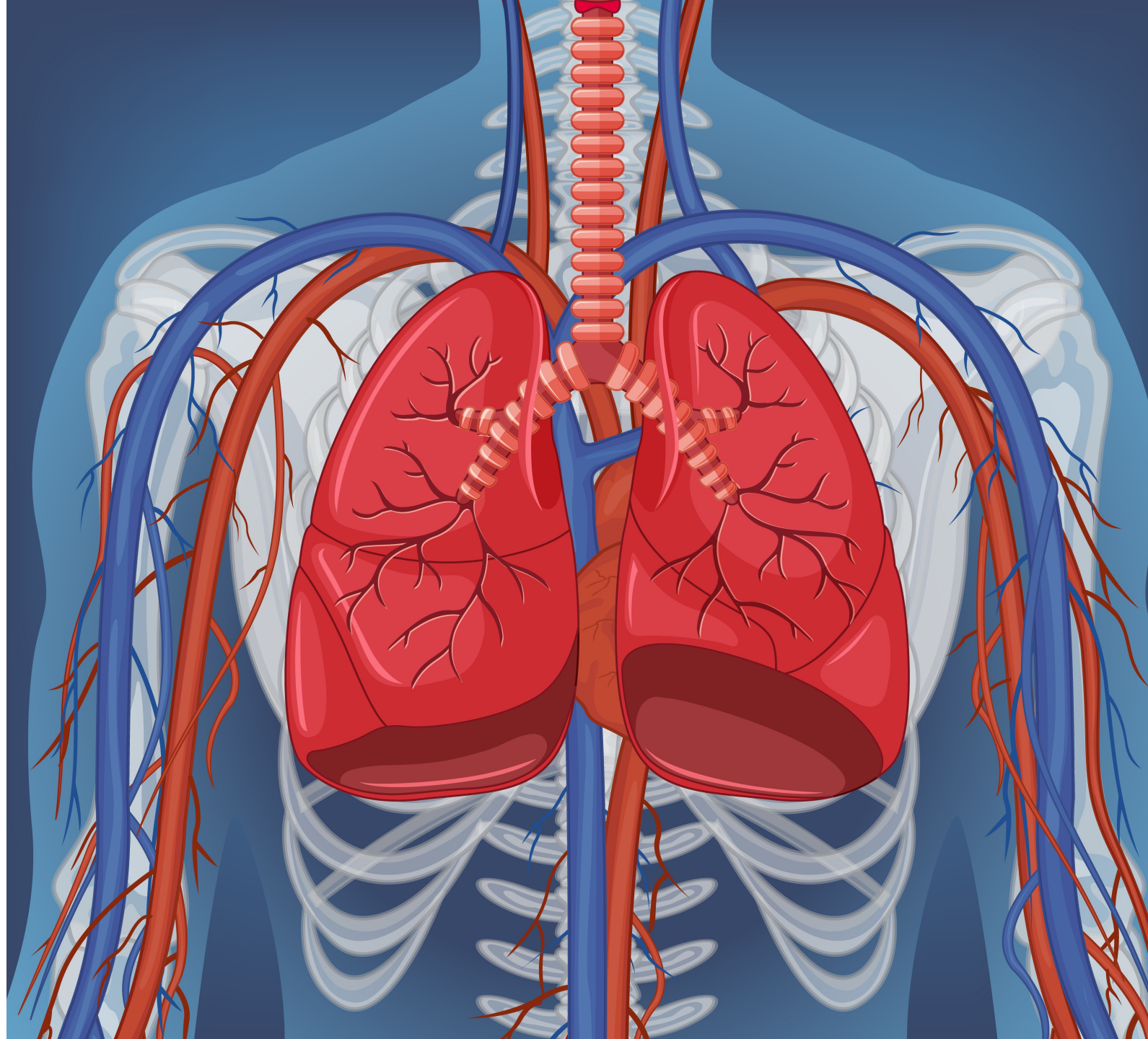


LAB 6: THE RESPIRATORY SYSTEM

Protocol slides
PCB 3702L
FIU



LAB 6 PROTOCOL OBJECTIVES



1. Explain inhalation and exhalation by using the bell jar lung model.



2. Explain acid-base balance due to respiration.



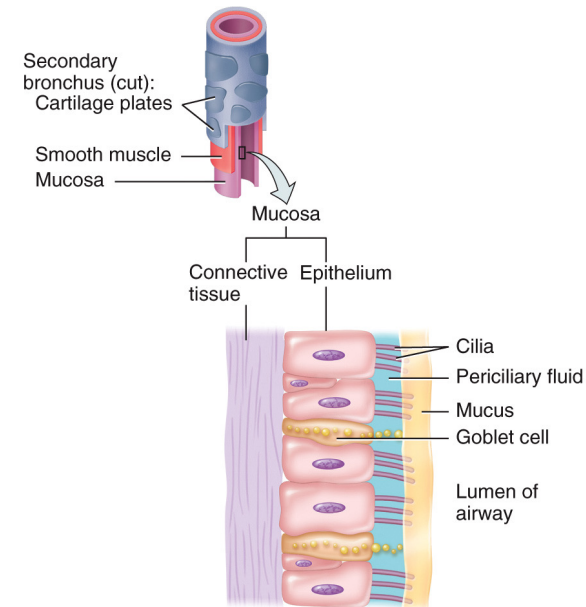
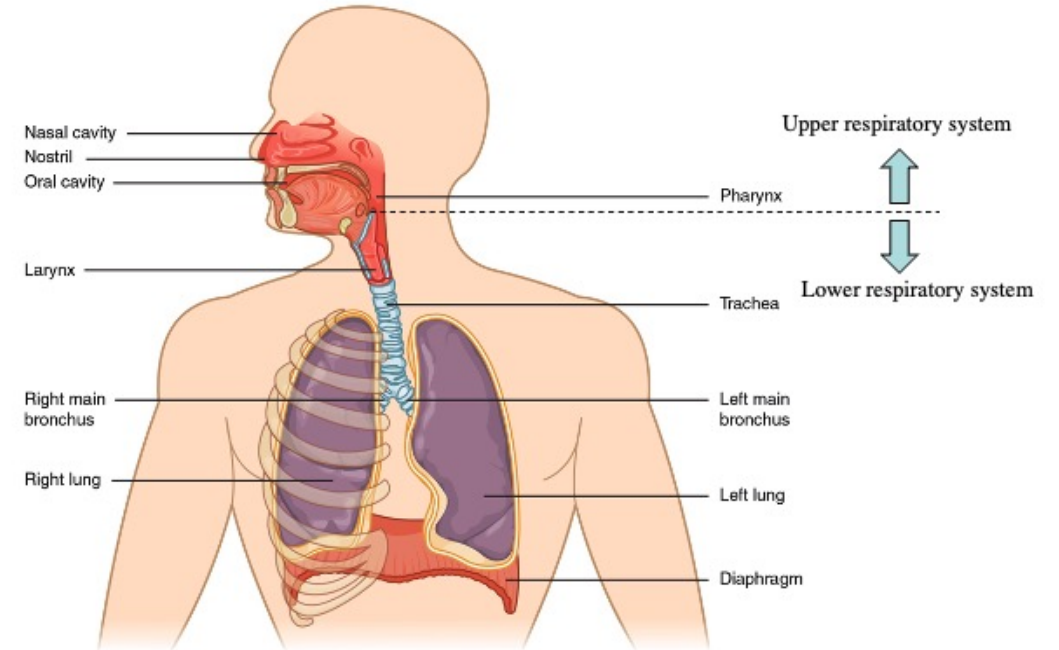
3. Determine respiratory volumes and capacities at rest and following exercise.



4. Explain blood typing.

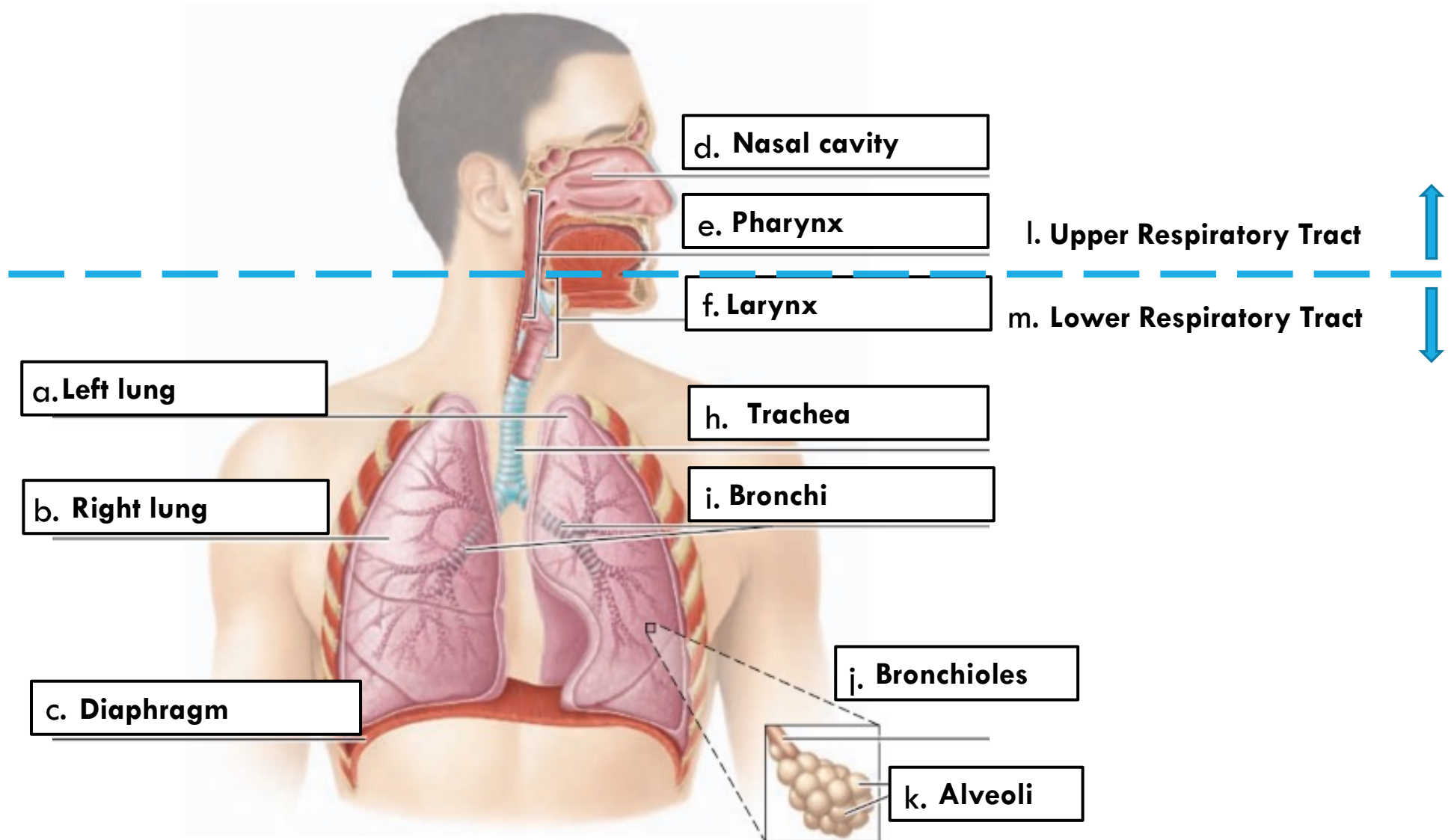
RESPIRATORY ANATOMY

- **Pharynx:** shared passageway for both air designed for the lungs and food destined for the esophagus. Part of both the respiratory & digestive systems
 - **Larynx:** voice box. Guards the entrance to the trachea
 - **Trachea:** sturdy tube supported by rings of cartilage. Located anterior to the esophagus
 - **What is the pathway of air?**
 - Nasal Cavity → Pharynx → Larynx → Trachea → Bronchi → Bronchioles → Alveoli
 - **Mucociliary escalator**
 - The respiratory epithelium contains goblet cells that secrete mucus to trap inhaled debris and microbes, as well as cilia that move the mucus to the pharynx, where it can be expelled or swallowed
- * Depending on the source used the larynx may be considered part of the upper or lower respiratory tract.



