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Respiratory system. Compendium.

Questions for the oral exam

- A22: Hypoxia and ischemia
- A25: Lung ventilation, volumes, measurement
- A26: Dead space, measurement
- A27: Resistance of airways, measurement
- A28: Maximal respiratory flow - volume curve (spirogram)
- A45: Alveolar surface tension. Surfactant
- A46: Compliance of lungs. Respiratory work. Pneumothorax
- A47: Composition of atmospheric and alveolar air. Gas exchange in lungs and tissues
- A48: Transport of O_2. Oxygen - haemoglobin dissociation curve. Transport of CO_2
- A49: Regulation of ventilation
- A50: Respiratory responses to irritants

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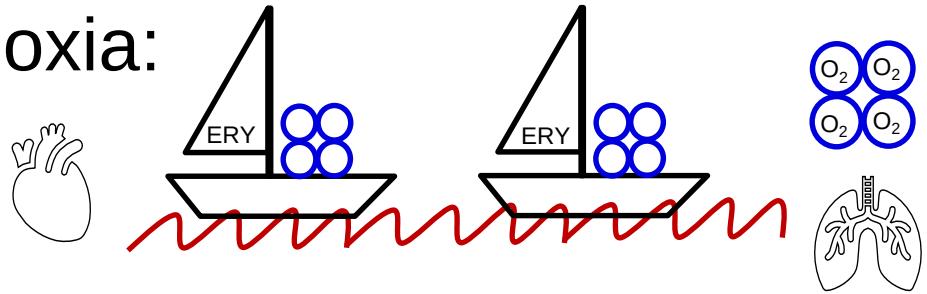
A22: Hypoxia and ischemia

- Hypoxia is a general name for a lack of oxygen in the body or individual tissues
- Ischemia, meaning insufficient blood flow to a tissue, can also result in hypoxia
- The most common types of hypoxia:
  - Hypoxic
  - Transport (anemic)
  - Ischemic (stagnation)
  - Histotoxic



ERY: ♀ 3.4 – 4.4 * 10^{12}/l
♂ 4.5 – 5.5 * 10^{12}/l
pO_2: 21kPa

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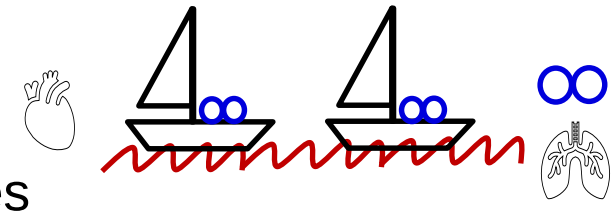
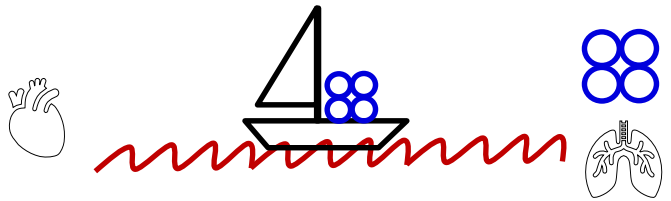
A22: Hypoxia and ischemia

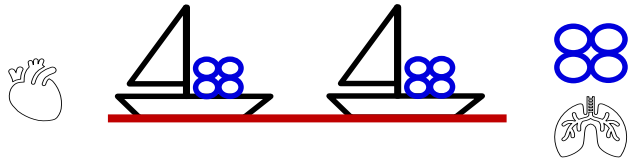
- Hypoxic:
  - physiological: stay at higher altitudes
  - ↓ pO_2; N Ery
  - pathological: hypoventilation during lung or neuromuscular diseases
  - ↓ ventilation; N pO_2; N Ery



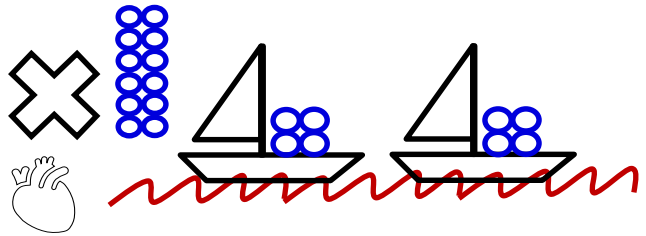
- Transport (anemic):
  - reduced transport capacity of blood for oxygen (anemia, blood loss)
  - N pO_2; ↓ Ery/Hb



