Respiratory Physiology

Respiratory Intro Video

- Respiratory Rap
- Respiratory Song

Respiration

- Pulmonary ventilation – breathing – air movement
- External respiration – gas exchange between pulmonary blood and alveoli
- Respiratory gas transport – transport via bloodstream
- Internal respiration – gas exchange between capillary blood and tissue cells

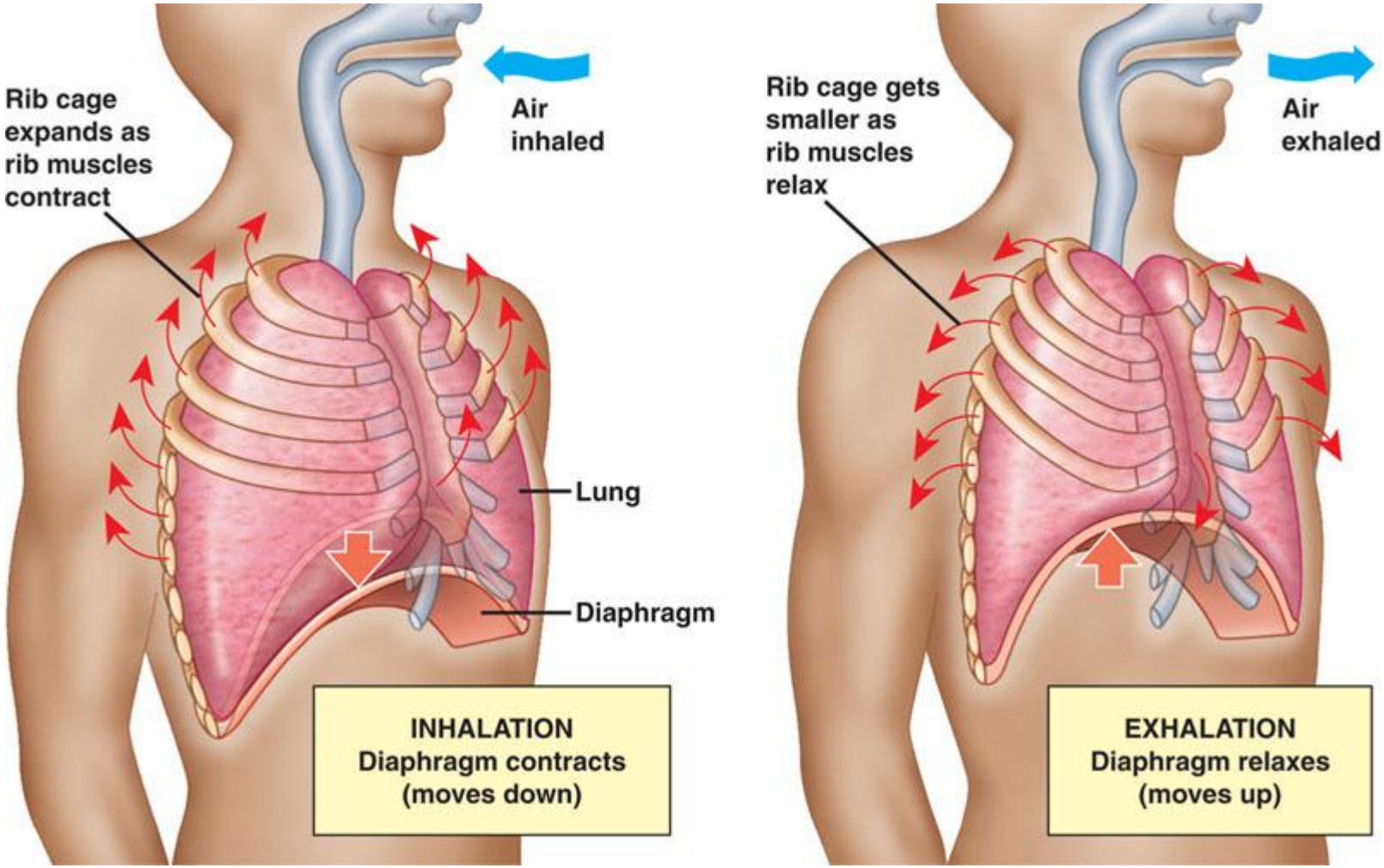
Respiration

- ***Ventilation*** = process by which gases flow between the atmosphere and the pulmonary alveoli (breathing)
  - Consists of inhalation and subsequent exhalation.

- ***Quiet Breathing*** = normal, unforced breathing

- **Mechanism of Breathing:**
  - Depends on volume changes in thoracic cavity
  - Volume changes lead to pressure changes, which lead to flow of gases to equalize the pressure

Inspiration and Expiration



Inspiration

- During quiet breathing, inspiration is driven by:
  - Diaphragm contracts by flattening and moves inferiorly
  - External intercostals (between the ribs): lifts rib cage and moves sternum forward

- During deep inhalations, the scalene, sternocleidomastoid, and pectoralis minor muscles become involved
  - this gets the rib cage to expand further than normal

Inspiration

- Thoracic cavity increases in size and since the lungs are attached to the walls it too increases in size
- Intrapulmonary volume increases as gas within lungs spreads out
- Decrease in gas pressure in lungs (lower than atmosphere pressure) causes air to be sucked into the lungs to equalize the pressure