(b) Respiratory mucosa

RESPIRATORY ANATOMY PRACTICE!



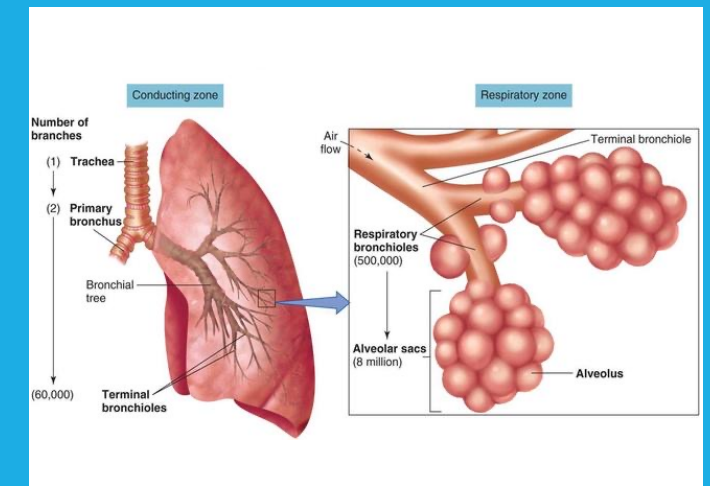
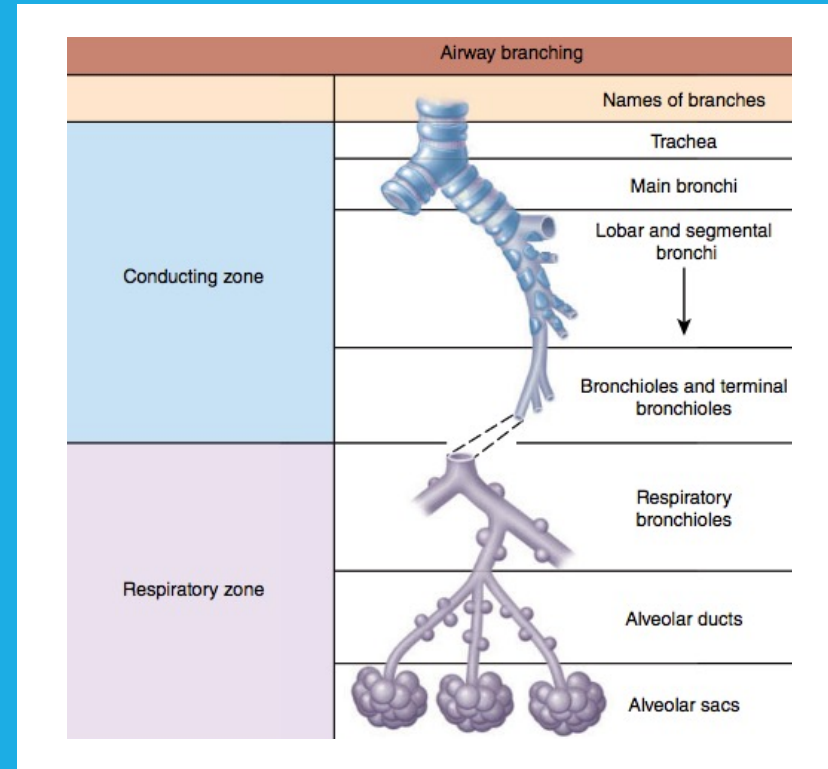
FUNCTIONAL ZONES OF THE RESPIRATORY SYSTEM

Conducting Zone:

- Structures include the nasal cavity, pharynx, larynx, trachea, bronchi (primary/secondary/tertiary), and the terminal bronchioles
- Filters, warms, and humidifies inhaled air and conducts it into the lungs
- NO gas exchange** takes place here since alveoli are absent

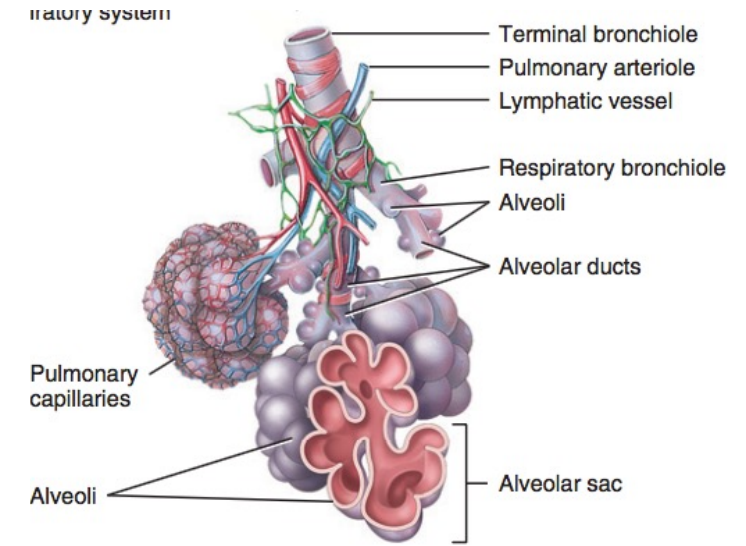
Respiratory Zone:

- Structures include the respiratory bronchioles, alveolar ducts, and alveolar sacs
- Carries out gas exchange since it contains alveoli

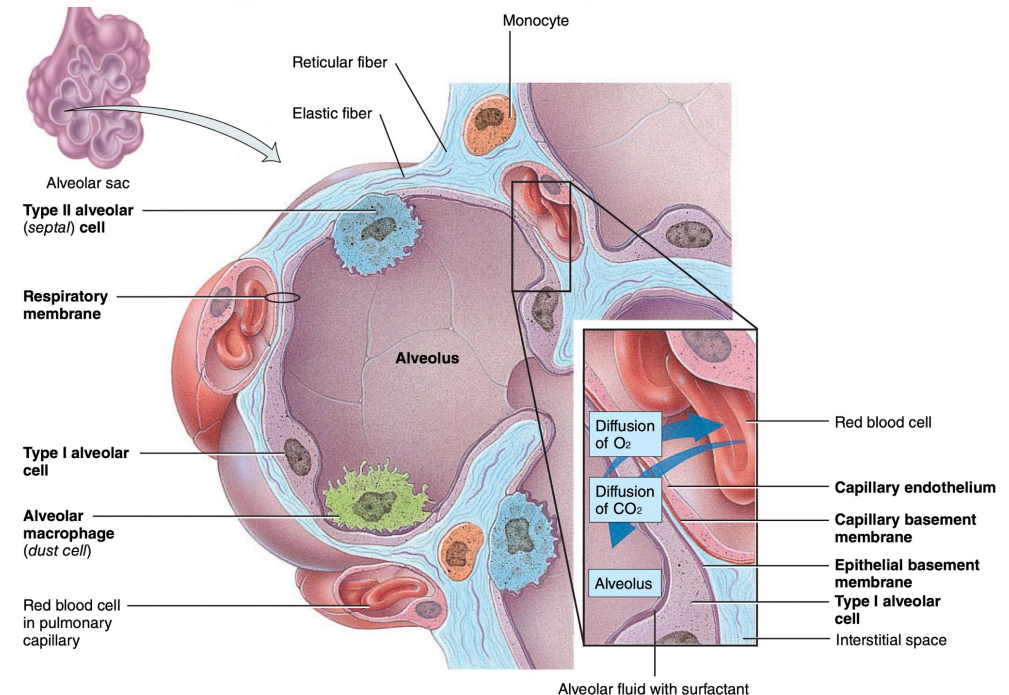


ALVEOLI

- Air-filled sacs that extend from the respiratory bronchioles, alveolar ducts, and alveolar sacs
- The thinness of alveolar wall epithelium is vital to the process of gas exchange
 - Inhaled O_2 diffuses from the alveoli to the blood in the capillaries, and CO_2 diffuses from the blood in the capillaries into the alveoli to be exhaled
- Each alveolus is surrounded by a dense network of **pulmonary capillaries**
 - Red blood cells ARE NOT located within the walls of the alveoli. Rather they are found in the pulmonary vessels **surrounding** the alveoli
- The epithelium of an alveolus consists of:
 - **Type I Alveolar Cells:** continuous lining of alveolar walls; main site of gas exchange
 - **Type II Alveolar Cells:** secrete surfactant (composed of lipids & proteins) to **reduce** the tendency of alveolar collapse; keeps surface between alveolar cells and the air moist
- **Alveolar Macrophages:** immune cells that wander around phagocytosing dust particles, debris, and microbes

