Respiration Module

Session 1 – Introduction

Presented by

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Aim

- the *aim* of this module is that you should understand
  - the structure and function of the respiratory system
  - how the respiratory system is affected by disease
  - basic principles of treatment of respiratory disorders

The respiratory system

- serves to ensure that all tissues receive the oxygen they need
- and can dispose of the CO_2 they produce

Transport & exchange

- blood carries gases to and from tissues
- lungs exchange with atmosphere

Blood

- has the intrinsic capacity to pick up oxygen
- and lose CO_2
- if exposed to the right gaseous environment
- which is what the lungs do

The Physics of gases

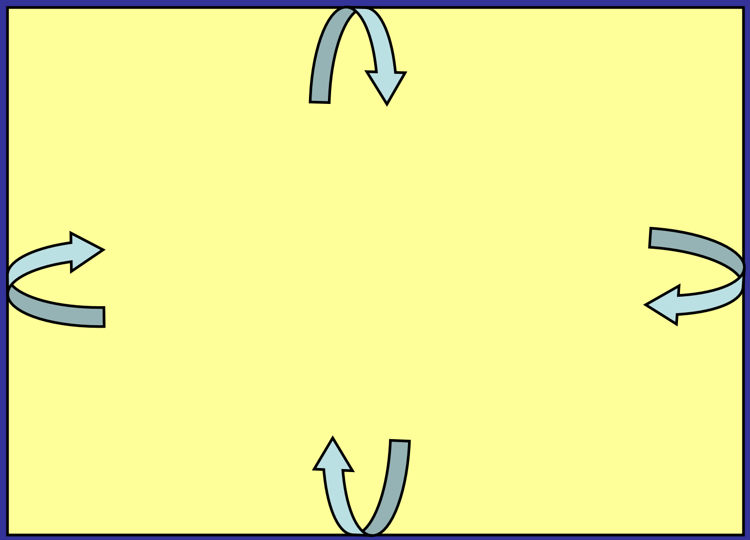
- the physiology is easy
- if you understand the physics

- What is atmospheric pressure?
- Atmospheric pressure is the force per unit area exerted against a surface by the weight of air above that surface in the Earth‟s atmosphere.
- Pressure = Force / per unit area → 1 Newton (N)/ square metre (m2) = 1 Pascal (Pa)
- pascal is the SI Unit of Pressure. As this is small, in medicine kilopascals (kPa) are used.
- 1 kPa = 1000 Pa

- Pressure is also expressed in mmHg (eg Blood Pressure of 120/80 mmHg).
- 1 kPa = 7.5 mmHg,
- 1 mmHg = 0.133kPa
- 1 standard atmosphere = 760 mmHg = 101.3 Kpa
- Also (torr) is almost identical to mmHg

Kinetic theory of gases

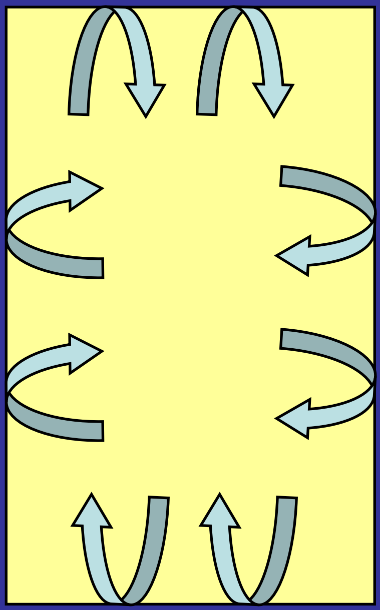
- gases are a collection of molecules moving around a space
- pressure generated by collisions of molecules with the walls
- the more frequent and harder the collisions
- the higher the pressure



Boyle's law

- if a given amount of gas is compressed into a smaller volume
- molecules will hit the wall more often
- and pressure will rise
- Pressure inversely proportional to volume

- Boyle s law: $P_1V_1 = P_2V_2$ (temperature constant)



