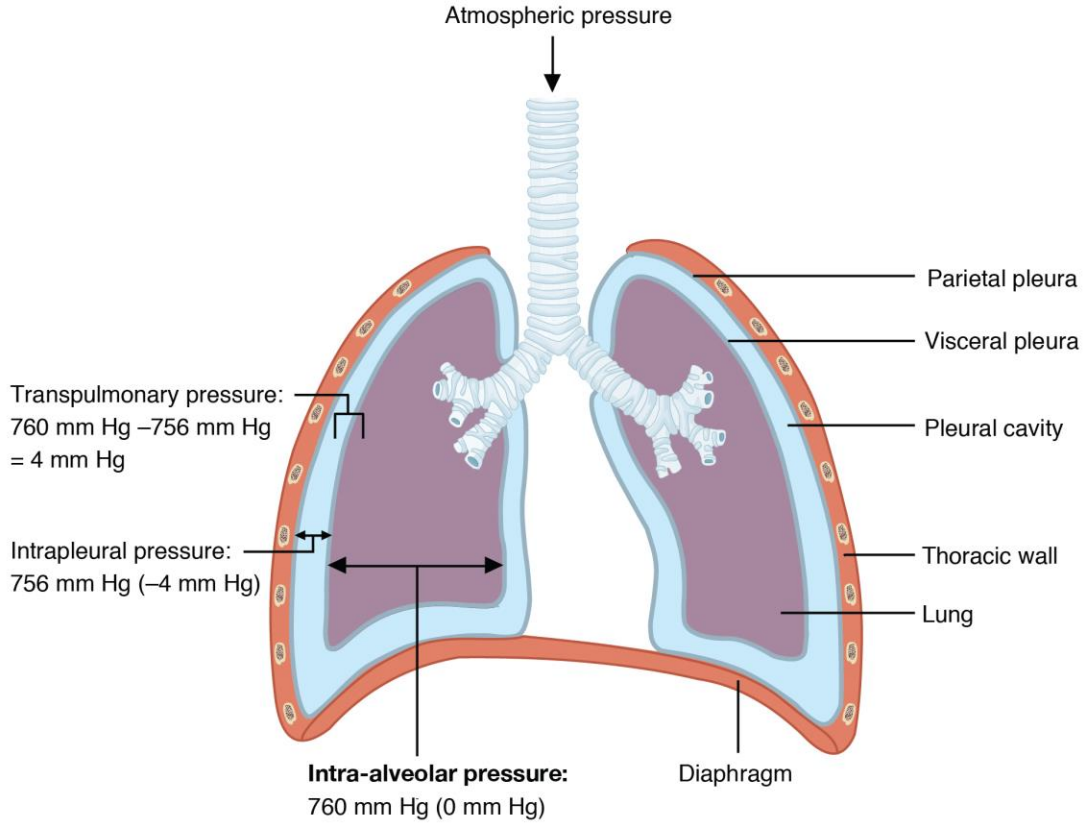
Pulmonary ventilation (breathing)

Laiba khan

Types of pulmonary pressure



- **Atmospheric** – pressure of air coming into body
- **Intrapulmonary**/alveolar – pressure inside lungs
- **Intrapleural** – between visceral and parietal pleura
  - should always be negative or lowest value (don't want air/pus/blood moving into pleural space)
- **Transpulmonary** – difference between intrapulmonary and intrapleural pressure
  - Keeps lungs as close as possible to thoracic wall – allows lungs to expand with thoracic wall

Air always moves from higher pressure to lower pressure!

Inspiration and expiration

Forced inspiration muscles = scalene, sternocleidomastoid, pec minor

Inspiration = breathing in

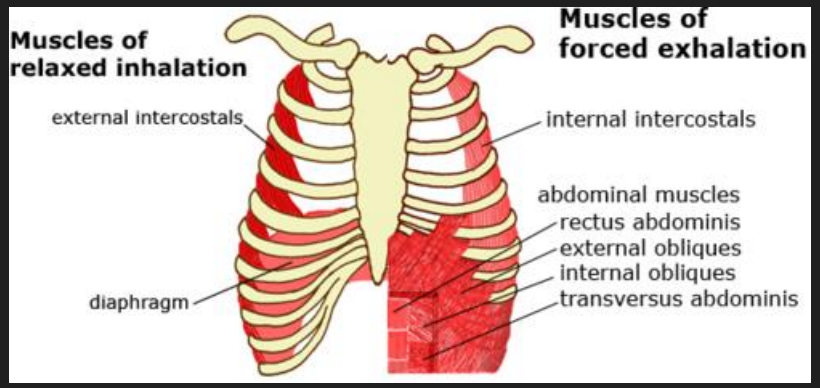
- **ACTIVE**
- Initiated by respiratory control centre in **medulla oblongata** (part of brainstem)
- Medulla is activated -> impulse sent to diaphragm along **phrenic** nerve (C3, 4, 5 keep you alive)
- Diaphragm **contracts** i.e. flattens out and **external** intercostal muscles **contract**
- Thoracic cavity volume increases
- So **pressure decreases**
- So air moves into lungs (from higher to lower pressure)