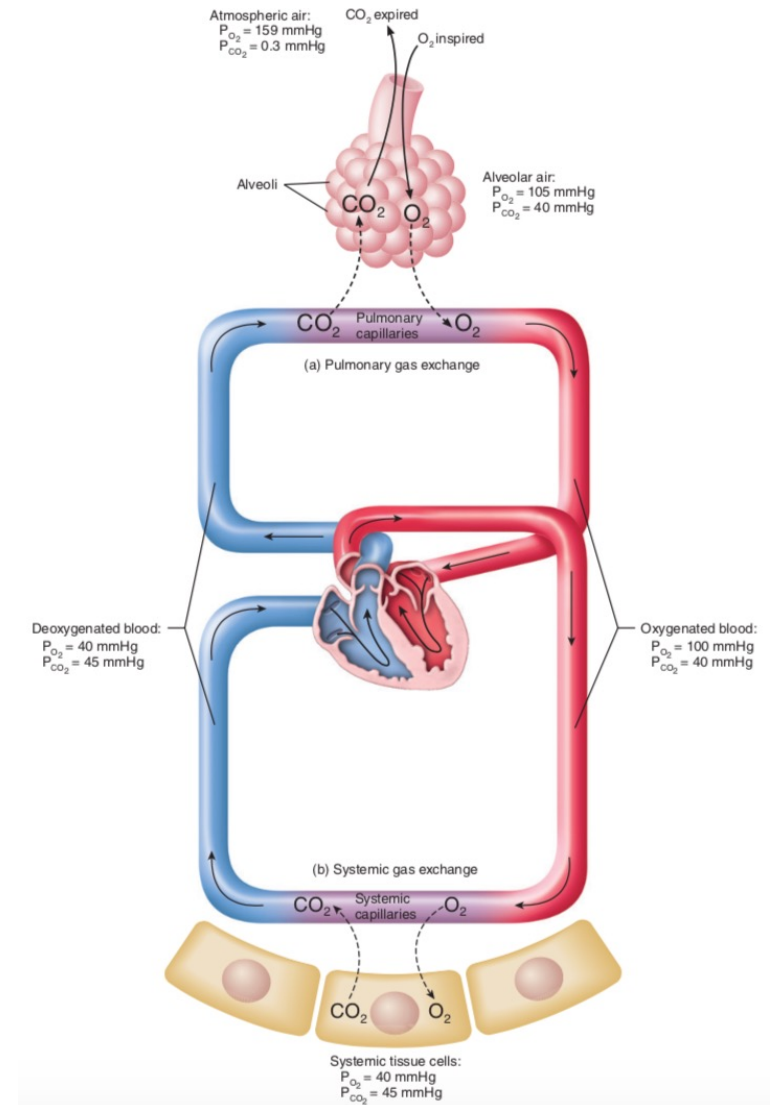


(c) Terminal bronchiole and subsequent branches



GAS EXCHANGE

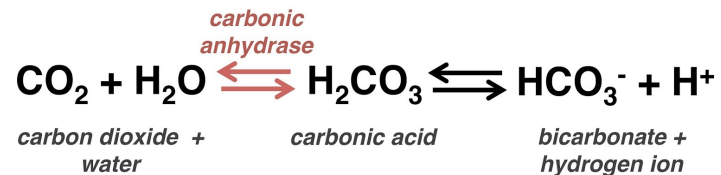
- Pulmonary gas exchange is the exchange of gases between alveoli and pulmonary blood capillaries. It depends on:
 - partial pressure differences,
 - a large surface area for gas exchange,
 - small diffusion distance across the respiratory membrane,
 - and the rate of airflow into and out of the lungs.
- Systemic gas exchange is the exchange of gases between systemic blood capillaries and tissue cells
- In pulmonary and systemic gas exchange, O_2 and CO_2 diffuses from areas of higher partial pressures to areas of lower partial pressures



REGULATION OF BREATHING



Bicarbonate Buffer System

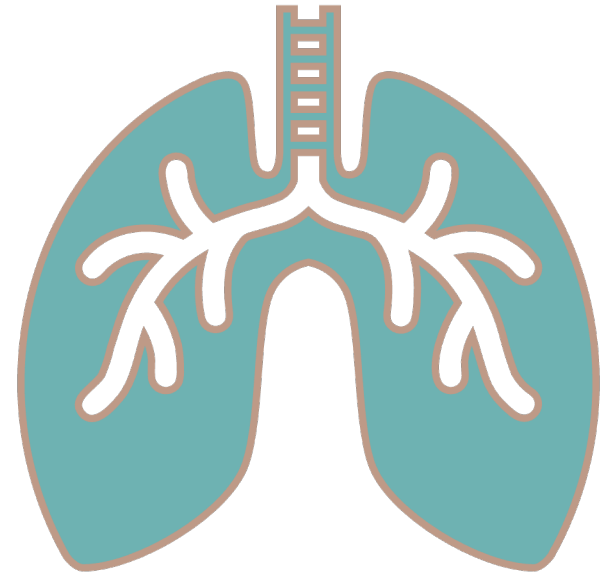


Optimal blood pH is around 7.35-7.45

- **Respiratory Control Centers of the Upper Brainstem (involuntary breathing):**
 - **Medulla oblongata:** signals the muscles involved in breathing
 - **Pons:** regulates the actual breathing (ventilation rate)
- These respiratory control centers contain **chemoreceptors** that detect changes in pH/CO₂ concentration and signal back to regulate the ventilation rate and bring those CO₂ levels back to normal
- **What is the relationship between CO₂ and blood pH?**
 - An increase in CO₂ leads to a decrease in pH (acidic)
 - A decrease in CO₂ leads to an increase in pH (basic)
- **How does blood pH affect ventilation rates?**
 - Decreased blood pH (**acidosis**) **increases** the respiration rate and depth of breathing (hyperventilation)
 - Increased blood pH (**alkalosis**) **decreases** the respiration rate and depth of breathing (hypoventilation)

HOW WOULD HYPERVENTILATING CHANGE THE BLOOD CHEMISTRY IN THE HUMAN BODY?

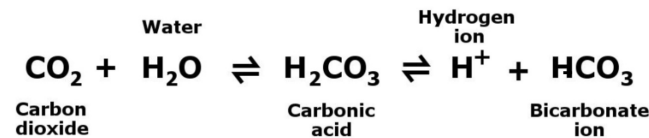
- A. expel CO_2 and decrease pH
- B. retain CO_2 and decrease pH
- C. expel CO_2 and increase pH
- D. retain CO_2 and increase pH



Oxygen & Hemoglobin

- **Hemoglobin** is a protein that transports bound oxygen inside red blood cells
 - it consists of four subunits, each with an iron-containing heme group that can bind one oxygen molecule
- The binding of oxygen to hemoglobin has **cooperativity**:
 - the binding of one O₂ molecule causes a conformational change in hemoglobin that increases its affinity to bind more O₂
- The affinity of hemoglobin for oxygen is affected by several factors, including:
 - ✓ **pH**
 - ✓ **CO₂ concentration**

- These two factors are related because:

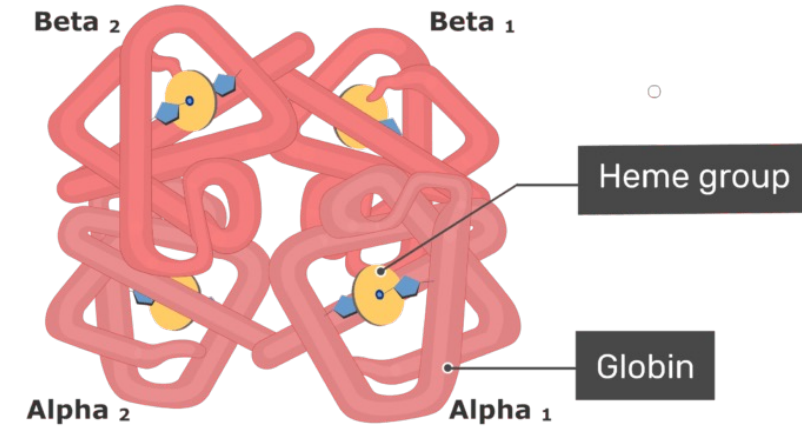


meaning that high CO₂ levels = **lower** blood pH

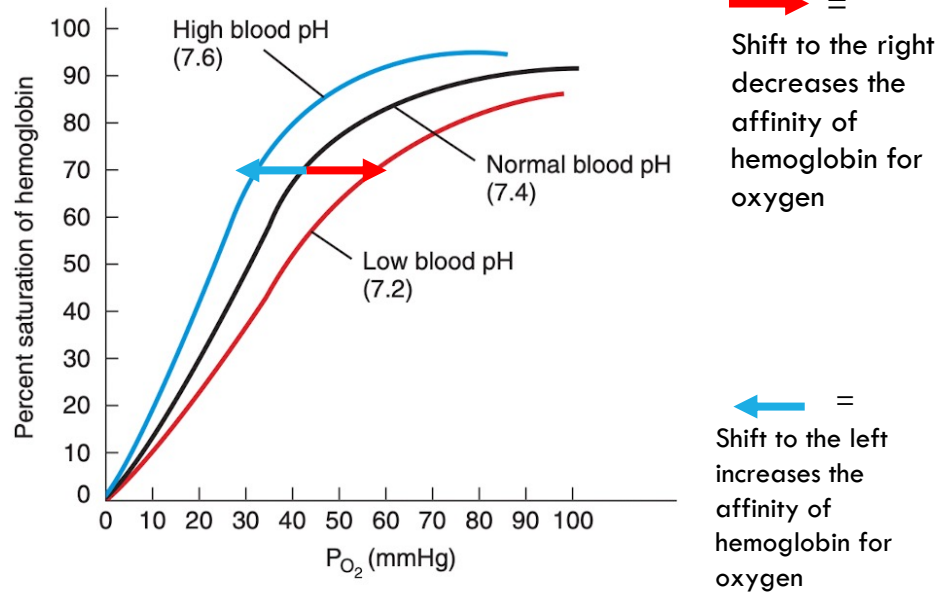
low CO₂ levels = **raise** blood pH

normal blood pH range: 7.35 - 7.45

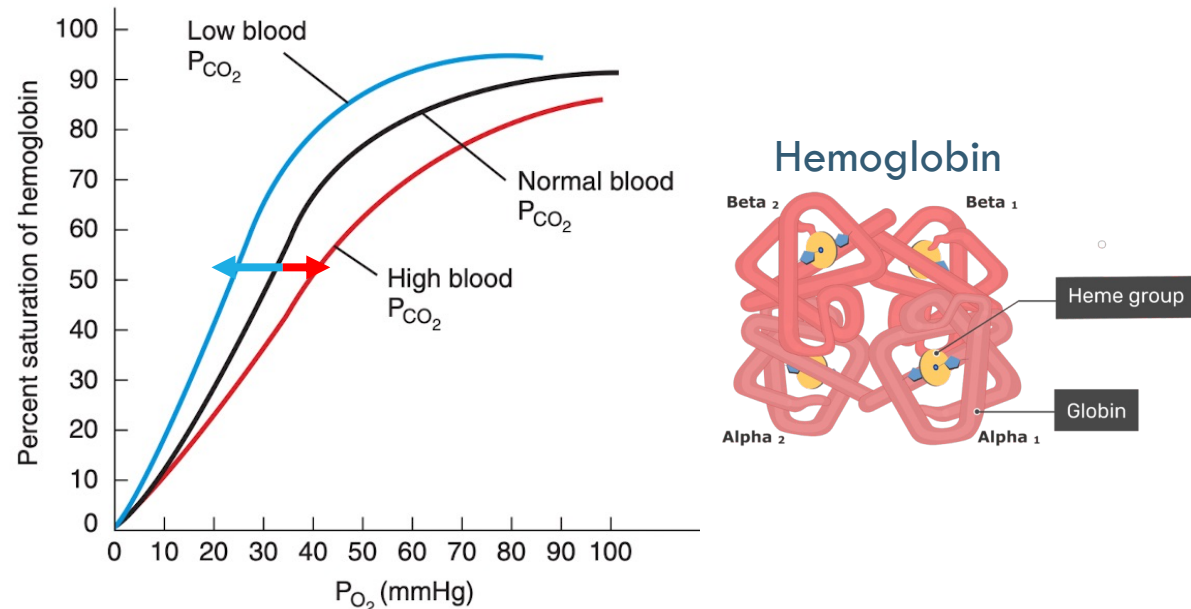
Hemoglobin



OXYGEN-HEMOGLOBIN DISSOCIATION CURVE



(a) Effect of pH on affinity of hemoglobin for oxygen



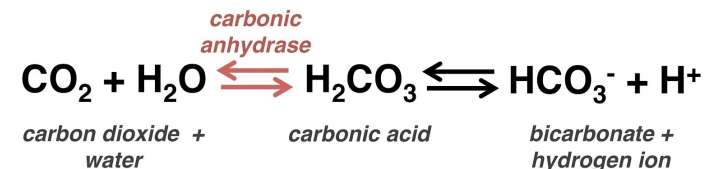
(b) Effect of P_{CO_2} on affinity of hemoglobin for oxygen

Oxygen-hemoglobin dissociation curve describes the affinity of hemoglobin for oxygen

- Several factors such as pH (acidity), P_{CO_2} and temperature can affect the affinity for Oxygen
- Hemoglobin is a protein that transports bound oxygen within RBCs

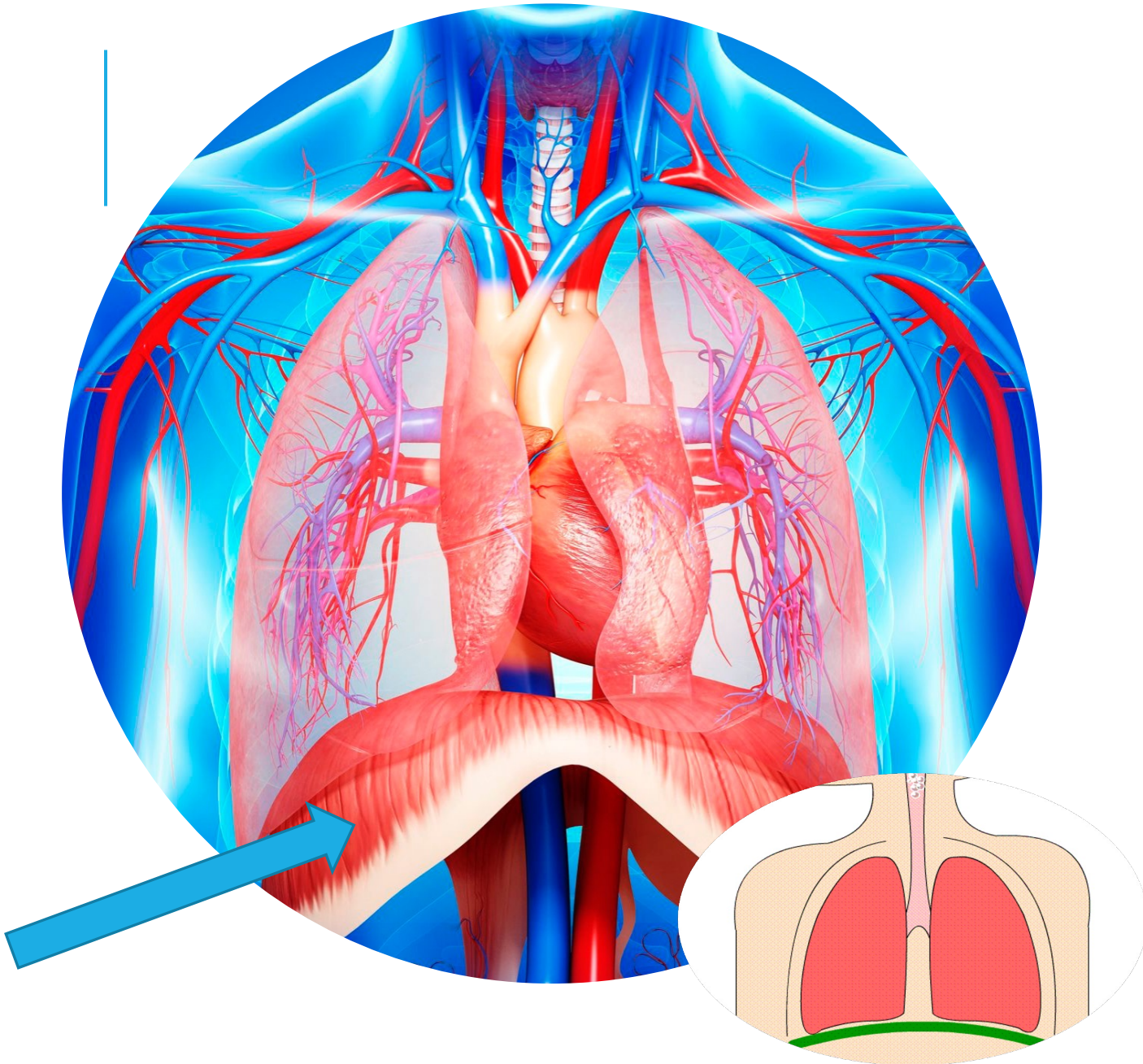
Bohr Effect: When there is a high concentration of H^+ ions (low pH), hemoglobin's affinity for oxygen is lower → Dissociation curve shifts to the right (downward shift)

- More oxygen is unloaded to the tissues
- Increasing CO_2 concentration causes lowered pH in the bloodstream, so the Bohr shift encompasses both increasing CO_2 and increasing hydrogen ion concentration

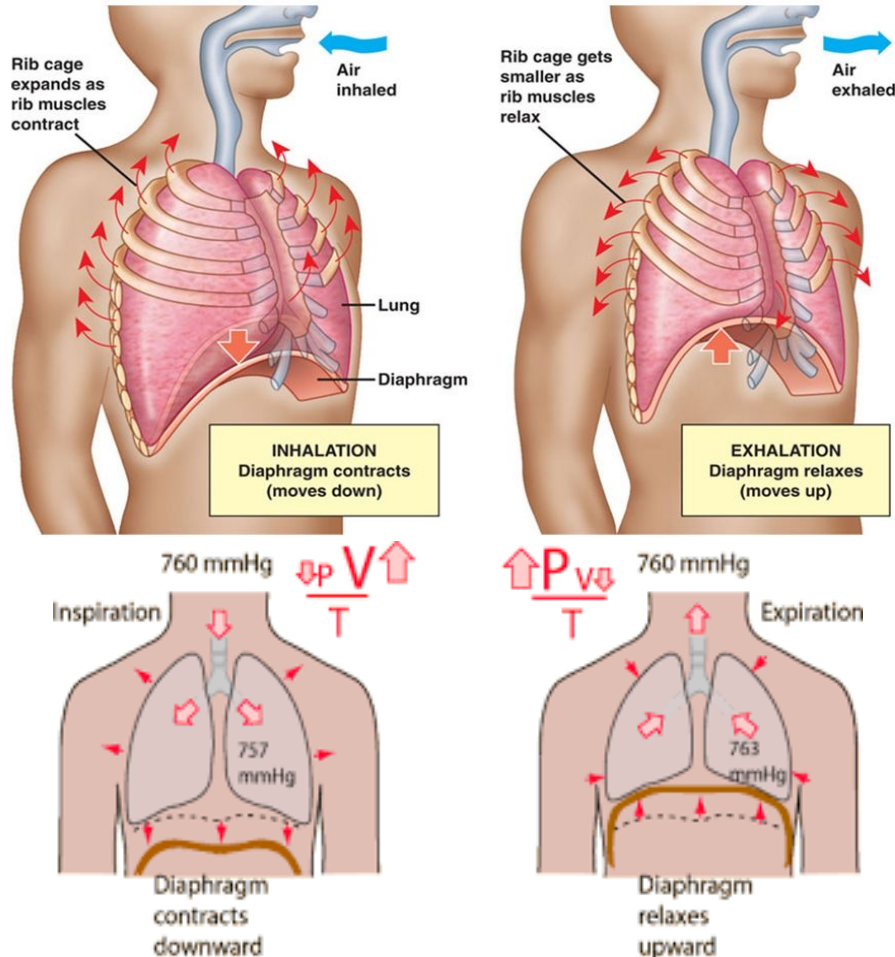


THE DIAPHRAGM

- The dome-shaped skeletal muscle that separates the thoracic and abdominopelvic cavities
- Most important muscle for inspiration
 - Responsible for about 75% of the air that enters the lungs during quiet breathing
- Innervated by fibers of the phrenic nerve
 - The phrenic nerve is a mixed (sensory & motor) spinal nerve
- **Is this muscle considered striated?**
- **What happens if there is damage to the phrenic nerve?**



MECHANICS OF BREATHING



Air moves from high to low pressure

- For air to move in & out of the lungs, a pressure gradient must be established between the lungs and the external environment (atmosphere)
- Pressure changes in the lungs occur due to changes in lung volume

Boyle's Law: Describes the **inverse** relationship between volume and pressure at constant temperature

Formula: $P_1 V_1 = P_2 V_2$

Inspiration: Contraction of the diaphragm increases lung volume and decreases pressure

- Diaphragm flattens out (moves down) as it contracts
- Normal quiet inspiration also involves contraction of the external intercostal muscles which elevate the rib cage

Expiration: Relaxation of the diaphragm decreases lung volume and increases pressure

- Diaphragm relaxation allows the muscle to return to its dome shape (moving up); External Intercostals relax to lower rib cage during normal exhalation
- Expiration results from the elastic recoil of the chest wall & lungs, termed elasticity
- Normal quiet expiration is a passive process since it does not involve muscle contraction

