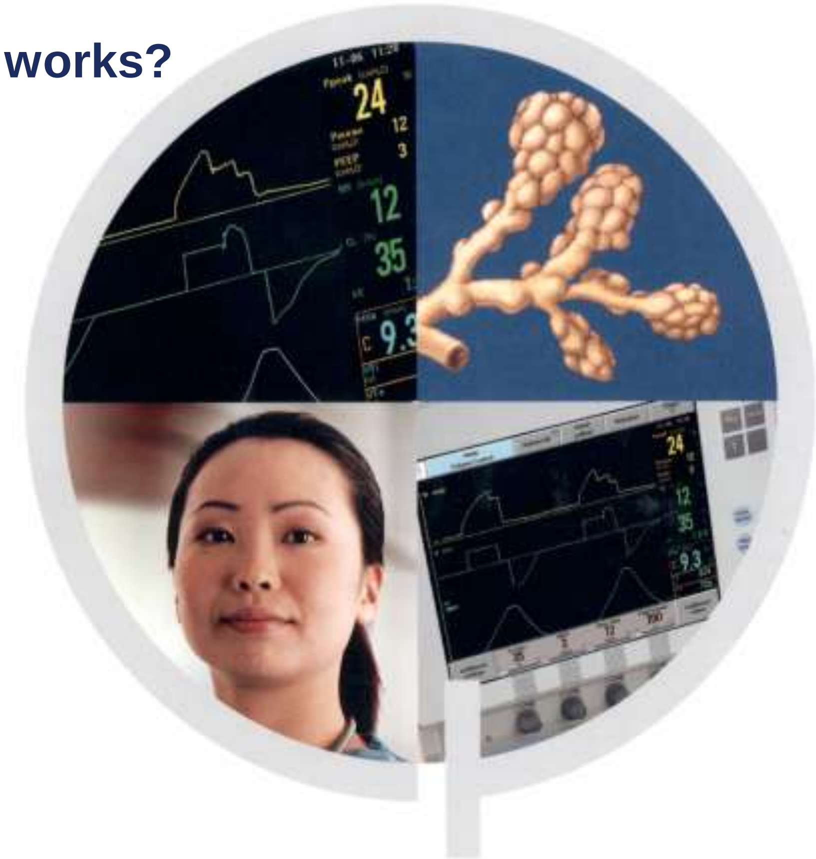
“Excellence in Care”

SERVO

Objective

- Anatomy & Physiology of Pulmonary System
- Who requires Ventilation?
- What is a Ventilator and how does it works?
- Type of Ventilation and Modes.
- Monitoring and Sensing.
- Alarms and Indications.



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What do you mean by Respiration?

Respiration is defined as the movements of gas molecules across the membrane.

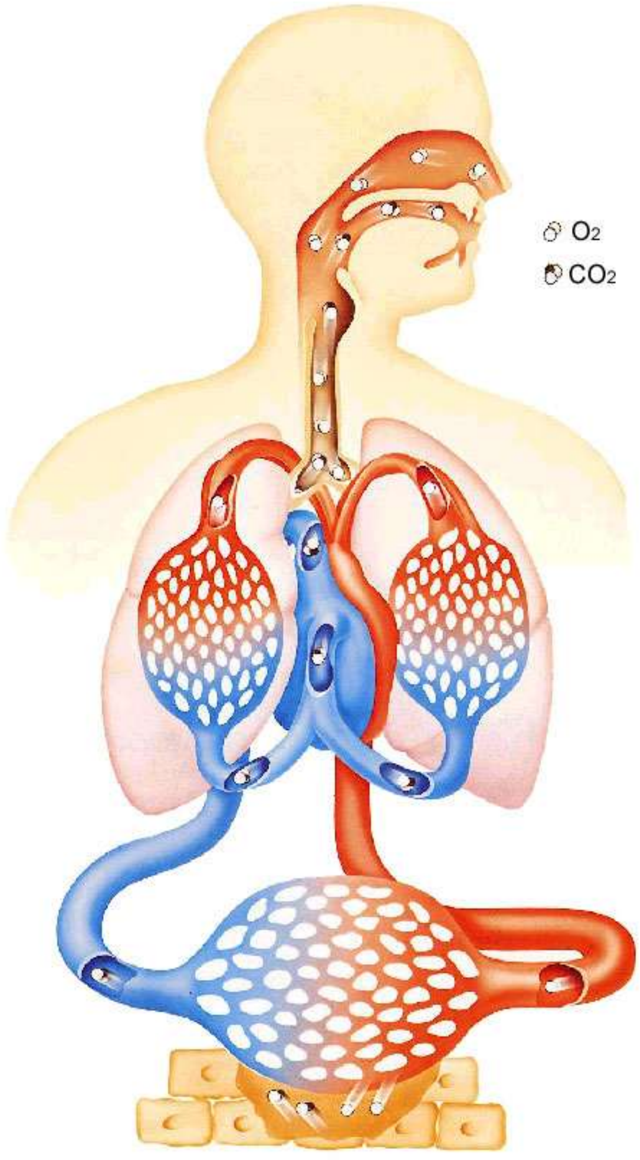
- The blood distributes oxygen and nutrients to the many different cells in the body, carries CO_2 generated by the cells to the lungs for exhalation
- This oxygen is used to provide energy for all the tissues and organs of the body.

1) External respiration

Oxygen moves in to the bloodstream and carbon dioxide moves from bloodstream in to the alveoli.

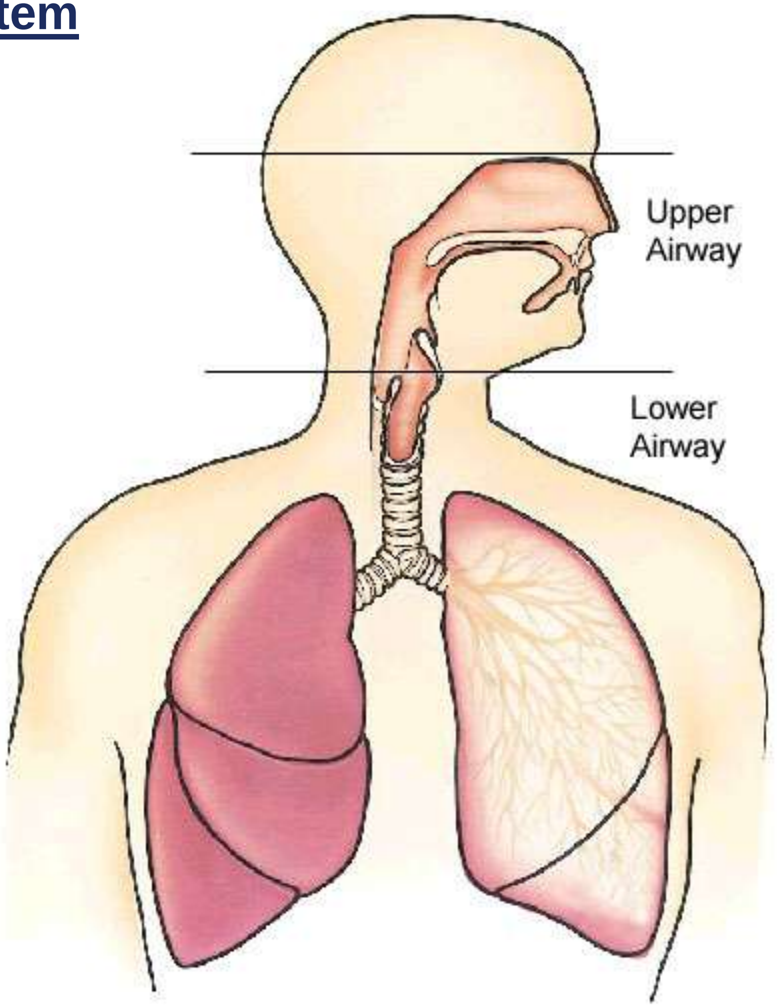
2) Internal respiration

At the cellular level, carbon dioxide moves from the cell in to the blood and oxygen moves from the blood in to the cell.

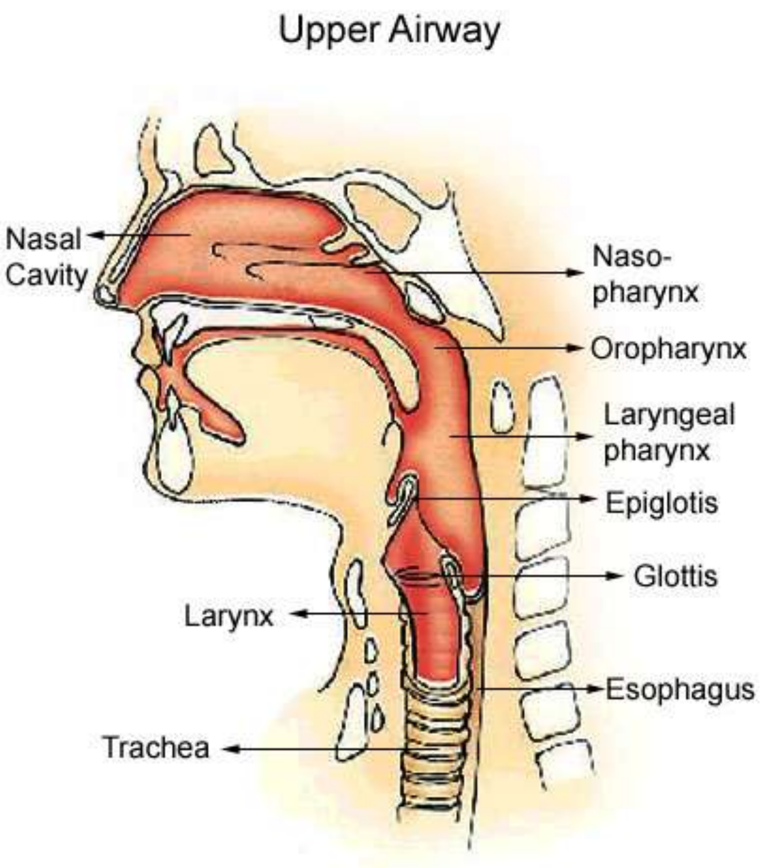


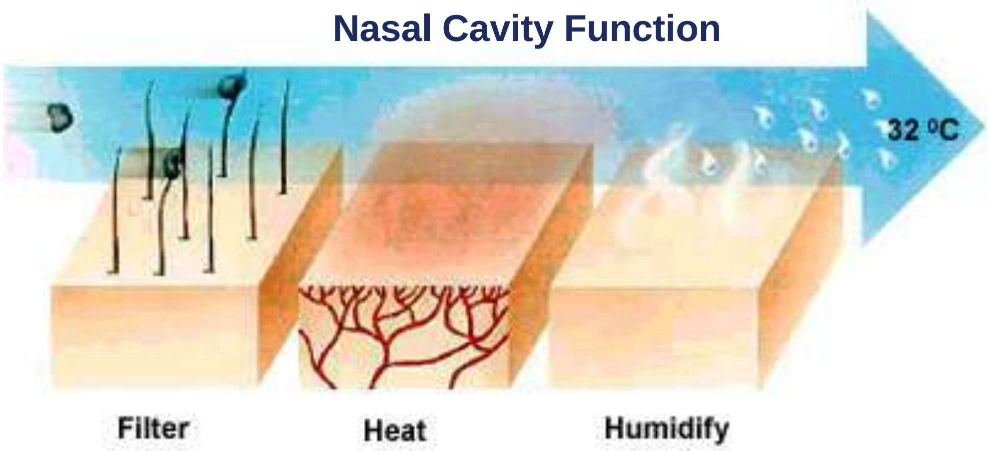
Anatomy and Physiology Pulmonary System

- **Upper Airway**
  - **Nasal Passages**
    Beyond the olfactory function, it warms, filters and moistens inspired air.
  - **Pharynx**
    1) Nasopharynx
    2) Oropharynx
    3) Laryngeal pharynx
  - **Larynx**
    1) Vocal cords
    2) Thyroid
- **Lower Airway**
  - **Conducting Airways:** Non-alveolar region
    Consists of series of tubes that divide like the branches of a tree. Its function are to conduct air and provide mucociliary defense.
  - **Respiratory Zone:** Alveolar Region
    Important perform external gas exchange**.**



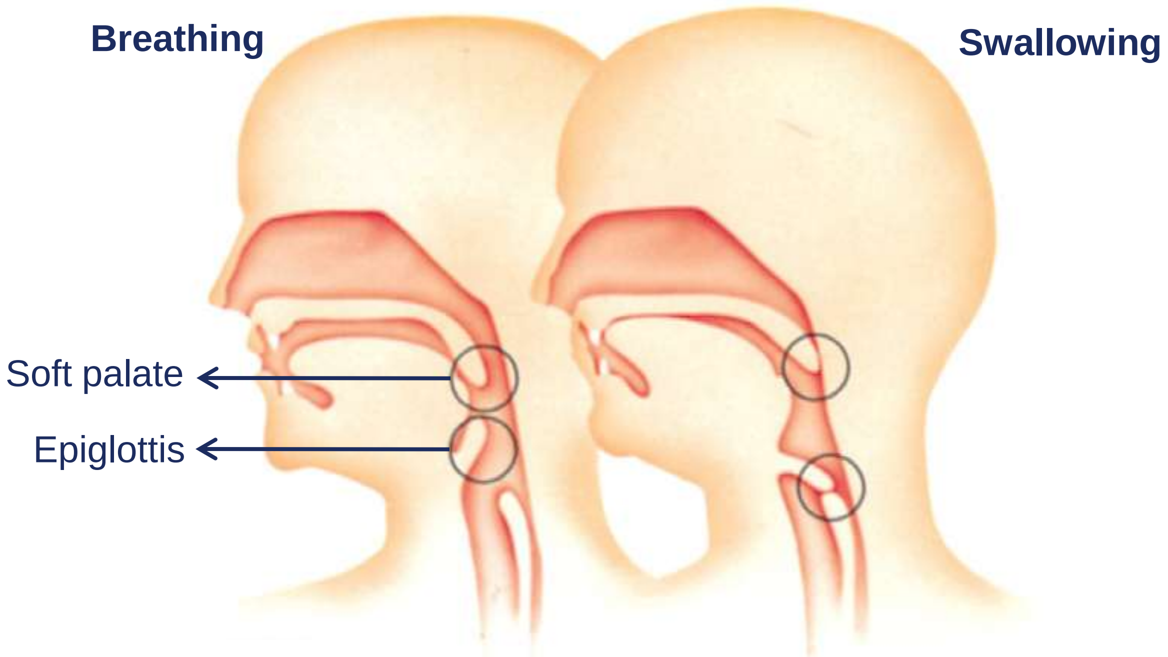
Upper Airway





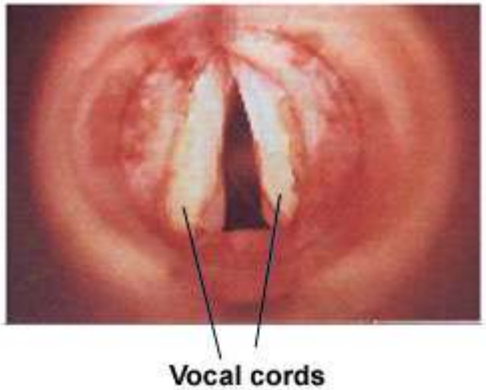
Pharynx

- The throat provides a transport function for both food and air.
- When swallowing, food is prevented from entering the nasal cavity by closing upward movement of the soft palate in the roof of the mouth.

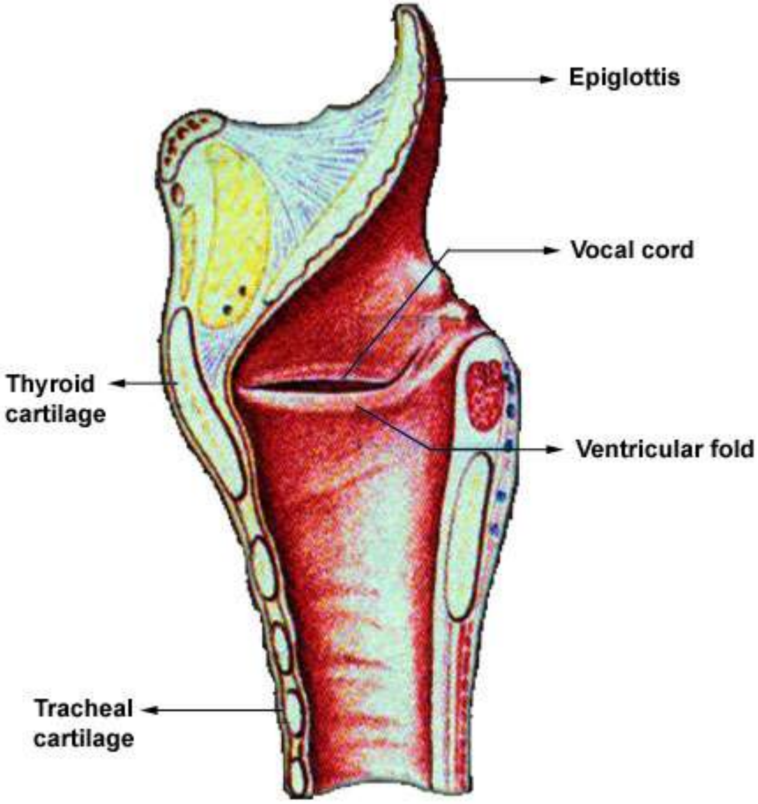


Larynx

- The larynx contains epiglottis is a leaf-shaped cartilaginous structure extending from the base of the tongue and attached to the thyroid cartilage by ligaments
- During swallowing the epiglottis flaps down to direct food into the esophagus.



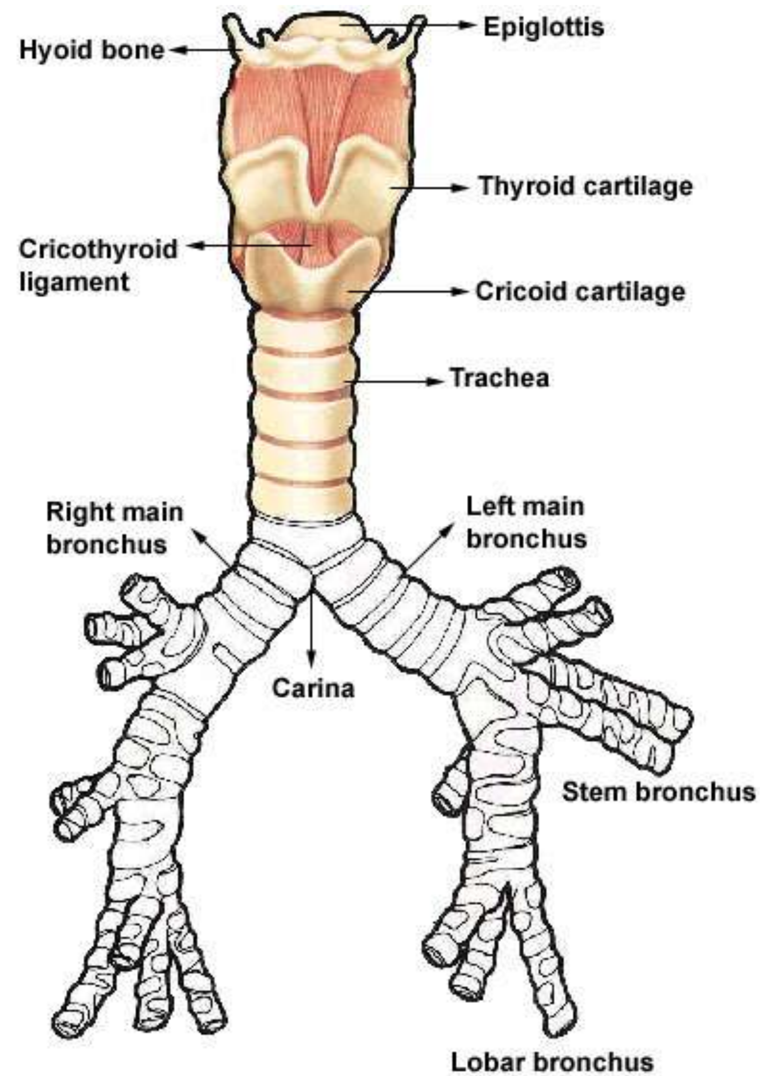
- Vocal cords for phonation and is also an organ with sphincter functions that help preventing aspiration.
- Vocal cords are drawn apart during inspiration and relax towards midline during expiration.



Lower Airway

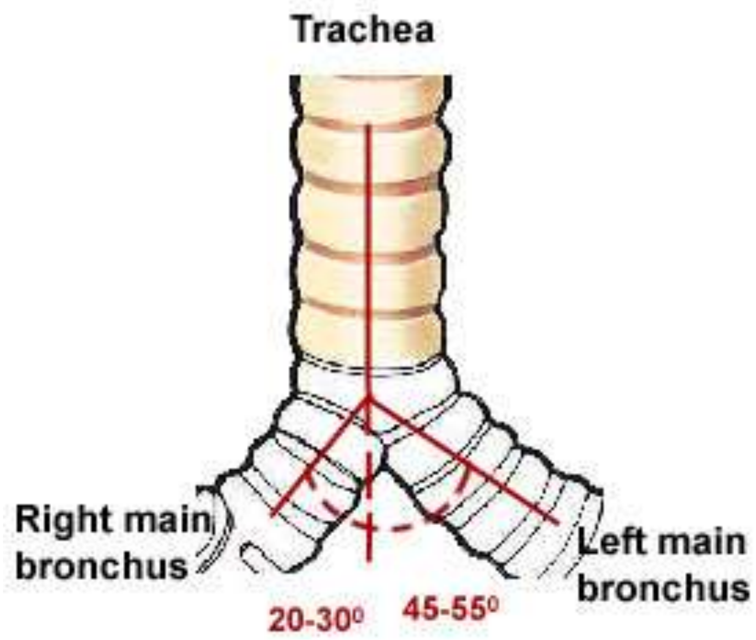
A. Conducting airways: Nonalveolate region

- Consists of series of tubes that divide like the branches of a tree. Its function are to conduct air and provide mucociliary defense.
- The trachea is made up16 to 20 C-shaped rings of cartilage, lined by ciliated epithelium and mucous producing goblet cell.



Trachea

- It is average 2 to 2.5 cm in diameter and 10-12 cm in length.
- The trachea divides at carina into right and left main-stem bronchus ,
- Right Main bronchus angle 20-30 degrees from the midline. This position promotes incidence of aspiration and right main stem intubation.
- Left main bronchus short , narrow and deflects sharply at 45-50 degree.
- Excessive pressure on this smooth muscle by the cuff of an artificial airway can lead to erosion and tracheoesophageal fistula.



