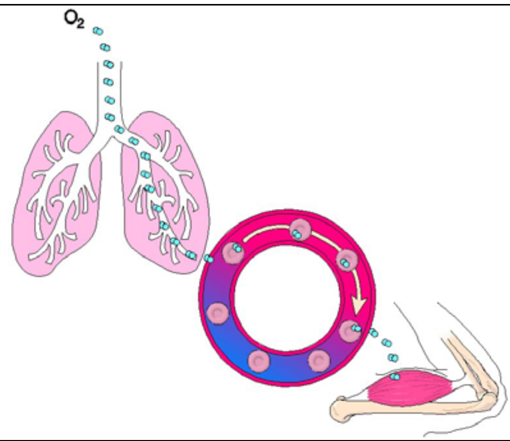
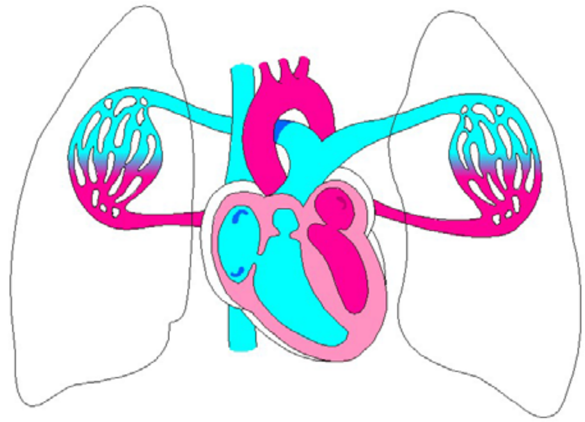
Respiratory/Pulmonary Laboratory Experimentation

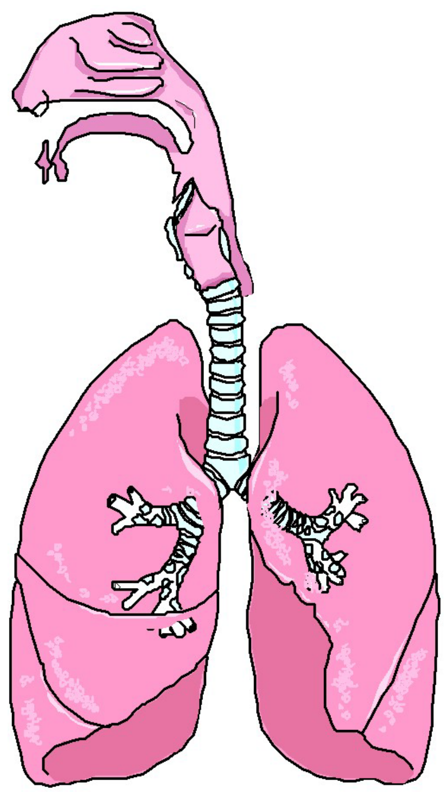
Introduction – Anatomy Review

The respiratory system has the dubious honor of being the system that permits the transport of gases from the environment inside our body and from our body back outside:

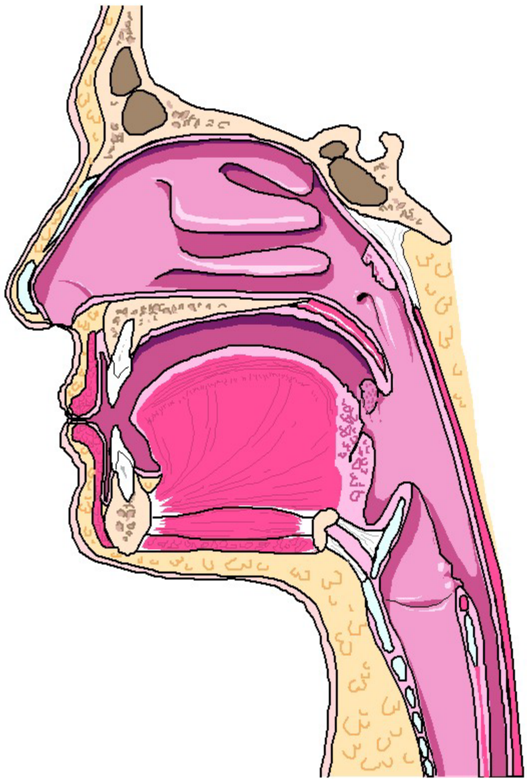
	
Uptake of oxygen from the environment, across the lungs, into the blood vessels to the target tissue for uptake and utilization.	Illustration of the venous (deoxygenated) flow from the right side of the heart to the lungs where the blood is oxygenated and returned to the left side of the heart (oxygenated) for flow to the rest of the body.

