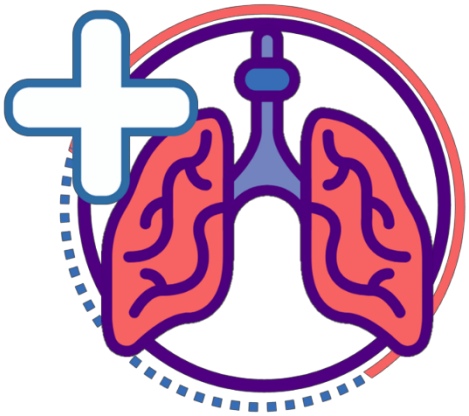

# RESPIRATORY SYSTEM

## Physiology

Sheet  Slide

| | |
|---|---|
| Number: | 8 |
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Let us retrieve our discussion about the ventilation-perfusion ratio **(V/Q)**.

- When **(V/Q) is Zero → this means that no ventilation is taking place, V is Zero; bronchial obstruction is an example.**

Side note: let us assume that alveolar ventilation has been totally diminished due to any reason, what do you think blood perfusion would act like?

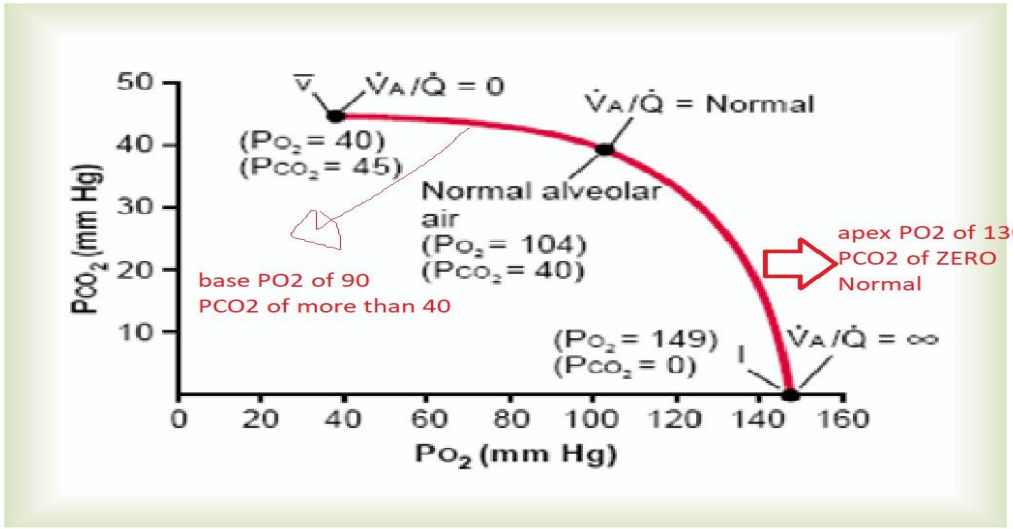
Not to mention the temporarily already existing blood flow, the capillary will soon get constricted and the blood flow to the unventilated area of the lung will drop dramatically; our bodies are machines of high efficiency, especially when it comes to blood, none should be wasted.

So, what should you keep in mind is that in hypoventilation state ***(V/Q)*** is zero, ***V*** being zero at first, then ***Q*** will follow, being zero too.

- When **(V/Q) is** ∞ → this means **that obstruction in the capillaries is taking place; thus, no perfusion to the desired area, pulmonary embolism is an example.**

Remember that any value over zero = ∞.

***How is this ratio represented using curves, and what data does it imply? This is very important***



x-axis → PO2
y-axis → PCO2

***X-axis intercept represents* (V/Q) =** ∞ → note that at that point alveolar PO2 is 150 mmHg while alveolar PCO2 is zero, same as the outer atmosphere, almost. No blood is there to consume O2 neither to give CO2. Pulmonary Embolism might be the cause.

→ *And this is a classic example of Physiological Dead space, where ventilation is present, but perfusion is absent.*

→ it is also called "*Alveolar wasted volume": part of the lung is being ventilated but not perfused.*

***At the other extreme, where PO2 is 40 while PCO2 is 45 is what represents a* (V/Q) of Zero. Why?**

*An airway total obstruction will cause diminished ventilation to the downstream area, yet O2 concentration won't drop to zero, the reason behind is that O2 is also present in the capillaries with a partial pressure of 40 mmHg, CO2 won't get exchanged too, remains 45 mmHg in its partial pressure within the capillaries. In this case,* ***PO2 & PCO2*** *within the alveolus will be same as the capillary,* ***40 mmHg and 45 mmHg****, Respectively.*

***Q:*** *Is obstruction only the cause of such a case, or can there be other causes to a (V/Q) of zero?*

***A:*** *remember that the value of V is what causes a* **(V/Q) of zero,** right to left pulmonary shunts is an example of which; skipping ventilation in the lungs, as the blood by-passes the whole pulmonary circulation to the systemic, hence, no ventilation.