Charles's law

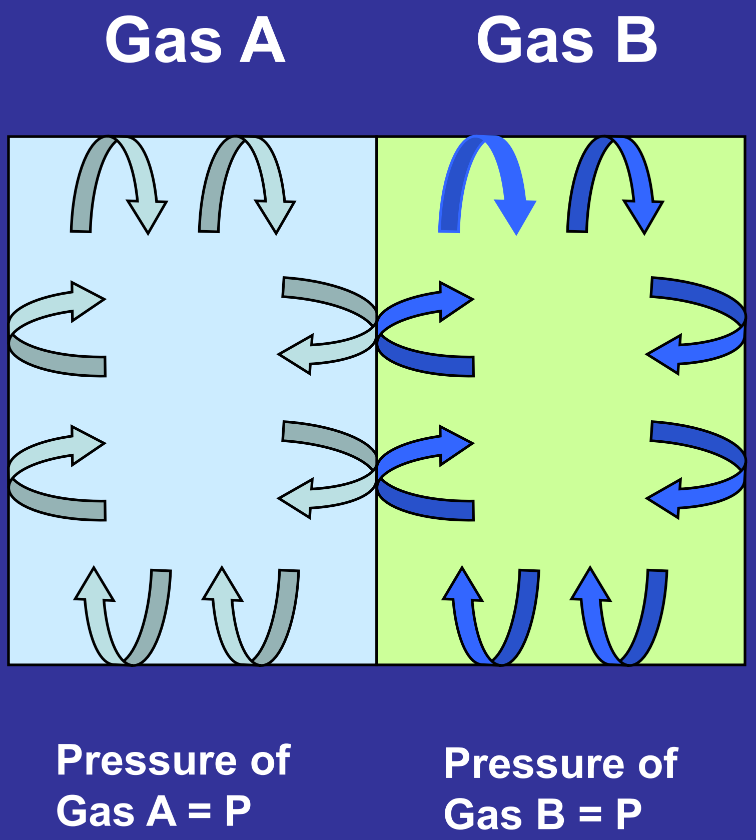
- kinetic energy of molecules increases with temperature
- as temperature increases molecules hit walls more often so pressure increases
- pressure proportional to absolute temperature
  - scale starts at -273 deg C absolute zero
  - Charle's law : $\frac{V_1}{V_2} = \frac{T_I}{T_2}$ (pressure constant)

Universal gas law

- P.V=R.T
- allows calculation of how volume will change as pressure and temperature changes
- volumes usually corrected to STP
- STP 273 deg K (0degC), 101.1 kPa

Partial pressures

- in a mixture of gases
- molecules of each type behave independently
- so each gas exerts a *partial pressure*
- calculated as the same fraction of the total pressure as the volume fraction of the gas in the mixture



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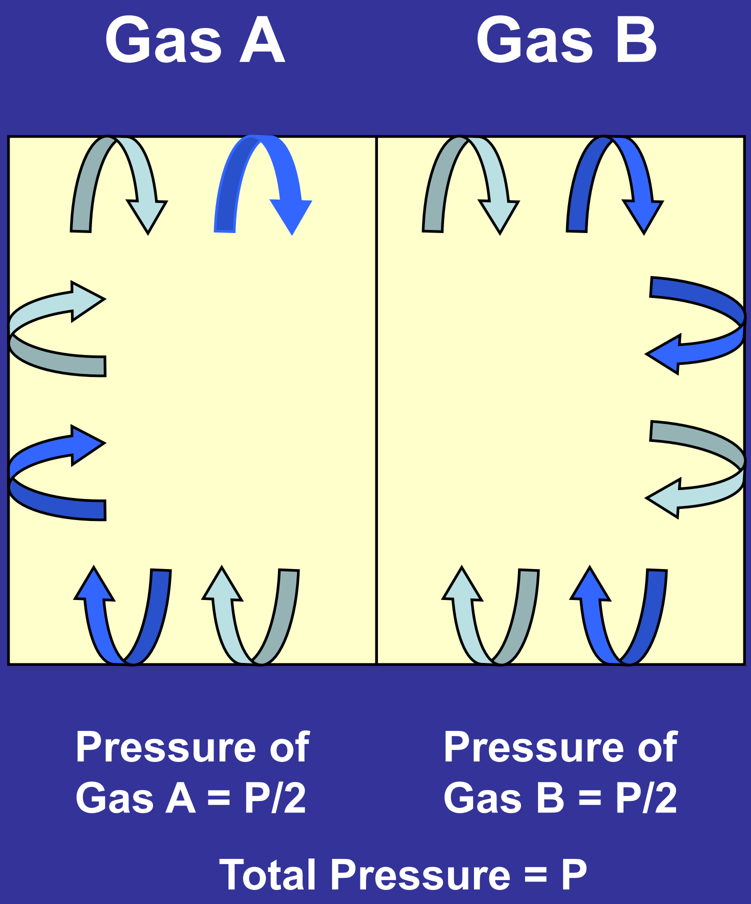