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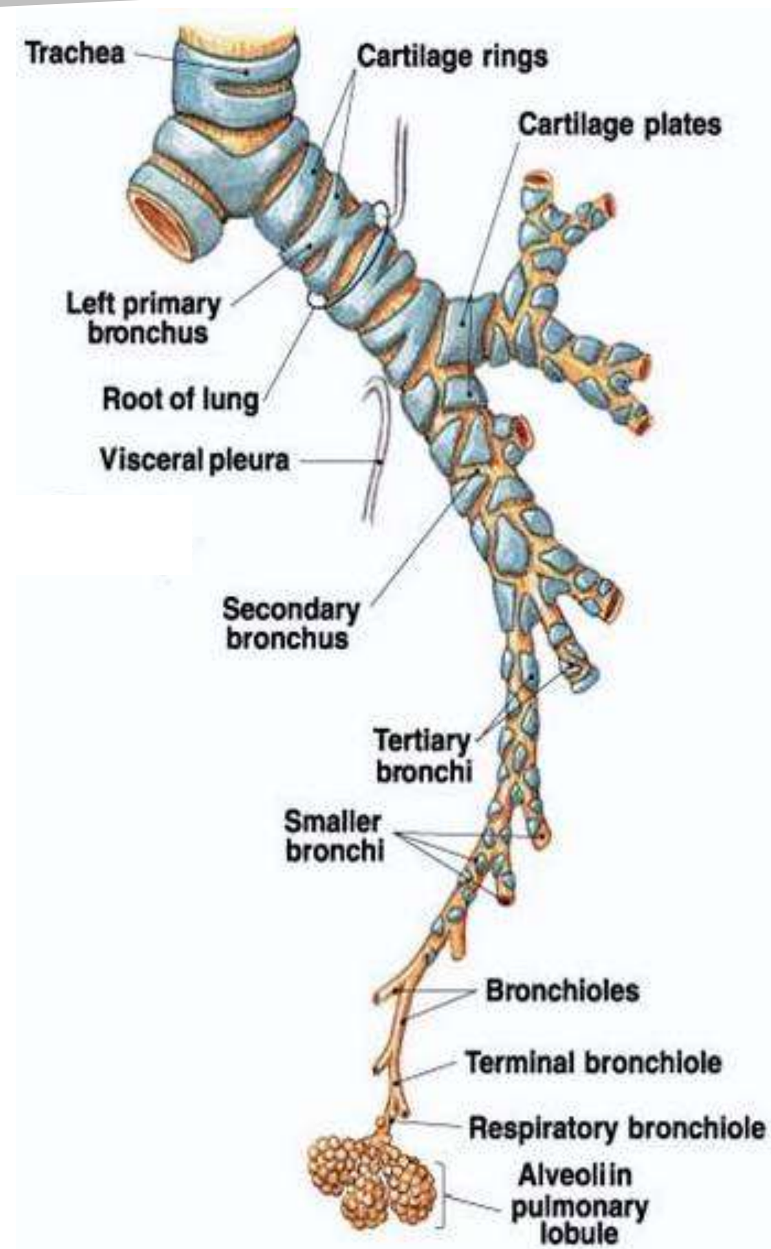
- The first 16 divisions of the tracheobronchial tree take no part in gas exchange.
- The volume is 150 ml approximately know as anatomical dead space.
- The large bronchi are supplied with sensory nerve receptors involved in cough reflex.
- There are 64,000 terminal bronchioles.

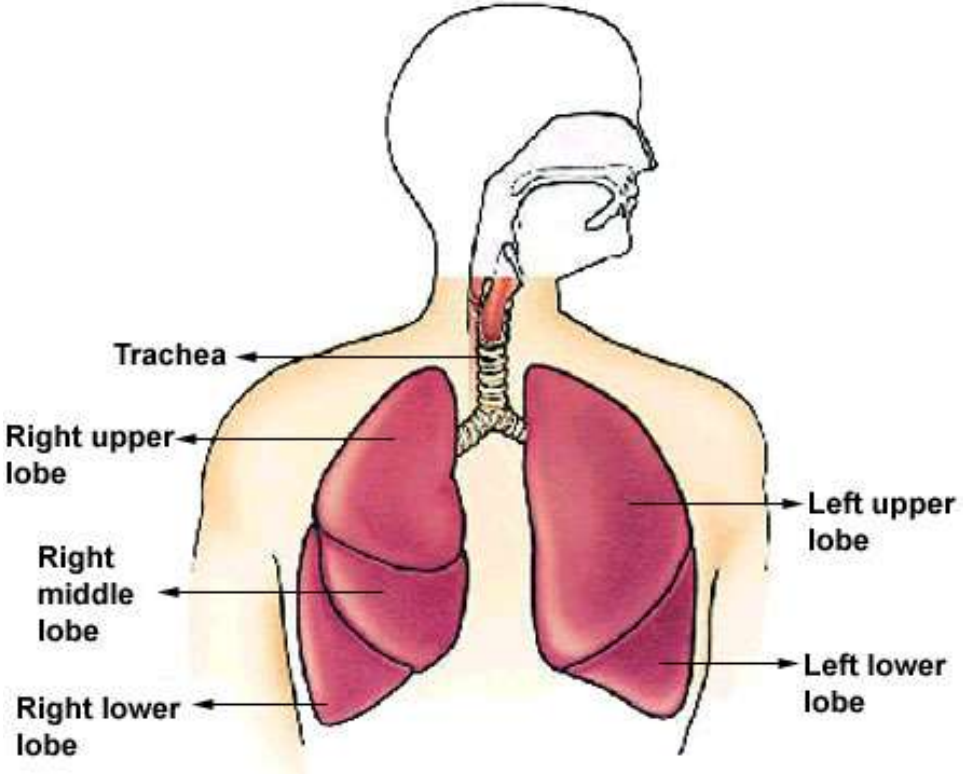


Lower Airway

B. Respiratory Zone: Alveolate Region

Lungs

- The lungs are paired, cone-shaped organs, average adult lung is 800g.
- The lungs are divided into lobes, the left has two and right has three.
- Lobes are divided into bronchopulmonary segments, there are 10 segments into right lung and 8 segments in left lung.
- This Segments divides into lobules, which are the lung smallest unit.



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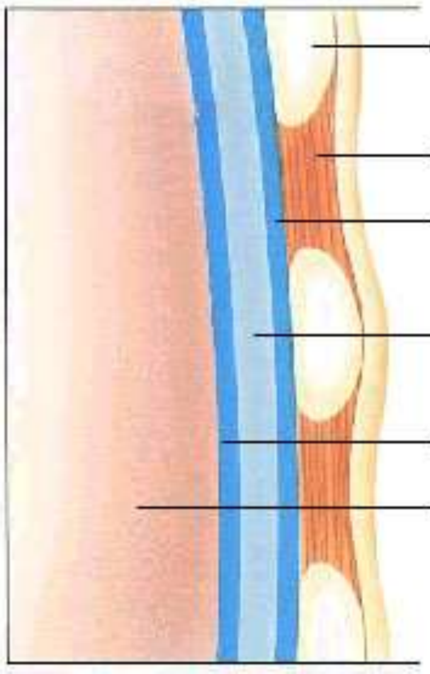
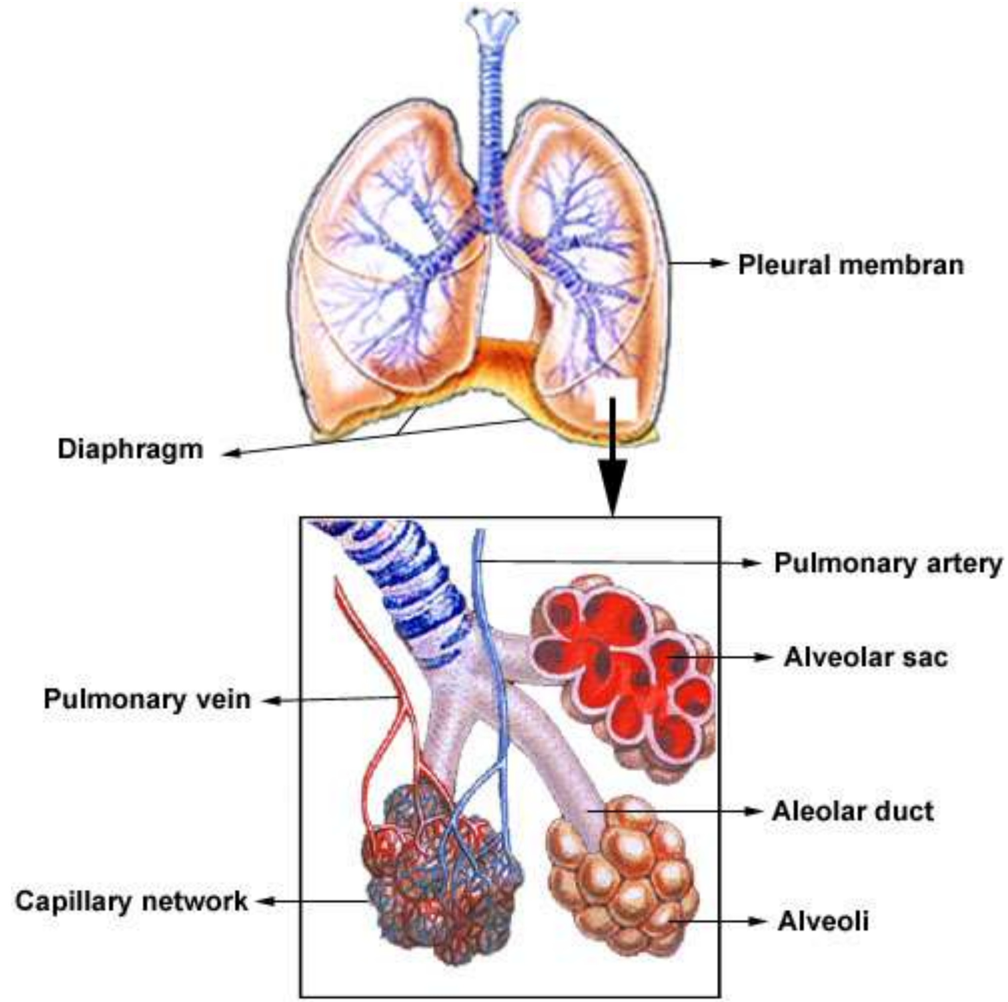
Pleura

- Each lung is enveloped in its pleural membrane, an inner and an outer which are in intimate contact with each other.
- The inner membrane closely envelope the lungs surface while the outer membrane covers the inside of the chest wall and the large respiratory muscles, the diaphragm.
- During inspiration the negative pressure is maintained by the rib cage, which pulls the parietal pleura outward, thus causing the lungs to expand and air to be sucked in.
- If air, blood or other fluid are introduced in to the plural space, the two plural surface can separate.



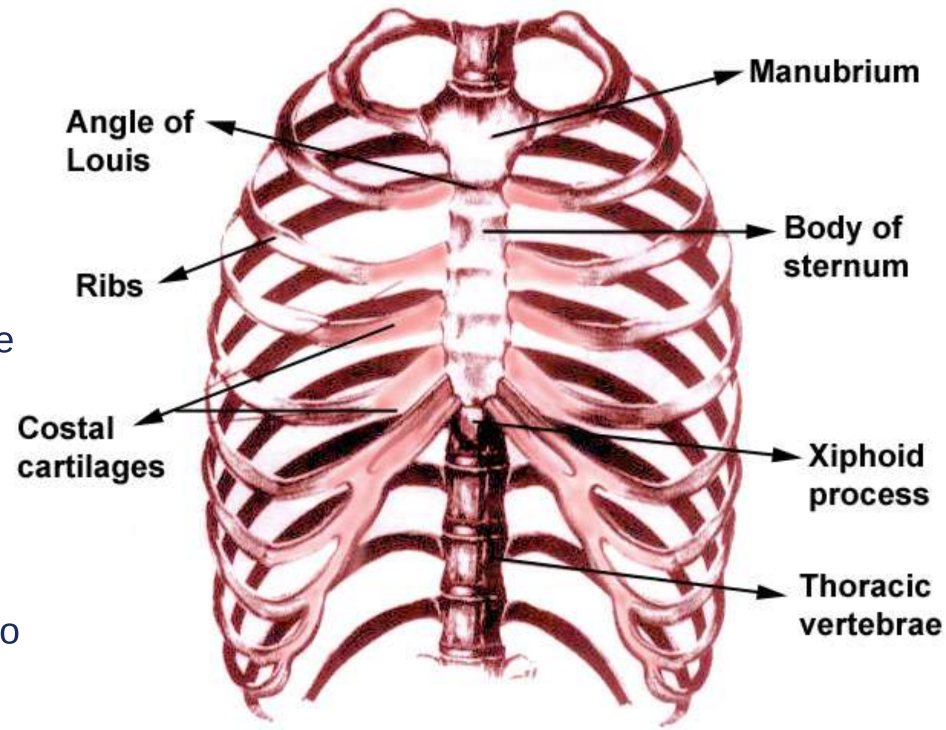
Transitional and Respiratory zone

- Acinus is the primary gas-exchanging unit consisting of the respiratory bronchiole, alveolar ducts, alveolar sacs and alveoli.
- There are approximately 300 million alveolar-capillary units in adult lung.
- The total surface area of lung parenchyma is 50 to 100m^2, about the size of a tennis court.
- The alveoli are surrounded by capillaries.
- The alveolar cells are squamous epithelium one cell layer thick, to promote gas exchange and prevent fluid transudation into alveolus
- Surfactant prevent the alveoli and bronchioles from collapsing.



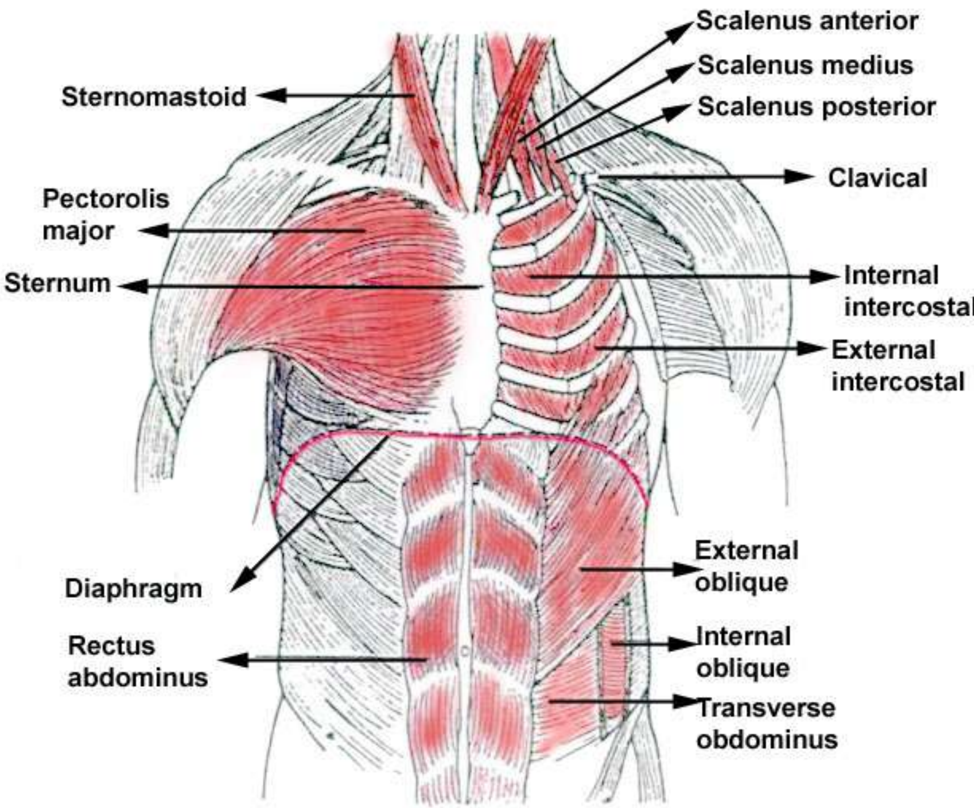
Thoracic cage

- The lungs are housed in the thoracic cage.
- Structure provide support and protection for the contents of thorax.
- Sternum is a dragger-shaped bony structure in the median line at the chest. In adult sternum averages 18cm in length.
- There are 12 pairs of ribs correspond to the twelve thoracic vertebrae and connect to the sternum via costal cartilages.
- 1- 7 rib are connect directly to sternum.
- 8-10 rib are connect indirectly to sternum.
- 11-12 ribs has no connection to sternum, so called as floating ribs.



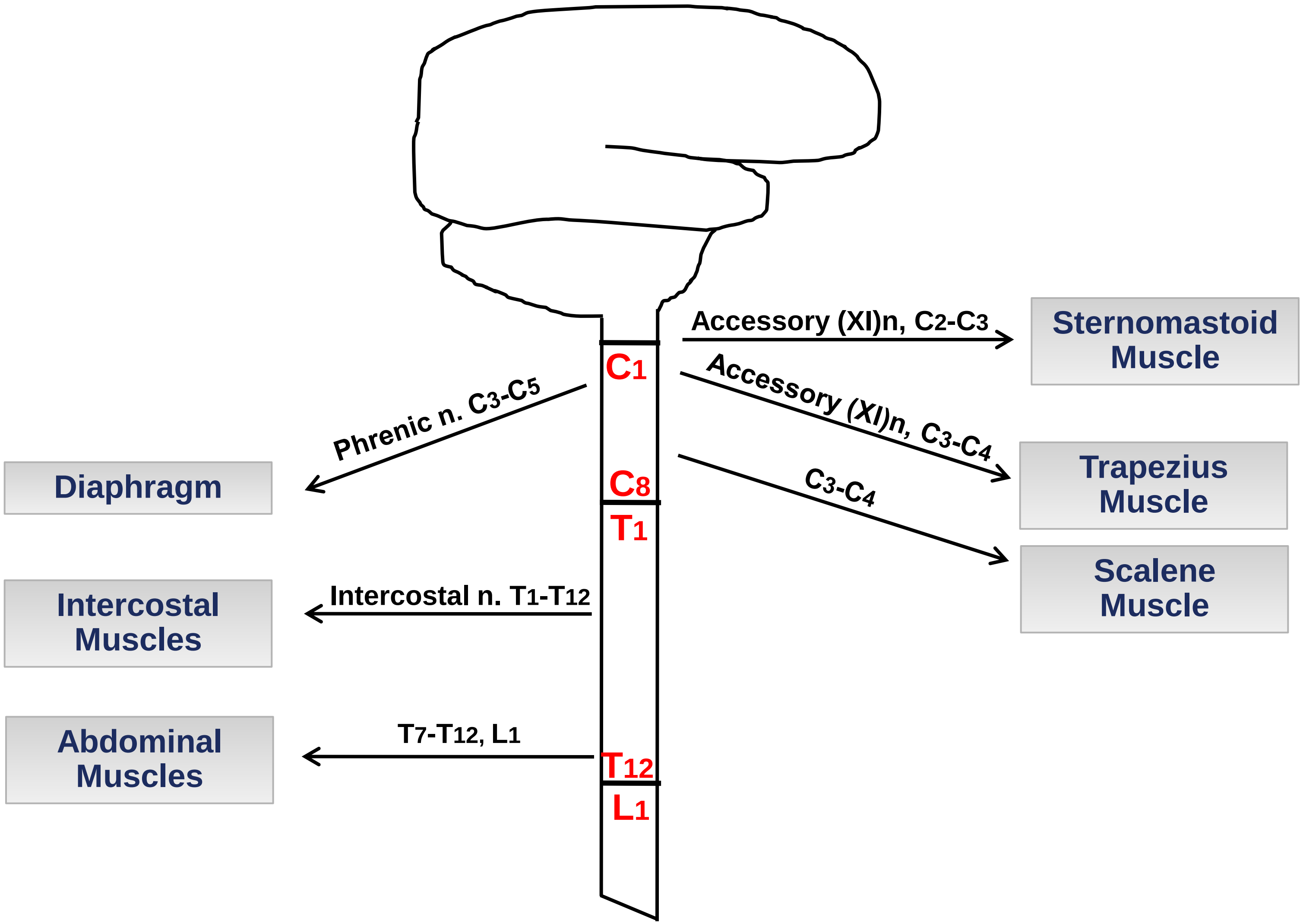
Respiratory Muscles

- The principle muscle of respiration is the diaphragm, made up of fibrous tissue.
- The resting position is dome shaped. On inspiration the diaphragm contracts, flattening the dome.
- The anterior-posterior dimension of the thoracic cavity elevate and increase during contraction of external intercostal muscles.
- During inspiration scalene muscles contract elevating first two rib.
- Sternomastoid assist in elevating the sternum.



Oxygen plays an important role in the energy metabolism of living organisms.

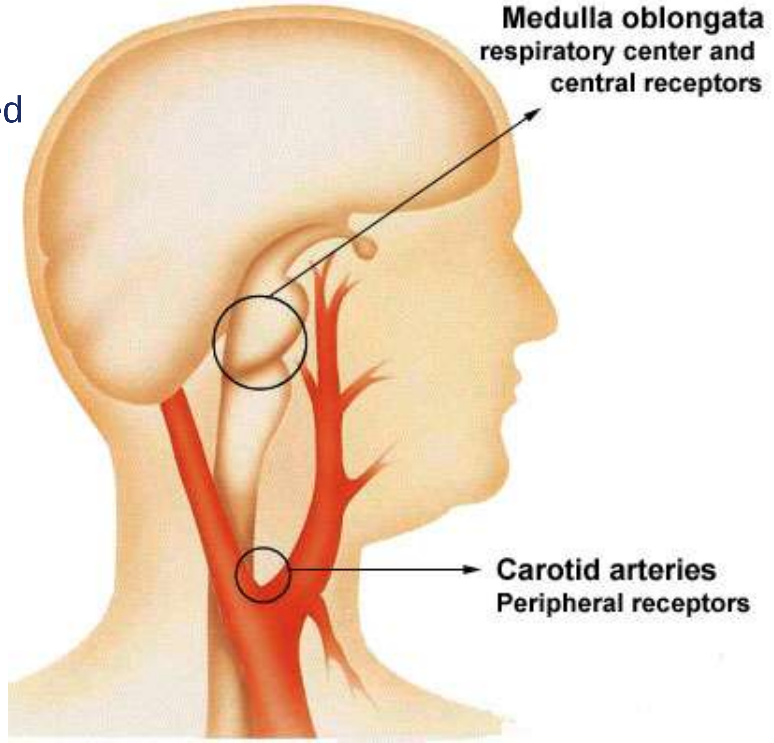
Innervation of the Ventilatory Muscles



Physiology of Pulmonary System

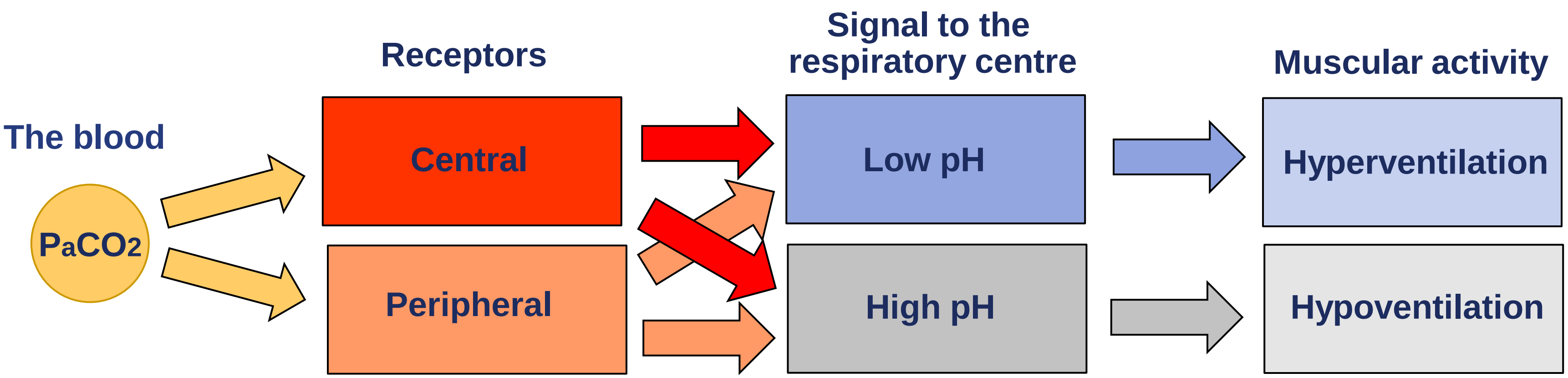
Regulation of breathing in the Brain stem.