Atmospheric pressure greater than intrapulmonary

Expiration = breathing out

- **PASSIVE** due to elastic recoil of lungs – lungs bounce back into shape, no effort required
- If **forced** expiration, eg exercising, **internal** intercostal muscles and **abdominal** muscles **contract**

Intrapulmonary is greater than atmospheric

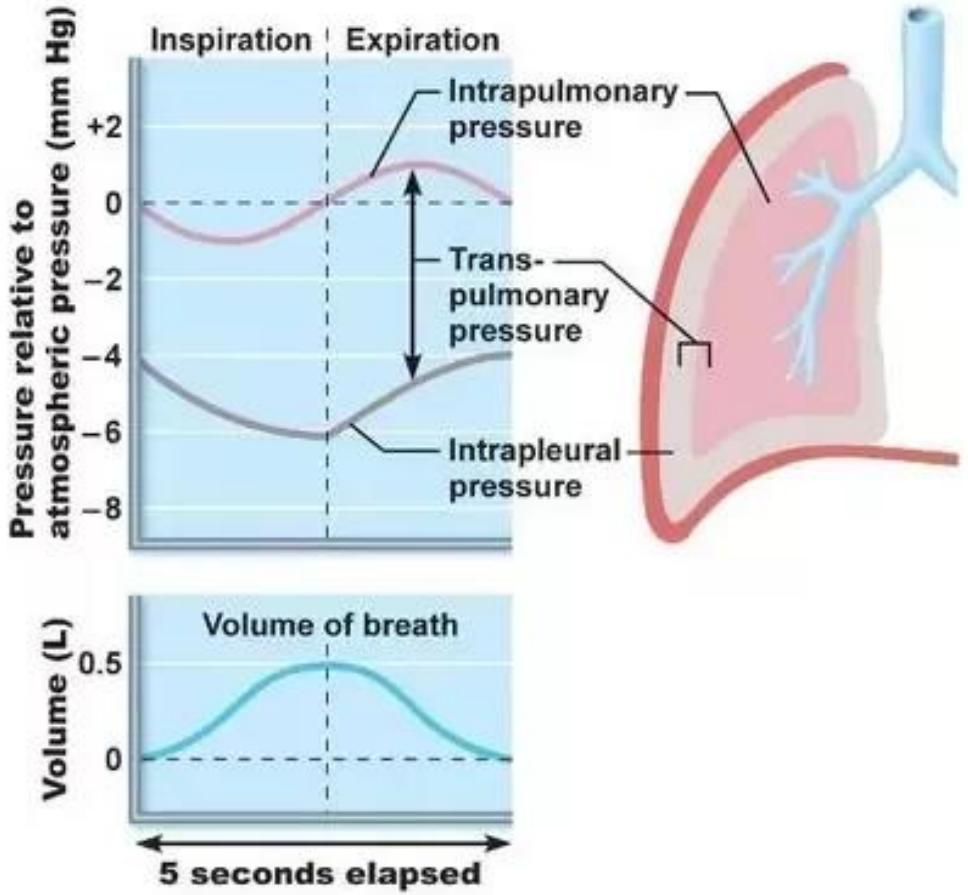


Putting it together…

Intrapulmonary pressure. Pressure inside lung decreases as lung volume increases during inspiration; pressure increases during expiration.

Intrapleural pressure. Pleural cavity pressure becomes more negative as chest wall expands during inspiration. Returns to initial value as chest wall recoils.

Volume of breath. During each breath, the pressure gradients move 0.5 liter of air into and out of the lungs.



Remember: lung vol and pressure are opposites, if one increases, other decreases

summary

Mechanism of Inhalation

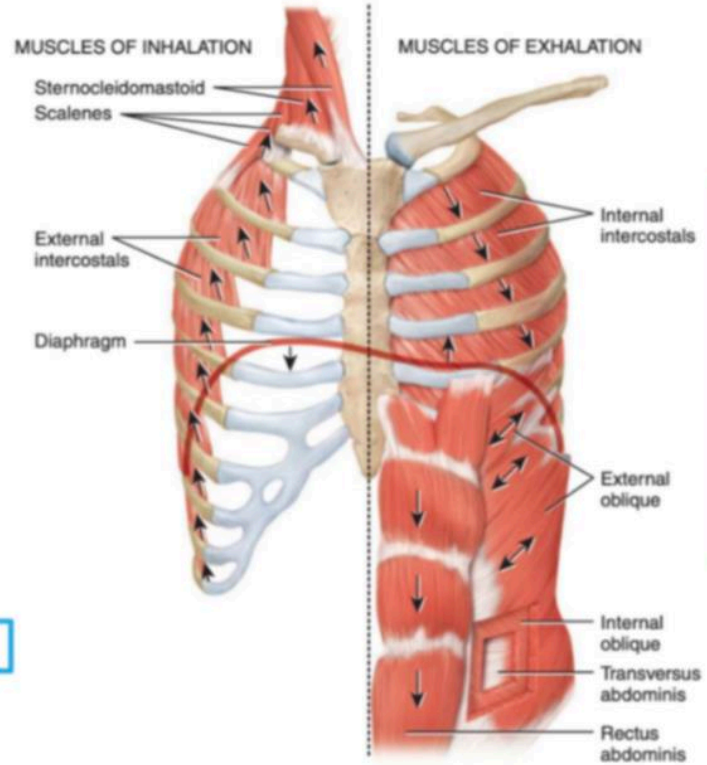
The volume of the **thoracic cavity** increases...