- Ischemic (stagnation):
  - restricted blood flow to tissue (heart failure, obstruction of an artery)
  - N pO_2; N Ery



- Histotoxic
  - cells are unable to utilize oxygen (cyanide poisoning)
  - N pO_2; N Ery



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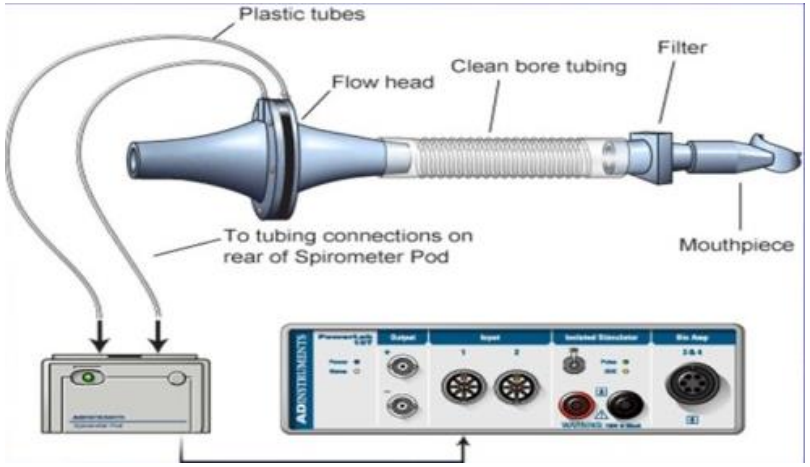
A25: Lung ventilation, volumes, measurement

- *Ventilation*, or breathing, is the movement of air through the conducting passages between the atmosphere and the lungs
- *Principle*: determination the air flow velocity from the measured pressure differences between the inner and outer spirometer membranes, the volumes being calculated (PowerLab spirometry)



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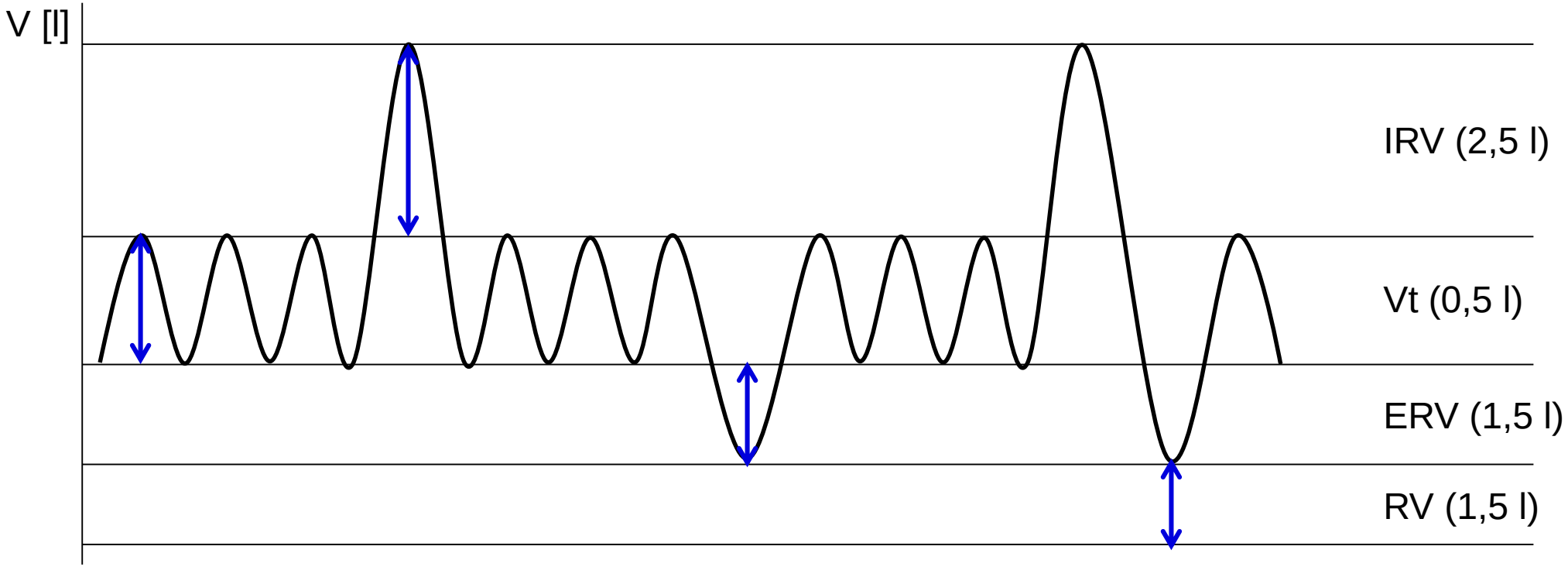
A25: Lung ventilation, volumes, measurement