Expiration

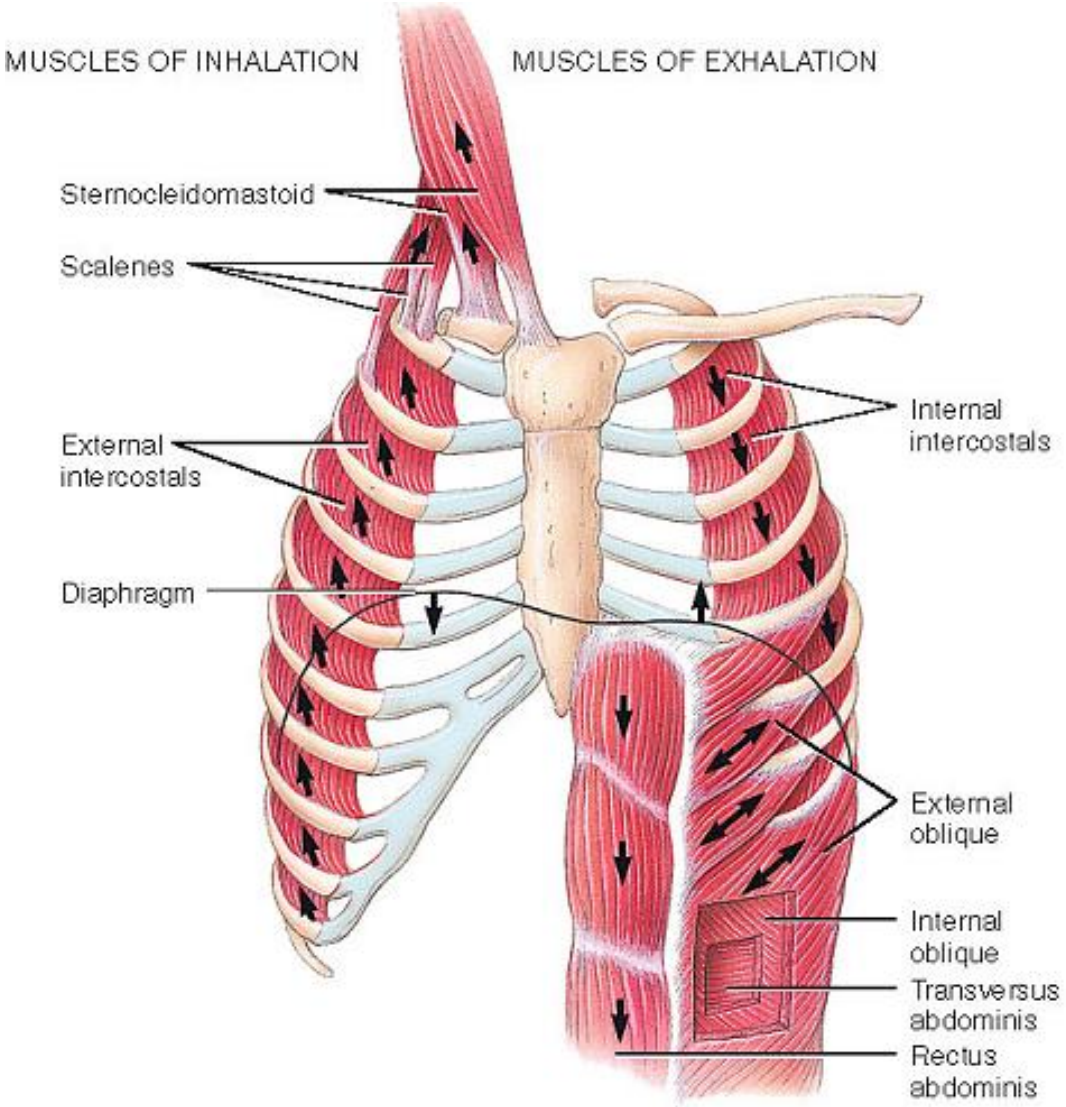
- *Passive process* during quiet breathing: requires no muscle contraction
  - The elastic recoil of the chest wall and the return of the diaphragm to its resting position are enough to drive it.

- Alveoli also have natural recoil, but the *surfactant* that is lining the inner walls keeps it from collapsing.

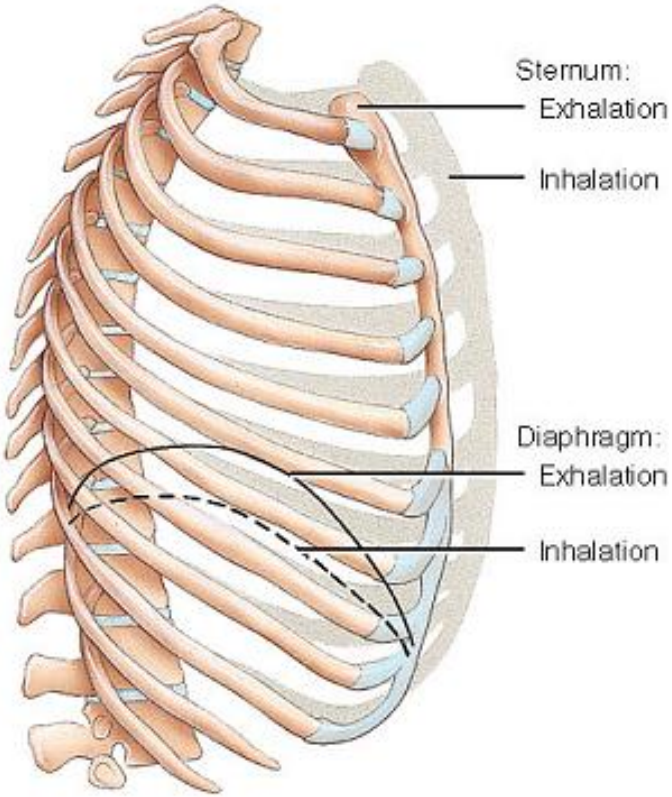
Expiration

- Intrapulmonary pressure increases to higher than atmospheric pressure and gases flow out to equalize the pressure

- If bronchioles become narrowed or clogged (asthma or pneumonia), expiration becomes active
  - During forced exhalation (sneezes, coughs, exercise) the internal intercostals, obliques, and rectus abdominis contract to compress the rib cage and force the diaphragm upwards.