Respiratory Volumes and Capacities

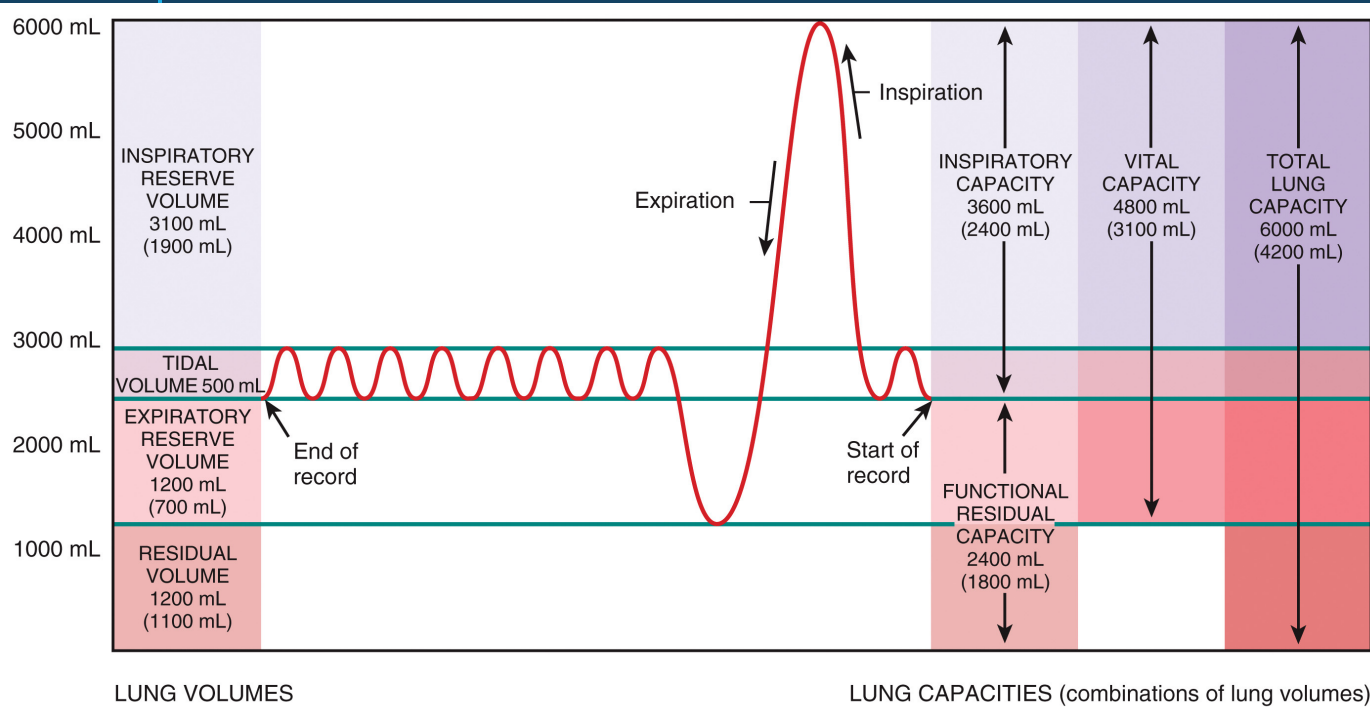


Table 27-1 Respiratory Volumes and Capacities

Volumes and Capacities	Definition
Tidal volume (TV)	Volume of air exchanged during each normal (quiet) breath
Inspiratory reserve volume (IRV)	Maximum volume of air that can be forcibly inspired after a tidal inspiration
Expiratory reserve volume (ERV)	Maximum volume of air that can be forcibly expired after a tidal expiration
Residual volume (RV)	Volume of air that remains in the lungs after a forced expiration
Inspiratory capacity	Total amount of air that can be inspired; equals tidal volume plus inspiratory reserve volume: (TV + IRV)
Functional residual capacity	Total amount of air that normally remains in the lungs after a tidal expiration; equals residual volume plus expiratory reserve volume: (RV + ERV)
Vital capacity	Total amount of exchangeable air; equals sum of tidal volume, expiratory reserve volume, and inspiratory reserve volume: (TV + ERV + IRV)
Total lung capacity	Total amount of exchangeable and nonexchangeable air; equals sum of all of the pulmonary volumes: (TV + IRV + ERV + RV)

Know the formulas and be able to do calculations!!!

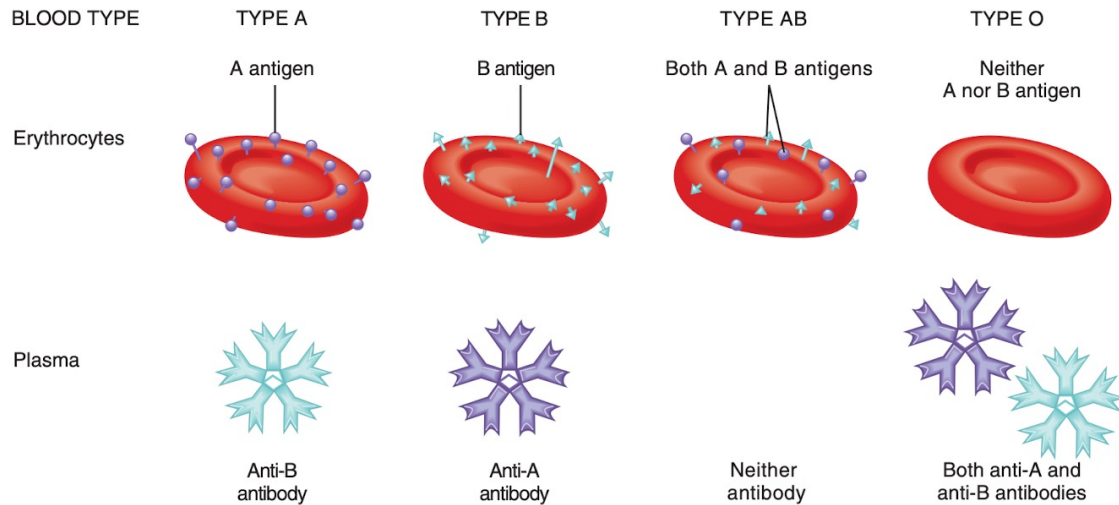
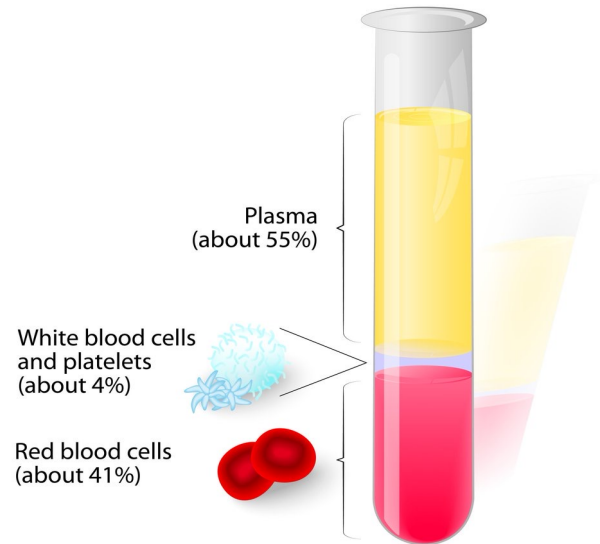
- **Respiratory volume** - the volume of air that flows into or out of the lungs during a specific pulmonary event
- **Respiratory capacity** - the sum of two or more respiratory volumes
- Respiratory volumes can be measured using a **spirometer** to produce a graphical representation called a **spirogram** (like the one seen above)

HEMATOLOGY

The study of the physiology of blood



COMPOSITION OF WHOLE BLOOD

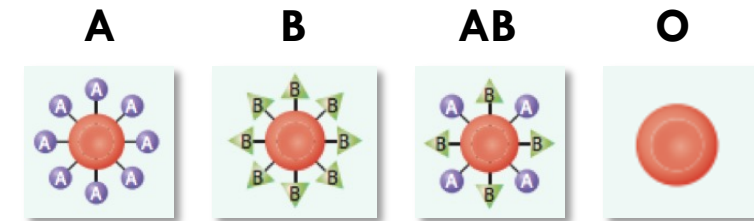


BLOOD TYPING - ANTIGENS

Antigens: Specific glycoproteins embedded in the cell membranes of red blood cells (RBCs/erythrocytes)

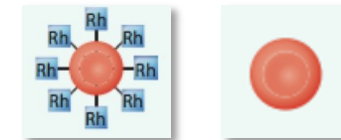
There are many antigens, but only two groups are routinely typed: **The ABO System & Rh System**

- ABO System has 4 variants





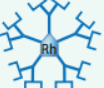

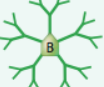


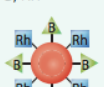

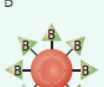

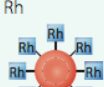
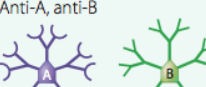
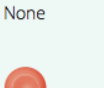
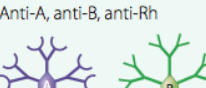
- Rh System has two variants

Rh (+) Rh (-)



- Creates eight major blood types: **A+, A-, B+, B-, AB+, AB-, O+, O-**

Table 20-2 The Eight Major Blood Types

Blood Type	Antigens Present on Erythrocyte Surface	Antibodies Present in Plasma	May Receive from	May Donate to
AB+	A, B, Rh 	None	Universal recipient	AB+
AB-	A, B 	Anti-Rh 	AB-, A-, B-, O-	AB+, AB-
A+	A, Rh 	Anti-B 	A+, A-, O+, O-	AB+, A+
A-	A 	Anti-B, anti-Rh 	A-, O-	AB+, AB-, A+, A-
B+	B, Rh 	Anti-A 	B+, B-, O+, O-	AB+, B+
B-	B 	Anti-A, anti-Rh 	B-, O-	AB+, AB-, B+, B-
O+	Rh 	Anti-A, anti-B 	O+, O-	AB+, A+, B+, O+
O-	None 	Anti-A, anti-B, anti-Rh 	O-	Universal donor

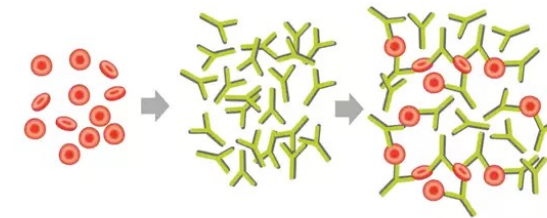
BLOOD TYPING - ANTIBODIES

Antibodies: Y-shaped immune system proteins produced in response to a foreign antigen and found in the blood plasma

- Humans do not normally produce antibodies against self antigens (autoimmune diseases)




























What happens when an antibody meets its antigen?