***Wikipedia:*** A pulmonary shunt occurs as a result of blood flowing right-to-left through cardiac openings or in pulmonary arteriovenous malformations. The shunt which means V/Q = 0 for that particular part of the lung field under consideration results in de-oxygenated blood going to the heart from the lungs via the pulmonary veins.

*To make a long story short, whenever there is no ventilation whatever the cause was {either bronchial or cardiac defects},* **(V/Q) Is zero.**

## Pulmonary Circulation

Notes to keep in mind:

Pressures in the Pulmonary Circulation are much lower than in the systemic circulation.
***Pulmonary arterial pressure is between 12-15 mmHg, while aortic pressure is 100 mmHg. Therefore we can conclude that the pulmonary vascular resistance is between 1/7 or 1/8 of the system vascular resistance.***

Resistance in the pulmonary circulation is much lower than in the systemic circulation.

Pulmonary blood flow is equal to the cardiac output of the right ventricle, which equals the cardiac output of the left ventricle.

**Let us talk about exercise effects on cardiac output:**

- An individual's blood pressure is represented by this equation →
  **P = Cardiac output * TPR**
  *During exercise the cardiac output increases, five times its normal value per say, yet the pressure remains constant or slightly increases, never ever increases by the same proportion because too much after load imposed on the ventricles will eventually lead to ventricular failure.*

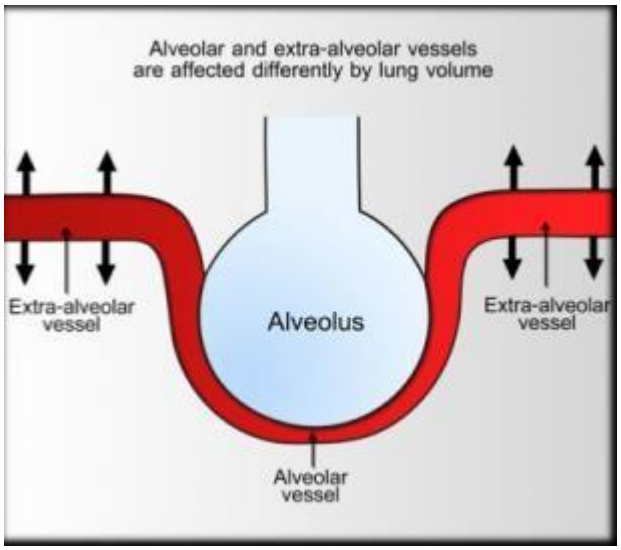
  *It's obvious that the resistance had to decrease almost to the same proportion of the cardiac output increment, two factors played a major role:*

  **a- Recruitment**: by increasing the number of opened capillaries.
  → Normally (2/3) of blood capillaries are closed and only (1/3) is open, during exercise they all open to increase the vasculature to the exercised muscles.

**b- Distension:** by distending all the capillaries and increasing the rate of flow; Expansion of their walls.

## Alveolar and Extra-Alveolar vessels

*This part of the lecture depends solely on this representation*




Each time you take a breath, the alveoli distend, compressing the part of the vessel that has direct contact with the surface of the alveolus (Alveolar vessel), the two tales of the vessel away from the center are called Extra Alveolar vessels.

So, whenever the pressure inside the alveolus become higher than that in the capillary, the latter will eventually close, and blood flow will decrease.