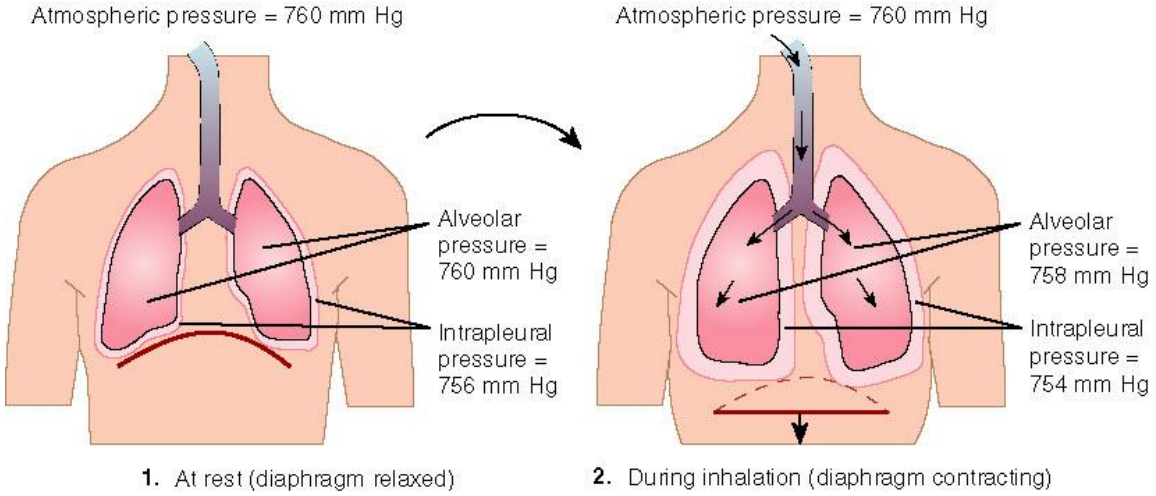
(a) Muscles of inhalation and their actions (left); muscles of exhalation and their actions (right)



(b) Changes in size of thoracic cavity during inhalation and exhalation

Pressure Changes During Breathing:

As inhalation and exhalation occur, pressure differences between the body and the atmosphere drive air either in or out of the lungs.



Note: The pleural cavity maintains pressure about 4 mmHg LOWER than atmospheric pressure. This is to ensure that the alveoli, even after exhalation, are always slightly inflated.

During inhalation, the volume _____ and the pressure _____. This causes air to be sucked into the lungs.

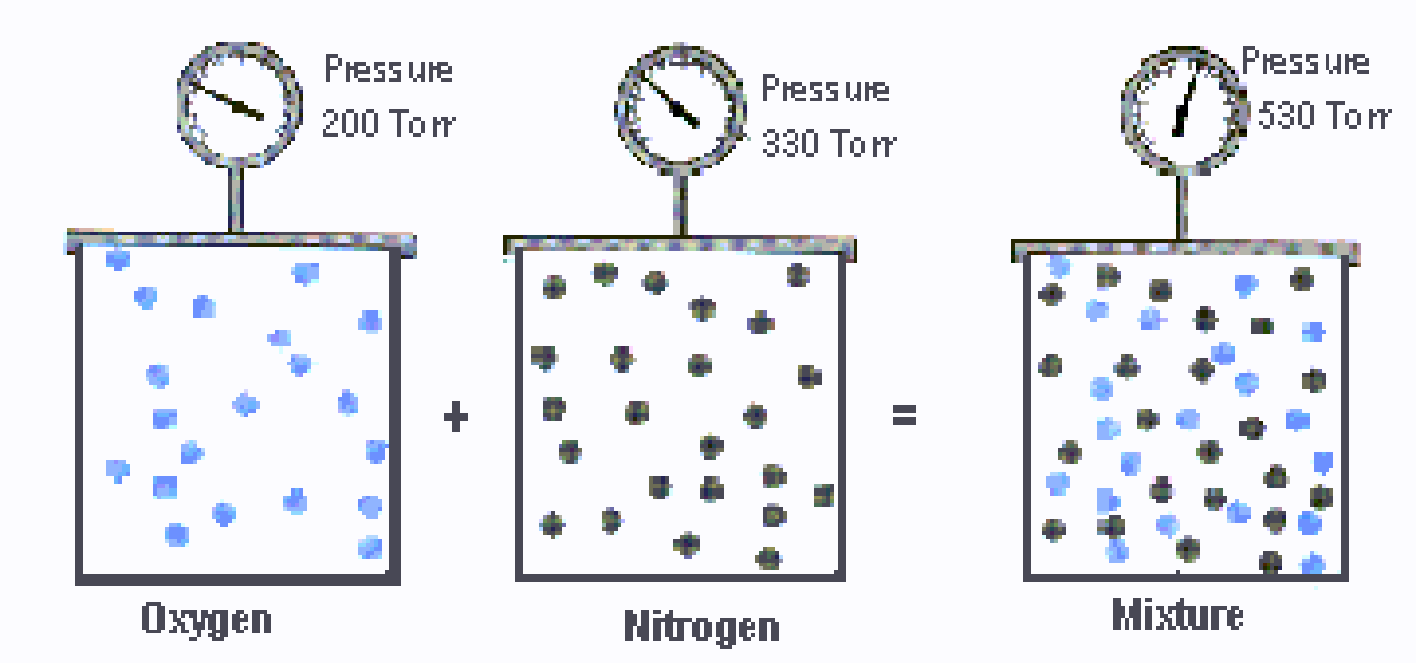
A. decreases; increases
B. Increases; decreases
C. does not change; increases
D. does not change; does not change

In its relaxed position, the diagram is in what shape?

A. Flat
B. Curved inferiorly
C. Curved superiorly
D. Diaphragm is not a structure in the body

Gas Exchange

- Based on the laws of ***partial pressures*** – gases will diffuse according to the pressure that they alone are exerting within a mixture.



