for MED Students

PHYSIOLOGY

RESPIRATORY SYSTEM

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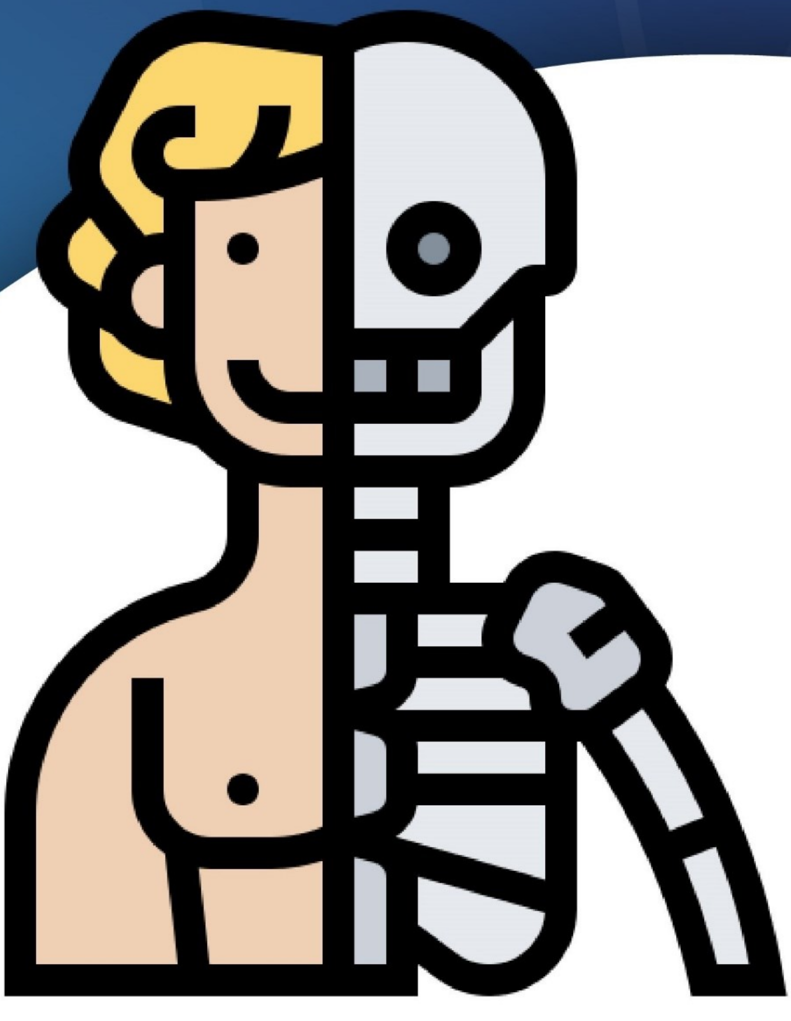


دكتور ٢٠١٩
كلية الطب الجامعة الأردنية

STUDENTS CLUB
School of Medicine

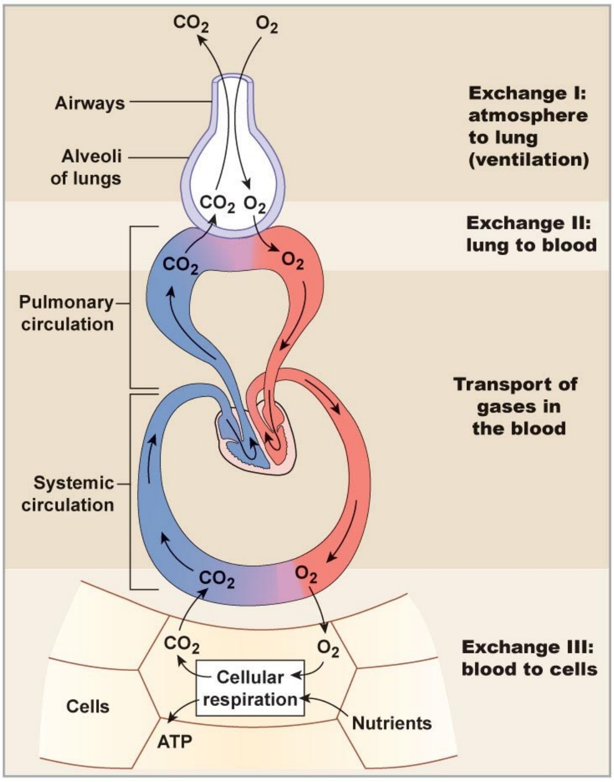
ملاحظة: هذا الملف هو إعادة تنسيق لتفريغ زملائنا من دفعة ٢٠١٦ مع إضافة صور من Guyton لغايات توضيحية
هذا الملف من كتابة أنس رائد و تدقيق زيد عماد

I highly recommend watching the lecture before going through this file as it will be the same as the illustrations mentioned by the doctor.