- The volume and the frequency of ventilation is determined by impulses from the respiratory center in the Medulla oblongata to the respiratory muscles.
- The impulses from the central receptor depends on the CO_2 in the blood, affect the fluid value of pH in the brain and spinal cord.
- In the peripheral receptors when PaO_2 is lowered about 60 mmHg then the respiratory center is stimulated.

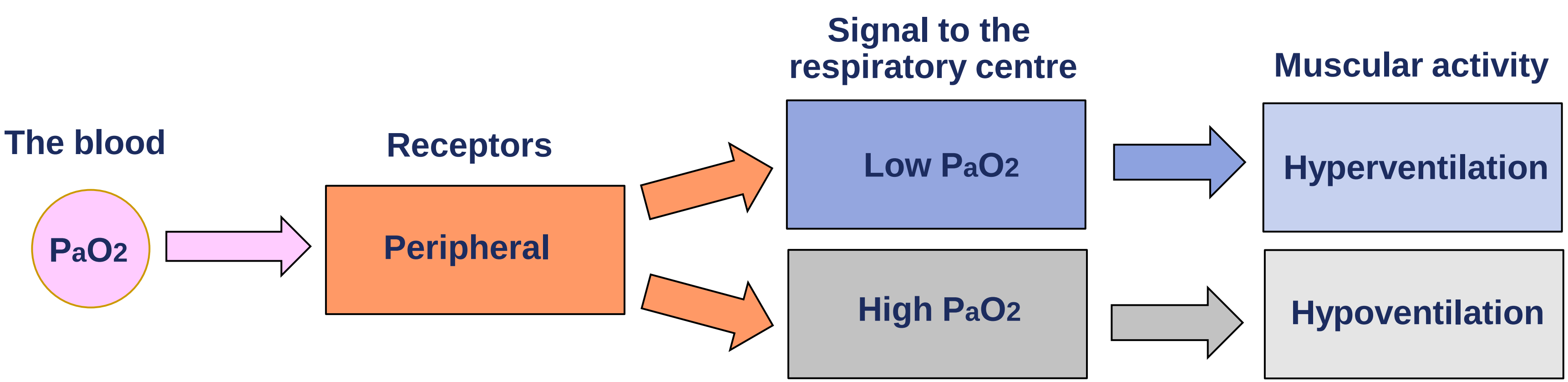


Brain cells are extremely sensitive to oxygen deprivation and can begin to die within five minutes after oxygen supply has been cut off.

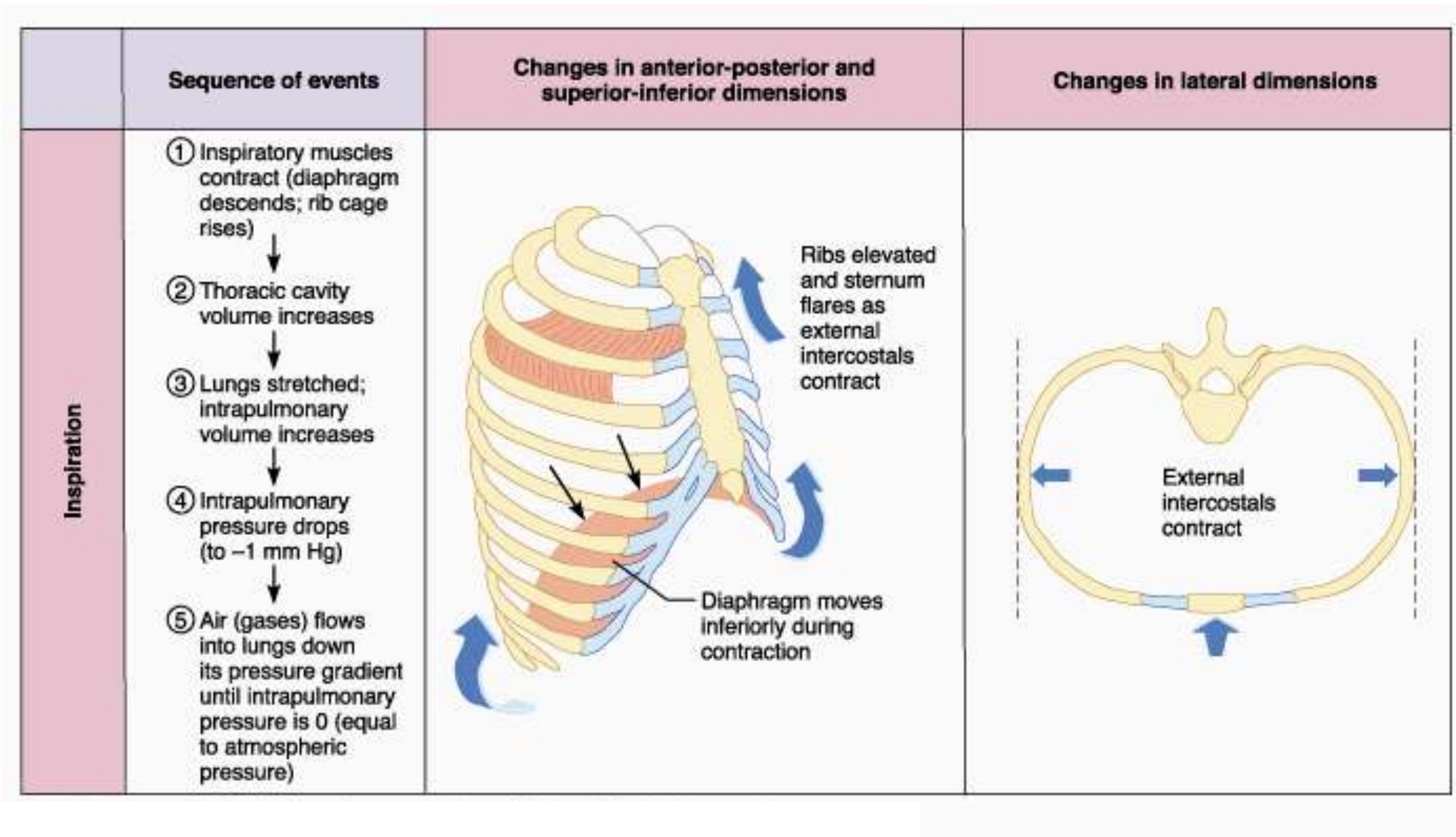
Impulses from receptors and regulation of breathing



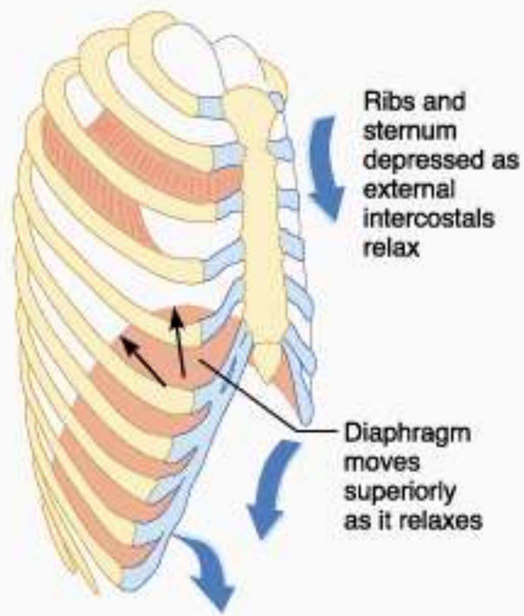
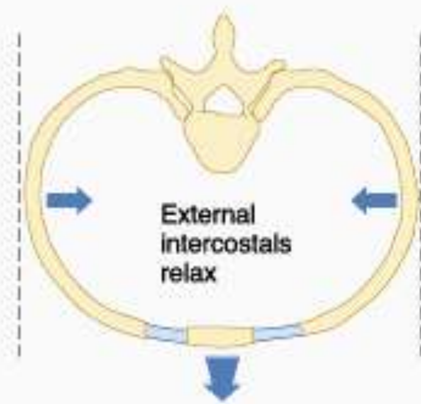
The regulation of breathing in a patient with chronic lung disease



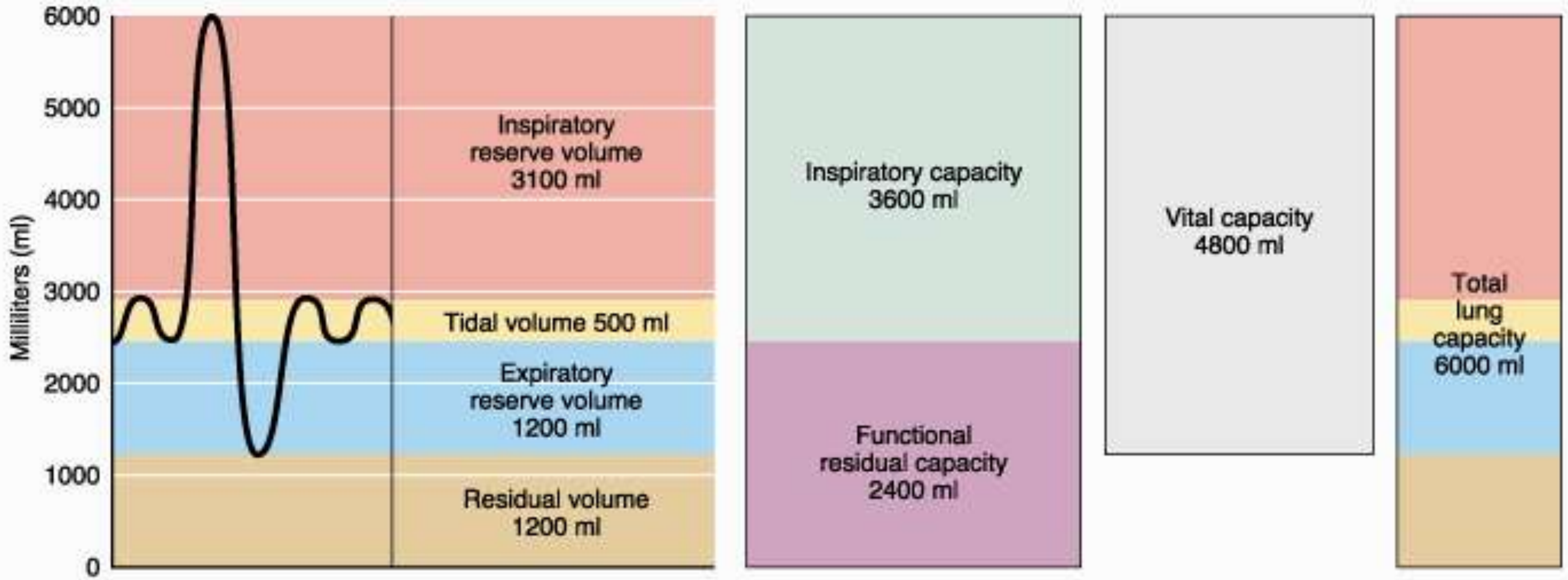
Muscular activity during Inspiration



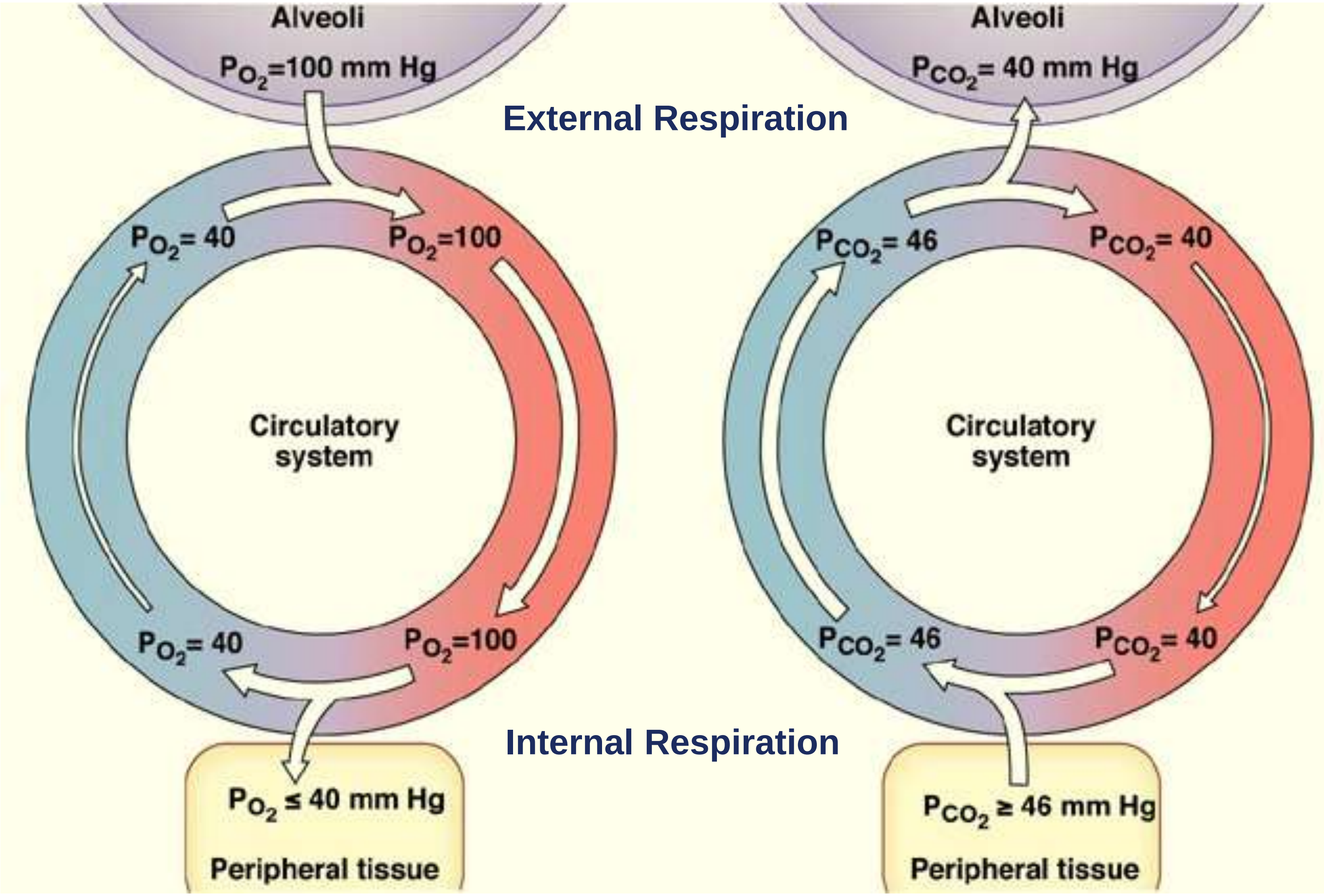
Muscular activity during Expiration

	Sequence of events	Changes in anterior-posterior and superior-inferior dimensions	Changes in lateral dimensions
Expiration	① Inspiratory muscles relax (diaphragm rises; rib cage descends due to gravity) ↓ ② Thoracic cavity volume decreases ↓ ③ Elastic lungs recoil passively; intrapulmonary volume decreases ↓ ④ Intrapulmonary pressure rises (to +1 mm Hg) ↓ ⑤ Air (gases) flows out of lungs down its pressure gradient until intrapulmonary pressure is 0		

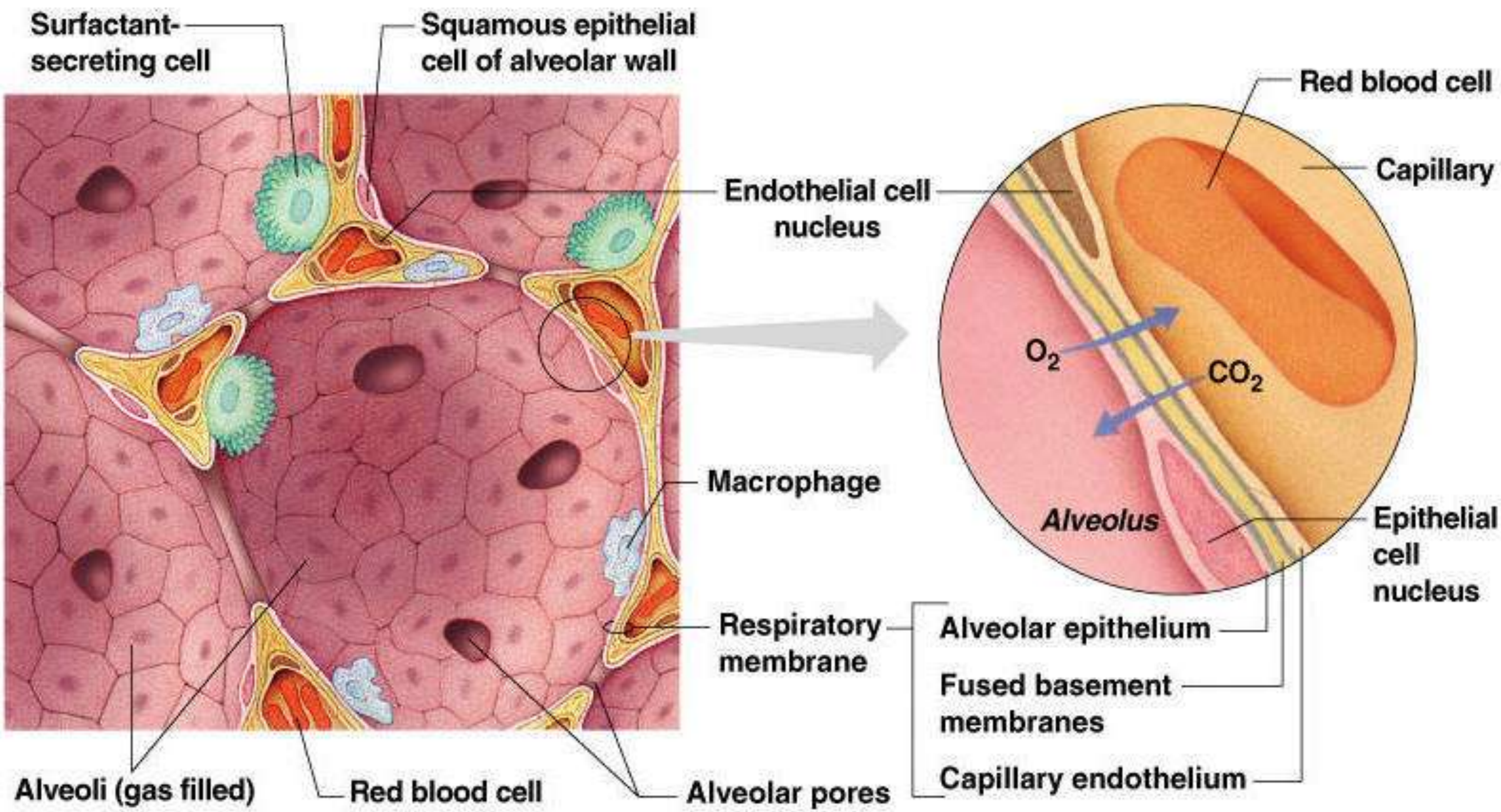
Measurement of lung volumes and capacities with spirometer



Physiology Pulmonary System



Physiology Pulmonary System



Factores affecting ventilation

a) **Compliance**

Measurement of the distensibility of the respiratory tissue. Elasticity of the pulmonary tissues is primarily due to its interstitial makeup of elastin and collagen fibers.

$$\textbf{Total lung compliance} = \frac{\textbf{Change in Volume}}{\textbf{Change in Pressure}}$$

Two forms of compliance

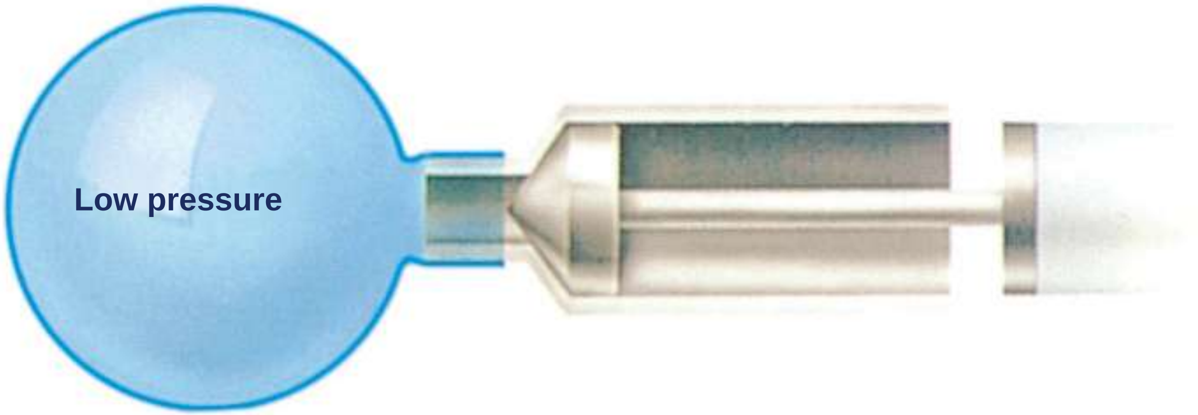
- **Static compliance**
  Truest measure of the compliance of the lung tissue. It is measured when there is no gas flowing into or out of the lung. (Normal value are 70 to 100 ml/cm H_2O)

$$\textbf{Static compliance} = \frac{\textbf{Exhaled tidal Volume}}{\textbf{Plateau – PEEP}}$$

- **Dynamic compliance**
  Measurement taken while gases are moving in the lung, therefore it measure the resistance to the gas flow too.(Normal value are 50 to 80 ml/cm H_2O)

$$\textbf{Dynamic compliance} = \frac{\textbf{Exhaled tidal volume}}{\textbf{Peak inspiratory pressure - Peep}}$$

High compliance



Low compliance

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b) Resistance

Measurement of the opposition to the flow of gases through the airways.
There are two type of resistance.

1) Tissue Resistance caused by tissue friction during inspiration and expiration normally makes up about 20% of total resistance.