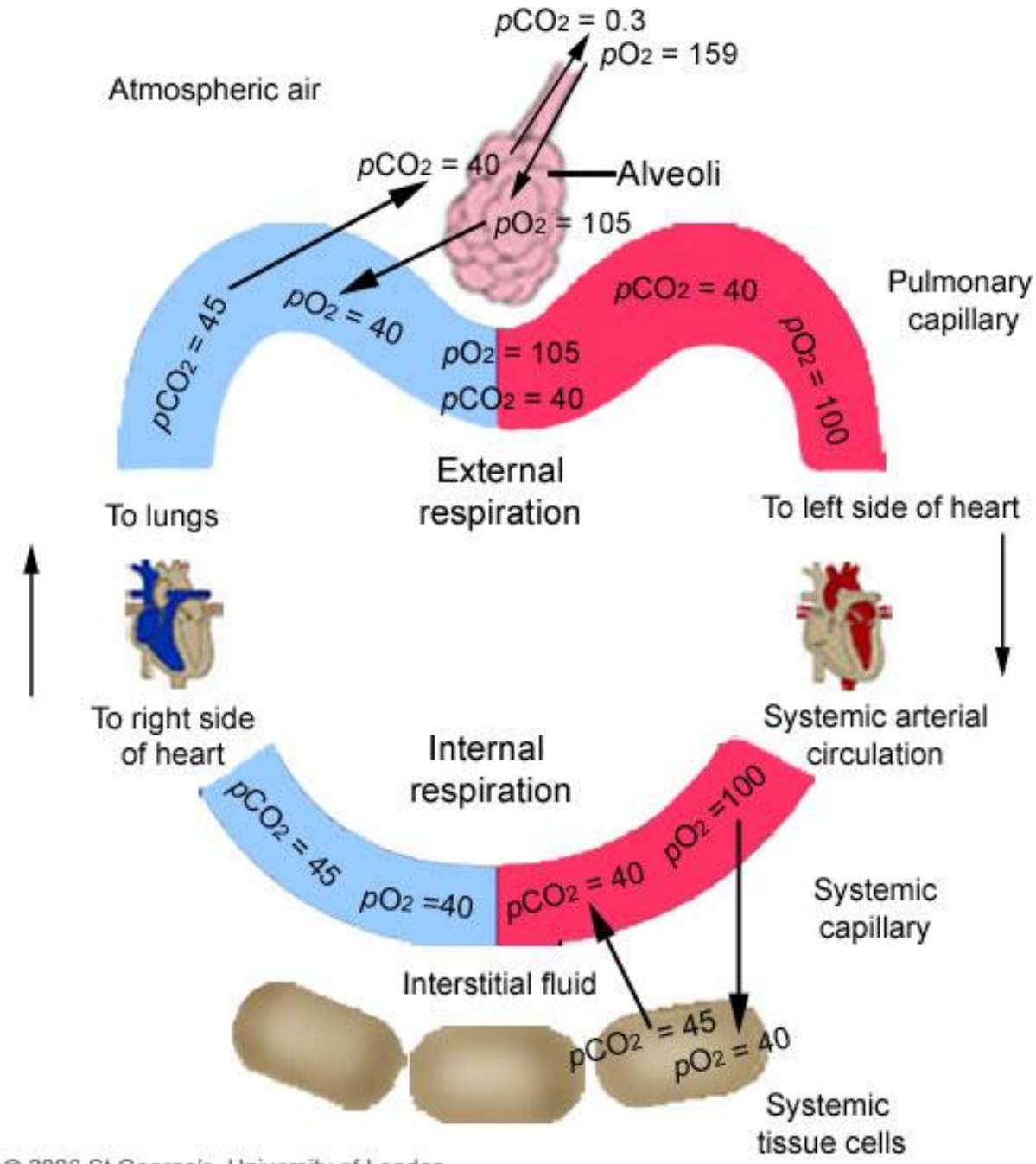
Gas Exchange

- **External respiration:** exchange between the lungs and bloodstream
  - Converts deoxygenated blood arriving through the pulmonary arteries to oxygenated blood
  - Blood dumps off carbon dioxide at the same time.
  - Each of these processes occurs *independently* – it is not truly an exchange as it is labeled.

Gas Exchange

- **Internal respiration:** exchange of gases between the blood stream and the systemic tissues.

- Both processes are driven by the *partial pressures* of oxygen and carbon dioxide in their respective locations.
  - The diffusion of oxygen does not influence the diffusion of CO2, and vice versa.



**As blood returns to the left heart from the lungs, oxygenated blood that runs from the alveoli mixes with blood returning from the conduction portions of the pulmonary circuit (no gas exchange). Thus, the oxygen pressure in the left atrium is down from 105 to 100 mmHG.

Factors that affect external respiration:

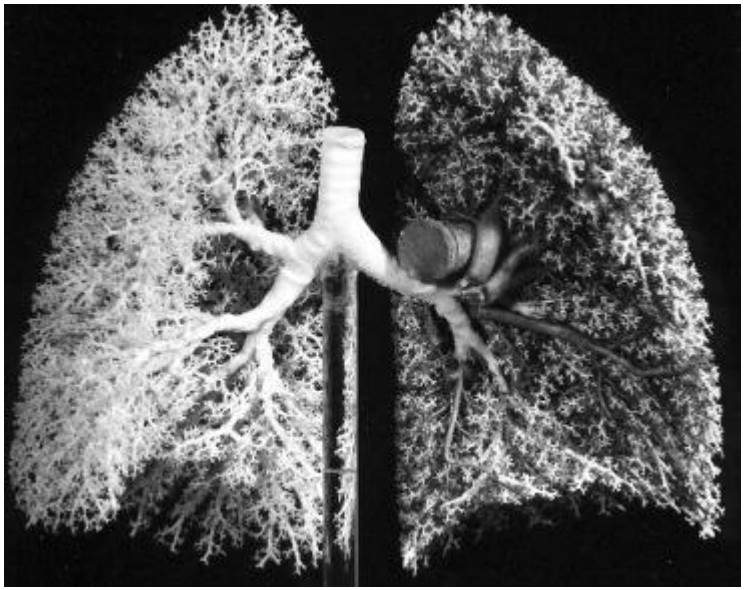
1) ***Partial pressure (concentration) of gases*** – if the partial pressure of the gases on the outside of the body changes, the rate of gas exchange will be affected.