- Vertically when the diaphragm contracts and flattens
- Laterally when the intercostals raise the ribs

As a result of the volume increasing, the **intrapulmonary** pressure decreases

Air moves **into** the lungs.

Inspiration begins as the diaphragm contracts!



(a) Muscles of inhalation (left); muscles of exhalation (right); arrows indicate the direction of muscle contraction

Mechanism of Exhalation

The volume of the thoracic cavity decreases...

- Vertically when the diaphragm recoils and domes
- Laterally when the intercostals passively relax, or when muscles of forced expiration forcibly lower the ribs

As a result of the volume decreasing, the intrapulmonary pressure increases;

Air moves **out** of the lungs.

Rectus abdominis is the strongest muscle of exhalation

Inspiration

Intrapulmonary pressure < atmospheric pressure = air moves into the lungs

Expiration

Intrapulmonary pressure > atmospheric pressure = air moves out of the lungs

questions

1. What are the accessory muscles of forced inhalation?

a. sternocleidomastoid, scalene, pectoralis major
b. Rectus abdominus + obliques
c. Sternocleidomastoid, scalene, pectoralis minor
d. Parasternal intercostal muscles

questions

1. What are the accessory muscles of forced inhalation?

a. sternocleidomastoid, scalene, pectoralis major

b. Rectus abdominus + obliques

c. Sternocleidomastoid, scalene, pectoralis minor

d. Parasternal intercostal muscles

questions

2. What is the strongest muscle for forced exhalation?

a. Transversus abdominus
b. Rectus abdominus
c. Internal oblique
d. External oblique
e. External intercostal

questions

2. What is the strongest muscle for forced exhalation?

a. Transversus abdominus
b. Rectus abdominus
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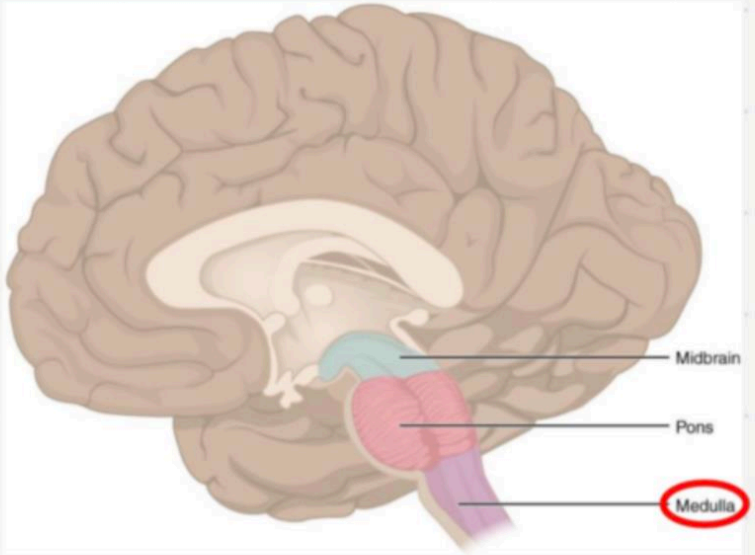
Neural control of respiration

- Control areas are in pons and medulla of brainstem
  - Pons: apneustic centre (lower pons) and pneumotaxic centre (upper pons)
  - Medullary respiratory centre in medulla



Note that the following only addresses *involuntary control* of breathing.
People can voluntarily control (singing, speaking, yelling) their breathing (for short periods of time) using the cerebral cortex.

Increases in body temperature will also *involuntarily* increase respiration rate.

Medullary Respiratory Centre

Ventral Respiratory Group (VRG)*	Dorsal Respiratory Group (DRG)
Inspiration and Expiration	Inspiration only
Forceful Breathing only	Quiet and Forceful Breathing

There are two methods of respiration:
- Quiet (normal) breathing
- Forceful breathing

Only the DRG is responsible for *quiet* breathing. However, quiet *exhalation* is a passive process, and so it simply requires the inactivation of the DRG.