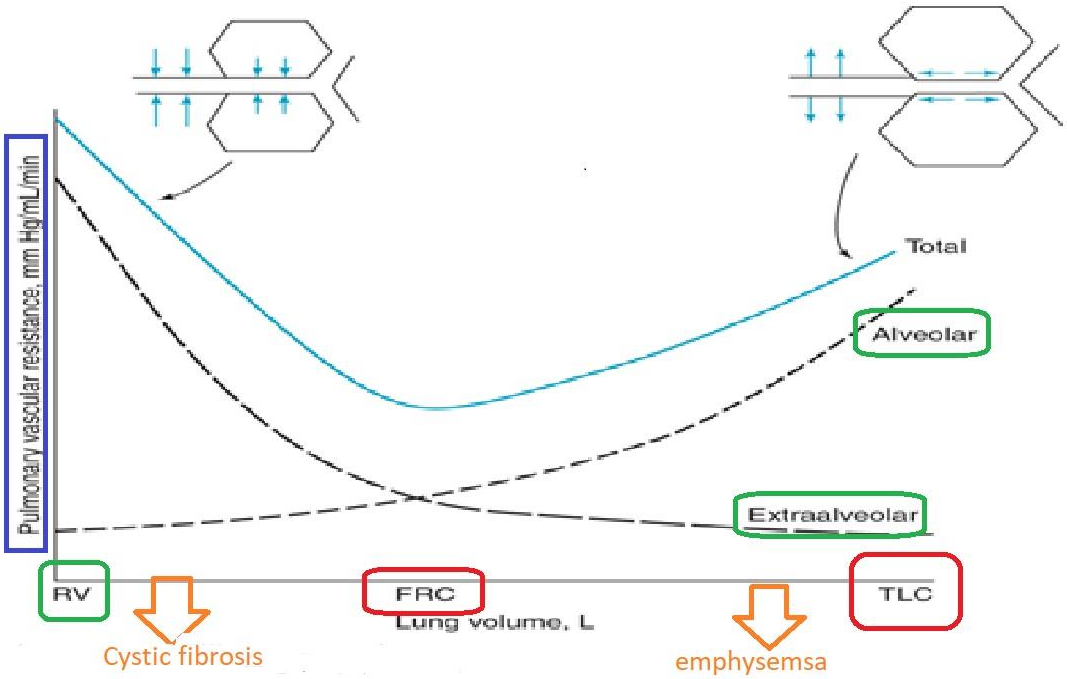
Whilst the alveolar pressure has increased, the pleural pressure will, by default, become more negative; thus, the extra-alveolar vessels will expand and distend.

**→ To summarize:**

- *The alveolar capillaries are distended by the blood pressure inside them and compressed by the alveolar air pressure on their outsides.*

- *If the alveolar air pressure becomes greater than the pulmonary capillary blood pressure, the capillaries will close and there is no blood flow.*

*The figure in the next page is of a great importance, it compares between the alveolar resistance and extra-alveolar resistance, and finally describing the mean pulmonary vascular resistance.*




***What should you learn from this graph?***

1- *When you increase your alveolar volume by stretching their walls and taking deep breath, you will increase the volume, approaching **TLC** "total lung capacity"; thus, increasing the resistance in the alveolar part of the capillary due to higher negativity in pleural pressure, the extra-alveolar parts of the capillary will distend; thus, low resistance.*
2- *If pleural pressure was less negative, the extra-alveolar resistance would increase, while the alveolar resistance would decrease.*
3- *FRC, is the lung volume where the minimal pulmonary vascular resistance resides.*

***Q: What if there is a certain pathology, how this curve would be affected?***
***A:***

***** In Emphysema, FRC is more **"can't exhale"** → which increases alveolar Resistance and thus Total Pulmonary Resistance. While extra-alveolar resistance is low.

* In pulmonary fibrosis where FRC is less **"can't inhale"** → extra-alveolar resistance is higher and thus Total Pulmonary Resistance. While alveolar resistance is low.

*Side note: always keep in mind the pleural pressure, is the hidden third party, contributing the most to what is going on. If it is less negative, -3 for example,* ***the alveolus won't distend*** → **alveolar Resistance is low.** At the same time, **extra alveolar Resistance will increase** because of the compression the pleural pressure exerts on the extra alveolar walls. On the other hand, if pleural pressure was -8, the alveolus will distend due to increased alveolar pressure, the pleural pressure will drop, relieving the compression on the extra alveolar walls, distending as a result.

**Clinical correlation:**

*Positive pressure breathing is used to help the collapsed alveoli to distend. using a machine that changes the atmospheric pressure to positive, consequently developing a pressure gradient, driving air in. However, if the positive pressure was optimal; it would open the collapsed alveoli without affecting the alveolar vessels, but what if the positive pressure increased more?*
*Before it ruptures the wall of the alveolus it would definitely obstruct the alveolar vessel, no perfusion → (V/Q) = ∞.*

***This procedure is so delicate, the professor implied, especially in the newborns whose alveolar membrane fragility is higher than adults.***

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**The flow in the capillaries, is it pulsatile or continuous**?

**Q: What is a Pulsatile flow?**
**A:** it is a pressure which develops a difference between systole and diastole, directly related to the cardiac cycle.

**Q: What is a Continuous flow?**
**A:** it is a pressure which remains the same during systole and diastole, not affected nor related to cardiac cycle.

**Q: So, is the flow in the capillaries pulsatile or continuous?**

**A: <u>the systemic</u>** capillaries pressure is neither pulsatile nor continuous, **it is intermittent**, meaning that on each side of the capillary there are **pre-capillary sphincters** which opens or closes due to local mediators such as O2, CO2, NO, H+ and many others. During exercise, these mediator's concentration changes {either increase or decrease, depending on the mediator} and the sphincter opens → increases flow → decreases resistance.
**So,** at the end of the arterioles and beginning of capillaries damping and disappearing of the pulse pressure starts, thus the difference between systolic and diastolic blood pressure, so called **Pulse Pressure**, is vanished.