- ***Tidal volume* (TV)** – the volume of air that enters the lungs during each inspiration (or the volume that is exhaled during every expiration).
- ***Inspiratory reserve volume (IRV)*** – the maximal amount of additional air that can be drawn into the lungs by determined effort after a normal inspiration at rest.
- ***Expiratory reserve volume (ERV)*** – the additional amount of air that can be exhaled from the lungs by determined effort after a normal expiration.
- ***Residual volume (RV)*** – the volume of air still remaining in the lungs after the most forcible expiration possible.

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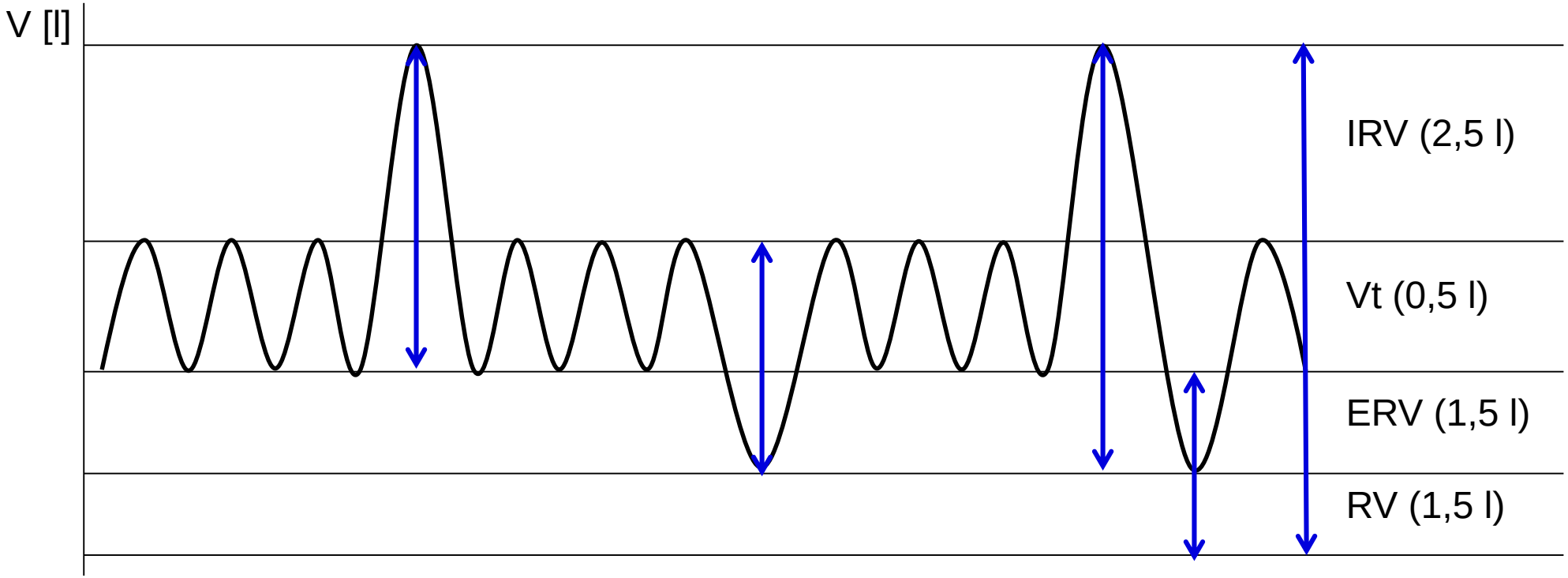
A25: Lung ventilation, volumes, measurement



Lung capacity:

- *VC = VT + IRV + ERV*
- *TLC = VC + VC*
- *FRC = ERV + RV*
- *IC = IRV + VT*
- *EC = ERV + VT*

Dynamic lung volumes:

- VE
- MMV

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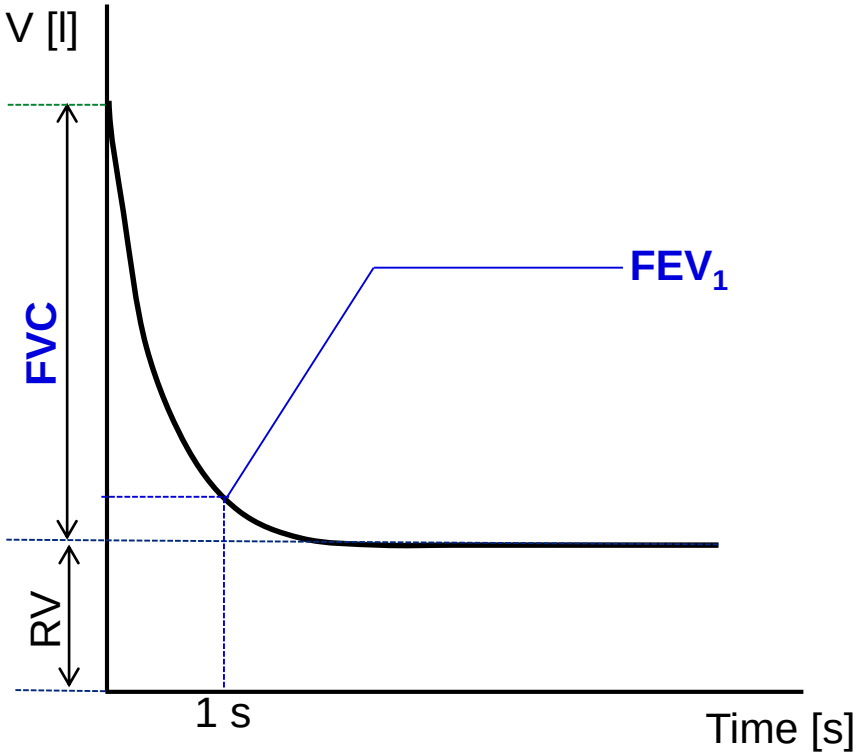
A25: Lung ventilation, volumes, measurement

Dynamic lung volumes



- **FVC** – the maximum volume of air that can be exhaled after maximum inhale
- **FEV_1** – the volume of air exhaled with the greatest effort in 1 second after maximum inhale
- **FEV_1/FVC (%)** – Tiffeneau index – around 0,8 (80 %)

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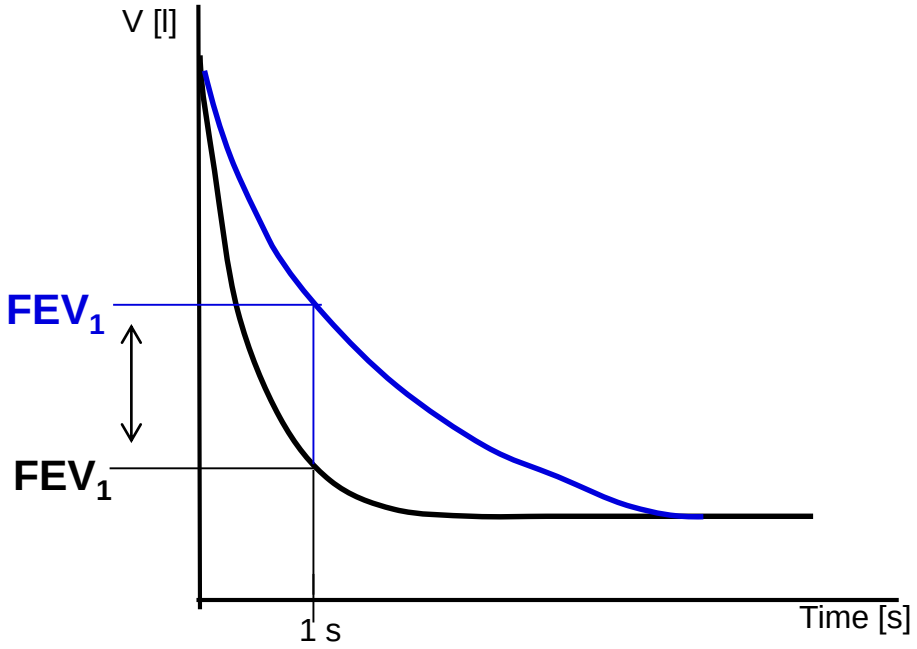
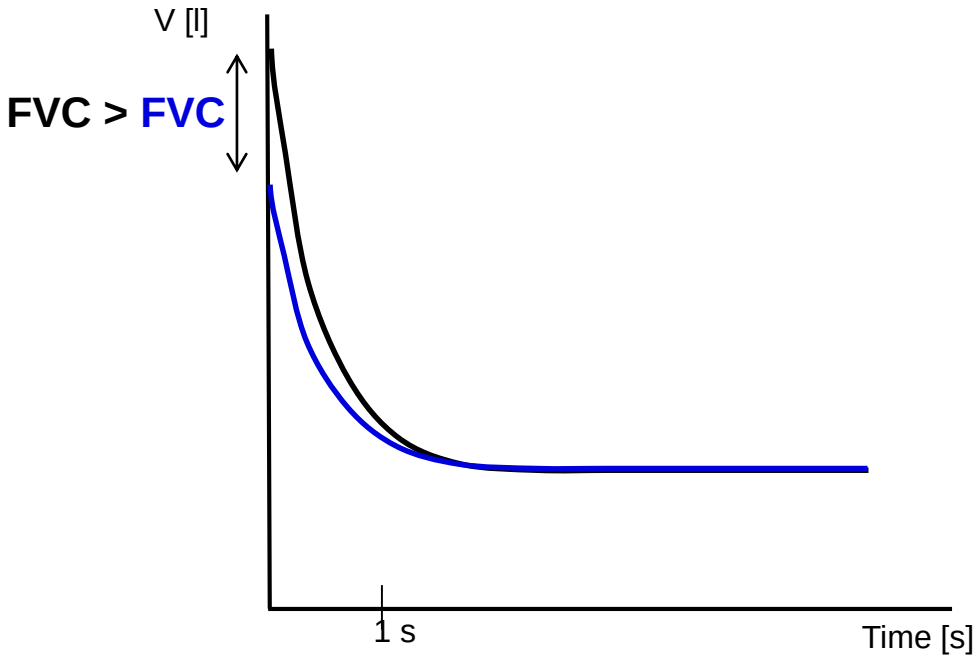
A25: Lung ventilation, volumes, measurement