Ultimately, the function of our respiratory system is to facilitate the exchange of oxygen and carbon dioxide into and out of the body, respectively. This, of course, occurs courtesy of lung activity – in conjunction with erythrocytes (RBC) and the blood plasma, per above graphic.

Before we get too far into the exchange, it would be helpful to review the anatomy of the respiratory system. The graphic to the immediate right provides a general overview of the total respiratory system. In the small amount of space allotted, label as many structures as you can.

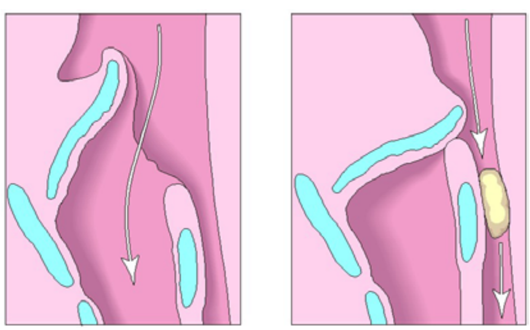


Going from the general to the specific, below is a graphic of the upper respiratory system:



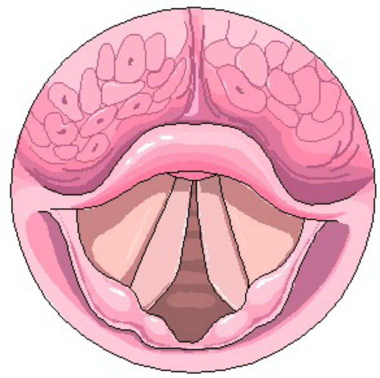
In the space, label as much of it as you can and as neatly as possible.

Above the larynx, above, is the epiglottis – a sort of "trash can lid" to keep food and drink and "junk" out of our airways. The graphic, below, shows the epiglottis opened during eupnea and closed during swallowing:

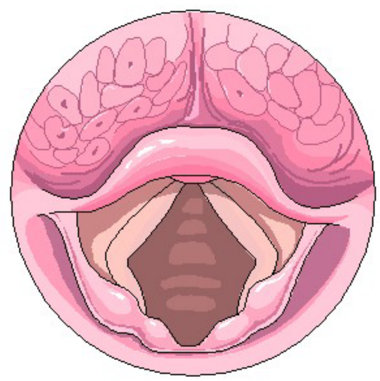


This mechanism prevents us from choking every time we eat and drink and attempt to inhale all at once.

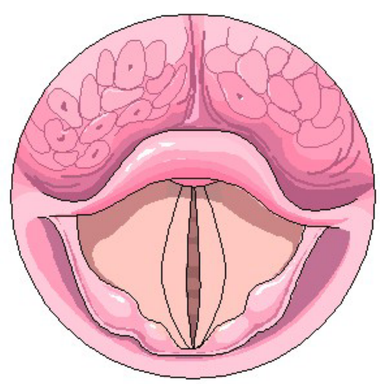
Inside the larynx are the vocal cords – vibrating bands that allow us to make noises to speak. The graphics, below, illustrate three distinct phases of cord activity:



Normal Respiration



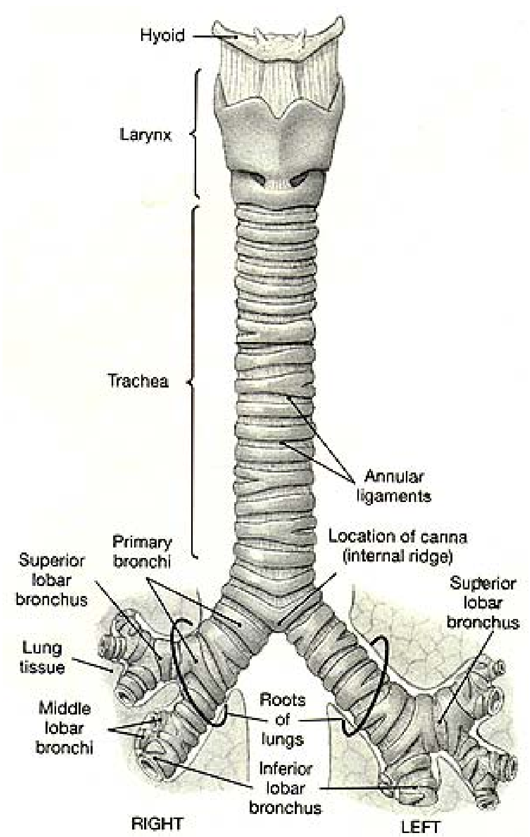
Deep Inspiration



Phonation

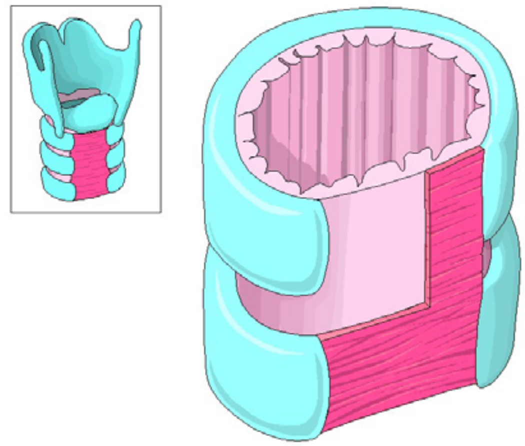
The part that is most impressive is that the cords are all drawn in perspective, i.e., they are drawn with the anterior most portions in the top of each illustration just as they would be seen if you were to intubate a patient.

As we continue deeper into the respiratory system, the next illustration shows us the main airways, the main bronchi:



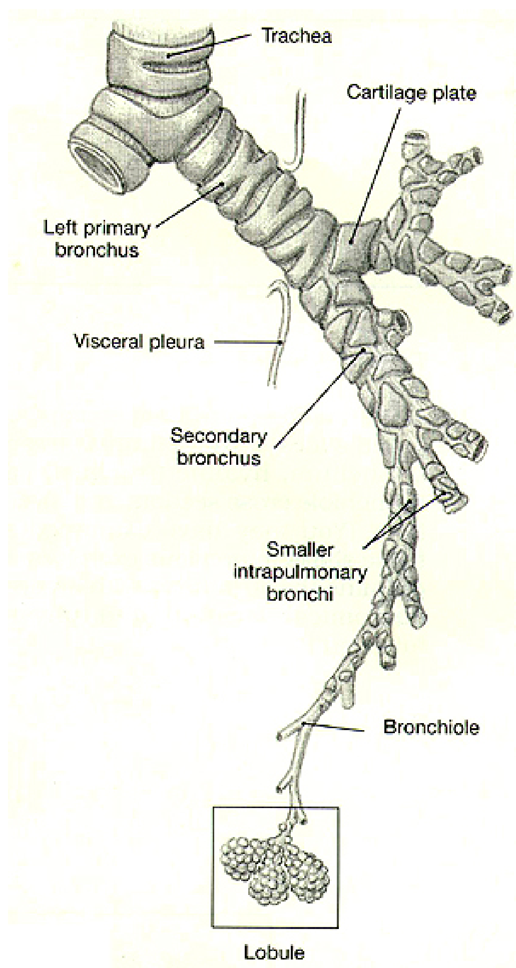
Note the characteristics of each main-stem bronchus as you read about them in your text and lecture.

Note, too, the tracheal rings that permit the trachea to remain patent instead of collapsing. Above right is an illustration of the backside of the tracheal rings that also shows the trachealis muscle:



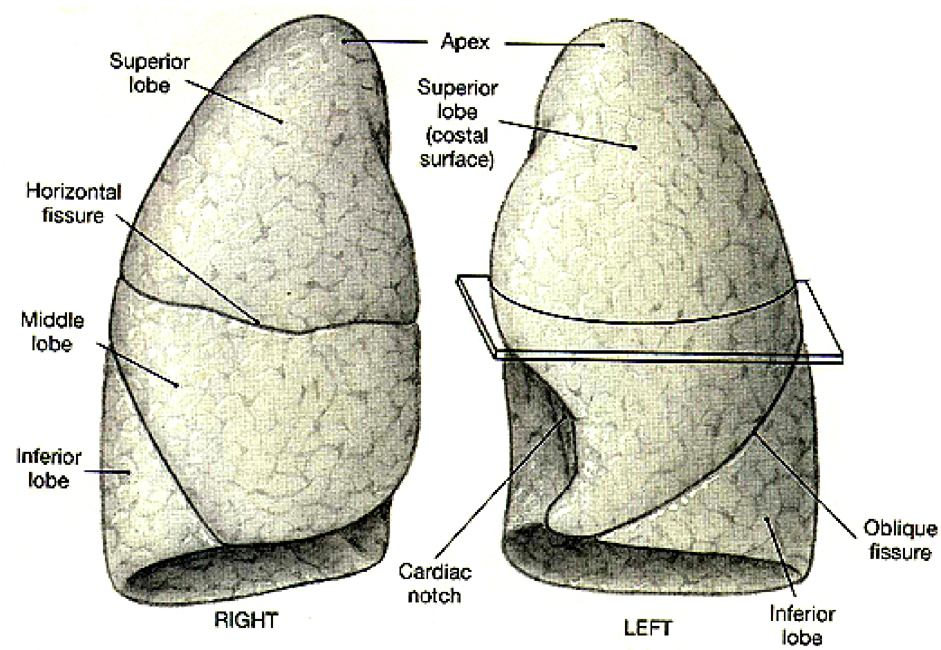
The trachealis muscle allows for the rings to “give a little”.

Extending from the secondary bronchi are additional airways that terminate in the alveoli of the lungs:

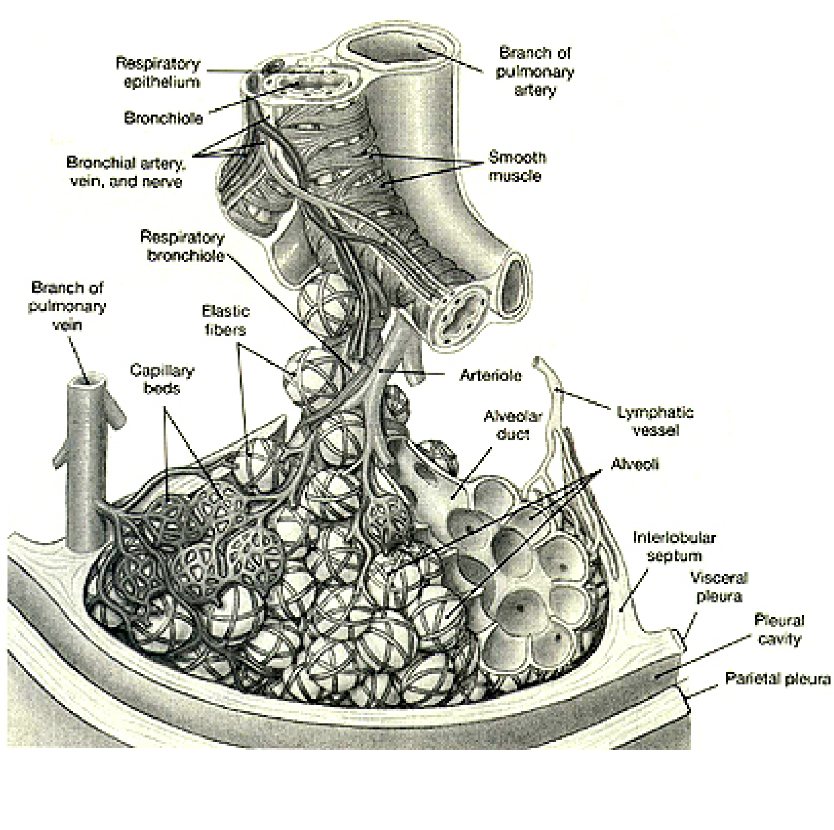


Remember the name of that last piece of tracheal cartilage? Write it in the space:

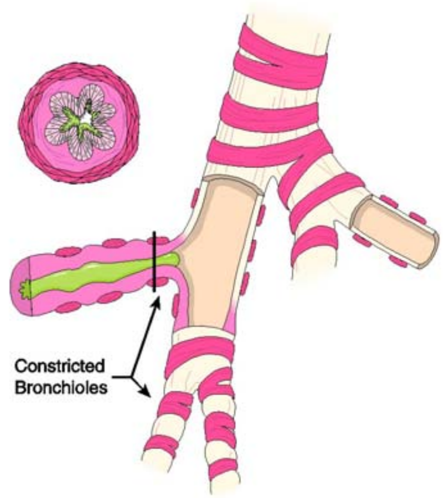
Wrapped around and contiguous with these airways are the lungs, themselves:

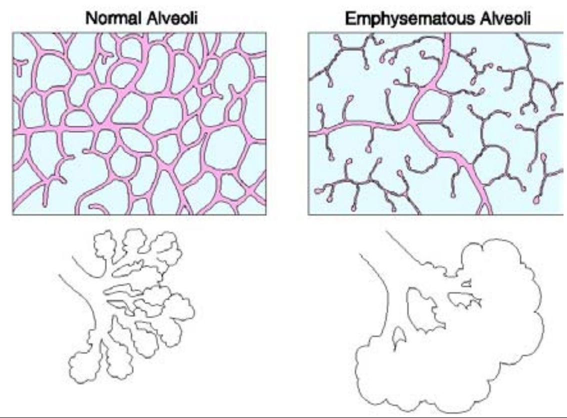


The ultimate lung structure is the alveolus (singular) or alveoli (plural):



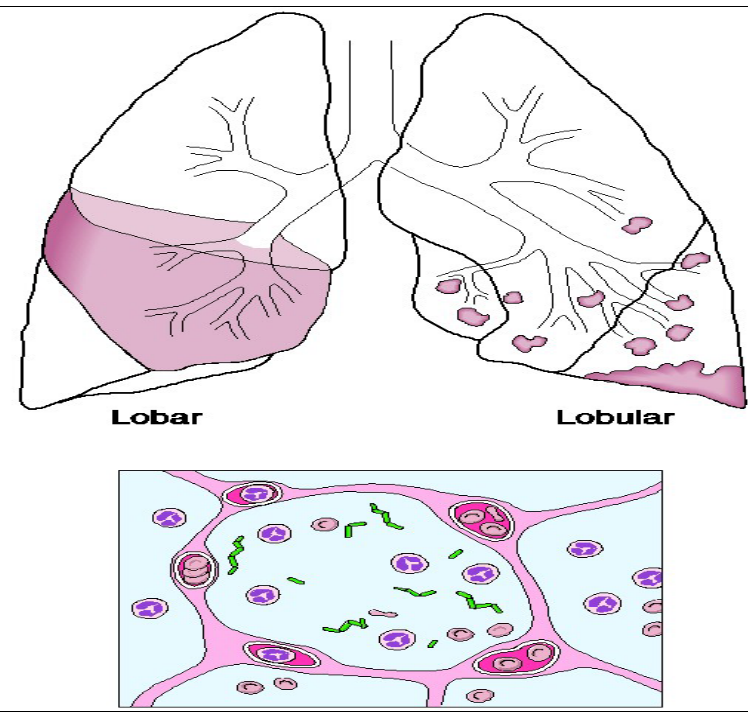
Diseases of the small airways (like asthma) and alveoli (emphysema) lead to difficulty in exchanging gases at the level of the lung:





Asthma	Emphysema

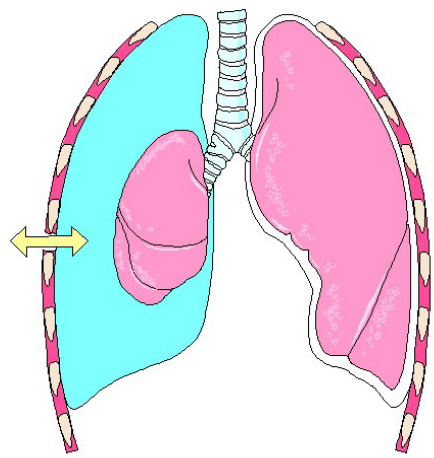
Both are diseases that allow air in – it's the "getting it out" that's the problem – these are "air-trapping" diseases, which is why "pursed-lip" breathing is taught to patients with chronic obstructive pulmonary disease. Pneumonia – whether viral or bacterial – causes breathing problems, as well:



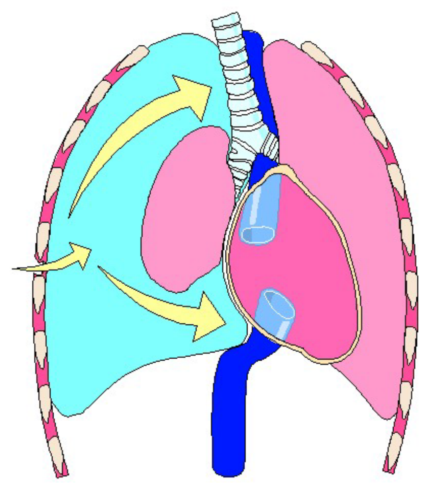
Lobar pneumonia on left – lobular pneumonia on right – distorted for illustrative purposes.

In addition to diseases that make breathing difficulty, it is possible to get air to enter the pleural space causing a pneumothorax. The following illustration demonstrates the effects of having excessive air in the pleural space on the lung:

Normal Pneumothorax



Tension Pneumothorax



After looking at this graphic, I have to admit to some confusion – having been in this business for right at 27 years, I honestly didn't know that there was a difference between the two kinds of pneuomothoraces shown above. So, I went online and did a little scrounging. Here are the two links to help square this up: 1) for tension pneumothorax (http://www.nlm.nih.gov/medlineplus/ency/article/000090.htm) and 2) for pneumothorax (http://www.nlm.nih.gov/medlineplus/ency/article/000087.htm) – didn't help much did it?! – yes, you're accountable for these sites' information. Either way, the treatment is pretty much the same: chest tube and under-water vacuum. Typically, a chest tube is inserted high to get rid of air (air rises) and low to get rid of blood (hemothorax – blood settles due to gravity). A spontaneous pneumothorax seems to arise as a result of a weak spot "blowing out" of a lung (sort of a "pulmonary aneurism" to coin a phrase using a cardiovascular term "out of school").

Introduction – Physiology

In general, one may visualize the diffusion of oxygen from the lung across the alveolar membrane into the blood with some ease. It is, however, a bit more difficult to visualize that which happens next. The oxygen is attracted to the heme portion of deoxyhemoglobin (DHb) in an RBC. As the oxygen binds to the DHb, it causes the removal of protons (H^+) for the formation of oxyhemoglobin (OHb) in the RBC. These protons react with bicarbonate ions (HCO_3^-) that have been transported from the plasma inside the erythrocyte and is condensed under the activity of carbonic anhydrase to form carbonic acid. Carbonic anhydrase also catalyzes the decondensation of carbonic acid to water and carbon dioxide. The latter is the gas that diffuses across the alveolar membrane from the blood for exhalation.

With the introduction of bicarbonate into the RBC, a net positive charge exists in the blood. This net positive charge is balanced out by the transport of chloride ions (the same number as bicarbonate ions) into the blood from the RBC. This is called "the chloride shift".

The RBC with the OHb travels through the capillary systems of the body until it reaches a cell which signals for the release of the oxygen from the OHb for transport into the tissue cell. This phase is regulated by carbon dioxide in the following manner. Carbon dioxide is released from the tissue cell into the blood. 70-80% of the carbon dioxide released into the blood is transported as bicarbonate. The majority of the remaining carbon dioxide is bound to the globin portion of the OHb. When the carbon dioxide binds to the OHb, it causes the removal of the oxygen from the heme with the addition H^+ to the carbon-dioxide-bound Hb. The oxygen diffuses across the RBC membrane into the blood, thence to the tissue cell for utilization in metabolic processes.

With the binding of a proton comes the formation of bicarbonate ion for plasma transport. The bicarbonate comes from the carbonic anhydrase-catalyzed reaction which, respectively, condenses carbon dioxide (from the tissue cell) with water in the RBC and then the decondensation of carbonic acid to protons and bicarbonate ions. The bicarbonate ions are released into the plasma for transport. This movement of bicarbonate causes blood to take on an excessive negative charge. This excessive negative charge is counter-balanced by the movement of chloride ions into the RBC. This phenomenon is referred to as the "backside of the chloride shift" and the cycle continues with respiration and metabolism.