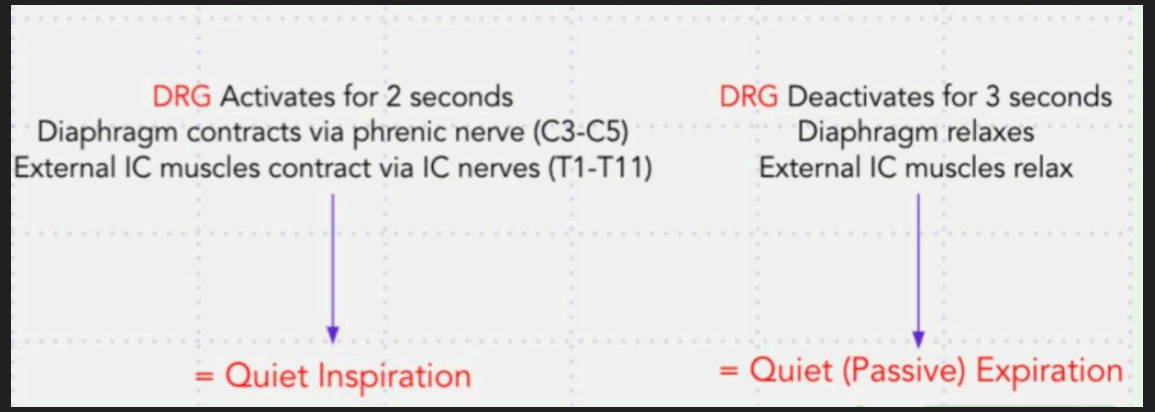
Both the DRG and VRG are required for *forceful* breathing (inhalation and exhalation).

*Note that the VRG also contains a structure called the Pre-Bötzinger complex. These help to modulate the rhythm of breathing. Think of it as being similar to a pacemaker.

Limbic system + hypothalamus also alter breathing pattern during affective states eg rage, fear

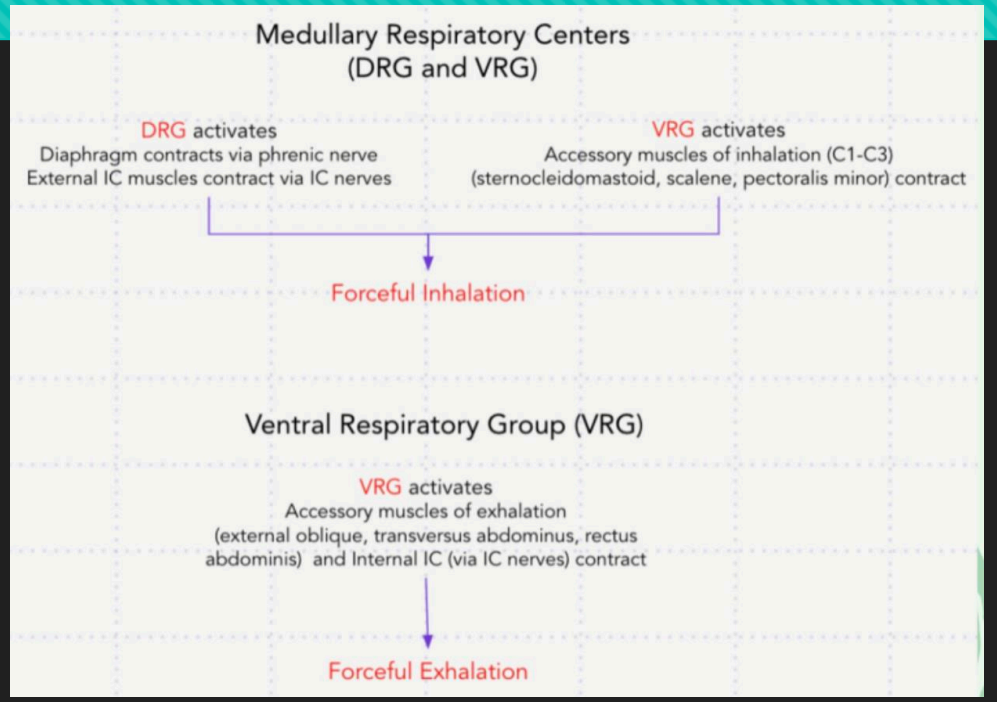
Quiet respiration control: DRG

- For both quiet breathing and forceful breathing
- Quiet inspiration
  - DRG activates for 2 seconds
    - Causes diaphragm to contract via phrenic nerve (c3, 4, 5)
    - Causes external intercostal muscles to contract via IC nerves (T1-T11)
- Quiet expiration
  - DRG inactivated for 3 seconds
    - Diaphragm relaxes
    - external IC relax
    - Quiet expiration occurs due to elastic lung recoil