- Agglutination (clumping of RBCs); when an antibody is mixed with its corresponding antigen and phagocytizes it. **Agglutination is NOT the same as blood clotting (coagulation)**



- Anti-A and Anti-B antibodies begin forming shortly after birth
- Anti-Rh antibodies are produced **only AFTER exposure to the Rh antigen**
 - Exposure to Rh antigens could occur during a blood transfusion or during pregnancy/childbirth
 - For this lab, unless we specify otherwise, assume that all individuals with negative blood types have been exposed to Rh factor before and therefore have developed anti-Rh antibodies**

TRANSFUSION COMPATIBILITY: DONATING & RECEIVING BLOOD

		DONOR BLOOD TYPES							
		O-	O+	B-	B+	A-	A+	AB-	AB+
RECIPIENT BLOOD TYPES	AB+								
	AB-								
	A+								
	A-								
	B+								
	B-								
	O+								
	O-								

- **Horizontally** (left and right): blood types you can **receive** blood from
- **Vertically** (up and down): blood types you can **donate** blood to

The normal components of one person's RBC plasma membrane can trigger damaging antigen-antibody responses in a transfusion recipient

An incompatible blood transfusion will lead to *agglutination*

- This is because the antibodies in the recipient's plasma bind to antigens on the donated erythrocytes

For ABO Group:

- When trying to find a compatible blood type between donor and recipient, look at the donor's antigens and the recipient's antibodies to ensure they WILL NOT react
- For example, a type-B individual will have anti-A antibodies, which will agglutinate with any donor that has A antigen.

For Rh Group:

- **Rh+:** These individuals can receive blood from both Rh+ & Rh- but can only donate to those with the Rh antigen (Rh+)
- **Rh-:** These individuals can only receive blood from Rh- but can donate to either Rh+ or Rh individuals

Universal Recipient: AB+: This blood type has A, B, and Rh antigens, but no antibodies. Since it has no antibodies, it will not agglutinate any incoming blood

Universal Donor: O-: Since this blood type has no antigens, it can be donated to anyone since recipient antibodies would have nothing to agglutinate with



PROTOCOL

ACTIVITY 1: LUNG MODEL DIAGRAM

1. What happens as you pull down the balloon at the bottom of the model?

- Diaphragm contracts (flattens out/moves down) → **Inspiration**

2. What happens as you push the balloon up?

- Diaphragm relaxes (returns to dome-shape/moves up) → **Expiration**

3. How does the movement of the diaphragm cause the air to go in and out of the lungs?

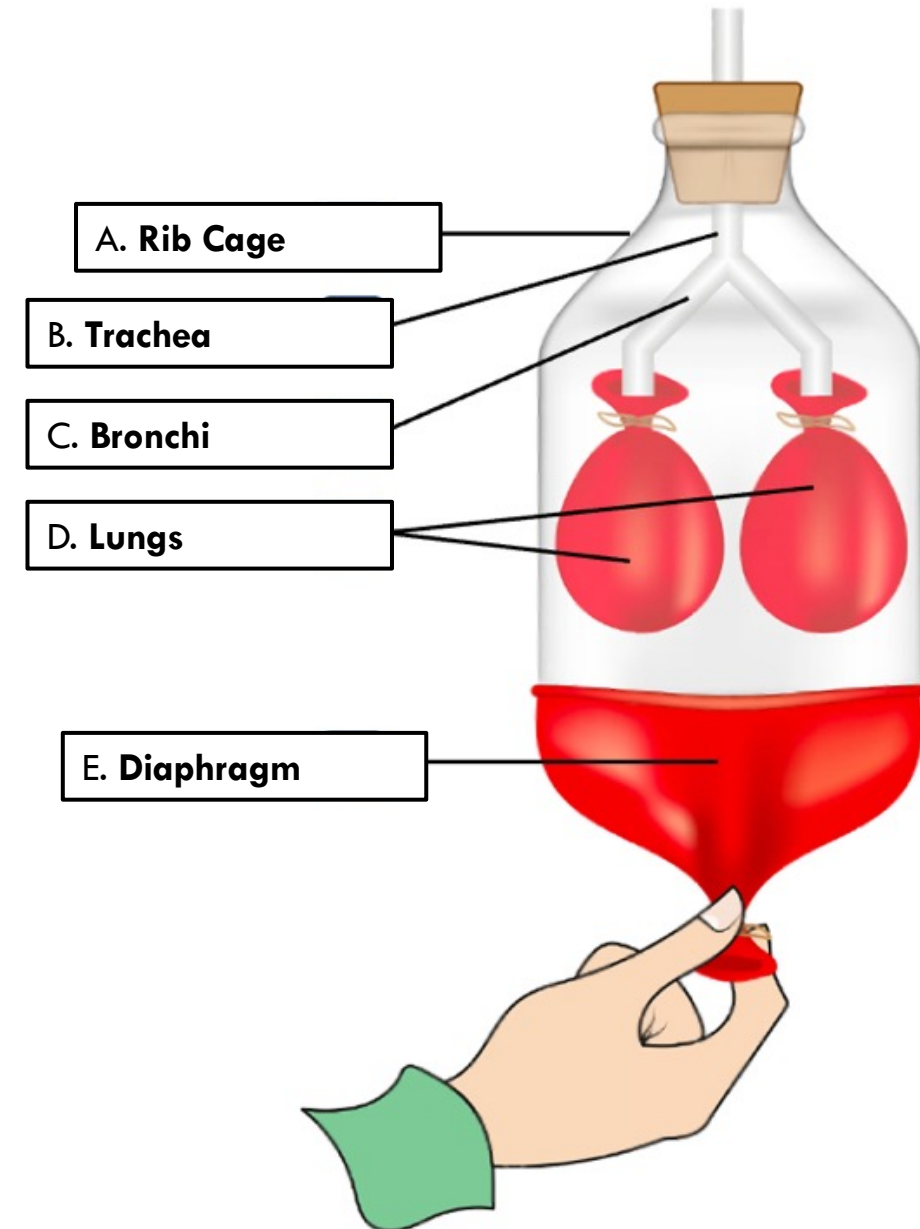
- **Contraction of the Diaphragm** increases the volume inside the thoracic cavity, decreasing the pressure within → **Inhalation**
- **Relaxation of the Diaphragm** decreases the volume inside the thoracic cavity, increasing the pressure within → **Exhalation**

4. What might happen if you prick the bottom balloon?

- This will halt pressure differentials between the atmosphere & thoracic cavity. Can no longer generate negative/positive pressures to allow inhalation/exhalation. Similar to what happens in the case of a **pneumothorax**.

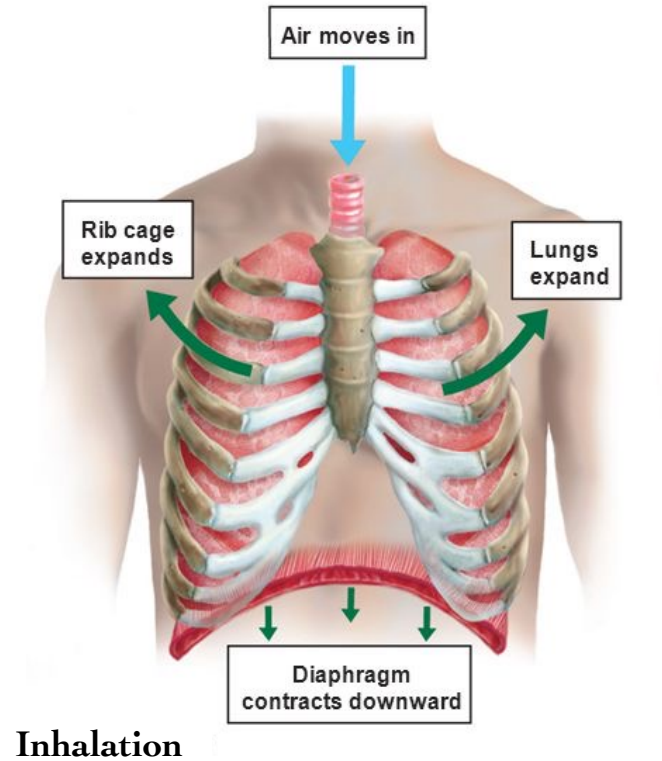
5. What position will the diaphragm be in when you are exhaling?

- Returning to dome-shape



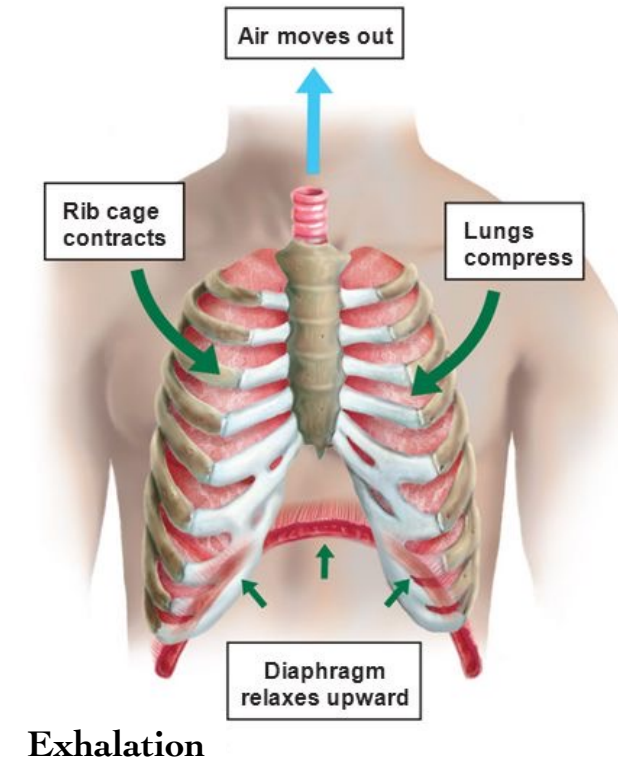
NOTE: The alveoli are **expanded** during inspiration!!!

NEGATIVE & POSITIVE PRESSURE BREATHING



Negative Pressure Breathing

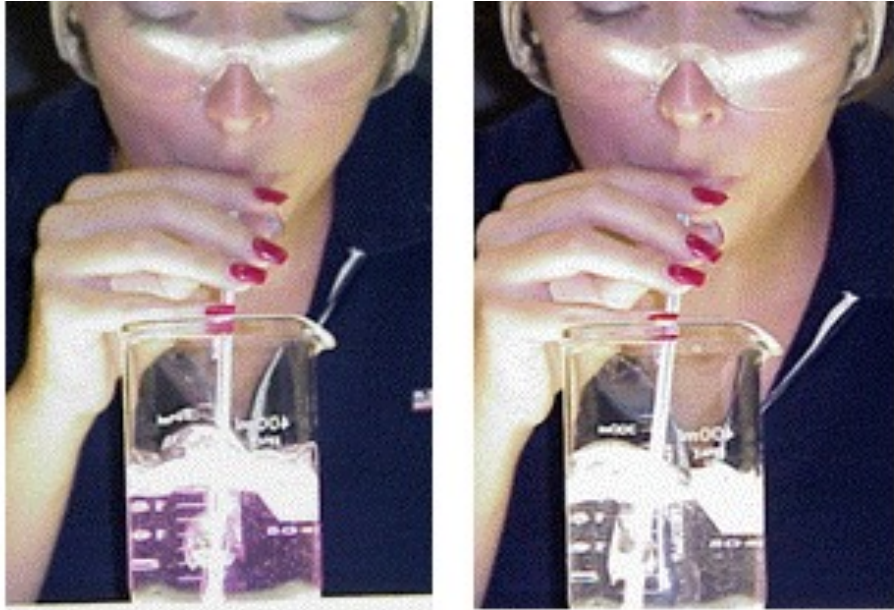
- When the diaphragm contracts, lung volume increases, and alveolar pressure becomes lower than atmospheric pressure. This causes air to flow into the lungs until the pressures equalize.