There are a number of important lung volumes that in one way or another play a role in the transfer/exchange of gases. These are summarized for you, below:

Abbreviation	Name	Definition	Volume (varies by height, age, weight, gender)
IRV	Inspiratory reserve volume	Very deep breath; the air exhaled after a maximally-deep inhalation to the end of NORMAL expiration; hard to measure so is calculated: IRV = VC – (TV + ERV)	3100 mL
TV*	Tidal volume	Normal breath	500 mL
*TV= 500 mL			
350 mL of TV in alveoli		150 mL of TV in air spaces in nose, pharynx, larynx, trachea, bronchioles; this volume is called the anatomic dead space	
IC	Inspiratory capacity	IRV+TV; total inspiratory capacity of the lungs	3600 mL
VC	Vital capacity	IRV+TV+ERV; vigorous and complete (all) exhalation after a very deep breath	4800 mL
RV	Residual volume	Air remaining in the lungs after the ERV; air left in lungs after maximal exhalation	1200 mL
ERV	Expiratory reserve volume	Normal inhalation with forced expiration	1700 mL

Abbreviation	Name	Definition	Volume (varies by height, age, weight, gender)
Derived Volumes			
FVC	Forced vital capacity	Total volume of air exhaled from lungs	
FEV1	Forced expiratory volume at one second	Volume of air exhaled in one second	
FEV3	Forced expiratory volume at 3 seconds	Volume of air exhaled in three seconds	

Four of these lung volumes may be easily and inexpensively determined in the laboratory by means of a wet bell respirometer: the VC, TV, ERV and IRV.

A wet bell respirometer works under the principle that when air is blown into a "bell" placed in water, the bell is displaced in a manner that gives the volume of air that the subject is expelling. The volume of air that is expelled is marked in some manner by the displacement of the bell. In this experiment, the displaced volume is marked by a pointer on a scale that is hooked to a chain on the bell.

Experimental

Even though you've experimentation, below, we'll crack the cadaver's chest, as well, and do a cricothyrotomy so you can intubate the lungs and see them inflate via bag apparatus. Your instructor will guide you through the dissection.

Follow the steps, below, to complete this experiment – work in pairs so that you each have a "coach" – your instructor will demonstrate this activity for you.

STEP 1: Obtain the respirometer. It is already filled correctly – please do not remove it from the lab bench. Make certain that the pointer on the scale is aimed at the "0" mark.

STEP 2: Obtain a cardboard or plastic mouthpiece. Insert it where your instructor demonstrates. You are the only one who may use this mouthpiece. Discard it when you have completed the experiment.

STEP 3: Take several deep breaths. Take another and place the mouth piece in your mouth and blow all your air out – as hard and as long as possible.

STEP 4: The value marked on the scale (and hopefully recorded by your partner) is your vital capacity (VC). Record this value in the space below:

________________________mL

STEP 5: Reset the pointer to "0" on the scale.

STEP 6: Take several NORMAL breaths. Take another normal breath and exhale NORMALLY into the mouth piece.

STEP 7: The value marked (and hopefully recorded by your partner) is your tidal volume (TV). Record this value in the space, below:

________________________mL

Step 8: Repeat step 5.

Step 9: Take several NORMAL breaths. Take another normal breath and exhale NORMALLY. After your normal exhalation, continue to exhale forcefully into the mouth piece until you have exhaled all the air you can.

Step 10: The value marked (and hopefully recorded by your partner) on the scale is your expiratory reserve volume (ERV). Record the value in the space, below:

_________________________mL

Step 11: Calculate your inspiratory reserve volume (IRV). Use the following equation to determine this value:

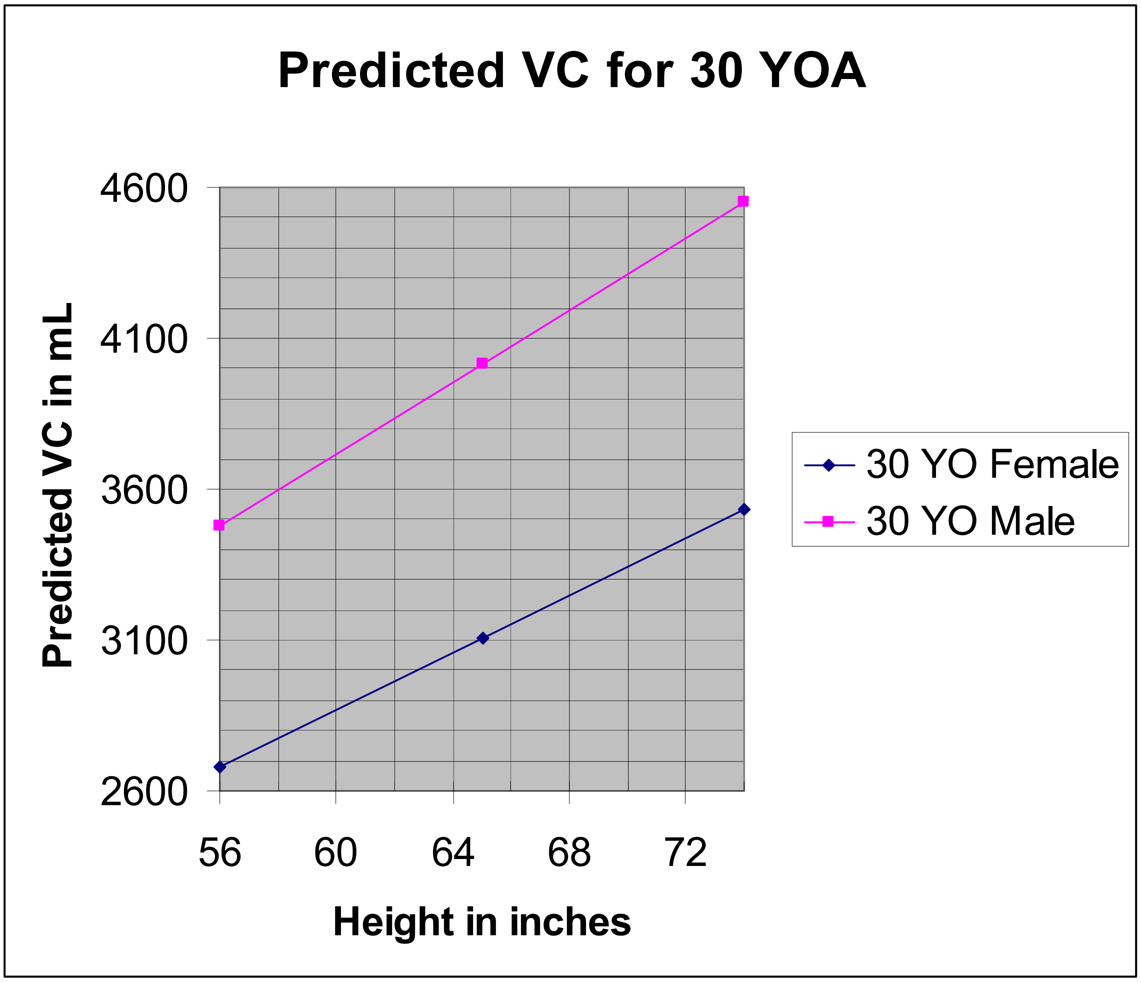
$$IRV = VC - (TV + ERV)$$

OR

$$IRV = \text{Step } 4 - (\text{Step } 7 + \text{Step } 10)$$

Record your value here: ______________________mL

STEP 12: Using the following "nomogram", determine your PREDICTED VC – assuming your age is 30 – men use the correct line, women use the correct line:



STEP 13: Calculate your %VC at which you are functioning:

$$\frac{Experimental\ VC}{PREDICTED\ VC} * 100 = \%VC$$

Record your value here: ______________________________%

Remember that if you're a smoker, your VC may look normal to elevated because of air trapping.

Questions

1) A patient was admitted into the emergency room complaining of GI bleed and renal failure. On admission, the attending physician ordered blood gases. The following report was issued after analysis:

pH	pCO_2	HCO_3^-	pO_2
6.857	12.3	2.2	126

Based upon what you have learned about arterial blood gases in class and your readings, determine a diagnosis for this patient:

A) Based on pH changes ONLY, how would you diagnose these gases (this patient)?

B) By examining the pCO_2 and HCO_3^-, what is the primary disorder in this patient?

C) Is the patient's body trying to compensate? Why or why not?

D) What is the patient's predicted pCO_2? How does this compare to the patient's actual pCO_2?

E) Does the patient's renal failure play any role in this problem? Why or why not?