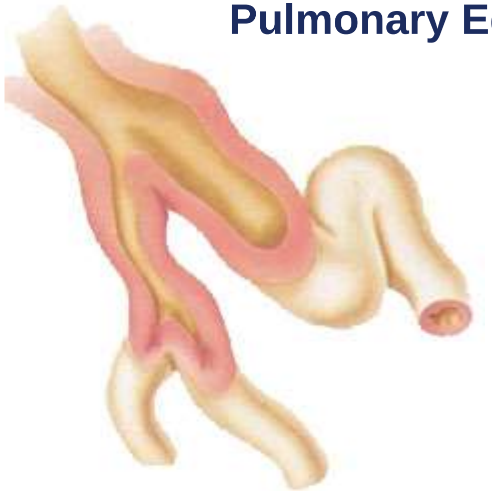
2) Airway resistance is opposition to the flow of gas caused by friction between the wall of the airway and gas molecules, as well as viscous friction between gas molecules themselves.(Normal values 0.5 to 3.0 cmH_2O/sec, at standard flow rate 0.5 L/sec)

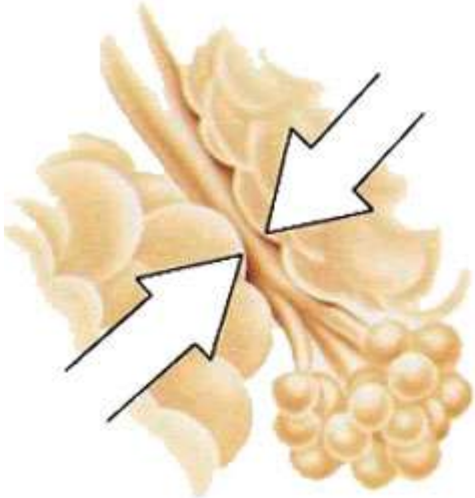
$$\textbf{Airway resistance} = \frac{\textbf{Peak pressure – Plateau pressure}}{\textbf{Flow}}$$

Factors affect airway resistance includes airway length, radius and the flow rate.

Bronchospasm

Pulmonary Edema





Emphysema

Foreign particles

Excessive Secretions

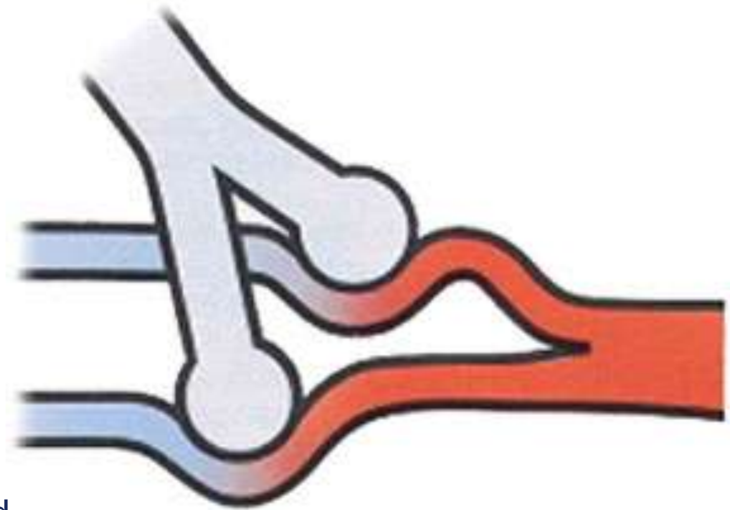
Ventilation and Purfusion Relationship

"V" - Ventilation - the air which reaches the lungs.

"Q" - Perfusion - the blood which reaches the lungs.

Normal ventilation - perfusion balance

- The blood flow is normally greatest in the most dependent parts of the lungs, due to the effect of gravity.
- If the flow of blood is cut off from one lung, then there will be twice the normal flow in the other lung.
- Normal alveolar ventilation of 4 l/min and a pulmonary blood flow of 5 l/min, the ratio is 4/5=0.8.
- If the ratio is high, PaO_2 rises and $PaCO_2$ diminishes.
- If the ratio is low, PaO_2 is markedly reduced and $PaCO_2$ rises somewhat.



An area with no ventilation (and thus a V/Q of zero) is termed "shunt."

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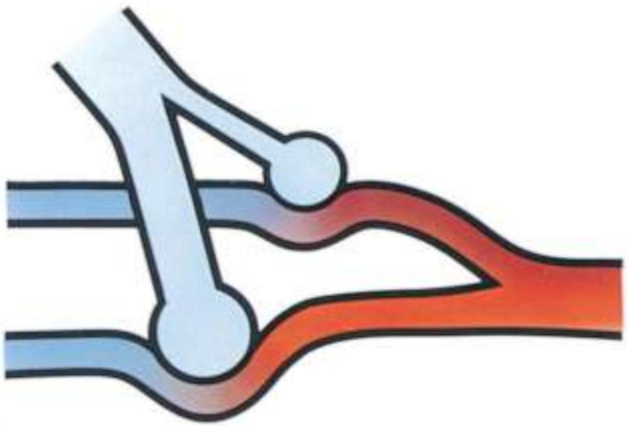
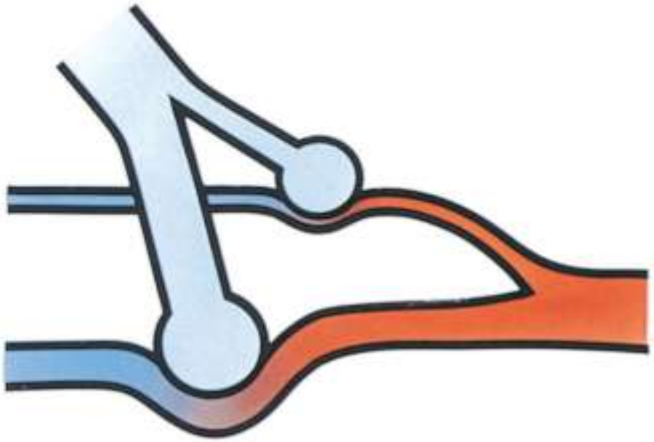
Impaired Ventilation

- Blood which supplies poorly ventilated alveoli (with low PaO_2) cannot be adequately oxygenated.
- Therefore a certain amount of incompletely oxygenated blood enters the arterial circulation and thereby reduces PaO_2 (physiological shunt).



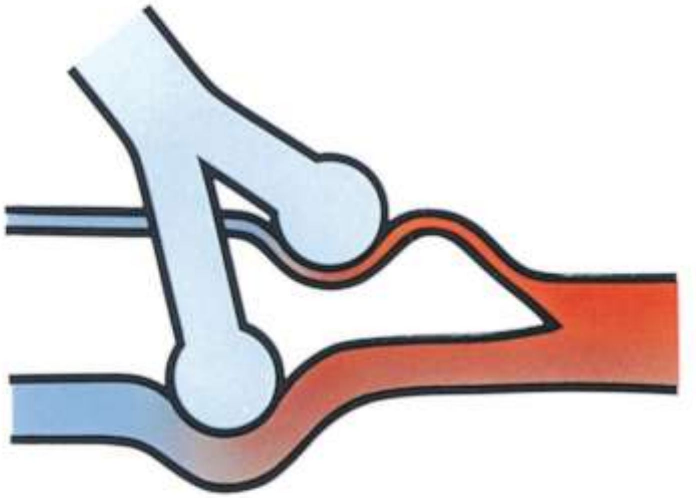
Compensatory changes in perfusion for impaired ventilation

- A low PaO_2 and a raised $PaCO_2$ initiates a blood vessel construction so that blood flow to under-ventilated alveoli diminishes and instead is redirected to well-ventilated alveoli.



Impaired Perfusion

- Good ventilation of poorly perfused sections of lung tissue, for example, in pulmonary embolus, gives rise to a large dead space.
- Cardiac output is then unevenly distributed within the lungs without a corresponding redistribution in ventilation.



An area with no perfusion (and thus a V/Q of infinity) is termed dead space.

Arterial blood gases

An arterial blood gas (ABG) test measures the pH and the levels of oxygen and carbon dioxide from the arterial blood.

This test is used to check how well the lungs are able to move oxygen into the blood and remove carbon dioxide from the blood.

Four-step guide to ABG analysis:

1. Is the pH normal, acidosis or alkalosis?
2. Are the PCO_2 or HCO_3 abnormal? Which one appears to influence the pH.
3. If both the PCO_2 and HCO_3 are abnormal, the one which deviates most from the normal is most likely causing an abnormal pH.
4. Check the PO_2, is the patient hypoxic.

Normal Arterial Blood Gas Values

pH = 7.35 - 7.45

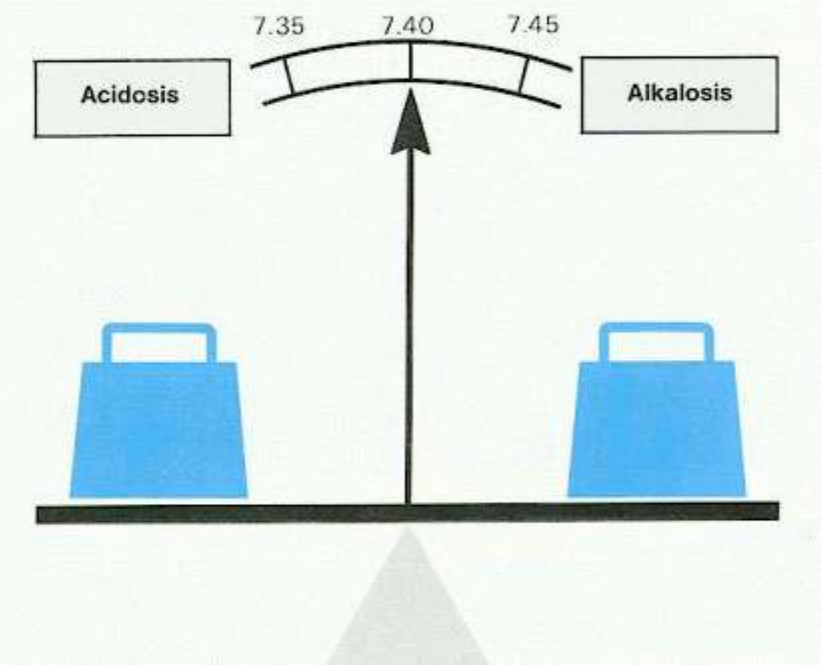
$PaCO_2$ = 35 - 45 mm Hg

PaO_2 = 80 - 95 mm Hg

HCO_3 = 22 - 26 mEq/L

O_2 Saturation = 95 - 99%

BE = +/- 1



Why ABG Is Done

- Check for severe breathing problems and lung diseases, such as asthma, cystic fibrosis, or chronic obstructive pulmonary disease (COPD).
- See how well treatment for lung diseases is working.
- Find out if you need extra oxygen or help with breathing (mechanical ventilation).
- Find out if you are receiving the right amount of oxygen when you are using oxygen in the hospital.
- Measure the acid-base level in the blood of people who have heart failure, kidney failure, uncontrolled diabetes, sleep disorders, severe infections, or after a drug overdose.

	pH	$PaCO_2$	HCO_3
Respiratory Acidosis			
Acute	< 7.35	> 45	Normal
Compensated	Normal	> 45	> 26
Respiratory Alkalosis			
Acute	> 7.45	< 35	Normal
Compensated	Normal	< 35	< 22
Metabolic Acidosis			
Acute	< 7.35	Normal	< 22
Compensated	Normal	< 35	< 22
Metabolic Alkalosis			
Acute	> 7.45	Normal	> 26
Compensated	Normal	> 45	> 26

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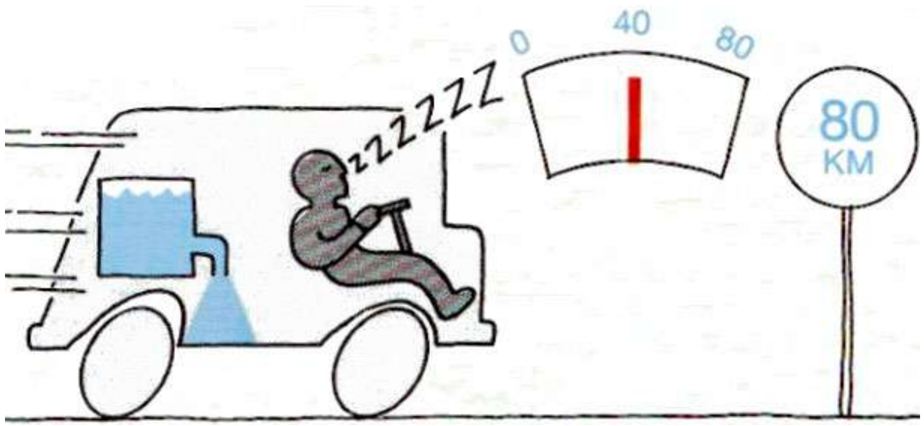
Who requires ventilator?

Post-Operative	Respiratory	Circulatory	Neurological	Trauma
• Major Abdominal • Brain • Cardiac surgery	• ARDS • Pneumonia • COPD • Acute Asthma • Interstitial Lung Disease • Pleural Disease • Disorder of sleep • Aspiration Pneumonia • Smoke inhalation • Drowning	• Venous thromboembolisum • Cardiac arrest • Myocardial Infarct • Left ventricular failure • Low cardiac Output	• Stork • Status epileptics • Drug overdose • Poisoning • Respiratory Muscles failure • Head injury	• Poly trauma • Spinal cord injury • Burns

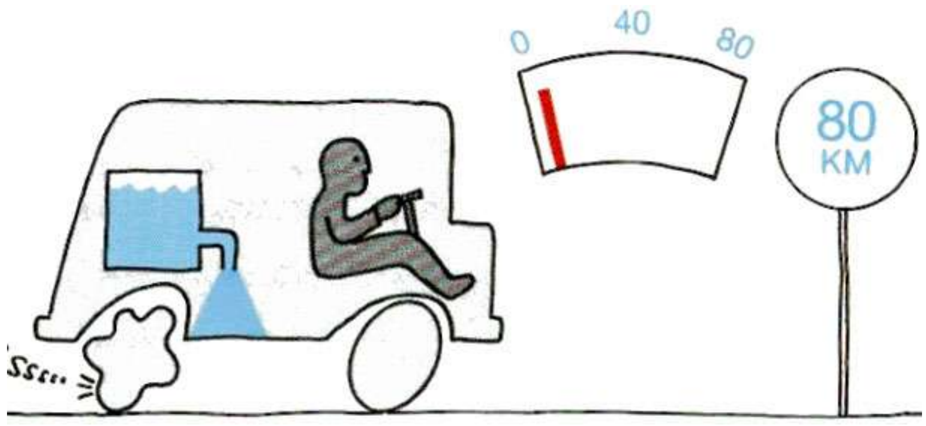
Type of respiratory Failure

	Type I PaO_2 < 60 mmHg and $PaCO_2$ < 45mmHg Acute	 Chronic	Type II PaO_2 < 80 mmHg and $PaCO_2$ > 45mmHg Acute	 Chronic
Typical blood gases	PaO_2 ↓↓ $PaCO_2$ ⇔ or ↓ pH ⇔ or ↓ HCO_3 ⇔	PaO_2 ↓ $PaCO_2$ ⇔ pH ⇔ HCO_3 ⇔	PaO_2 ↓ $PaCO_2$ ⇔ pH ↓ HCO_3 ⇔	PaO_2 ↓ $PaCO_2$ ↑ pH ↓ or ⇔ HCO_3 ↑
Causes	Asthma Pulmonary embolus Pulmonary oedema ARDS Pneumothorax Pneumonia	Emphysema Lung fibrosis Lymphangitis carcinomatosa R → L shunt Anaemia	Severe acute asthma Acute epiglottis Inhaled foreign body Respiratory muscle paralysis Flail chest injury Sleep apnoea Brain-stem lesion Narcotic drugs	COPD Primery alveolar hypoventilation Kyphoscoliosis Ankylosing spondylisis
Therapy	Treat underline cause; High-concentration O_2; Mechanical ventilation	Treat underline disorder; Long-term O_2	Treat underline disorder; Controlled low-concentration O_2; Mechanical ventilation or tracheostomy if necessary	Treat underline disorder; Controlled long-term O_2; Mechanical ventilation if necessary

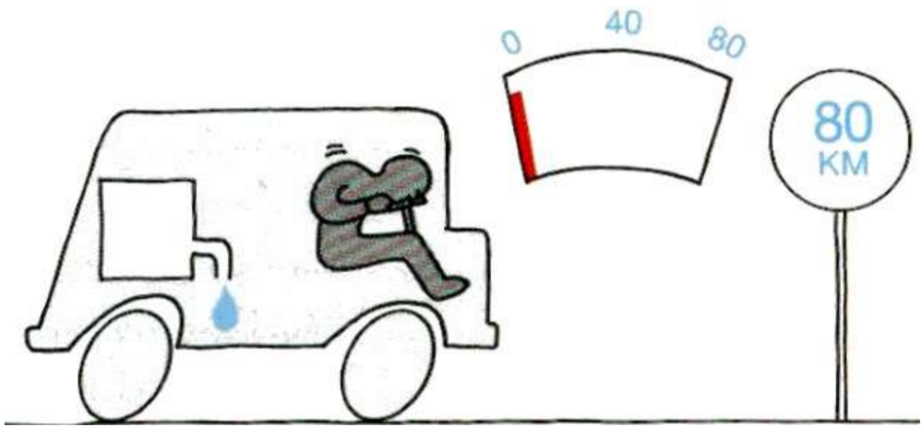
Reduction in central drive



Mechanical defect in chest wall



Respiratory muscle fatigue



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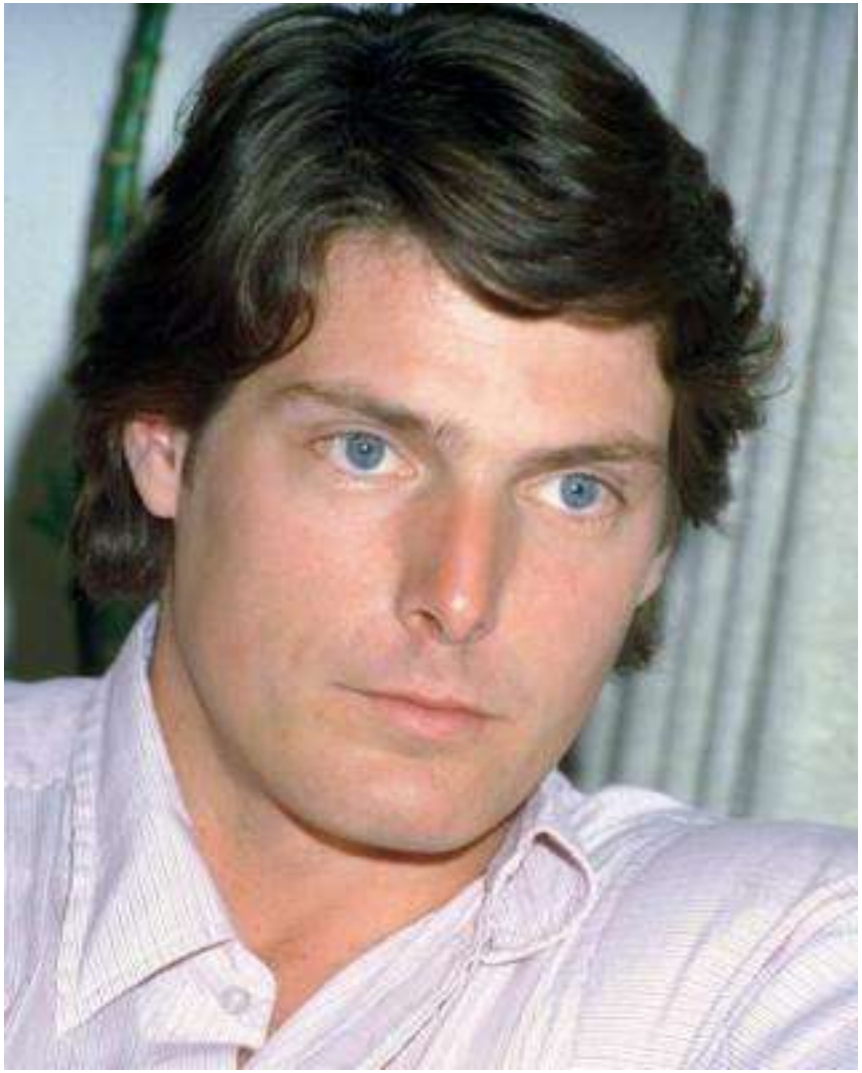


Christopher Reeve

Superman

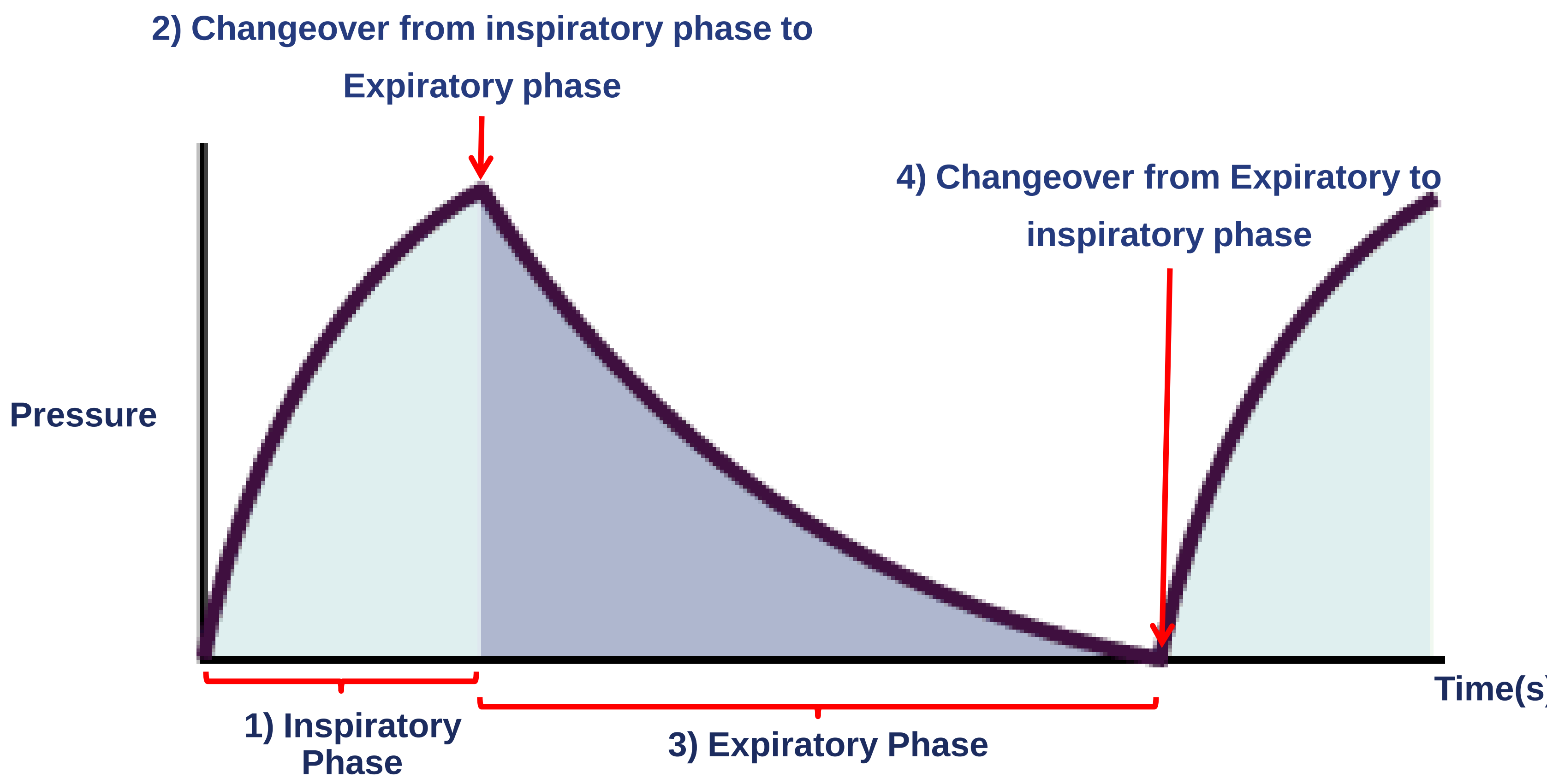
What is a Ventilator and how does it works?