Forced respiration control: DRG + VRG

- Forced inhalation
  - DRG activated
    - Diaphragm and EIC contracts
  - VRG activated
    - Accessory muscles of inhalation contract via nerves C1-3
      - Sternocleidomastoid, scalene, pectoralis minor
- Forced exhalation – JUST VRG
  - VRG activated
    - External oblique, internal oblique, rectus abdominus, transversus abdominus (accessory muscles) and internal IC contract



UPAL – upper pneumotaxic apneustic lower

Apneustic and pneumotaxic centre

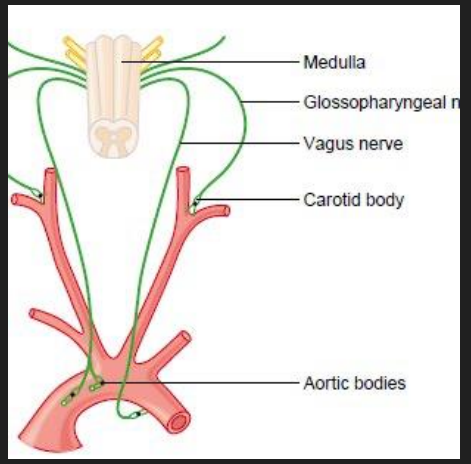
- Both centres in pons and responsible for **modifying rhythm of breathing** eg when sleeping
- Apneustic – lower pons
  - **Stimulates inspiratory centres (DRG)** i.e. signal for inspiration to occur -> longer, deeper breaths
  - If lesions/disease in apneustic centre -> no signals to inspiratory centre -> "apneuses" (**gasps**, more missed breaths)
- Pneumotaxic – upper pons
  - **Inhibits DRG**+ apneustic centres i.e. regulates and fine tunes breathing
  - Lesions in this area -> hypoactivation (prolonged breaths in as inspiratory centre 'on' for too long) or hyperactivation (**shallow** inspirations)
  - Thought that lesions still mean normal resp can occur tho bc pneumotaxic centre just for fine tuning

receptors

- Mechanoreceptors – in walls of bronchi + bronchioles in lungs, prevent overinflation of lungs
  - Hering-Brewer reflex
  1. Stretching of walls (due to air flowing through) activates mechanoreceptors
  2. Impulses sent from receptors to inspiratory centre (drg) via vagus nerve
  3. Inspiration stopped
  4. Expiration starts, reduces stretch, inactivates receptors, vagus stops sending signals i.e. –ve fb
  5. Inspiration starts

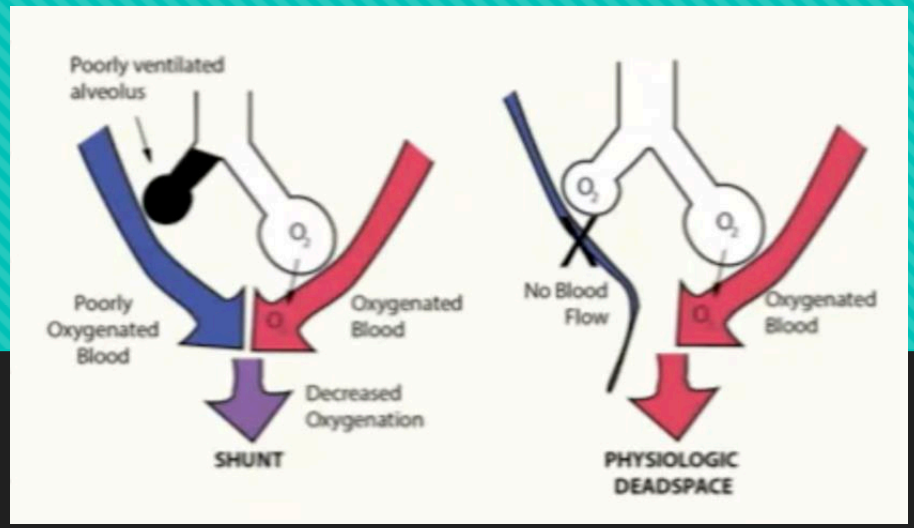
receptors

- Chemoreceptors – monitor o2, co2 and pH levels
- Peripheral chemoreceptors – in bifurcation of carotid artery and arch of aorta
  - Monitor levels of o2 in blood and send signals to DRG and VRG accordingly
  - Carotid artery via glossopharyngeal nerve
  - Arch of aorta via vagus nerve
- Central chemoreceptors – on surface of medulla, exposed to CSF
  - Responds to changes in H^+, indirectly monitoring CO_2 levels
  - When CO_2 levels increase, CO_2 diffuses into CSF and liberates H^+
  - High H+ > stimulates receptors > hyperventilation > breathe out co2