- The respiratory system and the cardiovascular systems are highly interconnected, as a matter of fact if you have a lung disease you probably will develop heart failure and vice versa.
- For example: **left heart failure** will result in **pulmonary edema**, and **decreased O2** supplied by the lung due to lung disease will result in **right heart failure**.
- The right ventricle ejects the blood through the pulmonary artery to the pulmonary capillaries to **pick up O_2** and **give away CO_2**, then the oxygenated blood will come back to the heart through the pulmonaryveins, and it will be ejected by the left ventricle as arterial blood.

- As we know, the space between the cells and the systemic capillaries is called the interstitium, so for O_2 to diffuse into the interstitium, the partial pressure in the blood must be more than the interstitium, *then (blood coming from the interstitium)* to the cells according to pressure difference also.

➔ **CO2 diffuses the other way around as PCO_2 in the cells is higher than PCO_2 in the interstitium.**



Writer's note: what we are trying to say is that the gases diffuse from one compartment to another based on their partial pressure, for the oxygen to diffuse into the interstitium and supply the tissues, its partial pressure in the blood has to be higher than in the tissues, so it can diffuse.
HOWEVER, for CO_2, we need it to diffuse from the tissues into the blood so it can be expired out and SO its partial pressure in the interstitium is more than that in the blood.

The end result is the utilization of O_2 by the mitochondria; if this utilization is decreased it's called **hypoxia**.

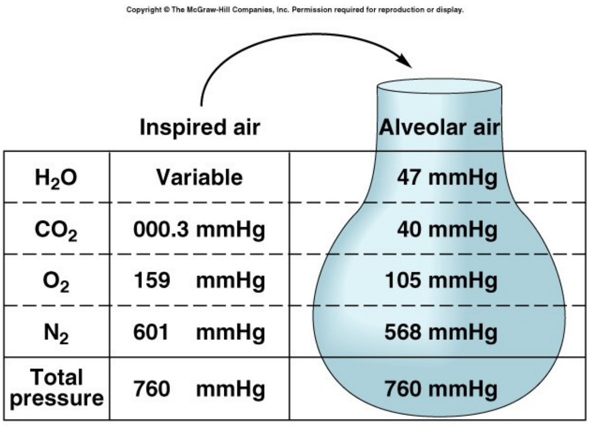
- We need the oxygen inside the

mitochondria in the electron transport chain to generate ATP.

- If O_2 is present then the cell will generate 36 ATP *(through aerobic respiration → glycolysis and oxidative phosphorylation)*, if not it will generate only 2 ATP (anaerobic respiration).
- There are many respiratory chain enzymes and the final electronacceptor in the mitochondria is O_2.

Writer's note: The main goal is the utilization of oxygen by the mitochondria to form ATP, and the amount generated differs depending on the presence of oxygen (36 when present and only 2ATP when it's not). Oxygen acts as the final acceptor of electron in the ETC.

- At the sea level where atmospheric pressure= 760 mmHg the air composition is :
  1. 21% O_2 & PO_2 = 160 mmHg
  2. 79% N_2 & PN_2 = 600 mmHg
  3. PCO_2 = 0.3 mmHg (almost zero)



	Inspired air	Alveolar air
H_2O	Variable	47 mmHg
CO_2	000.3 mmHg	40 mmHg
O_2	159 mmHg	105 mmHg
N_2	601 mmHg	568 mmHg
Total pressure	760 mmHg	760 mmHg

- At the height of 5.5 Km the pressure drops to the half and becomes:

1. *atm = 380 mmHg
2. PO_2 = 80 mmHg
3. PN_2 = 300 mmHg

- At the height of 11 Km the pressure becomes:

1. *atm = 190 mmHg
2. PO_2 = 40 mmHg
3. PN_2 = 150 mmHg

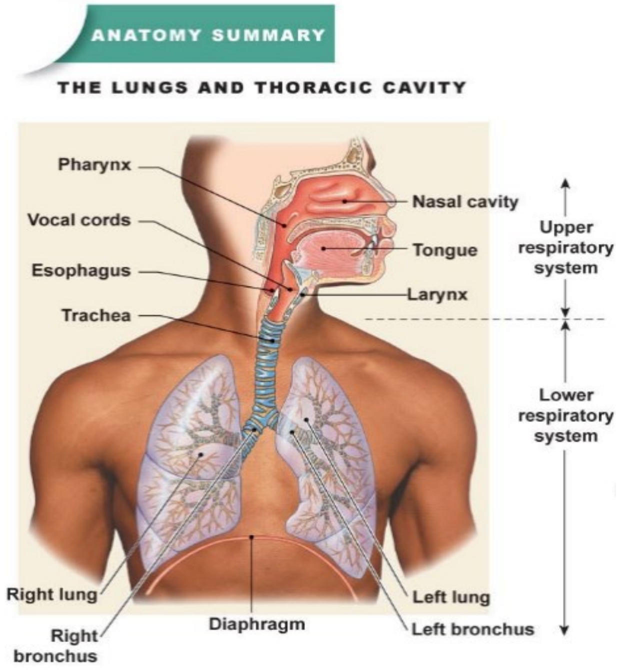
- Hypoxia has 4 types:

  1. **Hypoxic hypoxia**: decreased O_2 in the outside *(inhaled)* air.
  2. **Stagnant hypoxia:** due to blood obstruction.
  3. **Anemic hypoxia**: hemoglobin is there but it's occupied by another gas *(such as in CO poisoning).*
  4. **Histotoxic hypoxia**: the mitochondria aren't able to use O_2 although O_2 is available, like in **septicemia** where the toxins poison the mitochondrial chain, or like cyanide poisoning.

- RS can be considered a tube; this tube has two parts:

1. A bronchial tree (airways).
2. A balloon ending (lungs).

- Normally we have 300-600 million alveoli, that has three kinds of cells:
    1. **Thin squamous cells** that are appropriate for gas exchange
    2. **Columnar cells** that produce surfactant
    3. **Alveolar macrophages** that clean any foreign body in the alveoli.



(a) The respiratory system

- If the tube is patent (not obstructed), air leaves with no difficulty as airway resistance is very small.
- If an obstruction occurs, the diameter of the tube will become narrower and resistance (R) will increase as it is inversely related to the diameter (r) (or we could say the cross-sectional area), for example, if r is decreased slightly, R will increase highly.

- As we said before **hypoxia** is decreased O_2 utilization by the cells and its potential causes are:
    1. Oxygen isn't available in the air such as at high altitudes.
    2. Increased airways' resistance as in 70% of lung diseases which have an obstructive pattern (ex: COPDs as emphysema, bronchitis and some forms of asthma).
- Airways might be not patent and become narrower thus resistance is increased significantly.

1. **Balloon (lung) incompliance**, as it must be compliant (meaning that a small force is needed to inflate this balloon, if much force is needed then this is called incompliance).

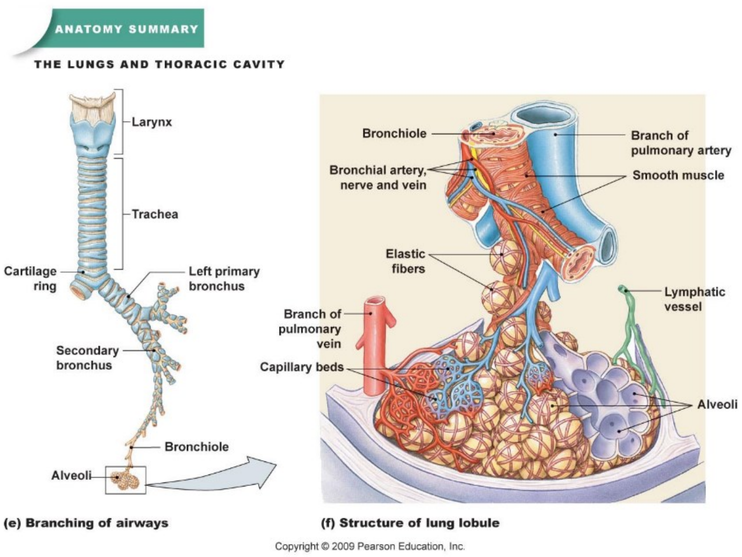
- Inflating a lung is hundred times easier than a child inflating a balloon, so if the lungs become incompliant (un-stretchable, rigid, collapsed) it will cause restricted pulmonary diseases (20-25% of lung diseases are of this pattern), such as: fibrosis and RDS (respiratory distress syndrome).