Obstruction lung disease
(FVC=N; FEV_1=↓)
- tracheal stenosis
- astma bronchiale
- CHOPN
- tumor



Restrictive lung disease
(FVC=↓; FEV_1=N)

Pulmonarzy etiology
- pulmonary fibrosis
- lung resection
- pulmonary edema
- pneumonia

Extrapulmonary etiology
- ascites
- kyphoscoliosis
- burns
- high diaphragm condition

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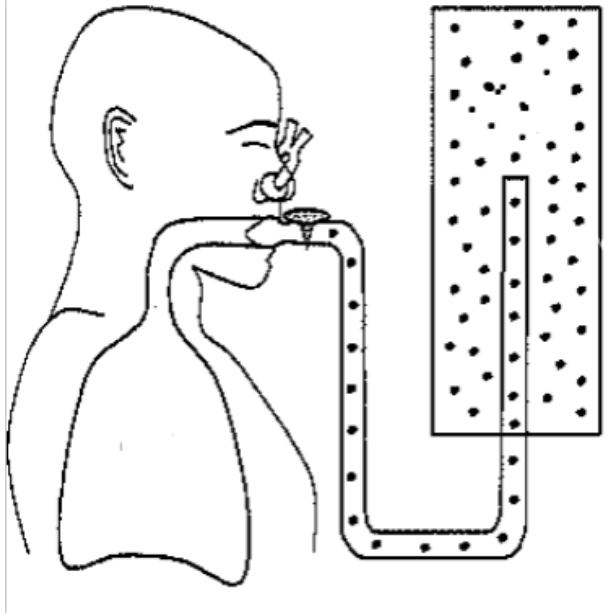
A25: Lung ventilation, volumes, measurement