Ventilator is machine designed to alter, transmit and direct applied energy in a predetermined manner to perform useful work.

- The principal benefits is to improved gas exchange and decreased work of breathing.
- All modern ventilators used in inpatient clinical settings are Positive Pressure Ventilators.
- Positive Pressure Ventilators uses a power source, known as the drive mechanism, to force air into the lungs during inspiration.
- Expiration occurs passively during Positive Pressure Ventilation.
- If the machine has to perform the respiratory cycle, it must be told.
  a) What the component phase of respiratory cycle.
  b) How to carry out each of the phases as determined by the setting of the phase variable.
- Ventilator has four basic phase that it must complete in providing a ventilatory cycle to the patients.

  1. **Inspiration**
  2. **Inspiratory-expiratory changeover**
  3. **Expiration**
  4. **Expiratory-inspiratory changeover**

Phase Variables of respiratory cycle in ventilator



1. **Inspiratory Phase**
   - Positive pressure is generated in order to create a pressure gradient that leads to lung inflation and the thoracic cavity to expand.
   - Pressure within the airway, alveoli and intrapleural spaces all become positive during inspiration.
2. **Inspirator-Expiratory Changeover**
   - Ventilator are classified by the mechanism that cycles ventilation from the inspiratory phase to expiratory phase.
   - The mechanisms that cycle the inspiratory-expiratory change over:
     a) **Volume cycle ventilation**.
     Ventilator cycle to end inspiration and begin expiration when a predetermined volume is delivered into the Pt's circuit.
     b) **Time cycled ventilation**
     Inspiration ends and expiration begins after a predetermined time interval has been reached. Cycling may be controlled by timing mechanism or I:E ratio.
     c) **Pressure cycled ventilation**
     Inspiration ends and expiration begins after a predetermined maximum airway pressure limit is reached.

3. Expiratory Phase

- Exhalation occurs passively because of the elastic recoil of the lung, but patient passively exhales to a controlled baseline pressure.
- The end-expiratory pressure may be equilibrium with atmospheric pressure or may be above, know as PEEP.

4. Expiratory-Inspiratory changeover

- Once the expiratory phase has been completed, the changeover to the next inspiration phase begins.
- This phase may be initiated by the patient or by the ventilator based on classified mode.
- The variable measured by the ventilator and that determines the initiation of a breath is know as Trigger variable:.

a) **Machine timed trigger**
The ventilator will trigger a breath after a preset time interval, determined by respiratory frequency.

b) **Pressure trigger**
The patient spontaneous respiratory effort decreases the pressure within the inspiratory circuit and inspiration begins.

c) **Flow trigger**
A patient effort draws flow from the circuit (continuous bias flow) and mechanical breaths are initiated when flow into the patient exceeds the set flow threshold.

MAQUET

Ventilator Settings

- O_2 concentration or Fraction of Inspired Oxygen Concentration (FiO_2) Depends on the patients disease condition and ABG report.
- Tidal Volume (Vt or TV) = 6 to 10 ml per body weight.

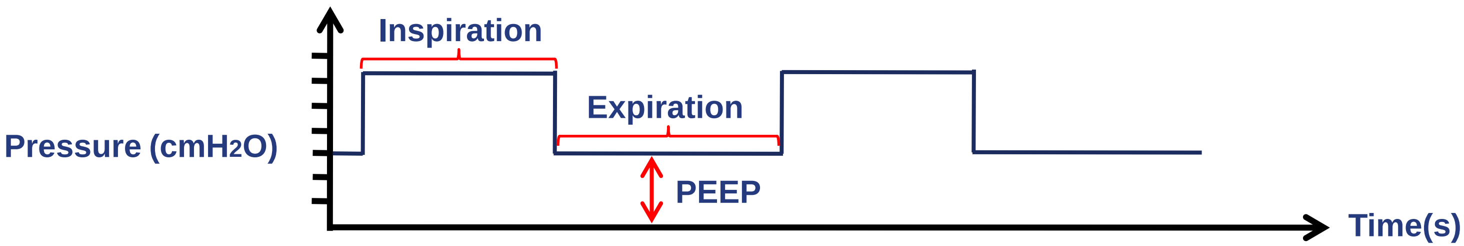
  Predicted Body Weight = {Height (cm) - 152.4} x 0.91+ 50 for male and 45.5 in female.
- Pressure Control level above PEEP
- Pressure Support above PEEP
- Respiratory Rate
- Peak End Expiratory Pressure (PEEP)
- Triggered Sensitivity
  1. Pressure Triggered
  2. Flow Triggered
- Inspiratory-to-Expiratory Ratio
- Inspiratory Pause Time
- Inspiratory Rise Time
- Inspiratory Cycle Off
- Trigger Time Out
- Breath Cycle Time

Ventilator Settings

- **Positive End-Expiratory Pressure (PEEP)**

  A method of ventilation in which airway pressure is maintained above atmospheric pressure at the end of exhalation by means of a mechanical impedance, usually a valve, within the circuit.

  The purpose of PEEP is to increase the volume of gas remaining in the lungs at the end of expiration.



FiO_2/O_2	0.3-0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0
PEEP	5	8	8-10	10	10-14	14	16-18	18-25

Positive physiological effects

1. Improved gas exchange
2. Alveolar recruitment
3. Increased functional residual capacity
4. Redistribution of fluids in the alveolus

Negative physiological effects

1. Decreased Cardiac output
2. Decreased venous return
3. Increased ICP
4. Barotrauma
5. Hypotension

Ventilator Settings

- **Inspiratory-to-Expiratory Ratio (I:E)**
  - It is the duration of inspiration in comparison with expiration.
  - Generaly the I:E ratio is set at 1:2; that is, 33% of the respiration cycle is spent in inspiration and 66% in the expiratory phase.

    Example: Set, RR = 15 b/min; I:E ratio is 1:2
    Therefore, time for one cycle is 60/15 = 4sec
    Than 4/3 = 1.3sec is the time inspiration and 2.7 sec is expiration.
  - Shorter inspiratory time contributes to dead space ventilation by over expanding the most compliant alveoli. Prolonged Expiration at 1:3, 1:4
  - Longer inspiratory time increases the Mean Airway Pressure (MAP), which may lead to hemodynamic instability. Inverse ratio at 2:1, 3:1 or 4:1

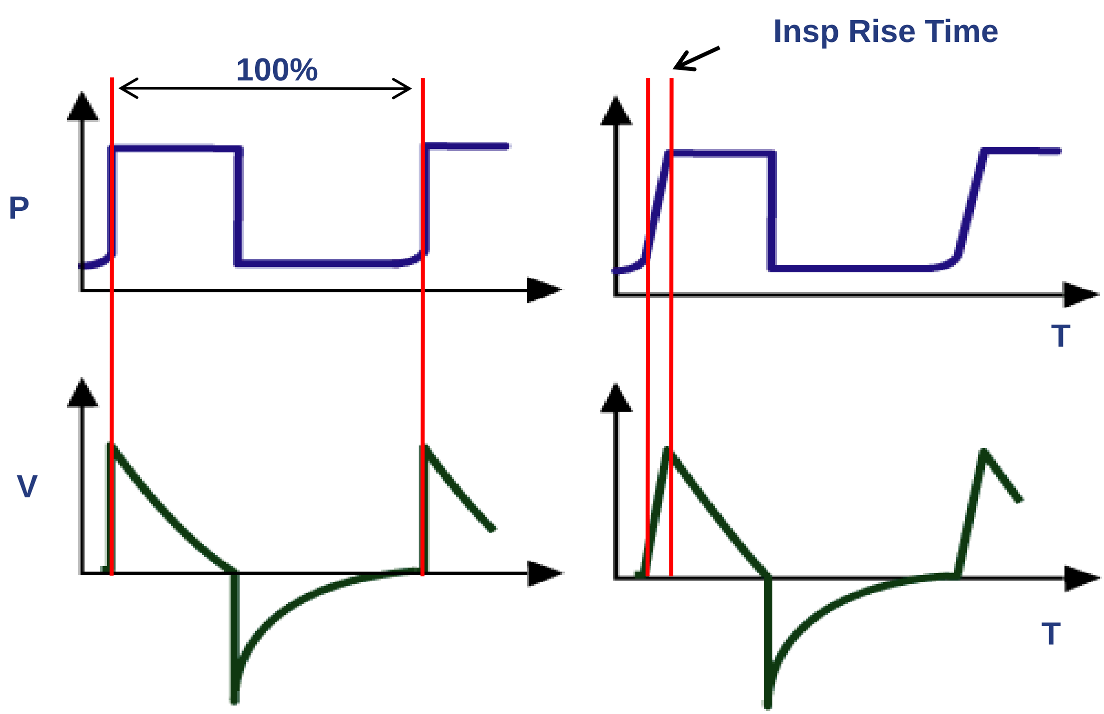
- **Pause time**
  - It is pause in between inspiration and expiration changeover to allowed the distribution of inhaled gases.
  - During this phase there is no flow, both the inspiratory and Expiratory valves are closed.
  - Monitoring the resistance and the compliance of the lungs.

Ventilator Settings

- **Inspiratory Rise Time (%/sec)**

  Is the time taken to reach peak inspiratory flow or pressure at the start of each breath. The flow and pressure can be adapted according to patient need.

  Example: Set RR = 15,
  so the time for each breath is 60/15 = 4sec
  If set Inspiratory rise time is 10%
  then, 4 x10/100= 0.4sec

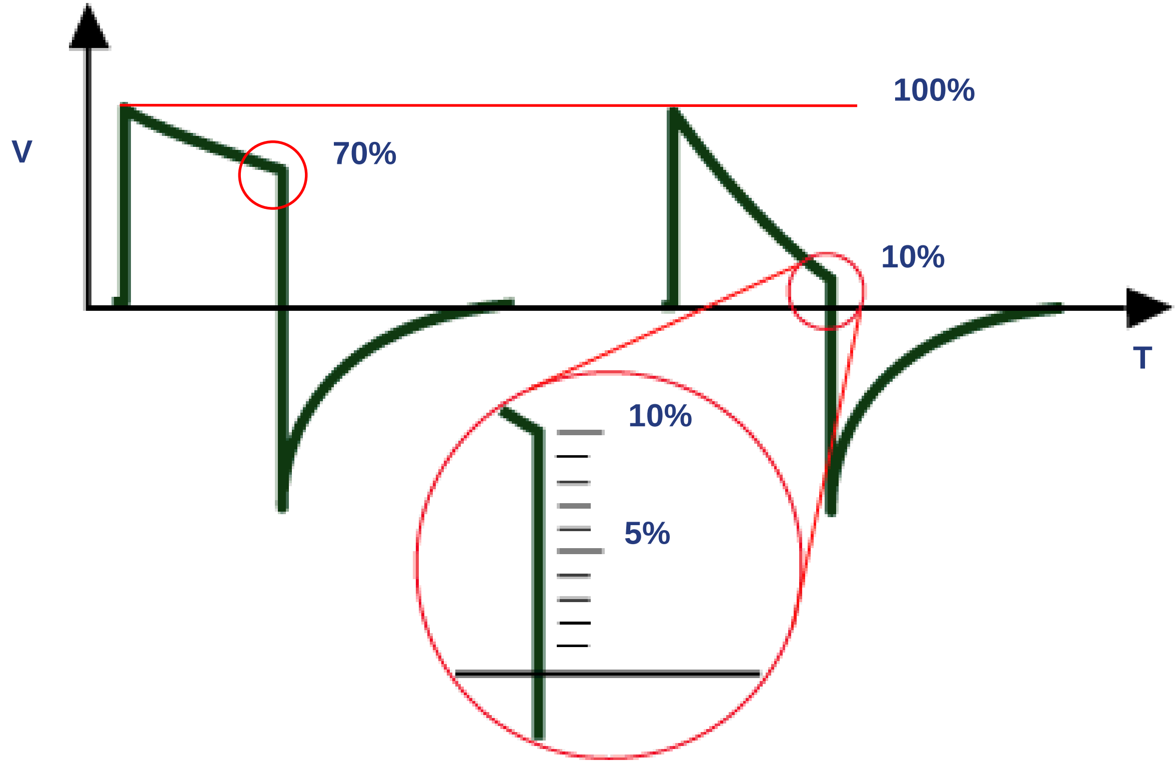


Ventilator Settings

- **Inspiratory Cycle Off (%)**

  Fraction of maximum flow at which inspiratory to switch to expiration.

  Is the point at which inspiration changes to expiration in spontaneous and support mode of ventilation to avoid hyperinflation of lung.



Ventilator Settings

- **Triggered Sensitivity**

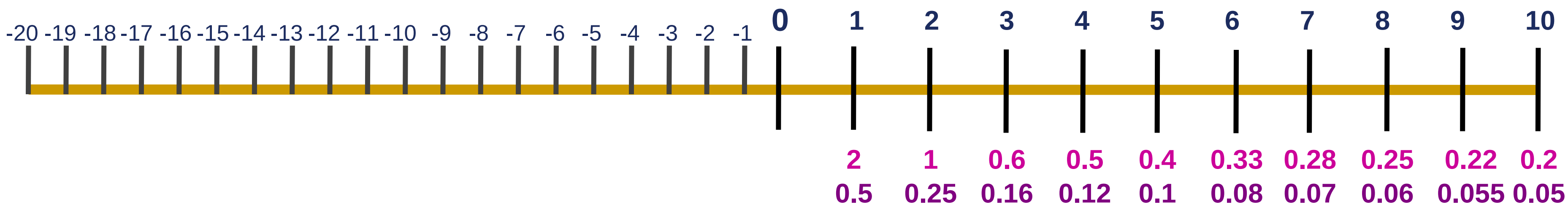
  Determines the level of patient effort needed to trigger the ventilator to start inspiration.

  It can be set either in Flow Triggering (Trigg.Flow) or Pressure Trigger (Trigg.Pressure).

  Flow triggered is preferable as this enables the patient to breath with less effort.

  When patient triggers T appears on the screen.

  - **Pressure Triggered**
    The pressure triggering threshold is indicated by a negative pressure level below baseline. The purple color indication appears on the pressure curve. Sensitivity can be set within the range 0 to -20 cmH_2O.

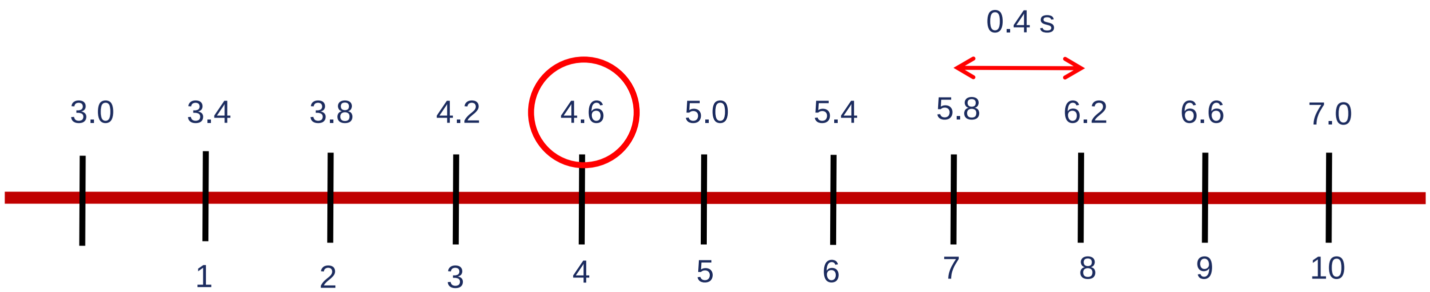


  - **Flow Triggered**
    When the difference between the inspiratory and the expiratory flow equals the preset flow trigger level, the ventilator will start a new inspiration. Threshold is indicated by an inspiratory flow above baseline bias flow (2L/min in Adult and 0.5L/min in Neonate) and purple color indication appears on the flow curve.

Ventilator Settings

- **Trigger Time Out**
  Is the maximum allowed apnea time before controlled ventilation is activated. It initially adapts with a dynamic trigger timeout, increases successively during the first 10 breaths.

  Example: RR set= 20 b/min
  Time for each breath is 60/20 = 3sec
  Trigger timeout set = 7 sec
  then, 7-3 = 4s, divided in to 10 steps = 0.4 sec

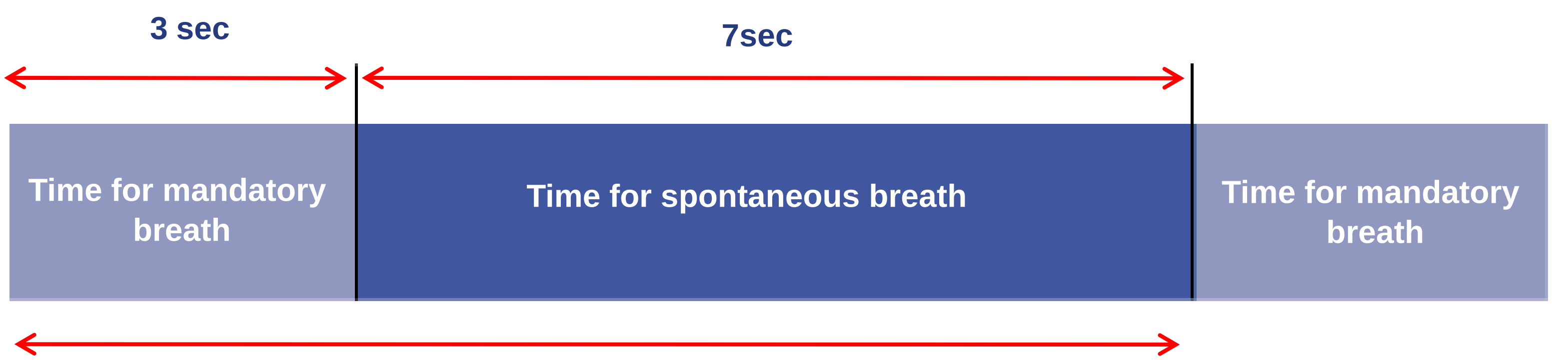


If the patient stop breathing after 4 breath, the ventilator delivers a controlled breath after 4.6s. After 10 triggered breath the ventilator waits 7s before providing a controlled breath.

Ventilator Settings

- **Breath Cycle Time**
  Is the length of the time allowed for total respiratory cycle for the mandatory breaths.

  Example: RR = 6 b/min
  If Breath cycle Time set is 3sec with I:E Ratio = 1:2
  so1 sec Inspiration and 2 sec Expiration.
  Time for one cycle is 60/6 = 10sec
  So, the time for spontaneous breath is 10 - 3 = 7sec



MAQUET

Type of Ventilation and Modes

1. **Non-Invasive Ventilation (NIV)**

   A flow of gas is delivered to the conscious patients airway via tight fitting face or nasal mask.

   - **NIV Presser Support (PS)**
   - **NIV Presser Control (PC)**
   - **Nasal CPAP (Infants)**

2. **Invasive Positive Pressure Ventilation (IPPV)**

   A flow of gas is delivered to the patients airway via Endotracheal / Tracheostomy tube.

Controlled modes	Supported modes	Combined modes
• VC • PC • PRVC	• PS • VS	• Automode: VC-VS PC-PS PRVC-VS • SIMV: VC +PS PC + PS PRVC + PS • Bi-Vent

Non-Invasive Ventilation (NIV)

Indications

A. Acute respiratory failure

1. Hypercapnic acute respiratory failure

- Acute exacerbation of COPD
- Post extubation
- Weaning difficulties
- Post surgical respiratory failure
- Thoracic wall deformities
- Cystic fibrosis
- Status asthmatic
- Acute respiratory failure in Obesity hypoventilation Syndrome

2. **Hypoxaemic acute respiratory failure**

Evidence is less convincing to show efficacy of NIV in hypoxaemic respiratory failure.

The possible indications are:

- Cardiogenic pulmonary oedema
- Community acquired pneumonia
- Post traumatic respiratory failure
- ARDS
- Weaning difficulties

B. **Chronic Respiratory Failure**

C. **Immunocompromised Patients**

D. **Do Not Intubate Patients**

Modes for NIV

PC - Pressure Control

PS - Pressure Support

Nasal CPAP for Infants -
Continuous Positive Airway Pressure

Prerequisites for successful Non-Invasive support

- Patient is able to cooperate.
- Patient can control airway and secretions.
- Adequate cough reflex .
- Patient is able to co-ordinate breathing with ventilator.
- Patient can breathe unaided for several minutes.
- Haemodynamically stable.
- Blood pH>7.1 and $PaCO_2$ <92 mmHg.
- Improvement in gas exchange, heart rate and respiratory rate within first two hours.
- Normal functioning gastrointestinal tract.

MAQUET

NIV Presser Support

- Provide adequate support for patients who do not have sufficient capacity.
- Provide ventilation in which every breath is patient triggered.
- Provide support during the patients inspiration according to the preset pressure support level.
- Maintain an adequate Positive End Expiratory Pressure PEEP.
- Provide a fast and flexible response to the patient's need.
- Provide an accurate monitoring and alarm function.
- Facilitate the weaning process.

Settings

- PS (Pressure support) above PEEP.
- PEEP (cmH_2O)
- Oxygen concentration (%)
- Inspiratory rise time (% of breath cycle time/sec)
- Inspiratory cycle off (%)
- NIV backup rate, (breaths/min)
- NIV backup Ti (time in sec)

Trigger sensitivity cannot be set in NIV, Pt's either lowers the pressure to 1 cmH_2O below PEEP during expiratory or an expiratory flow decrease of 6 ml during 100ms, breath is delivered.

MAQUET

NIV Presser Control

The ventilator delivers a flow to maintain the preset pressure at a preset respiratory rate and during a preset inspiratory time.