2. **Problems in the respiratory membrane.**
3. **Cardio-vascular problems** (problems in the heart, vessels or in the

blood).

4. **Respiratory muscles' problems**, mainly the diaphragm, whether these problems are due to contraction or excitation.
5. **Hypoxia** could be due to **polio infection;** it can **cause paralysis of the diaphragm**, or it could be due to **suppression of respiratory centers by anesthesia or drug overdose** as it inhibits the respiratory cells causing **respiratory arrest**.

- Each alveolus is surrounded by a huge network of capillaries that function to exchange gases.
- The interstitium is found between these capillaries and the lungs



The oxygen has to diffuse through the 6 layers of the respiratory membrane:

1. Surfactant (surface acting agent)
2. Alveolar epithelium.
3. Basement membrane of alveoli.
4. Interstitium.
5. Basement membrane of capillary.
6. Endothelium

- You need to know that O_2 can cross this membrane and any other biological membrane as if this membrane doesn't exist, so O_2 supply to the cells is **not** diffusion limited. However, CO_2 crosses the membranes 20 times easier than oxygen because it's 20 times more soluble than oxygen.
- When there is a lung disease **the first to be affected is the O_2.**

TYPE OF RESPIRATORY FAILURE	PO_2	PCO_2
TYPE 1	> 60 mmHg	40 mmHg (normal)
TYPE 2	> 50 mmHg	< 50 mmHg

- The diffusion becomes limited if the membrane is thickened; as in pulmonary edema, pneumonia, TB, fibrosis & infiltration of the interstitium
  ➔ **so the more the thickness, the less the diffusion.**

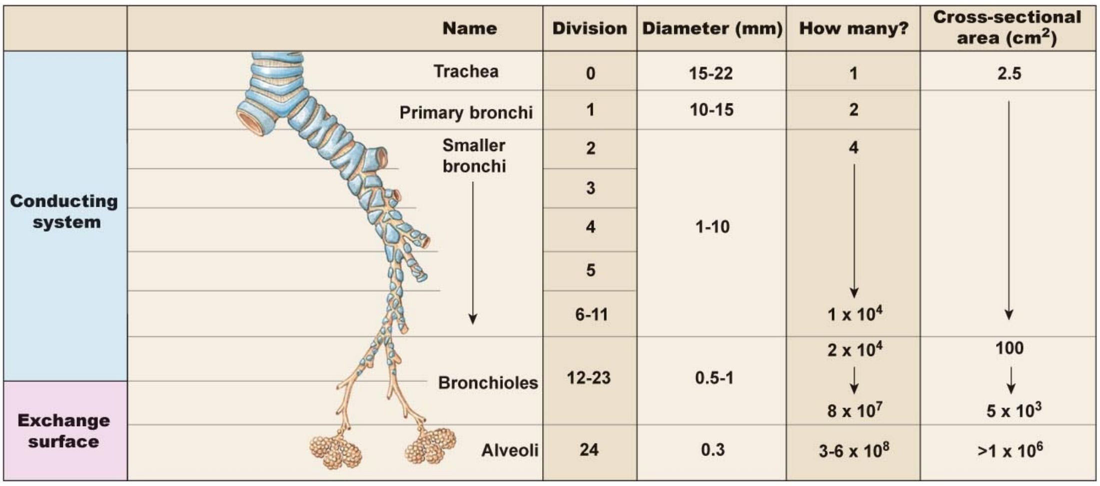
Side note: in cases of thickening of the respiratory membrane, it will be difficult for the lung to achieve full oxygenation of the blood coming from the pulmonary artery so **the PO_2 in the blood will be less than normal.**

- **As we said before**, the right ventricle ejects the blood through the semilunar valve to go to the pulmonary artery, and for this to happen, the pressure in the right ventricle must exceed thepulmonary artery pressure. →→→
- The pressure in the pulmonary artery is **14** (this is the mean pressure). this pressure is called the afterload AKA the pressure that the right ventricle has to overcome to eject the blood into the artery.
- If this pressure becomes 24 for example, the right ventricular pressure must become 25 to eject the blood, if it became 34 then the ventricular pressure must be 35 and so on.
- Eventually, this will lead to failure of the right ventricle, **that is why** any pulmonary hypertension will result in right ventricular failure.