Helium dilution method – residual volume

V_1
c_1

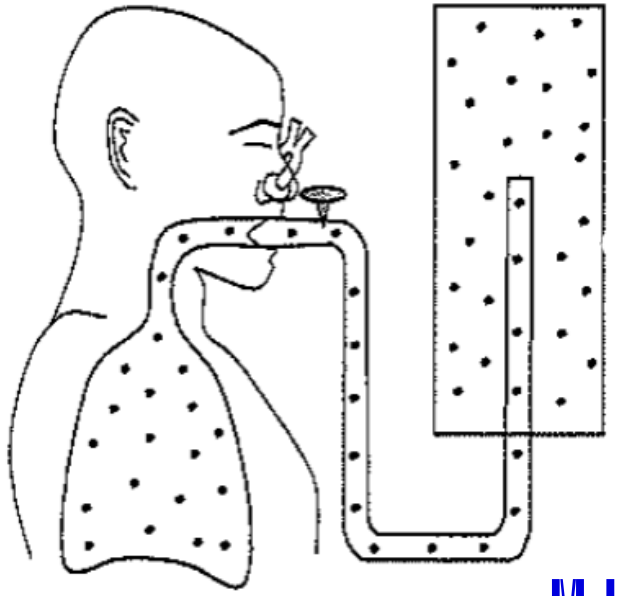


$c=\frac{n}{V}$

$$V_1 \times c_1 = (RV + V_1) \times c_2$$

$$RV = \frac{V_1 \times c_1}{c_2} - V_1$$

$V_2=RV+V_1$
c_2



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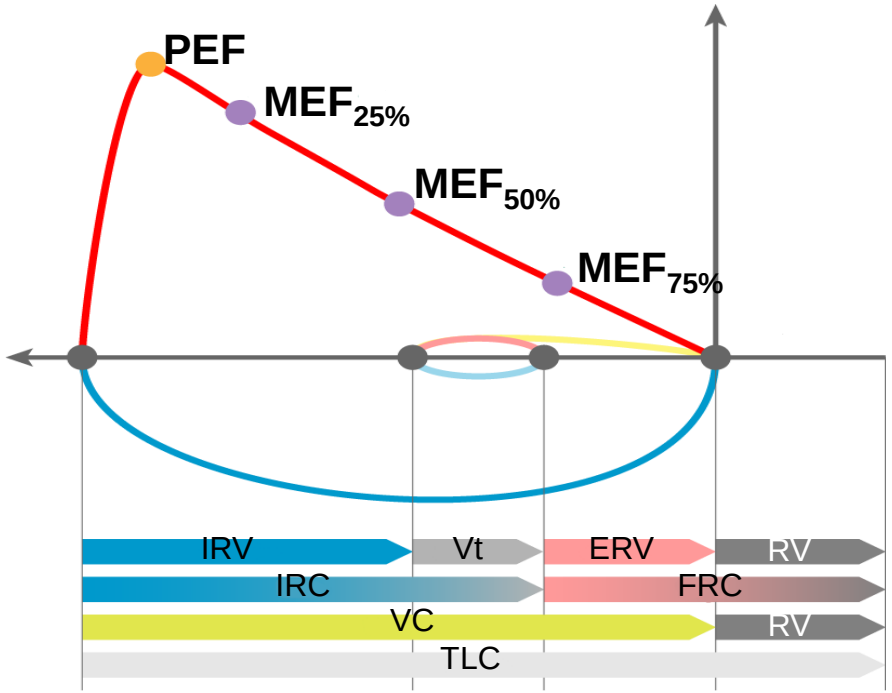
A28: Maximal respiratory flow - volume curve (spirogram)

Principle: the measurement of the air flow velocity according to the speed of the turbine and the volumes are calculated (Cosmed).

- **PEF** – peek expiratory flow; the highest speed of air flow at peak of exhale
- **MEF** – maximum expiratory flow rates at different FVC levels, which is still to be exhaled (75 %, 50 % and 25 % of FVC)