   – Ex: *altitude changes* – as altitude increases, the atmospheric pressure decreases, as do the partial pressures.

   – The partial pressure of oxygen, though it remains 20.9% of the inhaled air, sinks from 159 mmHG at sea level to 110 mmHg at 10,000 ft. and 73 mmHg at 20,000 ft.

Factors that affect external respiration:

2) ***Surface area*** – if surface area of alveoli decreases, then less gas exchange will take place.
   - This is why emphysema, smoking, and respiratory diseases are so dangerous. Emphysema, for example, causes alveolar walls to disintegrate.

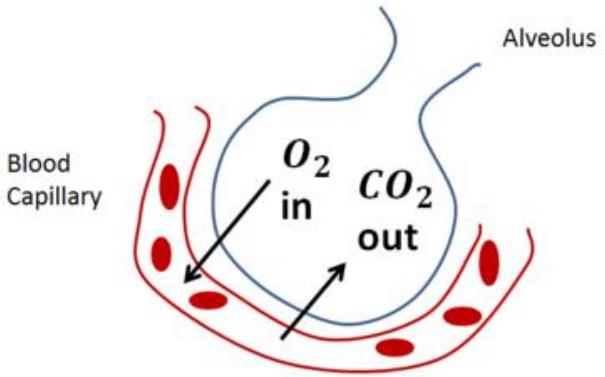


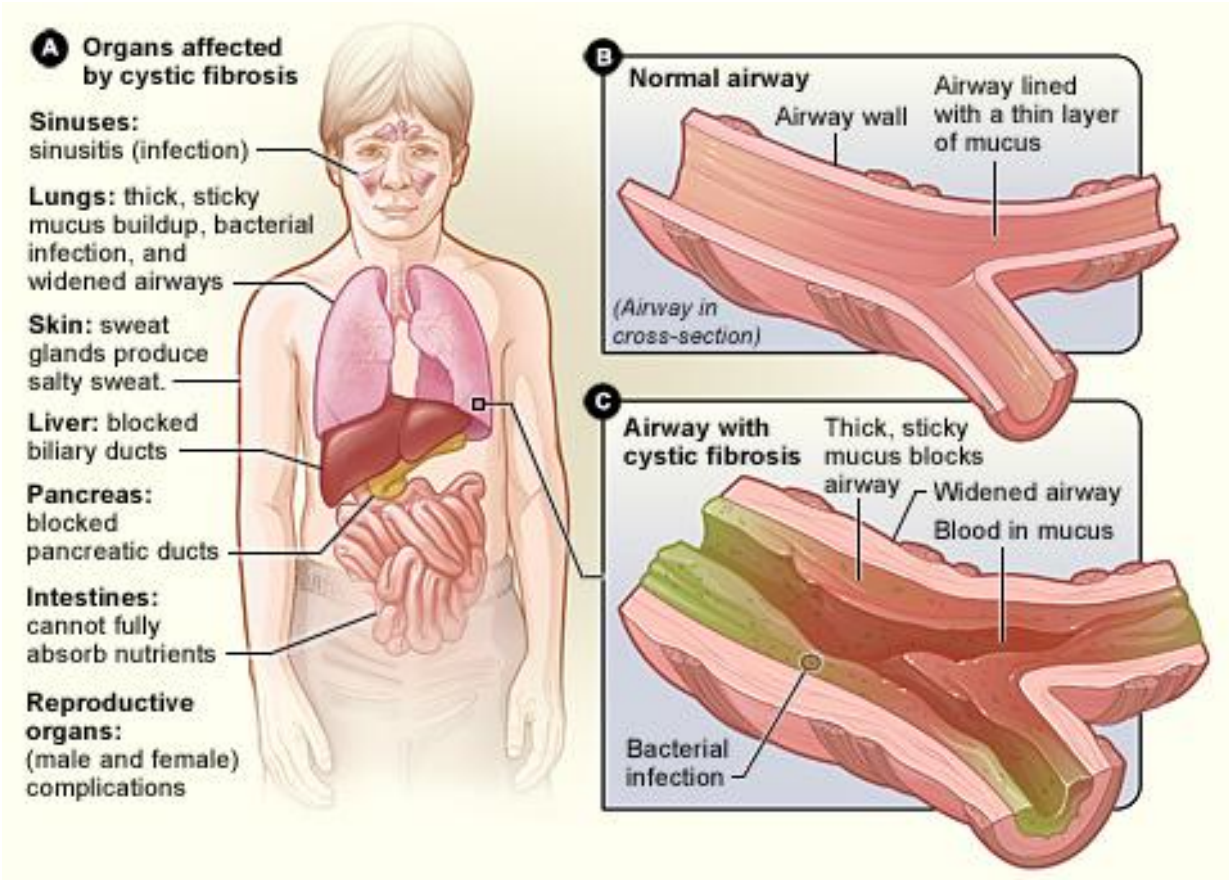
normal

emphysema

3) ***Diffusion distance*** – the farther the gases have to diffuse, the slower they'll go.

- Buildup of the alveolar wall or pulmonary fluid (edema) can significantly increase this distance.





