (an involuntary process)
- Infectious causes include viral URI, sinus infections, acute bronchitis, PNA, pertussis
- Noninfectious causes include flare-ups of chronic conditions such as chronic bronchitis, emphysema, asthma, and allergens

Sputum

- thick liquid that is coughed up from lungs
- can contain bacteria, tissue particles, blood, and really anything that is in the lungs
- Sputum is normally clear and a little thicker than water
- If it is frothy and in large amounts, this could be due to pulmonary edema (which is the buildup of fluid in the lungs)
- classified as mucoid or purulent
- white, gray, yellow, green or brown and is thicker than normal
- Mucoid - white or gray and can be caused by chronic diseases such as COPD and asthma
- Purulent -yellow and green = respiratory tract infections
- If the sputum is blood stained it could be caused by tuberculosis, lung cancer or a pulmonary embolism

Hemoptysis

- Blood expelled from the lungs by cough
- caused by bleeding within the lungs or after a severe nosebleed
- Symptoms can be confused with blood that is actually coughed up from the stomach rather than from the respiratory system
- Etiology:
- common cause is acute bronchitis d/t bronchi become inflamed or swollen. These cases usually clear on their own but can progress into more serious conditions.
- TB, is the most common cause of hemoptysis in the rest of the world

Abnormal breathing patterns

- Cheyne-Stokes
  - gradual increase in volume and frequency of respiration and it is followed by a gradual decrease in volume and frequency, followed by apneic periods of 10 – 30 seconds between cycles
- Kussmaul's
  - deep sighing respiration associated with metabolic acidosis. There is an increased rate and depth of breathing over a prolonged period of time. It occurs in response to metabolic acidosis where the body tries to flush out CO
- Orthopnea
  - Unable to breathe comfortable lying down
- Tachypnea
  - Increased respirations per minute

Hypoventilation

- ventilation which is not sufficient to meet the need of the body (too shallow or too slow)
- Hypoventilation causes an increase in blood carbon dioxide level and a decrease in oxygen level
- Etiologies include
- Obesity, Obstructive sleep apnea
- Severe chest wall deformities like kyphoscoliosis
- Severe chronic obstructive pulmonary disease
- Congenital Central Hypoventilation Syndrome

Hyperventilation

- increased rate and depth of breathing which results in abnormally low levels of carbon dioxide in the blood
- dizziness, light-headedness, weakness, unsteadiness, muscle spasms in the hands and feet, and tingling around the mouth and fingertips
- Causes include:
    - Anxiety
    - Head injury
    - Cerebrovascular event (pontine lesions)
    - Drugs which stimulate central nervous system
    - overventilation or ventilation in excess of the body's need
    - results in decreased $PaCO_2$, and a respiratory alkalosis

Cyanosis

- Bluish/purple cast to the skin and mucous membranes
- Peripheral cyanosis is when there is a bluish discoloration to your hands or feet
- Central cyanosis systemic arterial concentration of deoxygenated hemoglobin >5g/dL
- Etiologies include
    - Tight clothing/jewelry
    - DVT
    - Venous insufficiency
    - Raynauds
    - Heart failure
    - Hypotension
    - Lymphedema
    - Children
        - Respiratory causes-central
        - Upper airway obstruction
        - Smoke inhalation

Clubbing

- clinical finding characterized by bulbous fusiform enlargement of the distal portion of a digit
- usually is gradual enough that many patients are unaware of its presence
- some patients may report swelling of the distal portion of the digits, which may be bilateral or unilateral or may involve a single digit
- clubbing typically is painless, it rarely may present with pain in the fingertips

Pleuritic Pain

- CP exacerbated by forceful breathing
- Parietal pleura (not visceral) has sensory nerves that are irritated by inflammation or trauma
- Nerve distribution
- Intercostal nerves referred to associated dermatomes(Rib cage and Lateral hemidiaphragm)
- Phrenic nerve referred to ipsilateral neck, shoulder (Central hemidiaphragm)
- Provocative factors
- Movement & Forceful breathing
- Deep breathing, coughing, sneezing, Laughing

Hypercapnia

- defined as an elevation in the arterial carbon dioxide tension, is commonly encountered during the evaluation of patients with dyspnea and/or altered sensorium
- alveolar gas exchange units are unable to sufficiently excrete carbon dioxide=increase in the arterial carbon dioxide levels above the normal range of 35 to 45 mmHg (4.7-6.0 kPa)
- With the increase in carbon dioxide, hydrogen ions accumulate, causing the arterial pH to fall below the normal range

Hypoxemia

- Hypoxemia is a below-normal level of oxygen in your blood, specifically in the arteries
- measuring the oxygen level in a blood sample ABG
- It can also be estimated by measuring the oxygen saturation of your blood using a pulse oximeter
- Normal arterial oxygen is approximately 75 to 100 millimeters of mercury (mm Hg)
- < 60 mm Hg usually indicate the need for supplemental oxygen

References

Advanced Physiology and Pathophysiology: Essentials for clinical practice
Basic Pathology 10th edition Robbins
Epocrates (various topics)
Emedicine.Medscape.com (various topics)
Pathoma.com
Pathophysiology -The biologic basis for Disease in Adults and Children –McCance and Heuther, Brashers and Rote
Understanding Pathophysiology – McCance and Heuther
UP TO DATE various topics
Family Practice Notebook.com (various topics)