- In respiratory physiology, one deals with mixtures of gases, mainly of O_2, N_2, and CO_2.
- The rate of diffusion of each of these gases is directly proportional to the pressure caused by that gas alone, which is called the partial pressure of that gas.
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- The concept of partial pressure can be explained as follows.
- Consider air, which has an approximate composition of 79 % N_2 and 21 % O_2.
- The total pressure of this mixture at sea level averages 760 mm Hg (101.1 kpa)
- Therefore, 79 %of the 760 mm Hg is caused by N_2 (600 mm Hg) and 21 % by O_2 (160 mm Hg).
- P_{N2} = 760 X 0.79 = 600 mmHg (80 kpa)
- P_{O2} = 760 X 0.21 = 160 mmHg (21.1 kpa)

- Dalton’s law states that the partial pressure of a gas (x) in a gas mixture is the pressure that this gas would exert if it occupied the total volume of the mixture in the absence of the other components

- Thus, $P_x = P \cdot F_x$, where P is the total dry gas pressure, since F_x refers to dry gas.

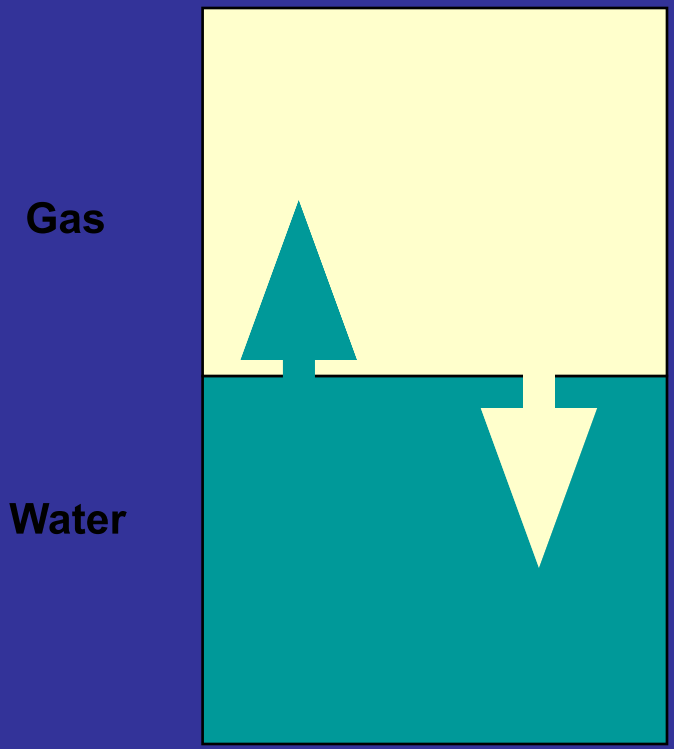
- In gas with a water vapor pressure of 47 mm Hg, $P_x = (P_B - 47) . F_x$