- Provide a constant pressure level during the entire inspiration.
- Enable controlled respiratory rate.
- Provide a decelerating flow pattern.
- Provide ventilation if the breath is patient triggered.
- Maintain an adequate Positive End Expiratory Pressure PEEP.
- Provide an accurate monitoring and alarm function.

Settings

- PC (Pressure Control) above PEEP.
- Respiratory rate (b/min)
- PEEP (cmH_2O)
- Oxygen concentration (%)
- I:E ratio or Ti (insp. time in sec)
- Inspiratory rise time (% of breath cycle time/s)

The bios flow is delivered with a constant flow of 7.5 l/min to detect the breathing effort of the patient.

MAQUET

Nasal CPAP

CPAP help to recruit collapsed alveoli, improve oxygenation, stabilize the chest wall and inhibits paradoxical movements during inspiration and collapse during expiration.

- Regarded as alternative to intubation.
- Treatment of respiratory condition like RDS in premature infants.
- Easy to wean infants off mechanical ventilation.
- Also handle the problem of apnea of premature.
- Infants from 500g to 10 kg can be ventilated via nasal mask or prongs.

Settings

- CPAP (Continuous Positive Airway Pressure)
- Oxygen concentration (%)

The maximum available flow in nasal CPAP is 33 l/min

Complications of NIV

- Leak causing redness to the eyes.
- Pressure source to the bridge of the nose.
- Abdominal distention.
- Aspiration.
- Discomfort.
- Claustrophobia (Fear of confined space)
- Dryness of nasal mucosa and mouth.
- Un synchronization.
- Patients no able to sleep because of sound.

MAQUET

Invasive Positive Pressure Ventilation (IPPV)

Control Modes

a) Volume Control mode (VC)

Preset tidal volume is delivered with a constant flow during the preset inspiratory time and the preset respiratory rate.

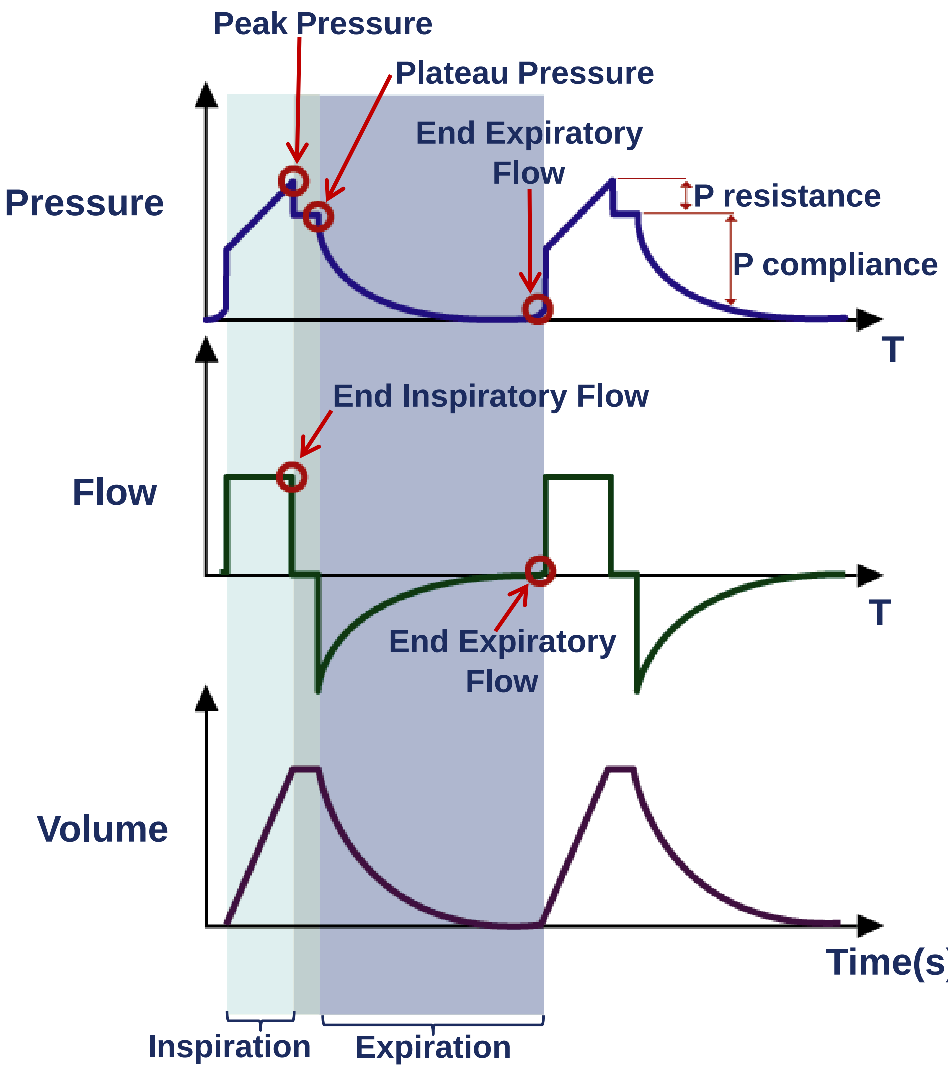
- Provide a controlled inspiratory time and pause time.
- During the pause time both inspiratory and expiratory valves are closed and no flow is delivered.
- Peak pressure can vary breath to breath if the pt’s compliance and resistance changes.
- Patient makes an inspiratory effort during the expiratory phase an assisted breath is delivered.
- Extra flow is delivered if the patients decrease airway pressure by 3 cmH_2O during the inspiratory phase.

If the patient exhale during Inspiration the pressure increases more than 3cmH_2O above set, expiratory valve opens and allows expiration.

VC

Settings
• Tidal volume (ml) • Respiratory Rate (b/min) • PEEP (cmH_2O) • Oxygen concentration (%) • I:E ratio • Pause time (%/s) • Inspiratory rise time(% breath cycle time/sec) • Trigger sensitivity

Alarm Settings
• Pressure (cmH_2O) • Minute Volume (cmH_2O) • Respiratory Rate • End Exp Pressure • Sound level



b) <u>Pressure Control mode (PC)</u>

Ventilator delivers a flow to maintain the preset pressure at a preset respiratory rate and preset inspiratory time.

- Pressure is constant during the inspiratory time and the flow is decelerating.
- The volume can vary from breath to breath if the patient's compliance and resistance change.
- Maximum available flow is 200l/min in Adult and 33 l/min in Infant.
- If for any reason, pressure decrease during inspiration, than the flow from the ventilator will immediately increase to maintain the set inspiratory pressure.
- If the pressure increases to the set upper pressure limit, than the expiratory valve opens and the ventilator switches to expiration.

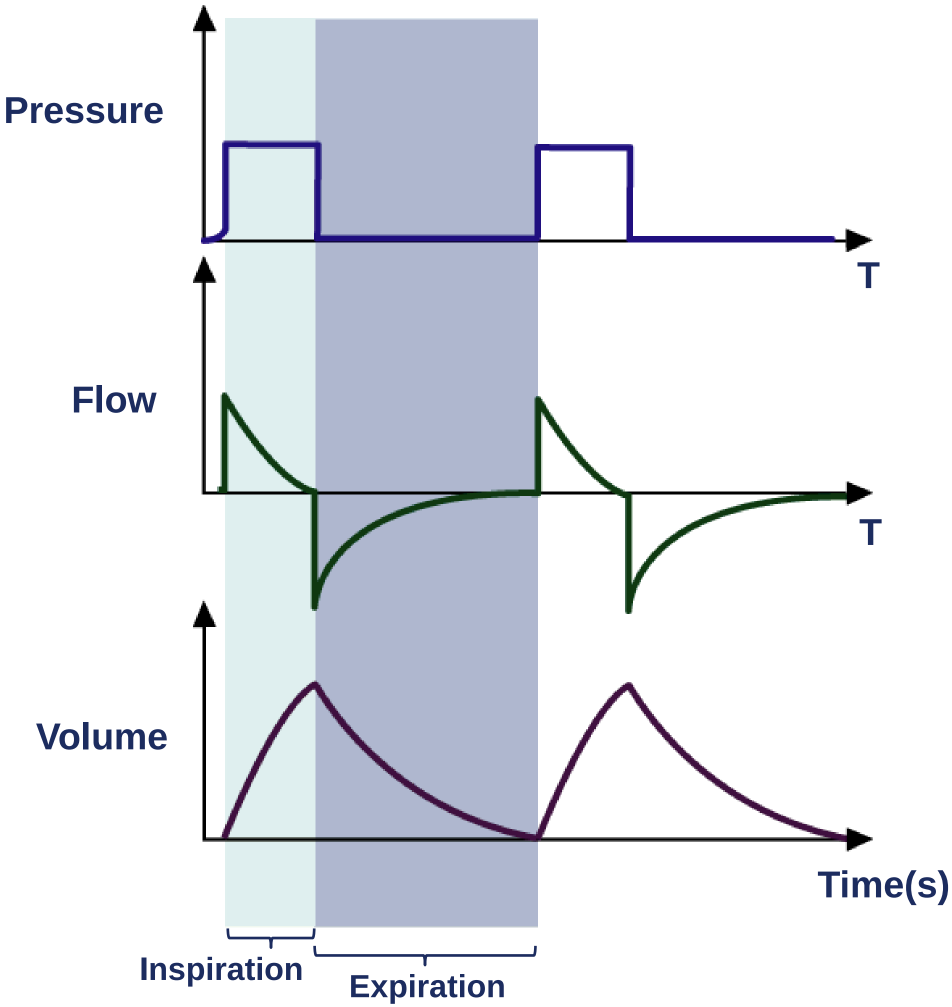
PC

Settings

- PC Pressure Control(cmH_2O)
- Respiratory Rate (b/min)
- PEEP (cmH_2O)
- Oxygen concentration (%)
- I:E ratio
- Inspiratory rise time(% breath cycle time/sec)
- Trigger sensitivity

Alarm Settings

- Pressure (cmH_2O)
- Minute Volume (cmH_2O)
- Respiratory Rate
- End Exp Pressure
- Sound level



c) Pressure Regulated Volume Control mode (PRVC)

Controlled mode of ventilation which combines the volume controlled and pressure controlled ventilation.

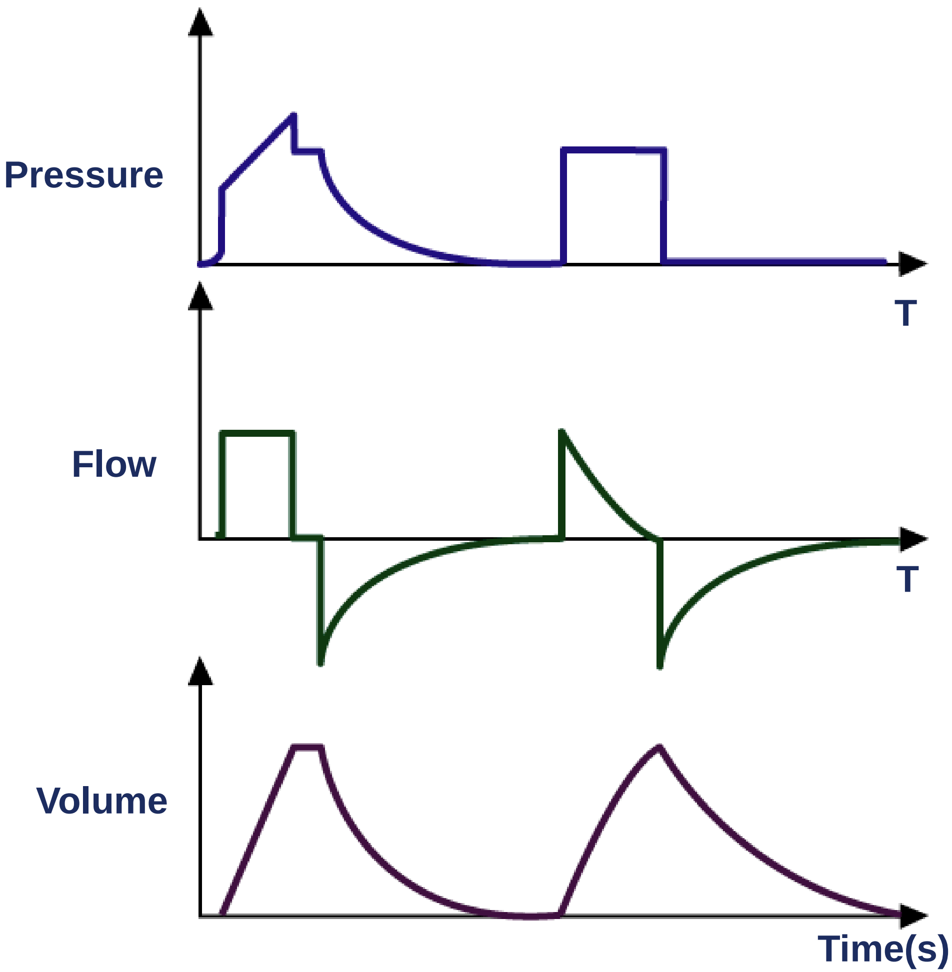
- The physician presets a desired tidal volume, and the ventilator delivers a pressure-limited (controlled) breath until that preset tidal volume is achieved.
- The breath is like a conventional pressure-controlled ventilation breath, but the ventilator can guarantee a predetermined tidal volume.
- First breath delivered to the patient is a volume controlled.
- The plateau pressure is used as the pressure level for the next breath.
- The set tidal volume is achieved by automatic breath-by-breath pressure regulation.
- The ventilator adjusts the inspiratory PC level to the lowest possible level to guarantee the preset tidal volume.
- If the tidal volume increases/decreases below the preset volume than the pressure increases/ decreases by 3cmH2O.
- The maximum available pressure level is 5cmH2O below the preset upper pressure limit.

MAQUET

PRVC

Settings
• Tidal volume (ml) • Respiratory Rate (b/min) • PEEP (cmH_2O) • Oxygen concentration (%) • I:E ratio • Pause time (%/s) • Inspiratory rise time(% breath cycle time/sec) • Trigger sensitivity

Alarm Settings
• Pressure (cmH_2O)



MAQUET

Supported Modes

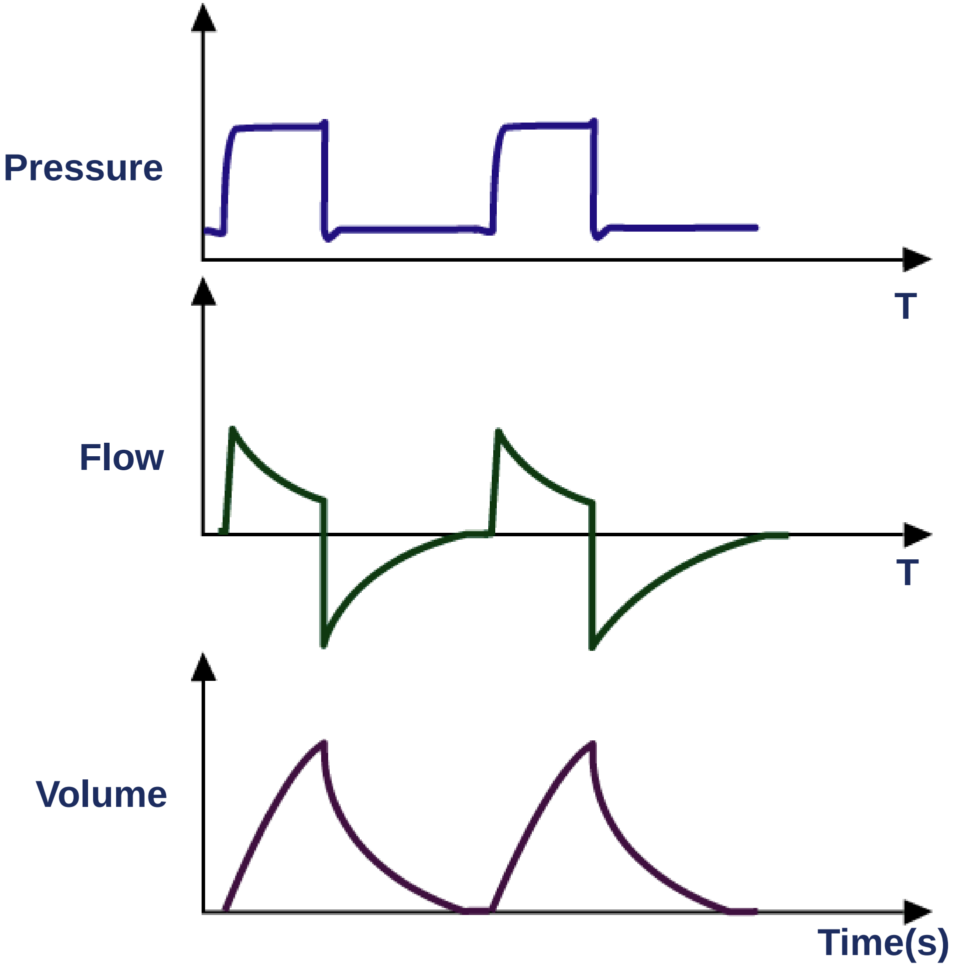
- A spontaneous mode of ventilation where no mandatory breath are given.
- Patient trigger each breath and ventilator delivers support with the preset pressure support.
- The patient regulate the respiratory rate and the tidal volume with support from the ventilator.
- If the patient is not breathing and the set apnea limit is reached, the ventilator will switch to backup controlled ventilation.

a) Pressure Support Mode (PS)

b) Volume Support Mode (VS)

a) Pressure Support Mode (PS)

Settings
• PS(Pressure support) above PEEP • PEEP (cmH_2O) • Oxygen concentration (%) • Inspiratory rise time(% breath cycle time/sec) • Trigger sensitivity • Inspiratory cycle off (%) • Backup ventilation - PC above PEEP (cmH_2O)



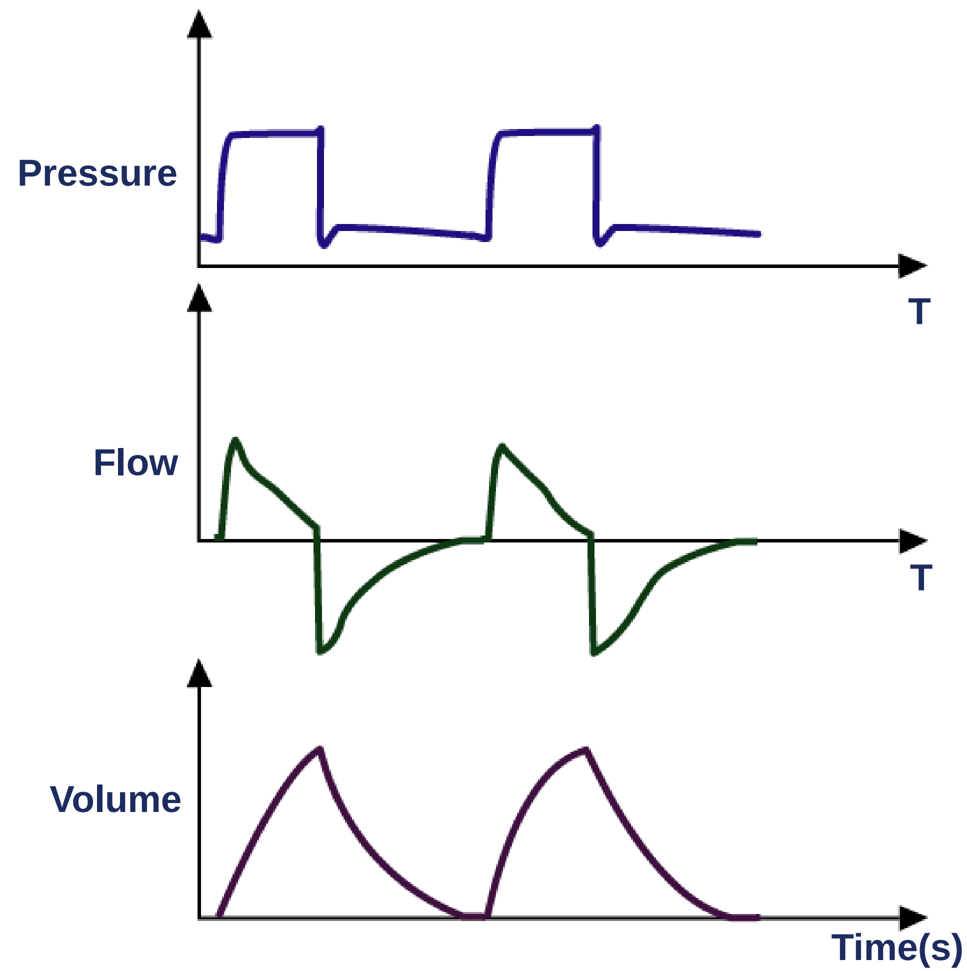
b) Volume Support Mode (VS)

- A spontaneous mode of ventilation where no mandatory breath are given.
- Patient trigger each breath and ventilator delivers support with the preset pressure support.
- The patient regulate the respiratory rate with support from the ventilator.
- Start-up sequence is 4 breath,
- The first breath is given with a support of 10 cmH_2O.
- The ventilator calculates and regulates the pressure needed to deliver the preset Tidal volume.
- During the remaining 3 test breath, the maximum pressure increased is 20cmH_2O.
- After the start-up sequence,the pressure support is automatically adjusted according to the patient's lung compliance and resistance to deliver a preset tidal volume.
- The pre-set tidal volume is maintained by increasing or decreasing the pressure support by 3cmH_2O.
- If the patient is not breathing and the set apnea limit is reached, the ventilator will switch to backup controlled ventilation.

b) Volume Support Mode (VS)

The pre-set tidal volume is maintained by increasing or decreasing the pressure by $3 cmH_2O$.

Settings
• Tidal Volume (ml) • PEEP (cmH_2O) • Oxygen concentration (%) • Inspiratory rise time(% breath cycle time/sec) • Trigger sensitivity • Inspiratory cycle off (%)



Combined Modes

a) Automode

- Automatically controls the transition between controlled and support mode in accordance with patient's breathing efforts.
- It is interactive mode of ventilation.
- It allows the patients to go into support mode automatically if they trigger the ventilator.
- Better adapted to the patients efforts.
- It provide the best possible means of starting the weaning period.