$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Ventilation-perfusion



- Ventilation (v) = how much air gets from air inhaled to alveoli i.e. air getting to alveoli in each breath
- Perfusion (q) = how much air from alveoli gets across into capillaries
- Determines quality of alveolar-capillary gas exchange
- Ideally, adequate amount of air reaches alveoli and adequate amount of blood flows through surrounding capillaries so v/q ratio = 1
- This never happens because of things like structure of lungs, gravity etc
- Shunt = perfusion of poorly ventilated alveoli eg pneumonia, acute asthma
  - Hypoxic pulmonary ventilation (HPV) combats this – arterioles constrict so blood flow diverted to better ventilated alveoli
- Physiological dead space = ventilation of poorly perfused alveoli eg COPD, pulmonary emboli

questions

1. What centres would be activated in forceful inhalation?

a. DRG only

b. VRG only

c. DRG + VRG

d. Apneustic centre

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questions

2. What is the main area of the brain used for voluntary breathing?

a. Limbic system
b. Hypothalamus
c. Cerebral cortex
d. Pons
e. medulla

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Definitions learn

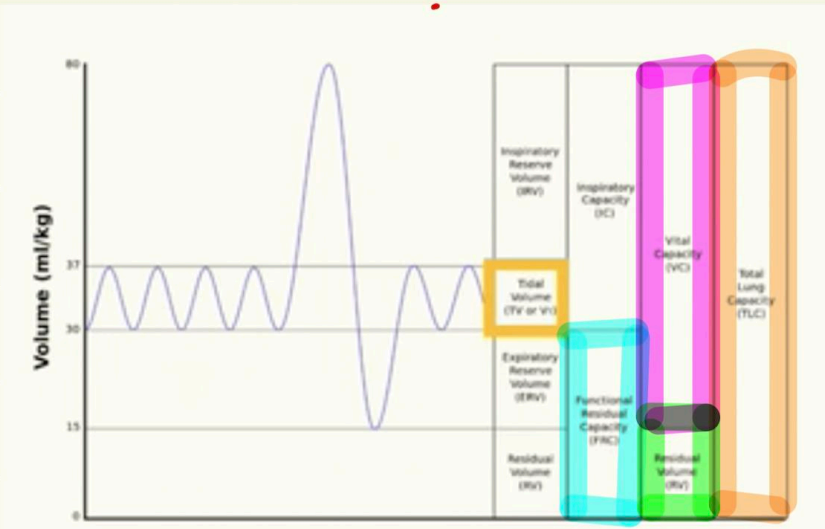
tidal vol = amount of air in/out of lungs in single inspiration/expiration 500ml

functional residual capacity = vol. of air that remains in lungs at end of normal respiration 2400ml

vital capacity = vol. of air that can be exhaled after a maximal inspiration 4800ml

residual volume = amount of air remaining in lungs after maximal expiration 1200ml

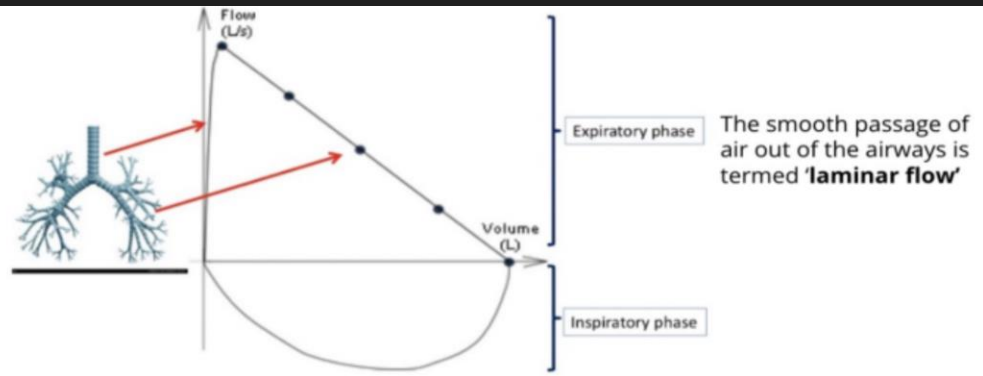
total lung capacity = max vol of air in lungs after a maximal inspiration 6000ml



spirometry

FVC = vol of air forcibly blow out after full inspiration
FEV_1 = vol of air forcibly blow out in **1s** after full inspiration

- Measures effort of inspiration and expiration
- Deep breath in, exhale into mouthpiece as hard as possible for 6 seconds
- Gives us flow volume loop + time volume curve

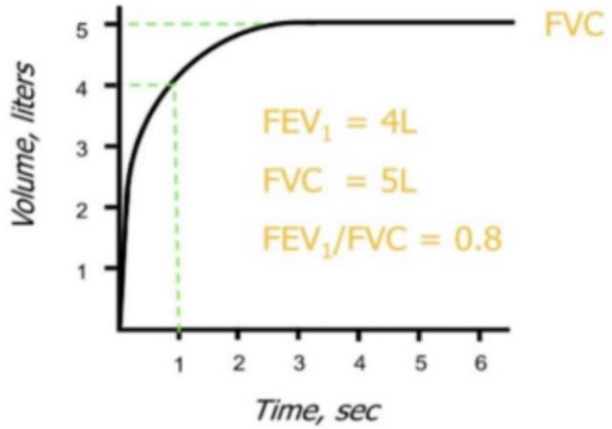


The smooth passage of air out of the airways is termed '**laminar flow**'