**Q: But is this the same case in the capillaries of the lungs?**
**A:** capillaries of the lungs are near to the heart, the main pump, being affected by this short distance; there blood flow is **pulsatile.**

**Having said that the alveolus acquires <u>*systolic (pS), diastolic (pD) and alveolar pressure (pA),*</u> let us see how they are related …**

## What if ?

- **pA > pS > pD (Zone 1) →** there will be *no flow,* alveolar air pressure (pA) is higher than pulmonary arterial pressure (pS, pA) during any part of cardiac cycle, this zone does not exist in human lung normally.

**Pathologically, it may exist; as the apex may be ventilated but not perfused, emphysema and hemorrhage are examples. A third case mentioned in the slides is when breathing against positive intra-alveolar pressure, PEEP, we may obstruct blood flow to certain areas of the lung.**

- **pS > pA > pD (Zone 2) →** *intermittent flow,* systolic arterial pressure is higher than alveolar air pressure, but diastolic arterial pressure is below alveolar air pressure. The flow is during systole only.

**This zone exists in human lung at the apex in the upright position. When a person lies down all lung become zone 3.**

- **pS > pD > pA (Zone 3) →** *continuous flow,* pulmonary arterial pressure remains higher than alveolar air pressure at all times, this what happens mostly in our lungs.

**There is blood flow during systole and during diastole. During exercise all lung become zone 3 even the apex.**

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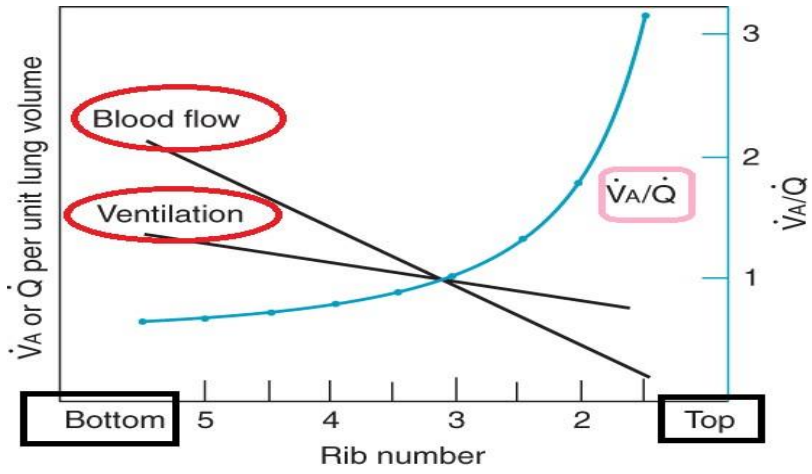
***(V/Q) ratio between the base and the apex is represented in the below curve.***

*Remember:*

*Qbase>Q apex*

*V base> Vapex*

*(V/Q) base < (V/Q) apex*




**Notice how are the variables represented.**
**Bottom=Base**
**Top=Apex**

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We have finished our talk about lungs and membranes. The rest of this lecture was a review to blood and hemoglobin.

## Hemoglobin

These numbers are a must to know, the professor said.

- Blood volume equals 7% the of total body weight, 5-L in a 70-Kg individual.
- 5-L = 5,000,000 µ liters, in each µ liter there is 5,000,000 RBC's.
- Each RBC possesses 280,000,000 Hb molecules, each capable of carrying 4 Oxygen molecules.

## *General facts about Hb, review:*

1- Hb concentration is (14-16) g/dL, each 1 gram of Hb can carry up to 1.34 mL of O2.

**2- Each dL of blood, containing 15 g/dL Hb on average, can carry up to 20 mL O2.**

3- Oxygen solubility in plasma = O2 partial pressure (PPO2) * solubility of O2 (SO2)
***This is called Henry's law.*** = 100 * 0.003

= ***0***.3 mL /dL blood, so 0.3 mL is dissolved in blood whilst 20 mL is bound to Hb, so the total Oxygen concentration equals to *20.3 mL/dL.*

**4- Fe++ (ferrous), binds O2 reversibly. Yet Fe+++ (ferric) binds O2 irreversibly.**

**5-** Hb is a tetrameric protein, 2α & 2β.

**6-** *HbA2 is* α2, β2.

**7- Hemoglobin behaves as an allosteric protein; each binding facilitates the next.**

*8-* Hb undergoes to different states, *R: high affinity to bind, T: low affinity to bind.*

***9*- Bohr effect: If CO2 or H+ binds hemoglobin, O2 will be released immediately, this is the case in the tissues.**

*10- Reversed Bohr effect " Haldane effect"* : If O2 binds hemoglobin, CO2 and H+ will be released immediately, this is the case in the lungs.

*What to cherish, she said, what to cherish? …*

*Not until then, they both realized*

*Love is wise … Hatred is foolish*