Also, in the alveoli,

$$PO2 + PCO2 + PN2 + PH2O = PB.$$

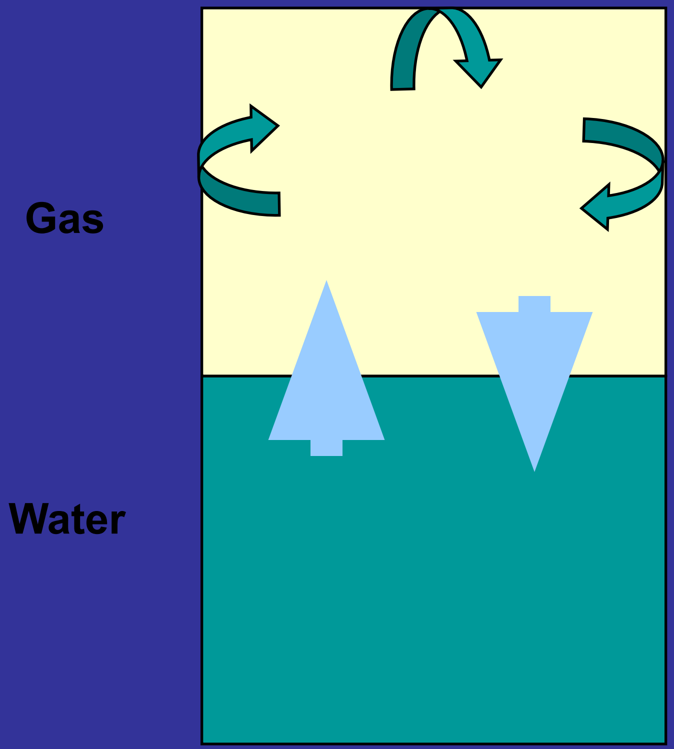
Water vapour

- in biological systems
- gas mixtures always in contact with water, so
- water molecules evaporate
- gas molecules dissolve



Evaporation

- water molecules entering the gas
- exert vapour pressure
- when molecules leave & enter water at same rate
- Saturated Vapour Pressure

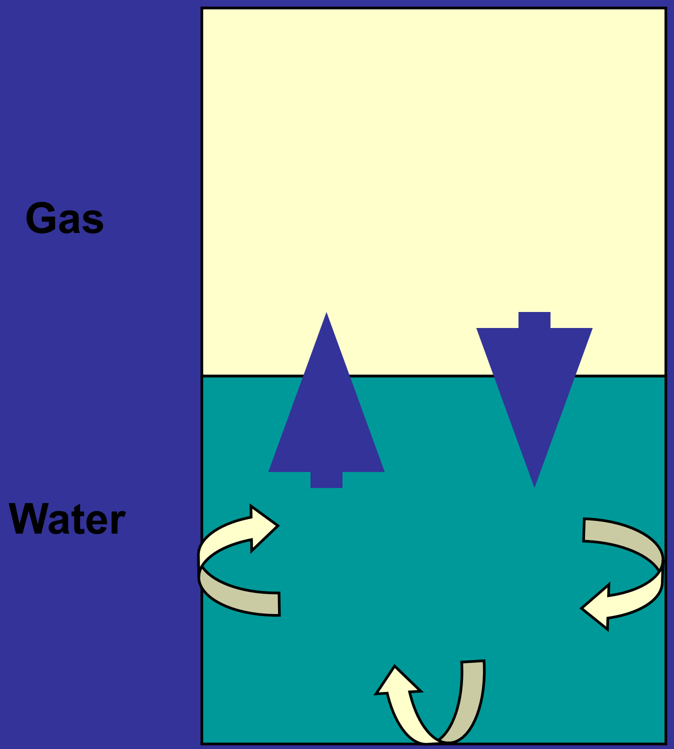


Saturated Vapour Pressure

- depends only on temperature
- water vapor pressure at 0°C is 5 mm Hg
- at 100°C it is 760 mm Hg.
- at 37°C it is 47mmHg (6.28 kPa)

Gases dissolving in water

- gas molecules enter water
- and exert ‘tension’
- like pressure if water not there
- at equilibrium tension same as partial pressure of gas in gas mixture



Gas Tension in Liquids

- indicates how readily gas will leave the liquid
- not (at least directly) how much gas is in the liquid
- The partial pressure of a gas in solution is its partial pressure in a gas mixture
- that is in equilibrium with the solution.
- Henry's law states that the concentration of gas dissolved in a liquid is proportional to its partial pressure. Thus,
- $C_x = K \cdot P_x$

Solubility

- the amount of gas which enters the liquid to establish a particular tension
- is determined by *solubility*
- *content* = solubility x tension

- **Solubility of Gases**: The amount of a gas dissolved in plasma = solubility of that gas x its partial pressure. Solubility is a constant for that gas. The units of solubility are mmol/Litre/kPa (i.e. the number of mmol of gas that will dissolve in a litre of water, at a given partial pressure). If the partial pressure of the gas increases, more will dissolve).
- The solubility of oxygen in plasma at 37^{C} (body temp) is known as the **coefficient of solubility of O2** and is 0.01 mmol/Litre/kPa
- The coefficient of solubility of CO_2 = 0.23 mmol/Litre/kPa
- (CO_2 is 23 times more soluble in plasma than oxygen)