Transport of gases in the blood:

- **Oxygen transport:** carried out by both hemoglobin and blood plasma…
  - Oxygen dissolves very poorly in water, so only about 1.5% of the oxygen that blood carries is in the plasma
  - The remaining 98.5% is bound to hemoglobin

$$Hb + O_2 \rightleftharpoons HbO_2$$

**Remember that each hemoglobin has four iron atoms, and can therefore bind four oxygen molecules.

Gas Transport in the blood:

- Oxygen transport

Transport of gases in the blood:

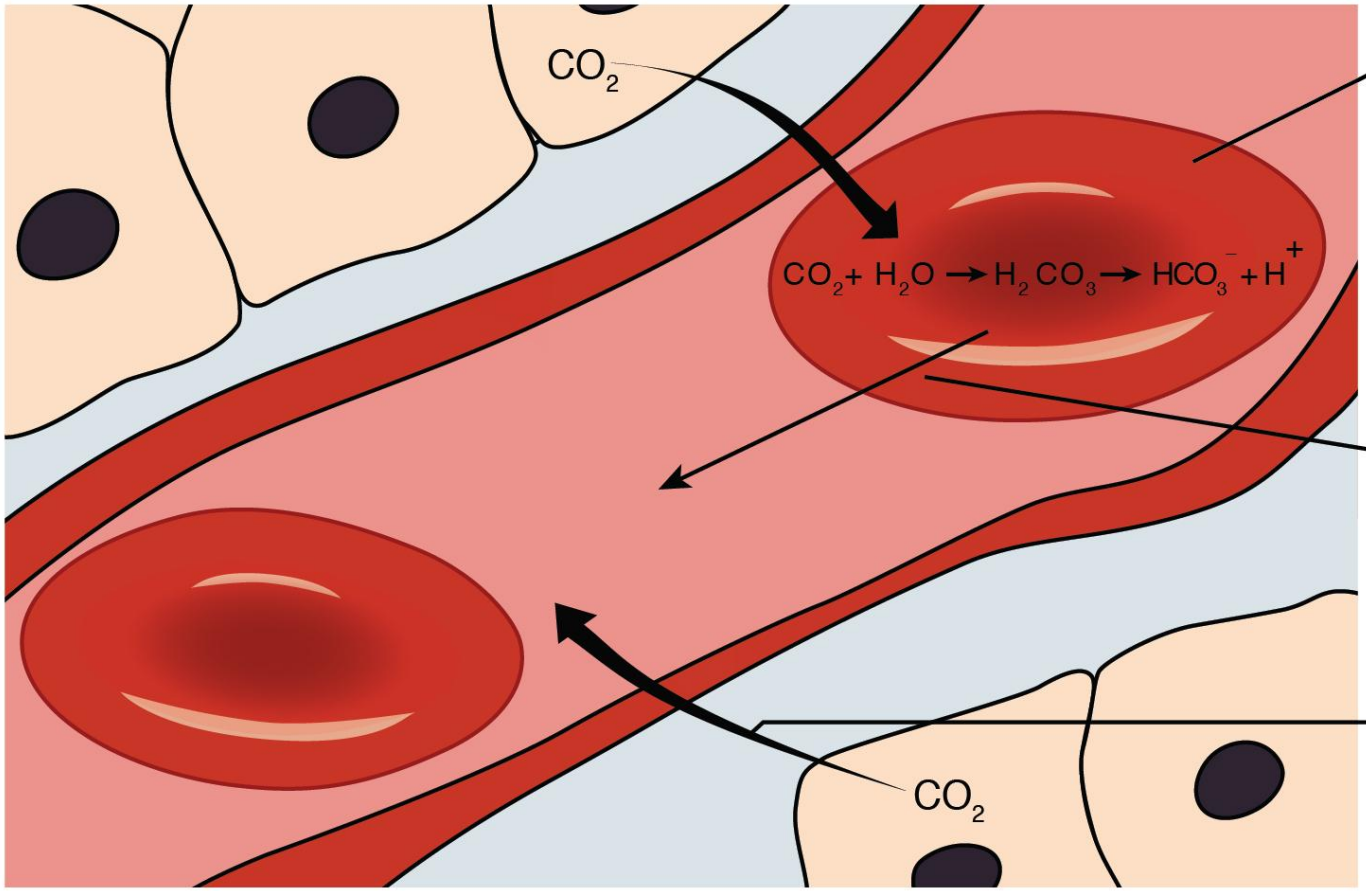
- Binding of oxygen with hemoglobin is dependent on the partial pressure of oxygen
  - The higher the pressure, the more effectively oxygen binds.
  - If the oxygen pressure is low, Hb will release oxygen (happens in the systemic capillaries)

Transport of gases in the blood:

- Other factors also effect the release of oxygen by hemoglobin:
  - **Carbon dioxide levels** – higher CO2 levels promote the release of oxygen
    - Tissues outputting a large amount of CO2 will receive more oxygen from bloodstream
  - **Acidity** – lower pH causes hemoglobin to release oxygen more readily
    - Active muscles produce lactic acid therefore blood will release more oxygen into the tissue
  - **Temperature** – higher temperature means higher oxygen release
    - Active tissues generate heat → more oxygen to active tissues

Transport of gases in the blood:

- **Carbon Dioxide Transport:** CO2 makes its way through the bloodstream in three forms:
  - **Dissolved in plasma --** about 9% is directly dissolved into blood plasma. In the alveolar capillaries it passes straight into the alveoli and is exhaled
  - **Bound to hemoglobin** -- about 13% binds to the amino groups of proteins in the blood; hemoglobin is the most abundant of these.
  - **Bicarbonate ions** -- most CO2 is transported as bicarbonate (HCO_3^-), which is a result of carbon dioxide combining with a water molecule in solution



(a) CO_2 carried in RBC

(b) HCO_3^- dissolved in plasma as carbonic acid

(c) CO_2 dissolved in plasma

Respiratory Sounds

- Flow of air through the respiratory tree
- Bronchial sounds – air through large passageways (trachea and bronchi)
- Vesicular sounds – air filling the alveoli (muffled breeze)
- Blocked airways can lead to rasping sounds or wheezing