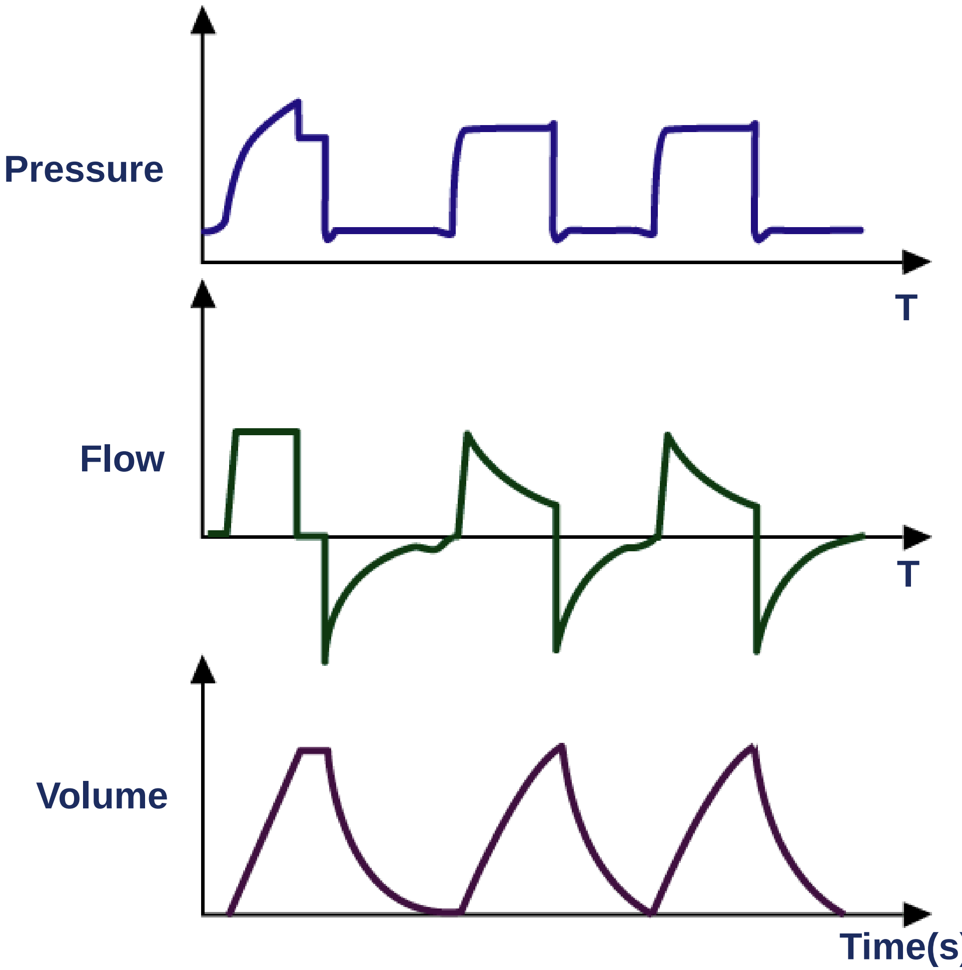
Three different coupling modes combining control and support:

1. **Volume Control ⇔ Volume Support**
2. **Pressure Control ⇔ Pressure Support**
3. **PRVC ⇔ Volume Support**

MAQUET

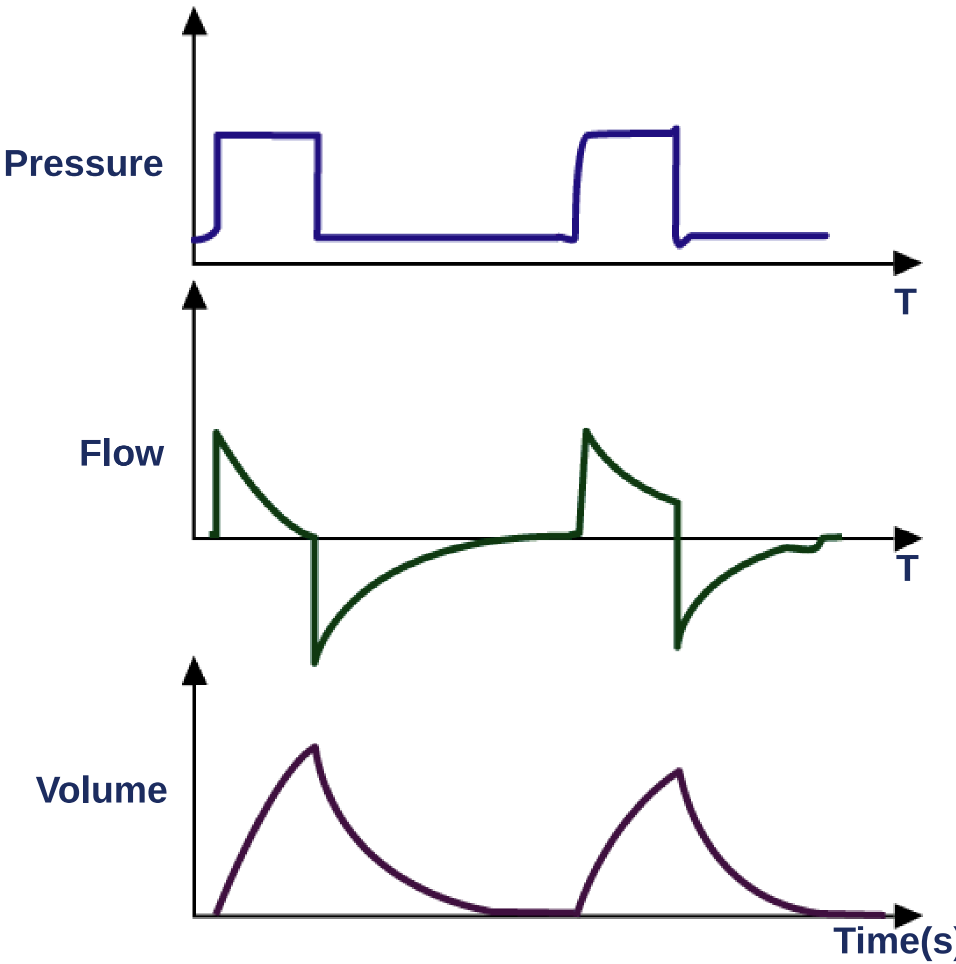
Volume Control-Volume Support Mode

Settings
• Tidal volume (ml) • Respiratory Rate (b/min) • PEEP (cmH2O) • Oxygen concentration (%) • Inspiratory Time (s) • Pause time (%/s) • Inspiratory rise time(% breath cycle time/sec) • Trigger sensitivity • Inspiratory cycle off (%) • Trigger Timeout (s)



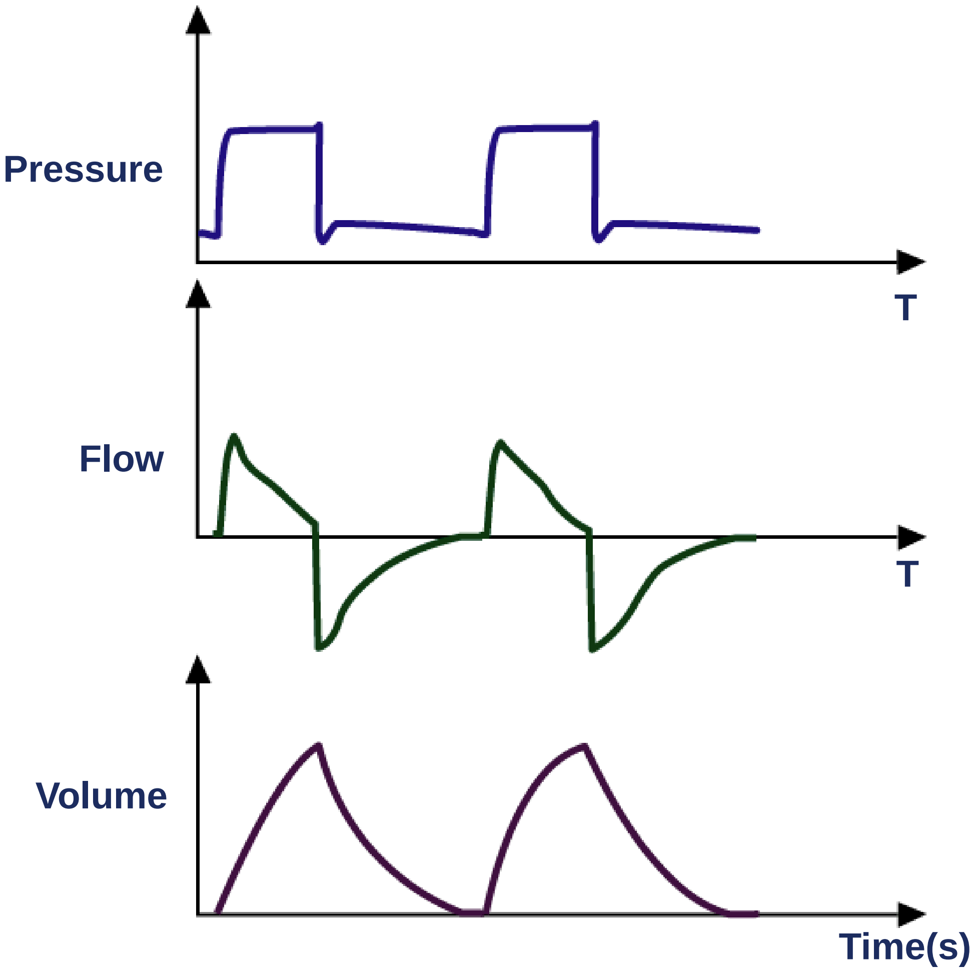
Pressure Control-Pressure Support Mode

Settings
• PC Pressure Control level (cmH_2O) • Respiratory rate (b/min) • PEEP (cmH_2O) • Oxygen concentration (%) • Time Inspiration (s) • Inspiratory rise time(% breath cycle time/sec) • Trigger sensitivity • Inspiratory cycle off (%) • Trigger Timeout (s) • Pressure Supported above PEEP (cmH_2O)



PRVC-Volume Support Mode

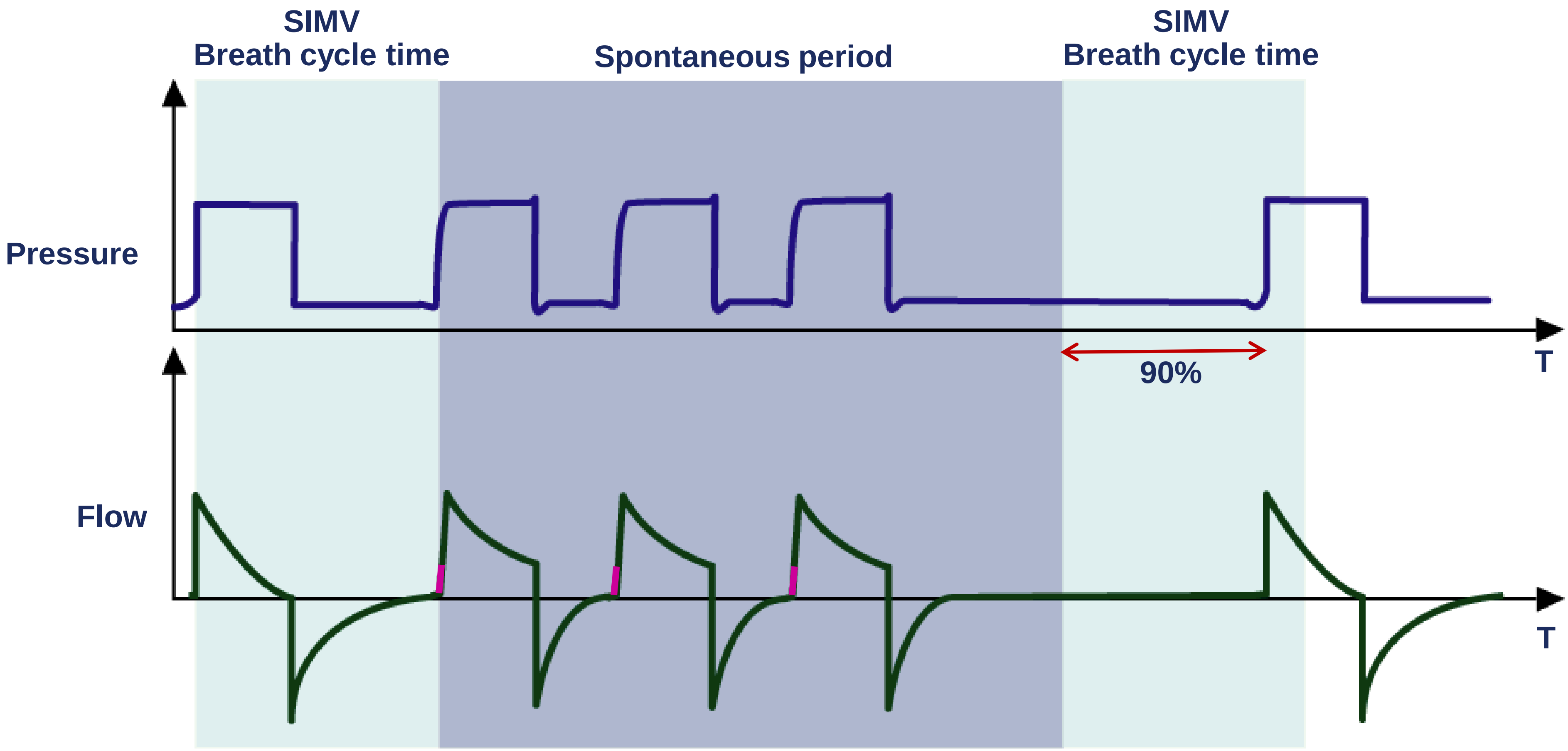
Settings
• Tidal volume (ml) • Respiratory rate (b/min) • PEEP (cmH2O) • Oxygen concentration (%) • Time Inspiration (s) • Inspiratory rise time(% breath cycle time/sec) • Trigger sensitivity • Inspiratory cycle off (%) • Trigger Timeout (s)



b) <u>Synchronized Intermittent Mandatory Ventilation (SIMV)</u>

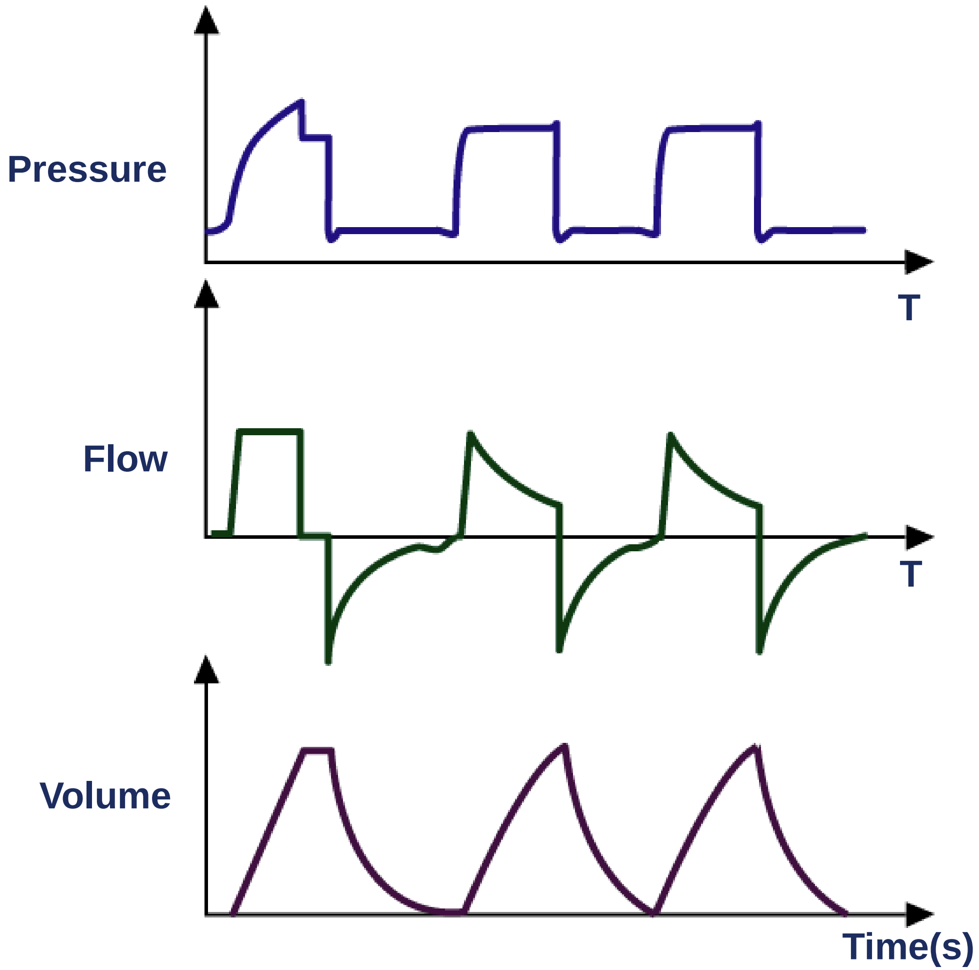
- Delivers mandatory breaths with preset tidal volume/minute volume or preset pressure and a preset respiratory rate.
- This mandatory breaths are synchronized with the breathing efforts of the patient who can breath spontaneous between the breaths.
- Spontaneous breathing is supported with a set pressure support above the PEEP.
- The ventilator will wait during the next SIMV period for the patient to trigger.
- Assist patients during weaning.
- Assist patient who have some, but not sufficient breathing.
- Assist patients who need some controlled breaths.
- If the patients has not triggered within the first 90% of the breath cycle time, than a mandatory breath is delivered.

SIMV


SIMV
Breath cycle time
Spontaneous period
SIMV
Breath cycle time
Pressure
T
90%
Flow
T

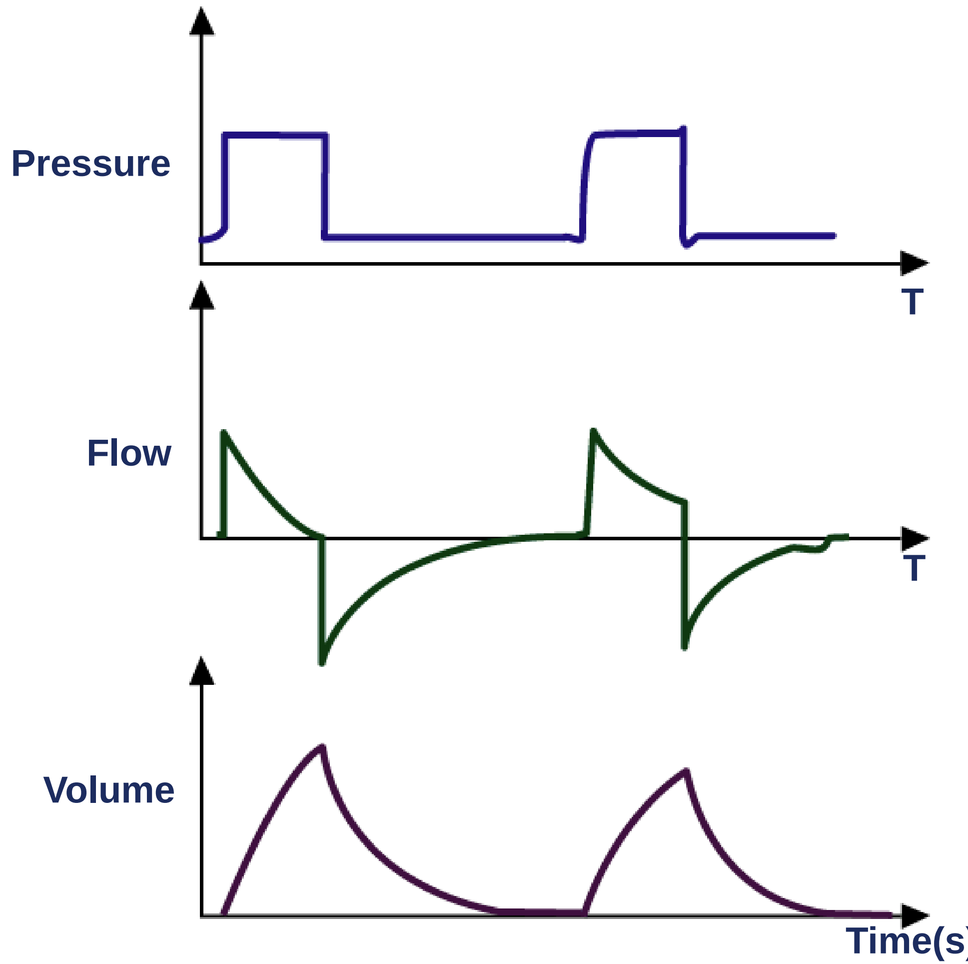
A. **SIMV (VC) + Pressure Support Mode**

Settings
• Tidal Volume (ml) • SIMV rate (b/min) • PEEP (cmH_2O) • Oxygen concentration (%) • I:E ratio • Pause time (%/s) • Inspiratory rise time(% breath cycle time/sec) • Breath cycle time (s) • Trigger sensitivity • Inspiratory cycle off (%) • PS(Pressure support) above PEEP(cmH_2O)



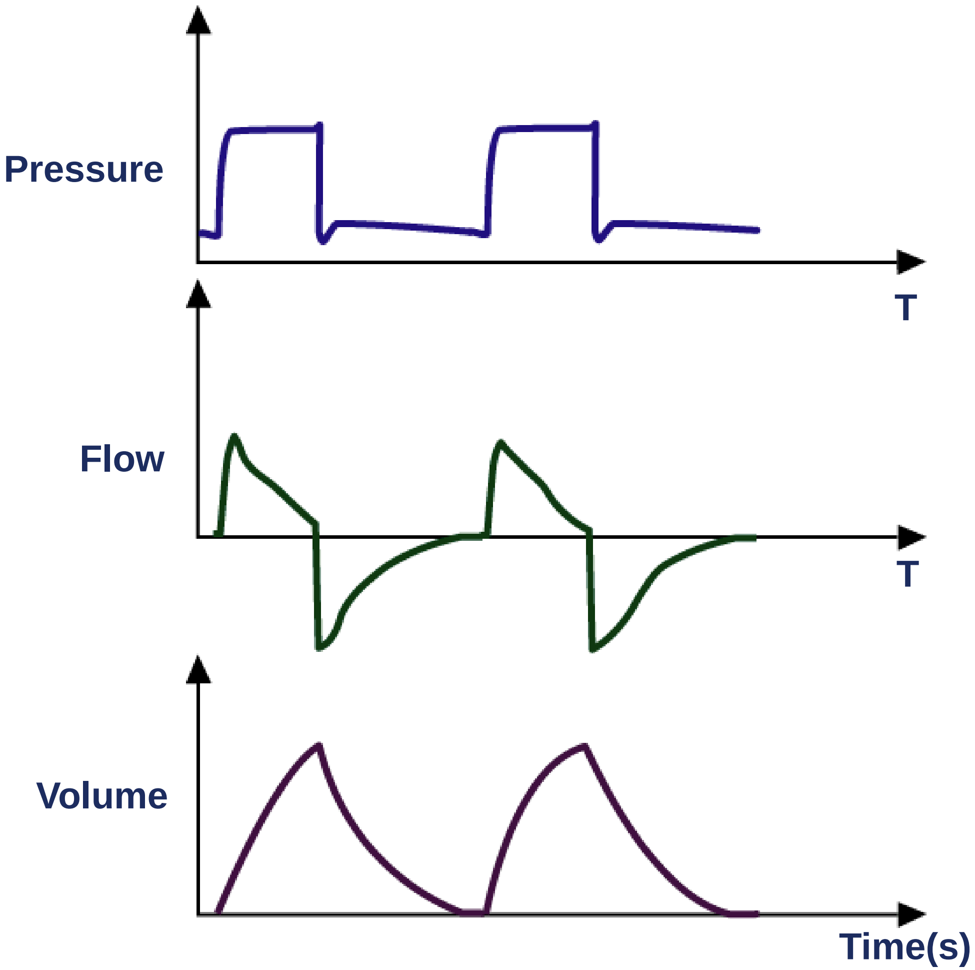
B. SIMV (PC) + Pressure Support Mode

Settings
• PC Pressure Control level (cmH_2O) • SIMV rate (b/min) • PEEP (cmH_2O) • Oxygen concentration (%) • I:E ratio • Pause time (%/s) • Inspiratory rise time(% breath cycle time/sec) • Breath cycle time (s) • Trigger sensitivity • Inspiratory cycle off (%) • PS (Pressure support) above PEEP (cmH_20)