In a healthy person, Flow-Volume Loop appears as above

1. Exhalation begins as a sharp peak – this is the air leaving the trachea.
2. Exhalation continues by the volume of air leaving at a steadily decreasing rate – this is the air leaving their bronchi
3. The negative loop backwards is the person inspiring air

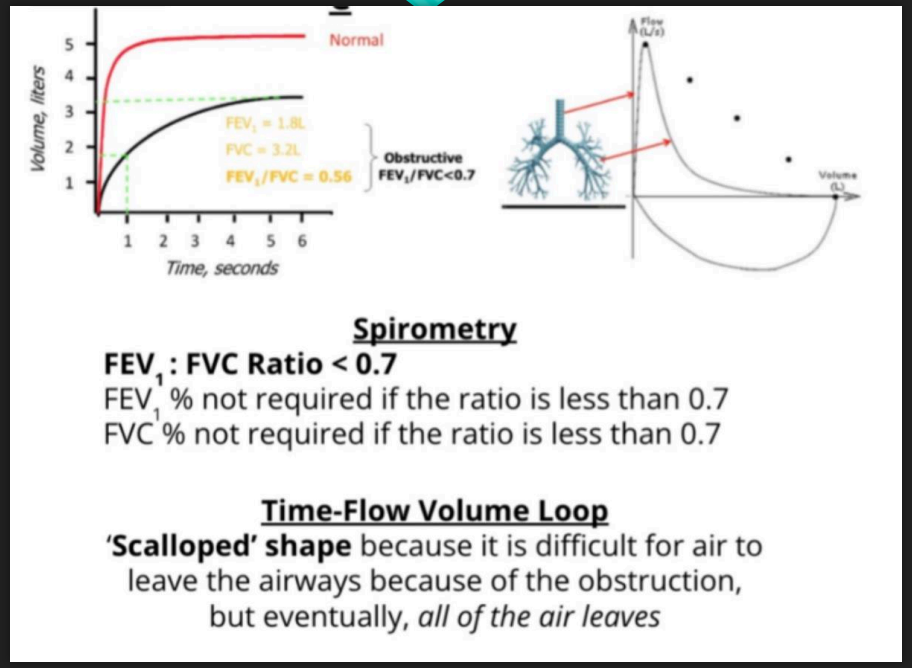
(This loop is distorted in shape for those with respiratory diseases)



In a healthy person, spirometry results are as follows:

- FEV_1 % Predicted ≥ 80%
- FVC % Predicted ≥ 80%
- FEV_1 : FVC Ratio = 0.7-0.8

Obstructive and restrictive diseases learn



Spirometry

FEV_1 : FVC Ratio < 0.7

FEV_1 % not required if the ratio is less than 0.7

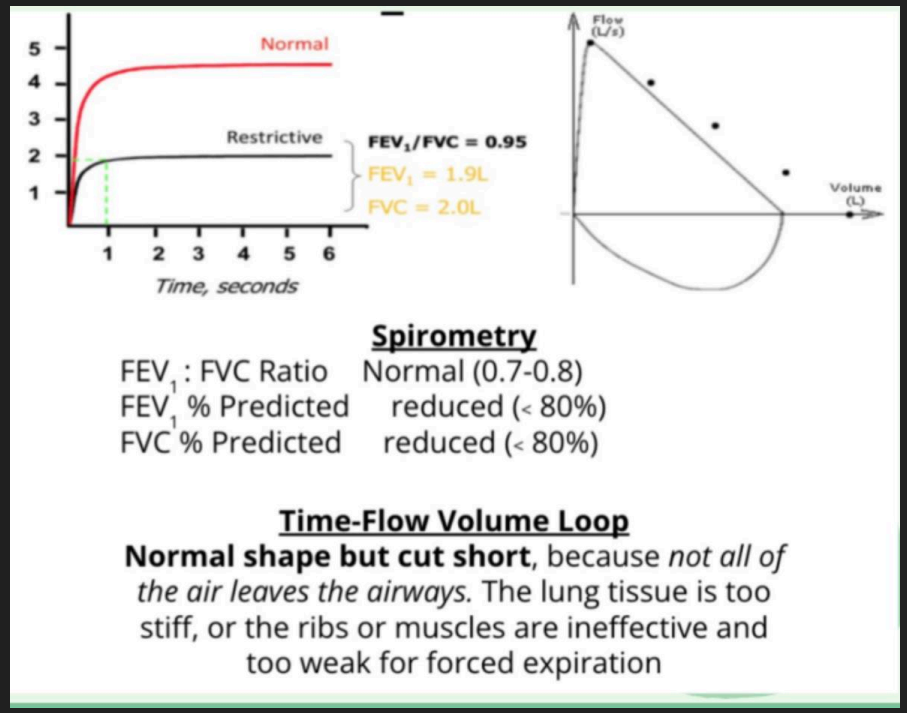
FVC % not required if the ratio is less than 0.7