Chemical reactions of gases with liquids

- if a gas reacts with a component of the liquid
- this reaction must complete
- before tension established
- total content therefore
- reacted gas + dissolved gas

Example

- plasma just dissolves oxygen
- at pO_2 of 13.3 kPa (100 mmHg)
- content 0.13 $mmol.l^{-1}$

- whole blood contains Haemoglobin
- which reacts chemically with oxygen
- at 13.3 kPa
- Haemoglobin binds 8.8 $mmol.l^{-1}$
- and 0.13 $mmol.l^{-1}$
- is dissolved in the water

Gas exchange in the lung

- at rest 5l of blood must pick up 12 mmol of oxygen per minute
- needs very large surface area
- a tennis court

Getting a tennis court into the thorax

- need a very large number of very small compartments
- 300 million *alveoli*
- each surrounded
- by a capillary

Airways

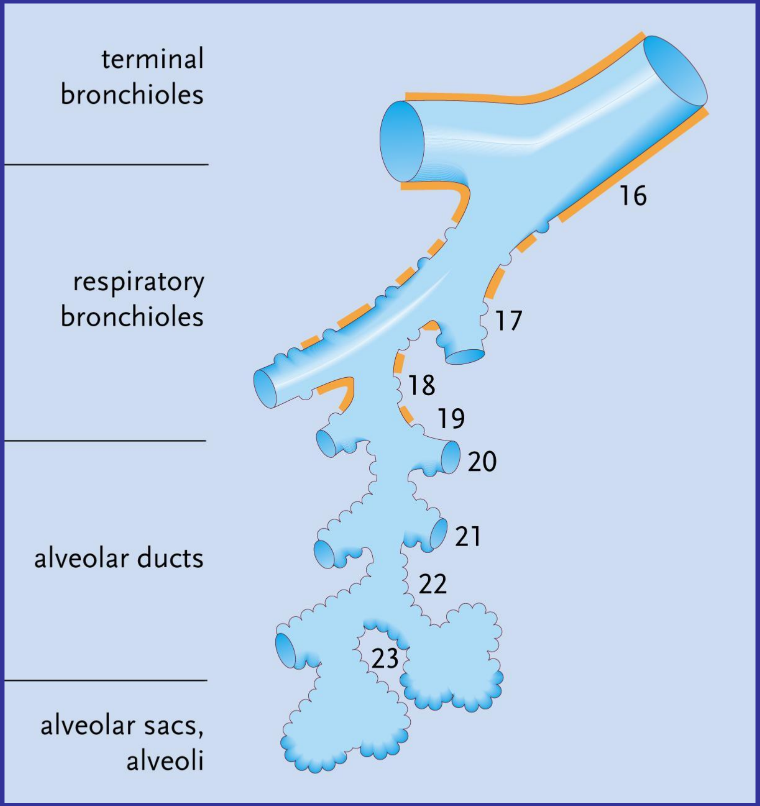
- air reaches the alveoli via a complex tree of airways
- over 20 divisions

Airways

- Trachea branches to main bronchi
- main bronchi to lobar bronchi
  - 3 on right 2 on left
- lobar bronchi to segmental bronchi
- then sub-segmental bronchi
- etc till reach bronchioles