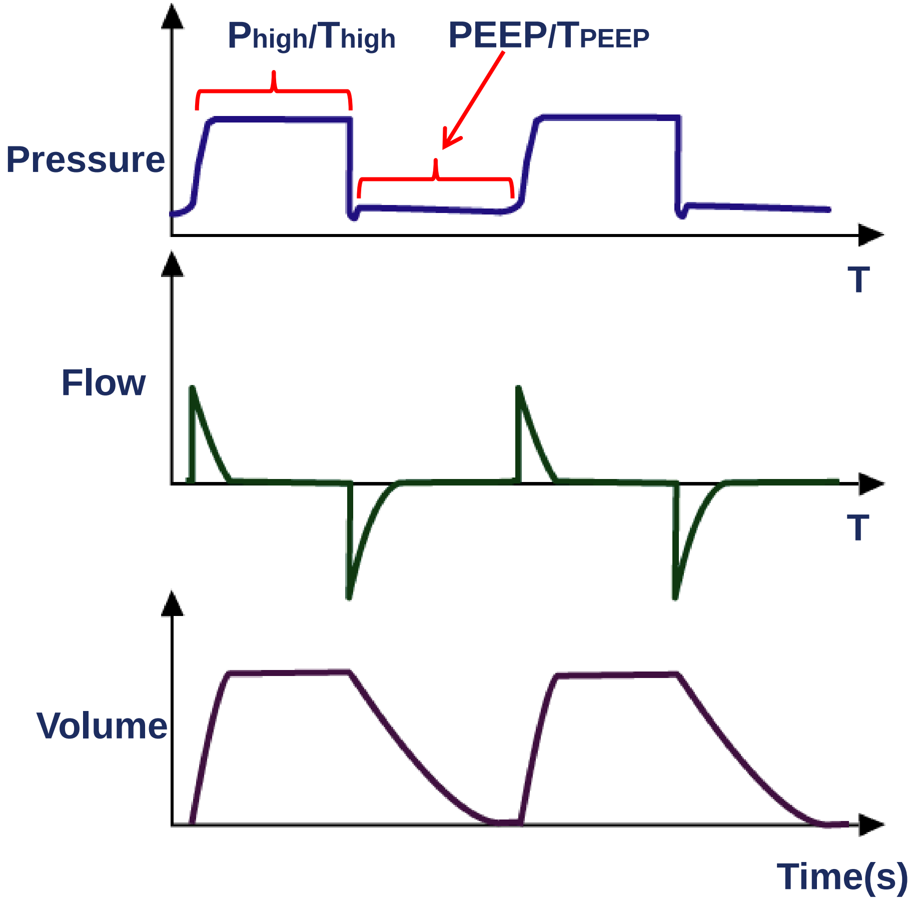
C. SIMV (PRVC) + Pressure Support Mode

Settings
• Tidal Volume (ml) • SIMV rate (b/min) • PEEP (cmH_2O) • Oxygen concentration (%) • I:E ratio • Inspiratory rise time(% breath cycle time/sec) • Breath cycle time (s) • Trigger sensitivity • Inspiratory cycle off (%) • PS (Pressure support) above PEEP(cmH_2O)



Bi-Vent

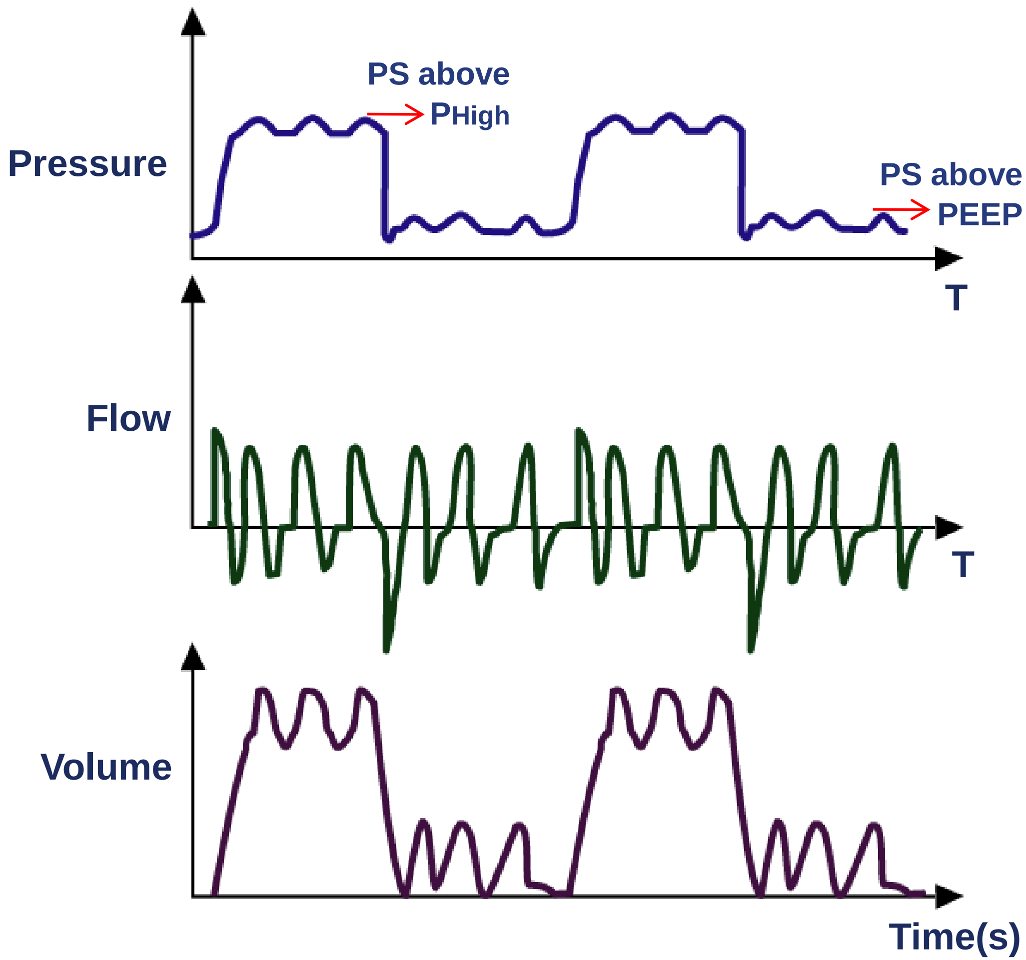
- Is classified as a time-cycled , pressure-limited mode of ventilation that allows spontaneous breathing throughout the entire respiratory cycle.
- It has two, time-cycled pressure levels and switches between these levels.
- Pressure support can be added to augment the patient's spontaneous effort at both the level.
- It can be used with inversed I:E ratio or as Airway Pressure release Ventilation (APRV)



Bi-Vent with Sponteneous Breathing

Settings

- P_{High} (cmH_2O)
- PEEP (cmH_2O)
- Oxygen concentration (%)
- T_{high} (s)
- T_{PEEP} (s)
- Inspiratory Rise Time (%)
- Trigger sensitivity
- Inspiratory cycle Off (%)
- PS above P_{High} (cmH_2O)
- PS above PEEP(cmH_2O)

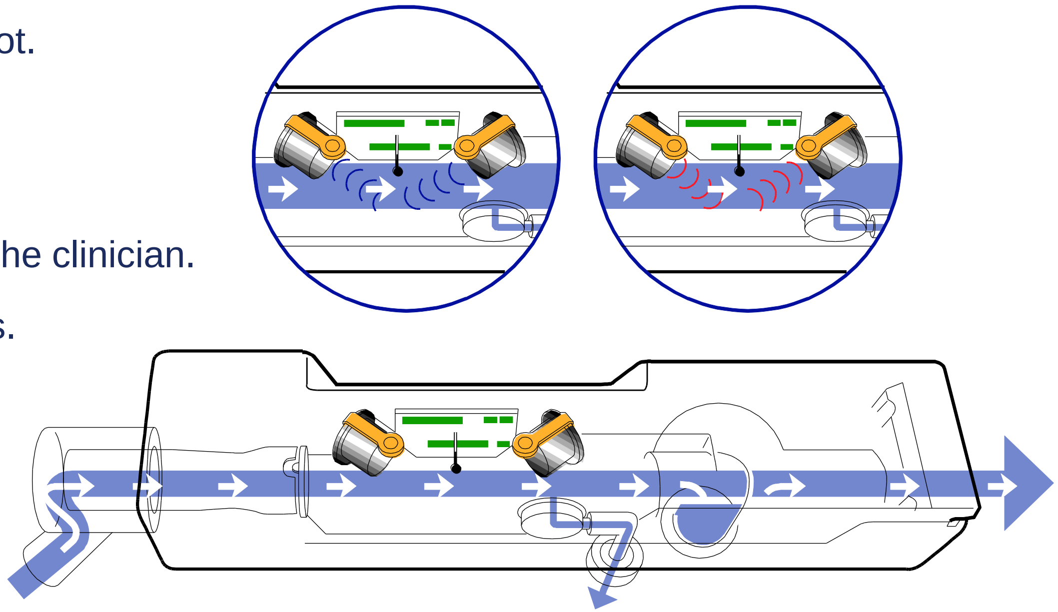


Sensing

The Servo controller system, senses and adjusts gas delivery faster than any device available on the market. Transducer refresh rate 2000 times/s

Benefits

- Immediate response to patient efforts.
- Smooth uninterrupted regulation during inhalation.
- Low resistance during exhalation.
- Avoids overshoot or undershoot.
- No delays in adjustments.
- Allows the patient to lead.
- Gives immediate feedback to the clinician.
- Gives real time measurements.
- Catches the Golden Moments.

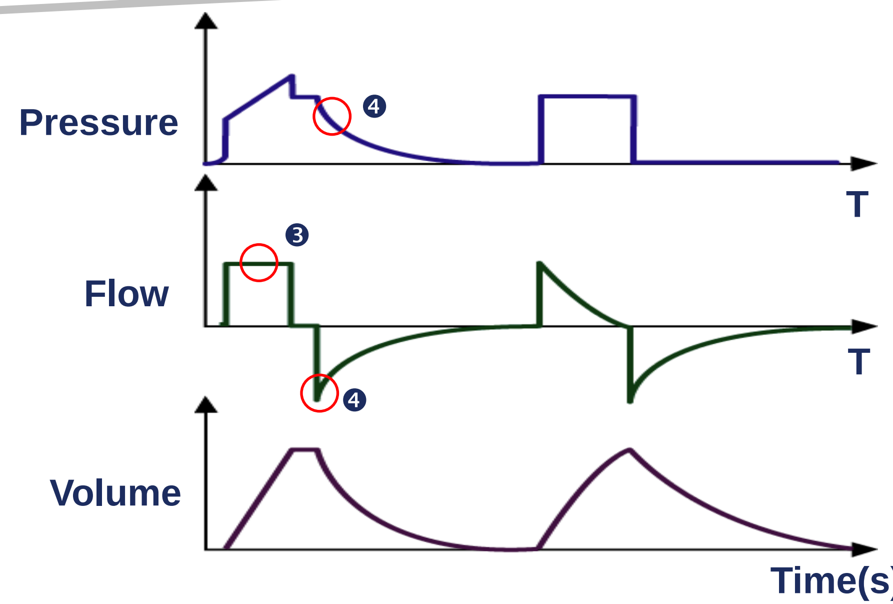


Golden Moments

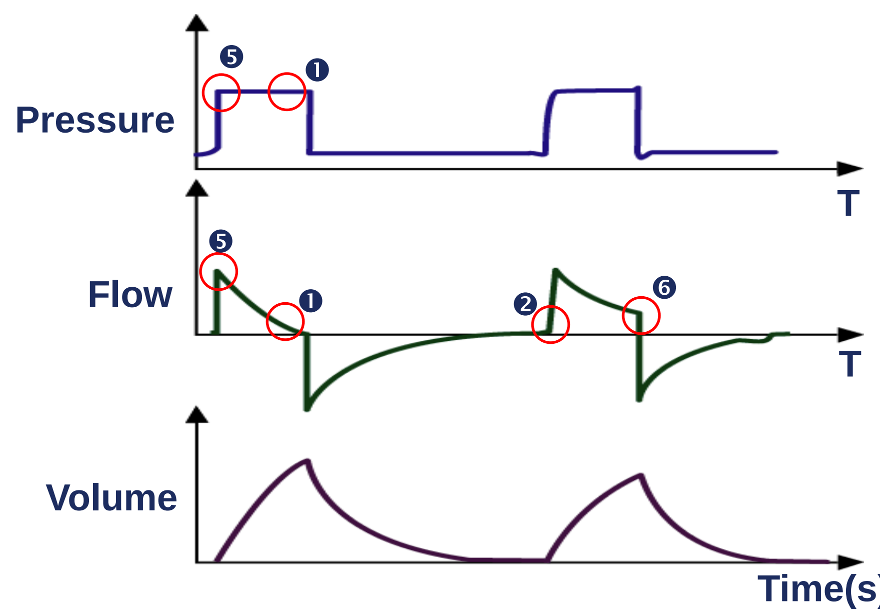
Patient benefits:

- Quicker weaning
- Less side effects
- Effective oxygenation and gas exchange
- Minimal influence on pulmonary and systemic circulation
- Minimal lung damage

1. Late Inspiratory Recruitment ❶
2. Breath Initiation ❷
3. Flow-Adapted Volume Control ❸
4. Early Expiratory Flow ❹
5. Patient-Adjusted Inspiratory Flow ❺
6. Inspiratory Cycle Off ❻
7. Early Weaning



Pressure Modes PC/PRVC & PS/VS



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Monitoring

Value	Definition
Ppeak	Maximum inspiratory pressure
Pplat	Pressure during inspiratory pause
Pmean	Mean airway pressure
PEEP	Positive end expiratory pressure
CPAP	Continuous positive airway pressure
RR	Respiratory rate
O_2	Oxygen concentration in vol.%
Ti	Inspiratory time
Te	Expiratory time
I:E	Inspiratory expiratory ratio
Ti/Ttol	Ratio of inspiratory time to total breath cycle time
Mve sp	Spontaneous minute volume

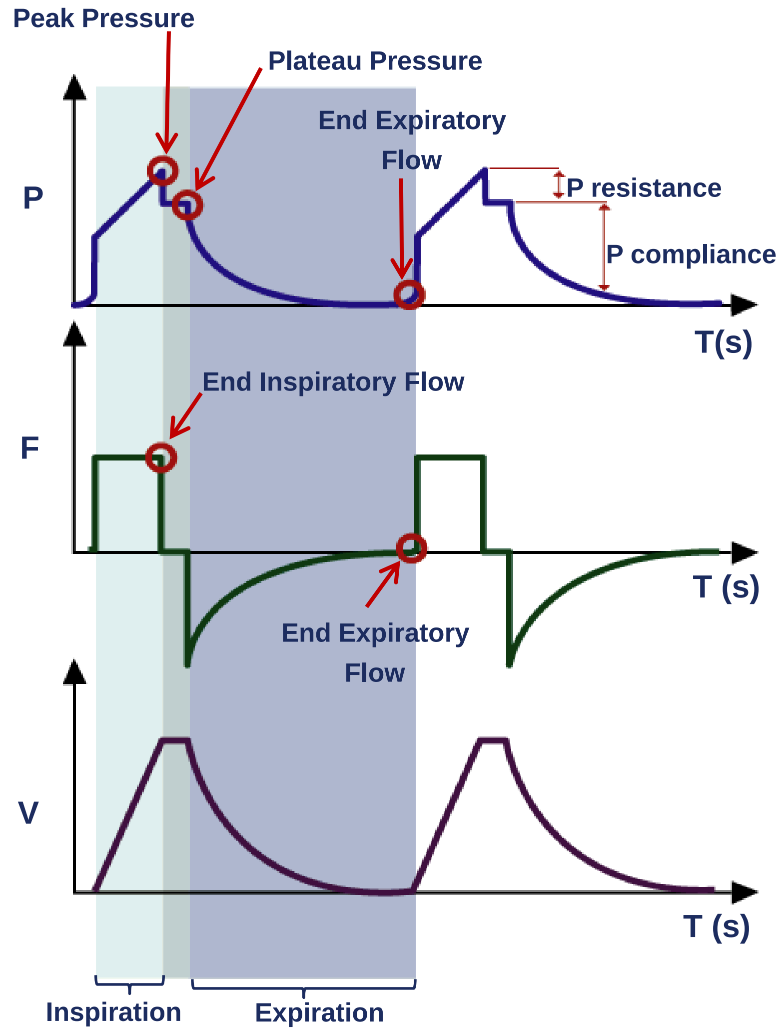
Value	Definition
Mve	Expired minute volume
Leakage	Leakage (%) in NIV
VTi	Inspiratory tidal volume
PEEP tol	Set PEEP+ intrinsic PEEP
Cdyn	Dynamic compliance
Cststic	Static compliance
E	Elastance
Ri	Inspiratory resistance
Re	Expiratory resistance
WOB v	Work of breathing, ventilator
WOB p	Work of breathing, patient
P0.1	Occlusion pressure
SBI	Shallow breathing index

Ventilator Graphics

A. Scalars

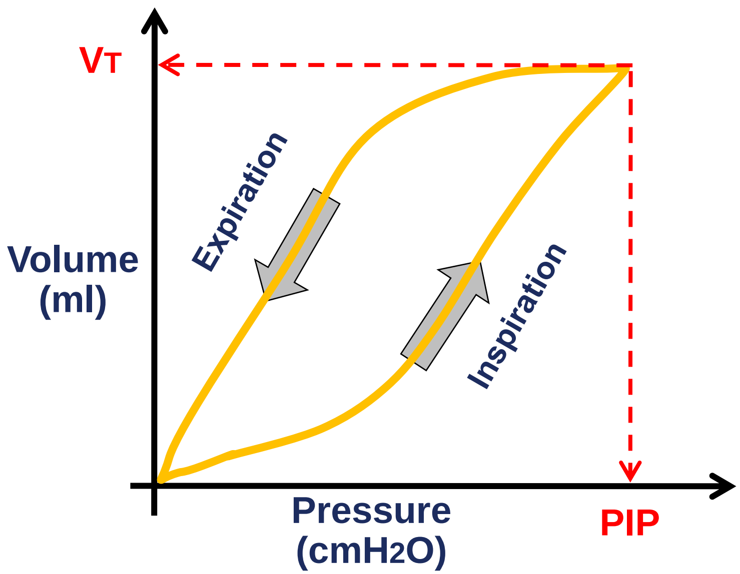
When viewing scalar graphics, time is conventionally shown on the horizontal (x) axis whereas flow, volume, and pressure are plotted on the vertical axis (y) axis.

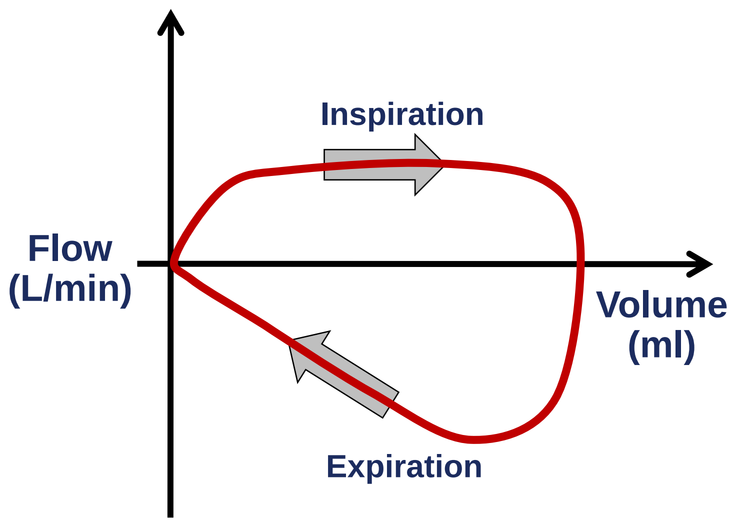
1. Increased airway resistance due to bronchospasm.
2. Accumulation of secretions
3. Response to Bronchodilator.
4. Auto-PEEP or air trapping.
5. A leak can be identified in.
6. Shows a negative deflection for trigger breath.
7. Peak Inspiratory Pressure (PIP).
8. Plateau Pressure (Pplat) or Alveolar Pressure.
9. Inappropriate inspiratory flow rates.



B. Loops

Are the two-dimensional graphic display of two scalar values. There are two loops available for interpretation. They are:





1. Inflection point can be identified.
2. Lung compliance and resistance.
3. Alveolar distension.
4. Inadequate sensitivity.
5. Inappropriate inspiratory flow rates.
6. A leak can be identified.

1. A leak can be identified.
2. Air trapping or auto-PEEP.
3. An increased airway resistance.
4. Presence of secretions.

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Trouble Shooting

Alarms	Possible Problem	Advice
High PAW **Caution:** If airway pressure rises 6 cmH_2O above the set pressure limit, the safety valve opens.	• Thick Secretion • ETT/TT block • Kinked by Pt • Pneumothorax • Pt coughing • Pt –Ventilator Asynchronization • High RR=>PEEPi • High VT/PP • Malfunction of Ventilator • Bronchospasm • Decreased lung Complience • Flow rate too high • ET touching carnia • Blocked HME	• Check Pt- Ventilator System • Do Suction • Increase FiO_2/100% O_2 for 2 min • Ambubag Ventilation • Sedation if required. • Check ETT patency • Give Nebulisation • Change Thermovent/HME • Need to change ETT/TT • CXR, ABG • Inform Dr
Low Minute Volume PIP/PAW	• Leak • Cuff not Inflated • Displaced ET • Apnea	• Check Pt- Ventilator System • Breathing system • Check ETT patency • Check Cuff Pressure • Consider increase ventilatory support.

Alarms	Possible Problem	Advice
Low O_2/Air Pressure	• Central Supply not connected or below 2kPa • O_2 sensor failure	• Check connections • O_2 Calibration • Inform respected person
Apnea	• Leak • Pt not breathing in SIMV& PS modes	• Inform Dr/RT • Check Pt- Ventilator System
High PEEP/PEEPi	• Auto PEEP generated due to high RR • Less expiratory time • Pt –Ventilator Asynchronization • Malfunction of Ventilator	• Check Pt- Ventilator System • Inform Dr • Adjust PEEP • Reset I:E ratio • Ambubag Ventilation • Sedation if required
High RR, MV, VT	• Fever • Infection • Decrease PaO_2 • Increase $PaCO_2$ • Increase lung compliance	• Check Pt- Ventilator System • ABG • 100% O_2 for 2 min • Sedation if required

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