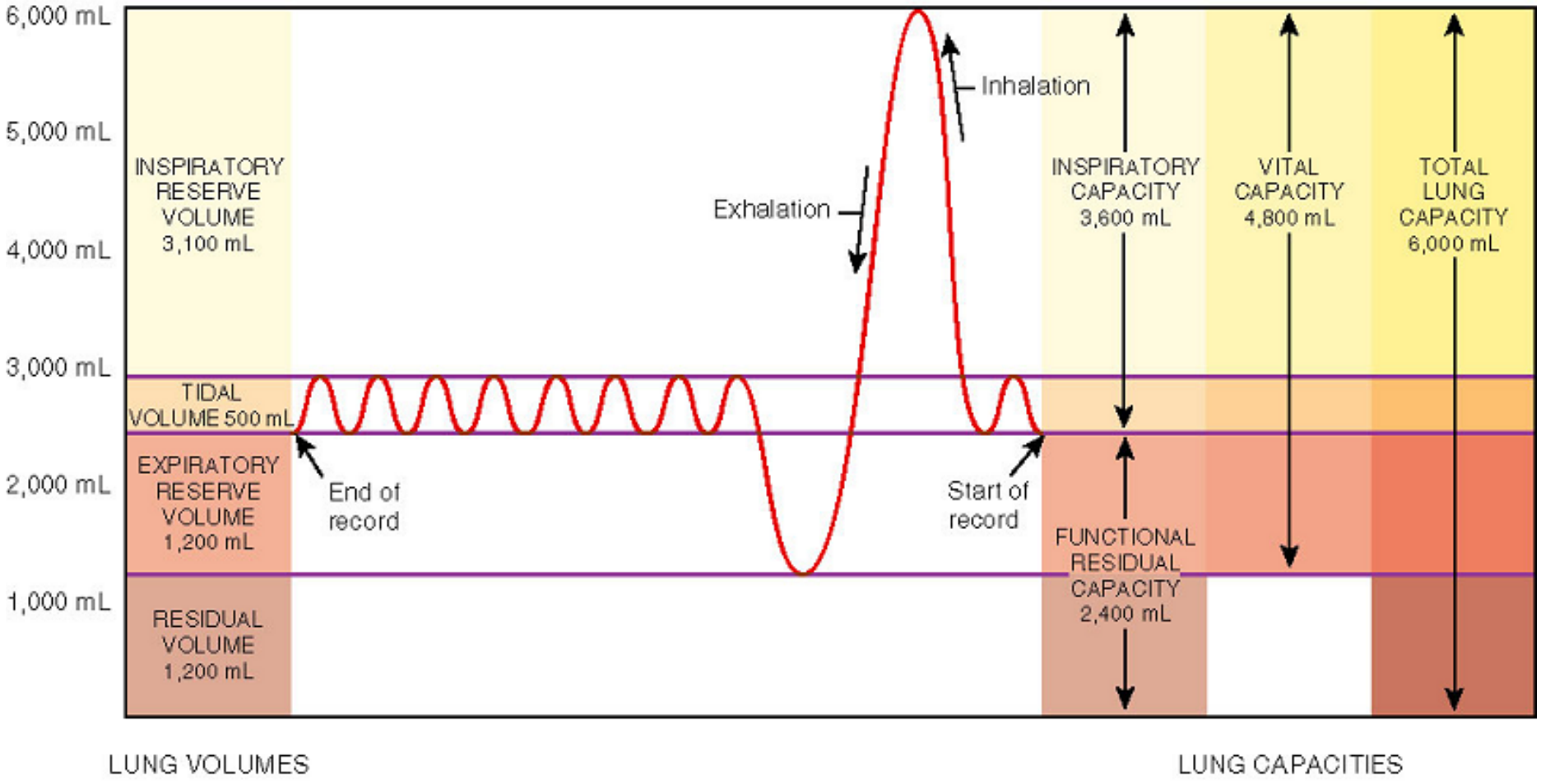
Non-respiratory Air Movements

- Cough – taking a deep breath, closing glottis (space between vocal folds), and forcing air superiorly from lungs against glottis. Then, glottis opens suddenly and a blast of air rushes upward. Coughs clear lower respiratory passageways
- Sneeze – similar to cough, except air is directed through nasal cavity. Uvula closes oral cavity. Sneezes clear upper respiratory passages.
- Crying – inspiration followed by release of air in a number of short breathes. Emotionally induced

Non-respiratory Air Movements

- Laughing – same as crying in terms of air movements. Emotionally induced
- Hiccups – sudden inspirations resulting from spasms of diaphragm. Initiated by irritation of diaphragm or phrenic nerve. Sound occurs when inspired air hits vocal cords of closed glottis.
- Yawn – very deep inspiration. Formerly believed to be triggered by need for more oxygen, but this theory is now being questioned. Ventilates all alveoli

Lung Volumes and Capacities:



Lung Volumes and Capacities

- **Tidal Volume:** volume of a normal breath during quiet breathing.

- **Minute Ventilation:** total volume of air inhaled and exhaled per minute - (breathing rate X tidal volume)
  - Only about 70% of each inhaled breath actually makes it into the alveoli. The rest is ***anatomic dead space***, as there is no gain from having fresh air in these areas

- **Inspiratory Reserve Volume:** the extra volume inspired if you take a “deep breath”

- **Expiratory Reserve Volume:** the extra volume expired if you try to push all the air out of your lungs.

Lung Volumes and Capacities

- **Residual Volume:** remains in the lungs even after you've breathed "all the way out".

- **Vital Capacity:** the max amount of air that can be exhaled after maximum inhalation

- **Total Lung Capacity:** total volume lungs can hold. Averages about 6 liters.

If you breathe all the way out, what is the term for the air left in your lungs?