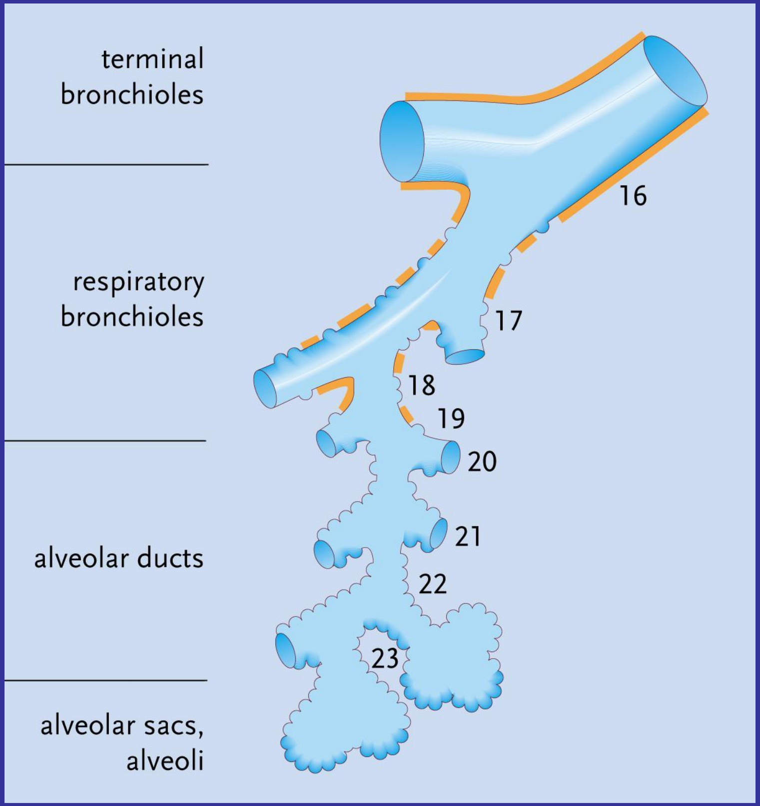
Bronchioles

- Bronchi have cartilage in walls
- bronchioles do not
- but do have more smooth muscle
- bronchioles divide and divide
- to form 200000 terminal bronchioles



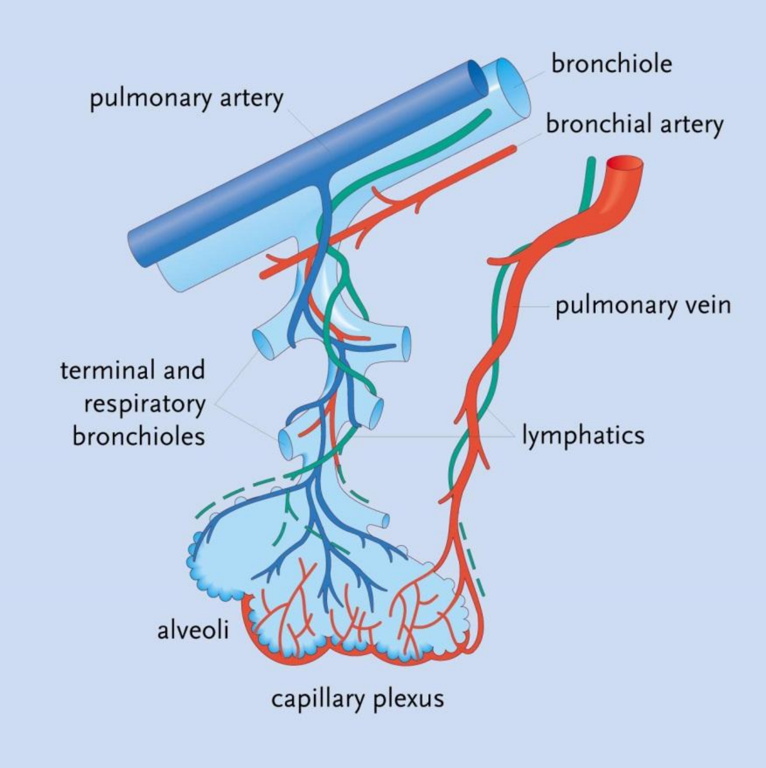
Terminal bronchioles

- the ‘twigs’ on the tree
- each connected to a set of respiratory bronchioles, alveolar ducts and alveoli
- the ‘leaves’



Blood supply

- each alveolus surrounded by a capillary
- branching blood vessels in the pulmonary circulation
- form a tree like the airways



The lungs

- are a means of
- getting air to one side
- and blood to the other side
- of a very thin membrane
- of very large surface area

The pulmonary circulation

- low resistance
- low pressure
- receives entire cardiac output

The pulmonary circulation

- forms practically no tissue fluid
- regional blood flow ‘matched’ to air supply (‘ventilation’)
- by local vasoconstriction
- when pO_2 is low

Ventilation perfusion matching

- is vital
- and often disturbed by disease

Ventilation

- air drawn into lungs by increasing volume of terminal and respiratory bronchioles
- as lungs expand in inspiration
- each breath draws a *tidal volume* into and out of the lungs

Ventilation

- changed to match needs of the body by varying
  - tidal volume
  - respiratory rate