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The respiratory system has **two types of functions**:

1- Non- respiratory:

a) Regulation of arterial blood pressure (it does that by converting Angiotensin I into Angiotensin II which constricts the vessels).

b) Acid-Base balance (by controlling H+ concentration).

2- Respiratory "major function "

provides oxygen to the tissues and removes carbon dioxide (Maintenance of CO2 and O2 content).

- If your lungs are functioning well, you should have normal ABG values (arterial blood gas).

ABG element	Normal value
pH	7.4
P CO2	40 mmHg
P O2	100 mmHg

Hypoxia: decreased O2 utilization by cells due to a decrease in O2 delivery. It differs from **Hypoxemia**: a decrease in Arterial pO2 (PaO2).

Even if you had normal lungs and ABG values, you may suffer from decreased O2 utilization by cells "hypoxia" (E.g. Septic shock).

Definition of respiration:

1) In biochemistry: generation of ATP in the mitochondria using O2.
2) In physiology: the process by which the body takes in and utilizes O2 and gets rid of CO2.

Dry Air (no water vapor) is composed of 79% nitrogen and 21% oxygen, the total pressure of this mixture at sea level averages ~760 mmHg (**P atmosphere**).

The partial pressure of a gas (**P gas**) is calculated by this equation:

P gas= Fraction of gas * P atm.

Each gas contributes for total pressure in direct proportion to its fraction therefore, 79% of the 760 mmHg is caused by N2 so pN2= 600mmHg and 21% by O2 so pO2 = 160 mmHg.

Potential causes of hypoxia:

(A) Unavailability of oxygen as in High altitudes

The atmospheric pressure decreases with increasing altitude (drops by ~50% for every 5.5km altitude increase so pO2 at 5.5 km = (760/2) mmHg X 21% = 80 mmHg

(B) Obstruction or narrowing of the airways (E.g.: COPD & asthma)

Narrowing of the airways prevents the normal amount of air from reaching the lungs.
Remember **(flow= ΔP/R)**
R is inversely proportional to the forth power of radius (**r^4**) according to **poiseuille's law**.

(C) Problem in the lung itself

Normally functioning lungs are elastic, efficiently expand and recoil as air passes freely through their passageways to the alveoli. If they become rigid (non-inflatable lung) due to restrictive diseases such as: RDS (respiratory distress syndrome), pulmonary fibrosis, inspiration is impaired resulting in hypoxia.

(D) Increased thickness of the respiratory membrane

This membrane is 0.2 µm thick and composed of 5 layers:
1- alveolar epithelium.
2- Alveolar basement membrane.
3- Interstitium.

4- Capillary basement membrane.
5- Capillary endothelium.

O2 and CO2 cross any healthy biological membrane as if this membrane doesn't exist (O2 availability **normally** is **not** diffusion-limited).
If the membrane gets inflamed or fibrotic or in cases of pulmonary edema (fluid accumulates in the interstitium), pneumonia or TB; its thickness will increase making it harder for O2 to cross (now it becomes diffusion-limited) **~** hypoxia

(E) Blood abnormalities

E.g.: Anemia, hypovolemia and hemoglobinopathies
*Remember that the majority of oxygen {98%} in the body is transported by hemoglobin

only 2% are dissolved in plasma.
In these cases, PO_2 and PCO_2 are normal but there's still hypoxia.

(F) Heart failure

Heart is unable to pump the oxygenated blood to the tissues.
Decreased CO= decreased blood flow.

(G) Occlusion of an artery "ischemia"

(H) Decreased O2 utilization by cells

The mitochondria can't use O2 to produce ATP (E.g.: **Cyanide poisoning or Septic shock**).

(I) problem in the diaphragm

The diaphragm is a striated, skeletal muscle, voluntary, need motor neuron excitation; lack automaticity (unable to create its own action potentials).
Nerve supply: phrenic nerve (C3-C5)
* myasthenia gravis, polio infection, damage to the medulla oblongata that sends signals to phrenic nerve and drug overdose (anesthetics, pethidine & heroin) can cause weakening or paralysis of the diaphragm.

How to inflate the lungs?
* Ohm's law (flow=driving force/resistance)
* Air flow= ΔP/R (the driving force for airflow is the pressure difference)

*Before inspiration the pressure outside= pressure inside = zero

So the DF (pressure gradient) and flow equal zero.
* To force air into lungs we have two options:
we either make the alveolar pressure < atmospheric pressure
or the atmospheric pressure > alveolar pressure
* when the **respiratory muscles (diaphragm and intercostals muscles)** contract, the volume of the thoracic cavity increases and the pressure decreases. Thus muscle deformity can cause hypoxia.

$$P \propto \frac{1}{V}$$

how does a skeletal muscle contract? It's a motor unit, it needs an order from the respiratory center by a motor neuron (body in spinal cord, dendrites and axon)
any problem that can inhibit the respiratory center (heroin or morphine poisoning, drug over dose and anesthesia), thus inhibiting the phrenic neurons, inhibiting respiratory

muscles, no respiration, hence producing acute respiratory failure and that's a cause of hypoxia.

When muscles contract, thoracic cavity increases, The pressure and the resistant decrease, therefore the alveolar pressure becomes less than atmospheric pressure thus increasing the flow. By time as the lungs inflate the alveolar pressure equals the atmospheric pressure and hence no more flow will take place..
The alveolar pressure goes within this range **0** to **-1** to **0**.

Respiratory system is divided *about 23 divisions* and can be distinguished to two parts:
1-Conducting part (passage for the air no gas exchange; Anatomic dead space) : the first 16 branches
2- respiratory part (gas exchange): from the 17^{th} branch to the 23^{rd}.

Anatomic dead space: some of the air the person breath never reaches the gas exchange areas but simply fills the conducting zone where gas exchange doesn't occur (nose, pharynx, larynx, trachea, bronchi, bronchioles, and terminal bronchioles)
* On expiration, the air in the dead space is expired first before any air from the alveoli reaches the atmosphere (in mouth to mouth breathing during CPR you are giving the patient fresh air! (first 150 ml expired))

***Tidal volume**: the volume inspired or expired with each normal breath= 500 ml.

When we take a breath, 500mL of gases enter.

First of all air flows through the airways and becomes humidified (fully saturated with (H_2O vapor) by goblet cells and cleaned by cilia.

the first 350ml goes to lungs and participates in gas exchange and the last 150 ml stays in the airways not used, so amount of oxygen used in exchange per minute equals 12*350=4800ml/min.
(12 = number of breaths per minute)

Total pressure inside the airways equals 760mmHg including 47mmHg for pH_2O so the pressure of the gases alone is 760-47=713 mmHg for pO_2 and pN_2.

Because fractions of O_2 and N_2 stay same, the partial pressure of PO_2 in inspired air now equals 0.21*713=150mmHg.

Total Pressure inside lungs also equals 760 mmHg, PH_2O=47mmhg, pco_2=40mmhg, PO_2=100 mmHg, pN_2=760-(47+40+100).

In conclusion, we are interested in pO2 and pCO2 only; because PH2O is always constant and N2 is a spectator molecule.

Gas	Dry inspired air	Humidified tracheal air	Alveolar air	Systemic arterial blood	Mixed venous blood
pO2	160	150	100	100	40
pCO2	0	0	40	40	46

Special thanks to معتصم السيد

Good Luck ☺

Keep your eyes on the stars and have your heart filled with hope