Positive Pressure Breathing

- When the diaphragm relaxes, lung volume decreases, and alveolar pressure becomes greater than atmospheric pressure. This causes air to flow out of the lungs until the pressures equalize.

ACTIVITY 2: MAGIC BREATH



Purpose: Observe the effect of CO₂ on the pH of a solution

Test solution = DI water + NaOH + Phenolphthalein

- Solution started off pink since the test solution was alkaline (basic) due to the presence of NaOH

Phenolphthalein is an indicator that changes color based on pH

- **Pink** in *basic* solutions
- Clear in *acidic* solutions
- At around a pH of ~8.3 or higher, the indicator is pink.
- Below a pH of ~8.3, the indicator is colorless.

Students exhale into the test solution using a straw until the solution changes from pink to colorless

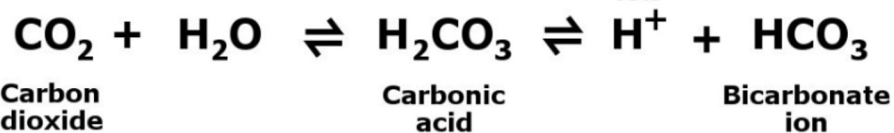
Trial 1: at rest Trial 2: after exercise

Why does the solution turn clear?

- You breathe CO₂ (acidic) into the solution which neutralizes it

Do you expect for the solution to turn clearer faster or slower after exercising? Why?

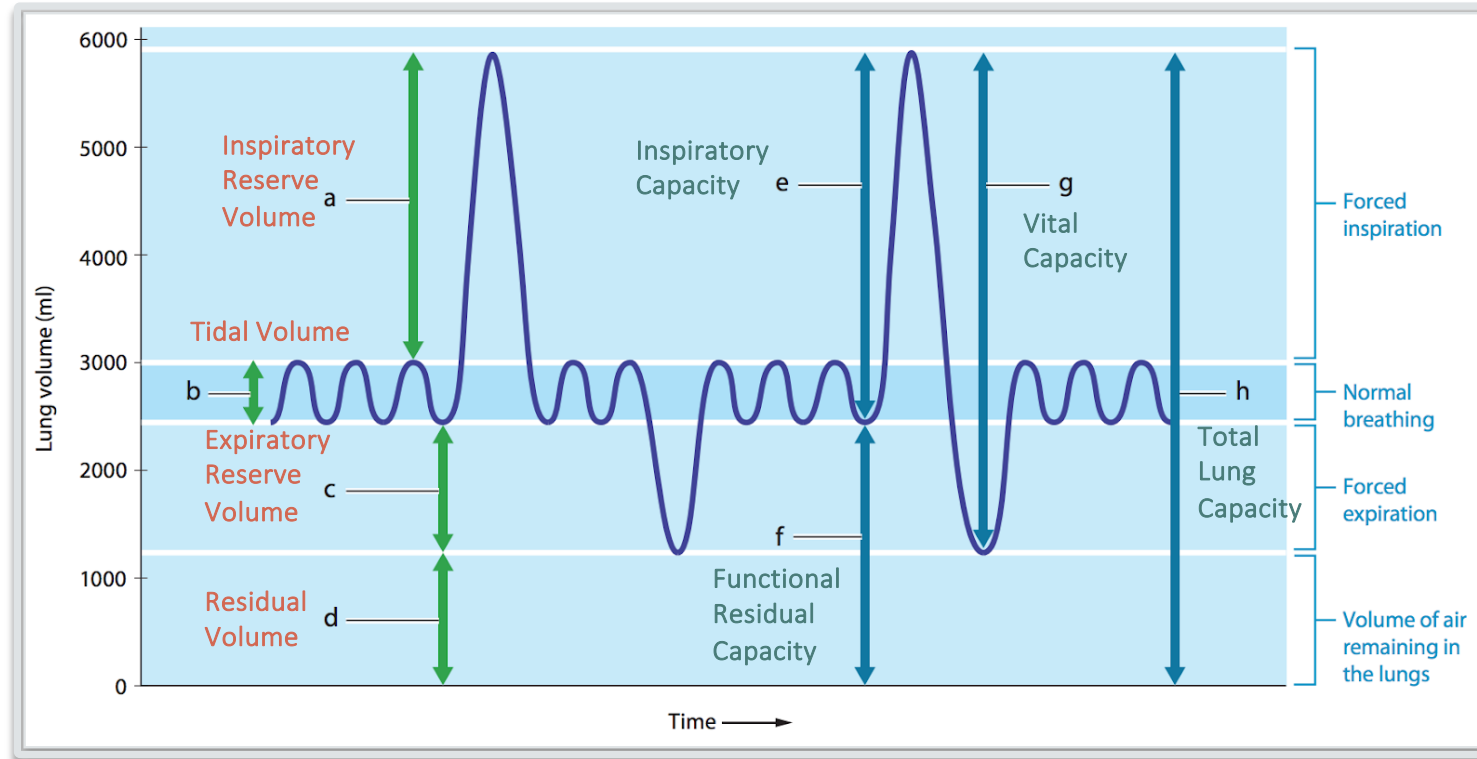
- The solution should turn clearer faster after exercise since you will be expelling CO₂ more rapidly due to increased ventilation rate; blowing CO₂ will neutralize the solution quicker



Spelling Tip: PHENOL PH THALEIN

ACTIVITY 3: RESPIRATORY VOLUMES AND CAPACITIES BEFORE & AFTER EXERCISE

- **Instrument Used:** Spirometer, which is an apparatus used to measure the volume of air inspired and expired by the lungs
 - The type of spirometer used in this activity only measures expiratory volumes, but can be used to **indirectly** measure inspiratory volumes
- **Measured the following before/after exercise:**
 - **Tidal Volume (TV):** normal breath (inhale and exhale normally)
 - **Expiratory Reserve Volume (ERV):** forced expiration (inhale normally but forcibly exhale)
 - **Vital Capacity (VC):** total amount of exchangeable air (inhale and exhale forcibly)
 - **Do you expect to see any changes in the volumes or capacities after exercising?**
 - Higher TV, lower ERV & IRV, VC stays the same
 - **How would you get the Inspiratory Reserve Volume?**
 - $VC = IRV + ERV + TV$
 - $IRV = VC - (ERV + TV)$



ACTIVITY 4: BLOOD TYPING ACTIVITY

Purpose: This activity will determine blood types based on direct interactions between antibodies and their corresponding blood antigens

Anti-A serum: contains Anti-A antibodies that agglutinate erythrocytes that possess A antigens

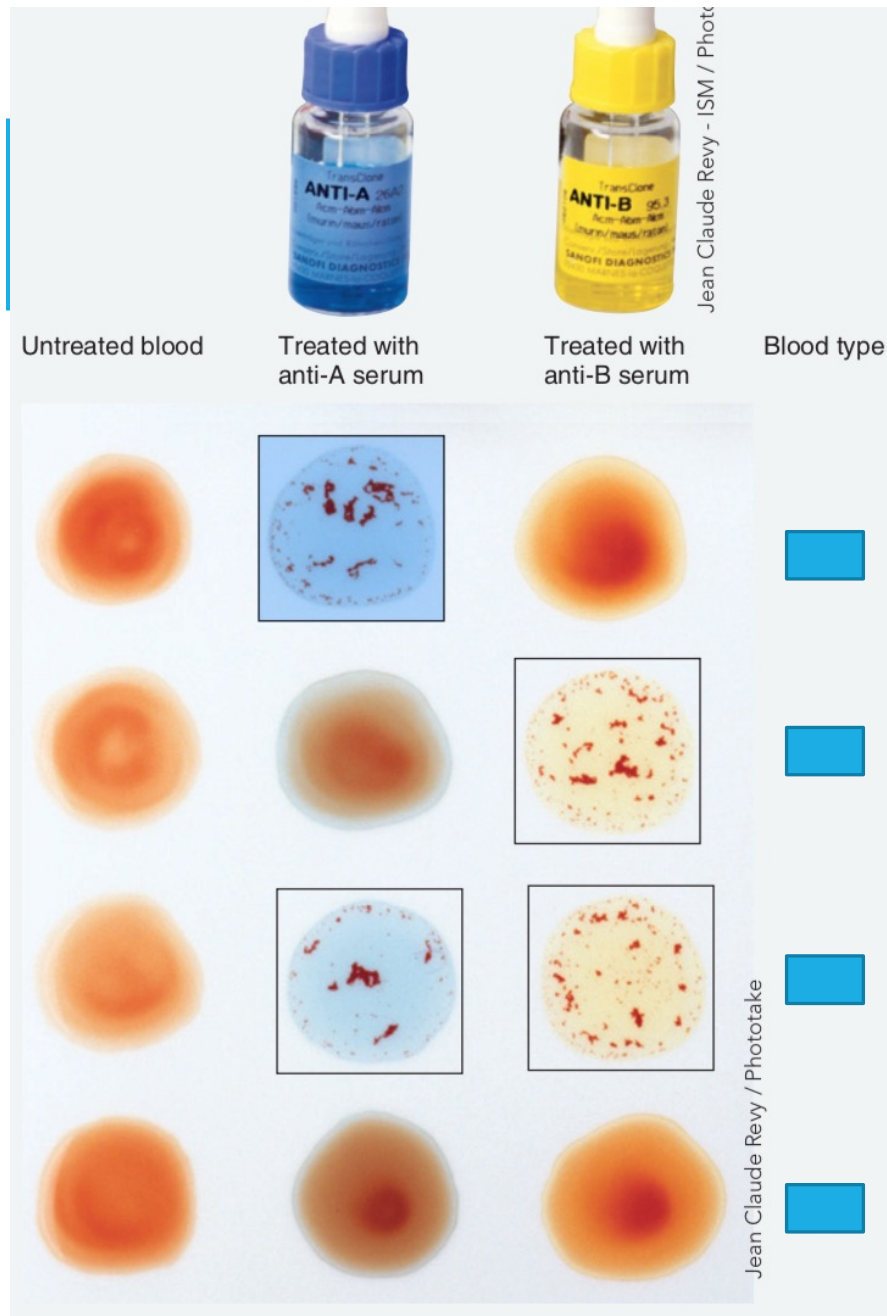
Anti-B serum: contains antibodies that agglutinate erythrocytes that possess B antigens