A. Residual volume
B. Tidal volume
C. Vital capacity
D. Expiratory Reserve volume

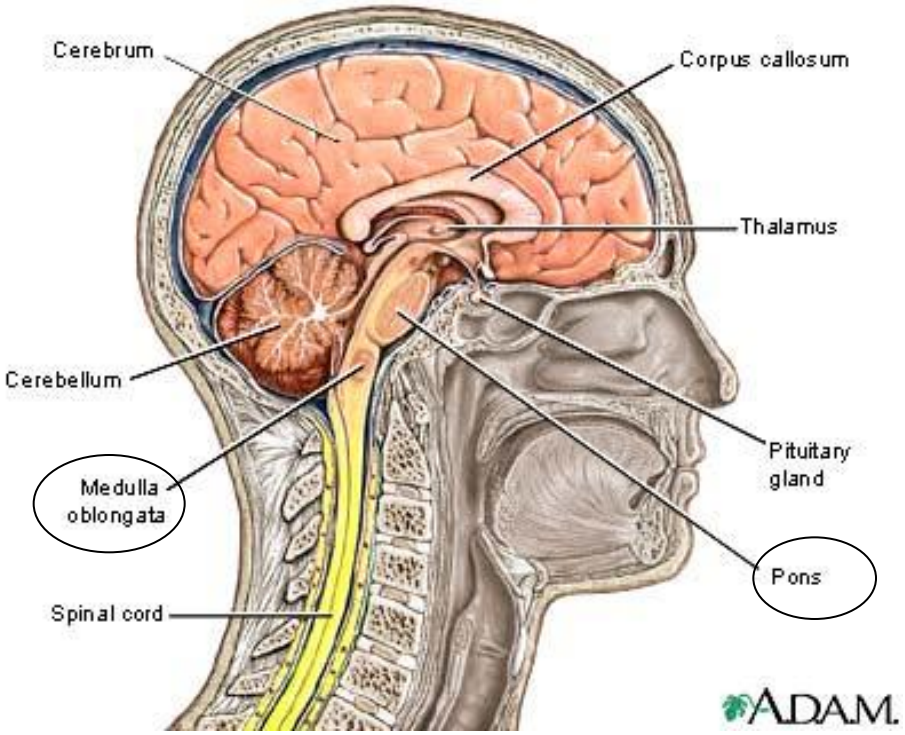
Control of Respiration:

The Respiratory Center: consists of groups of neurons in the medulla and the pons (brain stem)

- **Phrenic and intercostal nerves –** transmit impulses from brain to diaphragm and other muscles
- **Medulla –** self-exciting inspiratory center sets basic rhythm of breathing
- **Pons** – smoothes out basic rhythm that medulla sets

- At rest, the tissues use about 200 mL of oxygen each minute. During exercise, this consumption rate can increase 20 to 30 fold.

Control of Respiration:



Control of Respiration:

- **Eupnea** – normal respiratory rate of 12-15 respirations per minute

- Point when inspiration stops and expiration starts in due to stretch receptors in alveoli
  - Respond to over inflation

- During exercise – we breathe faster and deeper because of increase in signals from the brain
  - After strenuous exercise, expiration becomes active

Regulation of the Respiration:

1. **Physical Factors –** talking, coughing, and exercise
2. **Volition (Conscious Control)** –This is the voluntary control which you have over your breathing rate such as singing,
   - This is NOT absolute, you can't hold your breath, or breathe too deeply, forever. Influences of the chemical receptors become to powerful and overtake the voluntary controls.
3. ***Emotional factors*** – anticipation or anxiety may stimulate the limbic system, which will cause an increase in rate and depth of ventilation

Regulation of the Respiration:

4. **Chemoreceptors** – receptors in the body monitor levels of three quantities within the bloodstream: the partial pressures of oxygen and carbon dioxide, and the pH
   - A low pH or O2 level, or a high CO2 level (*hypercapnia*), will result in ***hyperventilation***
     - an increase in the breathing rate.
5. ***Temperature*** – higher body temp will increase respiratory rate.
   - Also, sudden cold stimulus will temporarily cause breathing to cease (apnea)

Regulation of the Respiration:

6. ***Proprioceptors*** – as soon as vigorous activity starts, breathing rate increases BEFORE levels of O2, CO2, or pH change.
   - This is because proprioceptors notice the activity in joints and muscles, and stimulate the inspiratory area.
7. ***Pain*** – Sudden, severe pain causes brief apnea
8. ***Irritation of the airways*** – will, obviously, cause breathing to stop, or significantly decrease.
   - Usually triggers coughing/sneezing as well.

- Effects of Smoking

Disorders

- Cleft palate – genetic defect in which bones forming palate fail to fuse and leads to difficulty with breathing and chewing
- Rhinitis – inflammation of nasal mucosa due to cold viruses
- Sinusitis – inflamed sinuses and can lead to sinus headaches
- Tonsillitis – inflammation of the tonsils
- Tracheostomy – surgical opening of trachea to aid in breathing

Disorders

- Pleurisy – inflammation of the pleura which causes a decrease in pleura fluid and leads to friction and pain with breathing
- Atelectasis – lung collapse
- Pneumothorax – presence of air in intrapleural space
- Apnea – cessation of breathing
- Dyspnea – difficulty or labored breathing
- Cyanosis – insufficient oxygen in the blood
- Asthma – chronically inflamed, hypersensitive bronchial passageways; responds to irritation

Disorders

- Chronic obstructive pulmonary disease (COPD)
  - Emphysema – alveoli enlarge and break; lungs become less elastic and airways become blocked; hard to exhale (uses a lot of energy)
  - Bronchitis – mucosa in lower respiratory tract becomes inflamed and pooled mucus impairs ventilation

- Lung Cancer – 1/3 of all cancer deaths in US
  - Squamous cell carcinoma – in larger bronchi and form masses that hollow out and bleed
  - Adenocarcinoma – peripheral areas of lungs
  - Small cell carcinoma – starts in primary bronchi and grow into clusters in mediastinum

Disorders

- Cystic Fibrosis – genetic disorder that over secretes mucus that clogs passageways; can lead to death in children (every day 2 children die from CF)

- Sudden Infant Death Syndrome (SIDS) – some cases result from problems with neural control, but 1/3 is due to heart rhythm abnormality