- The pressure in the pulmonary capillaries is **7 mmHg** (which is very little) as in the lung there is no need for filtration (Dry lung), while the systemic pressure is **30 mmHg** & the glomerular capillaries' pressure equals **60 mmHg** (needed for the huge filtration in the kidneys).
- **Side note**: The small pulmonary capillaries' pressure is needed to prevent pulmonary edema that can kill a person within 2 hours, that's why the lungs are filled with lymphatics that drain in the right lymphatic duct mainly and a little amount will drain in the thoracic duct.

- If some capillaries are destroyed for any reason, then the resistance will increase. (For example if you have 5 capillaries and three of them were destroyed, the same amount of blood will flow in the remainingtwo thus the resistance will be higher).
- According to Ohm's law **($F= \Delta P/R$)**, the flow is directly proportional to the driving force (pressure difference) and inversely proportional to resistance which is the pulmonary vascular resistance.
- So, if the pressure in the pulmonary artery increased 5 times for example ($14*5=70$ mmHg), the right ventricle will dilate and eventually will fail.
- Cor pulmonale: it's the right ventricular dilatation that may result from pulmonary hypertension and can lead to right ventricular failure

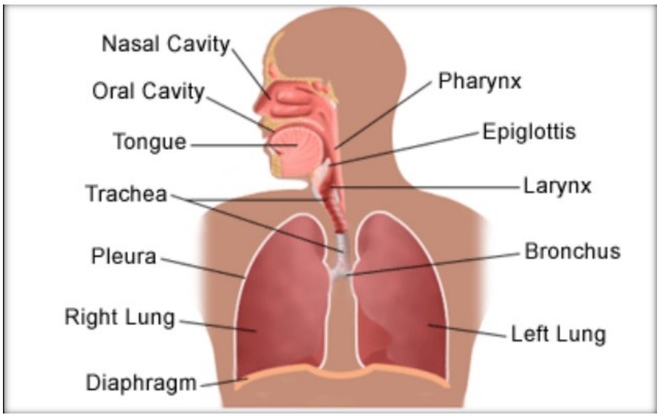
- The RS is composed of airways starting from the **trachea**, it divides into **right and left primary bronchi** and these primary bronchi will divide into **secondary bronchi** and the secondary will divide into **tertiary**, until we reach **23 divisions (number 23 is the bulb-like alveoli, number 0 is the trachea).**
- From (1-16) they're called the **conducting zone** as the air goes in and out with no gas exchange (NO.16 is called the **terminal bronchiole**).
- From (17-23) they're called **respiratory zone**, gas exchange takes place in this zone mainly in the 23^{rd} division which are the **alveoli** (NO.17 is called **respiratory bronchiole**).
- This dividing structure is called **the bronchial tree.**



	Name	Division	Diameter (mm)	How many?	Cross-sectional area (cm^2)
Conducting system	Trachea	0	15-22	1	2.5
	Primary bronchi	1	10-15	2	↓
	Smaller bronchi ↓	2	1-10	4 ↓	
		3			
		4			
		5			
		6-11		1×10^4	
	Bronchioles	12-23	0.5-1	2×10^4 ↓ 8×10^7	100 ↓ 5×10^3
Exchange surface	Alveoli	24	0.3	$3\text{-}6 \times 10^8$	$>1 \times 10^6$

- The air passes through the nose → pharynx → the larynx → the trachea → the 1^{st} 16 generations (all of the aforementioned parts are part of what's called an anatomical dead space, **because there is no gas exchange through them**).

- The volume of this dead anatomical space is 2 ml/Kg, so a person with 75Kg body weight will have 150 ml of air inside the dead space.
  If he inspires **500 ml** of air, **150ml** of it will stay in this dead space and the other **350ml** will continue to the other divisions where gas exchange takes place.



- Respiratory (alveolar) minute ventilation = Respiratory rate $*$ Alveolar air
- (4.2 L = 4200 ml = 12 * 350)