Time-Flow Volume Loop

'Scalloped' shape because it is difficult for air to leave the airways because of the obstruction, but eventually, *all of the air leaves*

Obstructive – collapse of smaller airways eg COPD, chronic asthma, bronchiectasis, cystic fibrosis

Restrictive – lungs have smaller volume, less air can get out eg lung fibrosis, obesity, pregnancy, MSK abnormalities



Spirometry

FEV_1 : FVC Ratio	Normal (0.7-0.8)
FEV_1 % Predicted	reduced (< 80%)
FVC % Predicted	reduced (< 80%)

Time-Flow Volume Loop

Normal shape but cut short, because *not all of the air leaves the airways.* The lung tissue is too stiff, or the ribs or muscles are ineffective and too weak for forced expiration

Limitations of spirometry

- Depends on patient cooperation, how willing they are to have spirometry done
- FVC can be underestimated (never overestimated)
- Needs to be repeated 3 times and each time results needs to be within 5% or 150ml of each other
- Side effects: light-headed, nauseous

Other tests for lung function

- Don't worry too much about learning these, just be aware they exist

VO_2 Max

The maximum amount of oxygen that a person can use at peak exercise.

That is, the intensity of the exercise can be increased, but the person's O_2 usage remains at a steady state.

Respiratory Muscle Strength

This can be measured by assessing someone's **maximal inspiratory pressure** (MIP) or their **maximal expiratory pressure** (MEP)

- MIP assess strength of inspiratory muscles (diaphragm, external intercostal muscles, accessory muscles e.g. scalenes)
- MEP assess strength of expiratory muscles (rectus abdominus, external abdominal oblique, internal abdominal oblique, transverse abdominus)

Diffusion Capacity

Measures the ability of the lungs to extract O_2 from inhaled air and move it into pulmonary capillaries. It is determined by surface area, length of the diffusion pathway and levels of haemoglobin.
The test for diffusion capacity is done with a small amount of CO, as it acts as a surrogate for O_2. The test for diffusion capacity is called TLCO (Transfer factor of the Lung for Carbon Monoxide [CO])

Learn * laws, recognise rest by bits in bold

Gas laws

- **Boyle's** Law*: if volume of a gas goes up, pressure will go down & vice versa
- **Dalton's** Law*: The total pressure is equal to the **sum of partial pressures** of a group of gases
- **Henry's** law: **Solubility of a gas into a liquid** depends on the partial pressure of the gas in the environment and the **solubility coefficient** of the gas in the liquid
- **Grahams Law:** The **rate of diffusion** depends on the **solubility coefficient** of the gas and the **square root** of its molecular weight
- **Fick's Law** of diffusion: the amount of gas **diffusing** through the resistance of a barrier depends on the surface area of the barrier, the diffusion constant, the partial pressure on each side and the thickness of the barrier

questions

1. Inspiration begins as...

A. The lungs contract
B. The external intercostal muscles contract
C. The lateral volume of the thoracic cage decreases
D. The diaphragm relaxes and domes
E. The diaphragm contracts and flattens

2. During inspiration...

A. Atmospheric pressure < intrapulmonary pressure
B. Intrapleural pressure > intrapulmonary pressure
C. Transpulmonary pressure < atmospheric pressure
D. Atmospheric pressure = intrapulmonary pressure
E. Intrapulmonary pressure = intrapleural pressure

3. Which of the following is NOT a muscle of exhalation?

A. Sternocleidomastoid
B. Internal oblique
C. External oblique
D. Transversus abdominis
E. Internal intercostals

4. Which of the following is the only one which does NOT require muscular effort?

A. Quiet inhalation
B. Quiet exhalation
C. Forced inhalation
D. Forced exhalation
E. They all require it :D

1. E
2. C
3. A
4. B

During hyperventilation, which of the following would be expected to happen?

- a decrease in PO_2 of arterial blood
- a decrease in PCO_2 of arterial blood
- an increase in acidity of arterial blood
- an increase in PCO_2 concentration of arterial blood
- a decrease in pH of arterial blood

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Which of the following is responsible for the fine tuning of the respiratory rhythm?

- the DRG
- the VRG
- the cerebellum
- the pneumotaxic centre
- the rostral fastigial nucleus (FNR)

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During ventilation-perfusion coupling:
bronchioles constrict in response to increased PCO_2

- lung arterioles constrict in response to decreased PO_2
- bronchioles dilate in response to increased PCO_2
- bronchioles constrict in response to decreased PO_2
- both bronchioles and lung arterioles dilate in response to increased PCO_2

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