Anti-Rh serum: contains antibodies that agglutinate erythrocytes that possess Rh factor

If the individual's blood agglutinates with a serum, then they have that corresponding antigen on their RBC cell surface; this is their blood type

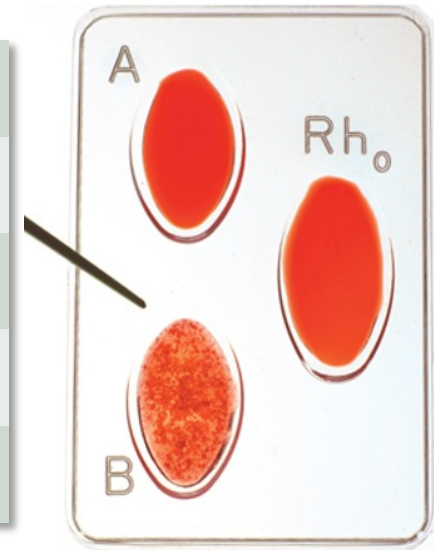
How to determine blood type of an individual using these serums:

- If the erythrocytes agglutinate only when mixed with anti-A serum, the blood type is A
- If the erythrocytes agglutinate only when mixed with anti-B serum, the blood type is B
- If the erythrocytes agglutinate with BOTH anti-A & anti-B serum, the blood type is AB
- If the erythrocytes agglutinate with NEITHER anti-A or Anti-B serum, the blood type is O
- Agglutination with the anti-Rh serum will indicate that the blood type is Rh+



ACTIVITY 4: BLOOD TYPING RESULTS

	Victim Mike	Donor Kim	Donor Ajax	Donor June	Donor Frank
Anti-A					
Anti-B					
Rh					
Blood Type	B+	AB+	A-	B+	O-



- A. You must use a donor whose blood will not agglutinate when mixed with that of the accident victim. Which, if any, of Mike's friends can donate blood to him?
- June and Frank (June would be the first choice because she has the same B+ blood type as Mike). Perfect match: June; Universal donor: Frank**
- B. The transfusion is made, but the emergency team needs more blood. Mike's first friend has donated all the blood that he or she can. Does Mike have a friend who, although not a preferred donor, can be used in this emergency? Yes If yes, who? Frank

Explain why this person can be used as a donor even though the blood types are not the same.

- Frank is O-, which means that his red blood cells have neither A, B, nor Rh antigens on their surface. Therefore, Frank's RBCs should not be attacked by the antibodies present in Mike's plasma.**

BLOOD TYPING QUESTIONS – PART 1

- C. What causes an agglutination reaction? How does this help in determining blood type?**
- Agglutination occurs because of the antibodies present that attack the antigens that are on the surface of red blood cells. Therefore, during blood typing, if agglutination occurs, that means your blood had the antigens for that specific antibody.
- D. What do + and – blood types mean? Does it matter if you're + or - to receive a specific blood type?**
- The + and – signs are in reference to the Rh factor, positive means the Rh factor is present on red blood cells and – means they are not.
- E. Tom and Jane participate in a Red Cross blood drive. Both are first time donors. As part of the screening process their blood is typed. Tom is A+ and Jane is AB+.**
- A.** What blood group antibody is found in Tom's blood?
- Tom has anti-B antibodies.
- B.** What blood group antigens are found in Jane's blood?
- Jane has A, B, and Rh antigens.
- F. Tom and Jane's blood donations are sent to a processing center where their blood cells are separated from their plasmas. Both their separated cells and plasmas are then sent to a hospital. A blood researcher wishes to use Tom's blood in an attempt to extract and identify the A antigen. Should she attempt the extraction process on his blood cells or his plasma?**
- The blood cells because antigens are embedded in the cell membrane of RBCs.

BLOOD TYPING QUESTIONS – PART 2

G. EMTs bring two accident victims into the ER. One victim is bleeding from a head wound and needs a transfusion of blood cells to replace what she has lost. She is AB+.

Victim 1: AB+ Tom: A+ Jane: AB+

- a) Could Jane's blood cells be used for this transfusion? Explain
 - Yes, both Jane and the victim are AB+. Since their antigens match, there should not be a problem. Remember, AB+ is the universal recipient.
- b) Could Tom's blood cells be used for this transfusion? Explain
 - Yes, the victim's blood plasma does not have antibodies for A, and both Tom and the victim are Rh+.

H. The second accident victim has also lost blood. He is B+.

Victim 2: B+ Tom: A+ Jane: AB+

Could Jane's blood cells be used for this transfusion? Explain

- No, the victim has antibodies for A which would react with the A antigens on Jane's RBCs

I. Could Tom's blood be used for this transfusion? Explain

- No, the victim has antibodies for A which would react with the A antigens on Tom's RBCs.

PRACTICE

What are the possible antigens that can be present on a blood cell?

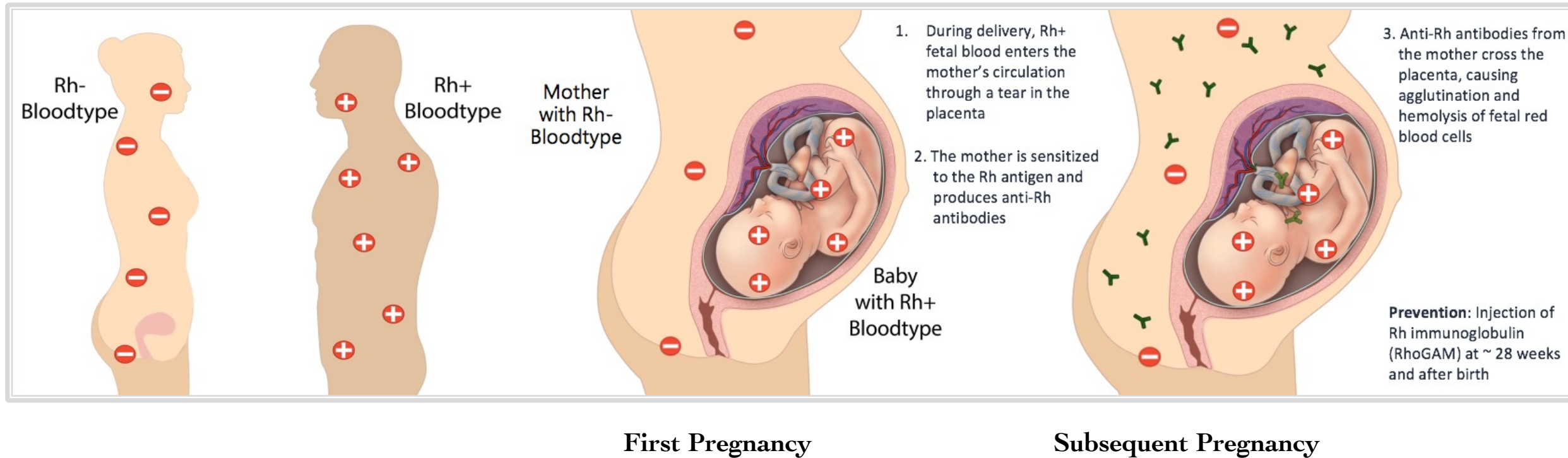
A Antigens
B Antigens
Rh Antigens

What are the possible antibodies that can be present ?

Anti-A Antibodies
Anti-B Antibodies
Anti-Rh Antibodies

BLOOD TYPE	ANTIGENS PRESENT	ANTIBODIES PRESENTS	CAN RECEIVE FROM	CAN DONATE TO
A+	2 A, Rh	1 Anti-B	4 A+ , A- , O+ , O-	2 A+ , AB+
A-	1 A	2 Anti-B, Anti-Rh	2 A- , O-	4 A+ , A- , AB+ , AB-
B+	2 B, Rh	1 Anti-A	4 B+ , B- , O+ , O-	2 B+ , AB+
B-	1 B	2 Anti-A, Anti-Rh	2 B- , O-	4 B+ , B- , AB+ , AB-
AB+	3 A, B, Rh	X	Universal Recipient	1 AB+
AB-	2 A, B	1 Anti-Rh	4 AB- , A- , B- , O-	2 AB+ , AB-
O+	1 Rh	2 Anti-B, Anti-A	2 O+ , O-	4 A+ , B+ , AB+ , O+
O-	X	3 Anti-A Anti-B Anti-Rh	1 O-	Universal Donor

CLINICAL APPLICATION: RH INCOMPATIBILITY: HEMOLYTIC DISEASE OF THE NEWBORN



CLINICAL APPLICATION: FOREIGN BODY ASPIRATION

- The right primary bronchus is steeper and larger in diameter than the left
- More likely to aspirate foreign objects into the right lung as opposed to the left lung

Case report

Go to: 






A 33-year-old man presented with a 1-week history of intermittent minor hemoptysis. On questioning, he admitted to swallowing a foreign body 2 months earlier. His action was inspired by a television show on swallowing foreign bodies. He had tried to swallow a knife blade, after breaking the handle, which was then accidentally aspirated. He immediately suffered a severe choking sensation that eventually resolved. He continued to experience episodes of violent coughing but decided against obtaining medical advice. In fact, he proceeded to swallow a metallic spoon a few days later without any obvious clinical consequences.



FIG. 1. Posteroanterior (left) and lateral (right) chest radiographs showing a metallic object (a steak-knife blade) in the right main-stem bronchus.

What makes this case unusual is the rather delayed and innocuous presentation after aspiration of such a large foreign object. It emphasizes the fact that healthy adults may tolerate aspiration of foreign bodies for a long time without acute life-threatening consequences. As seen in this case, the chest radiograph shows the rather vertical position of the right main-stem bronchus, facilitating more frequent aspiration than that of the left side. Bronchoscopic removal of large aspirated objects in general is an arduous task because

EXTRA PRACTICE USING THE AGGLUTINATION TABLE

	Dave	Nichole	Alain	Adriana	Teresita
Serum Used					
Anti-A Serum	Yes	Yes	Yes	No	No
Anti-B Serum	No	Yes	No	No	No
Rh Serum	Yes	Yes	No	Yes	No
Blood Type					

Yes/No indicates whether agglutination occurs

Scenario: Dave has been in an accident. Nichole, Alain, Adriana, and Teresita decide they want to donate blood to save his life.

- **Whose blood donation can Dave take?** List the possible answers based off the agglutination test to the left.
 - Dave can receive blood from **Alain** (closest match) as both share the A antigen
 - He can also receive blood from **Teresita** (universal donor) and from **Adriana** (can donate to ABO blood types with RH factor)