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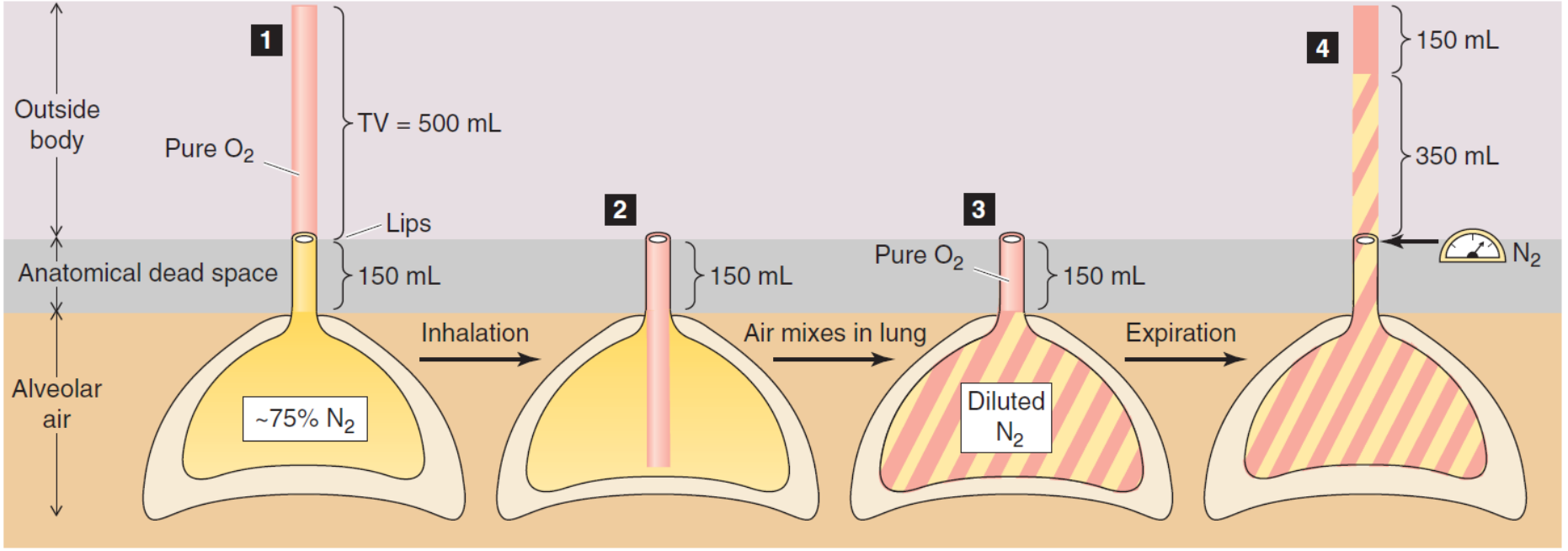
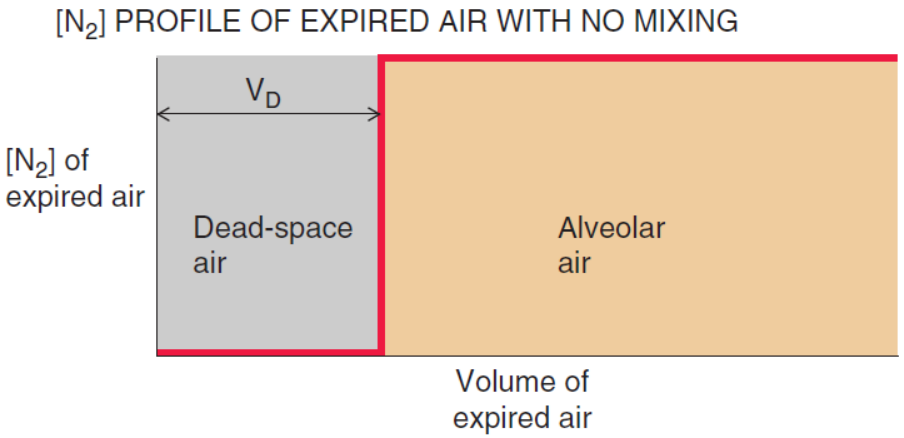
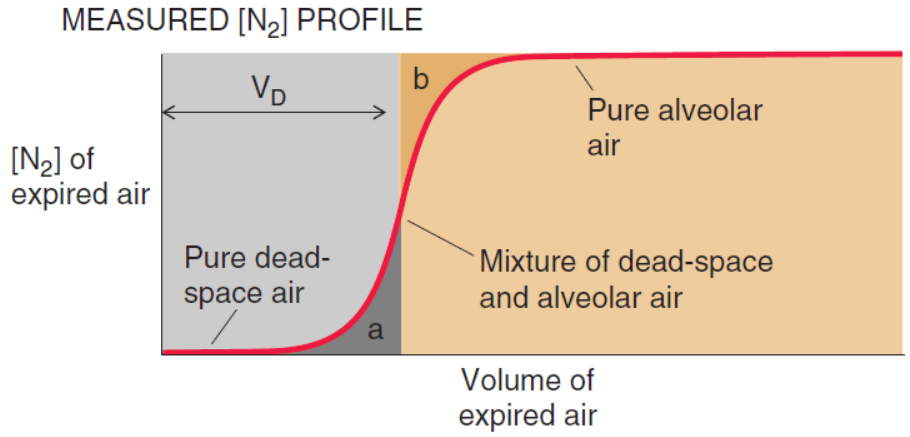
A26: Dead space, measurement







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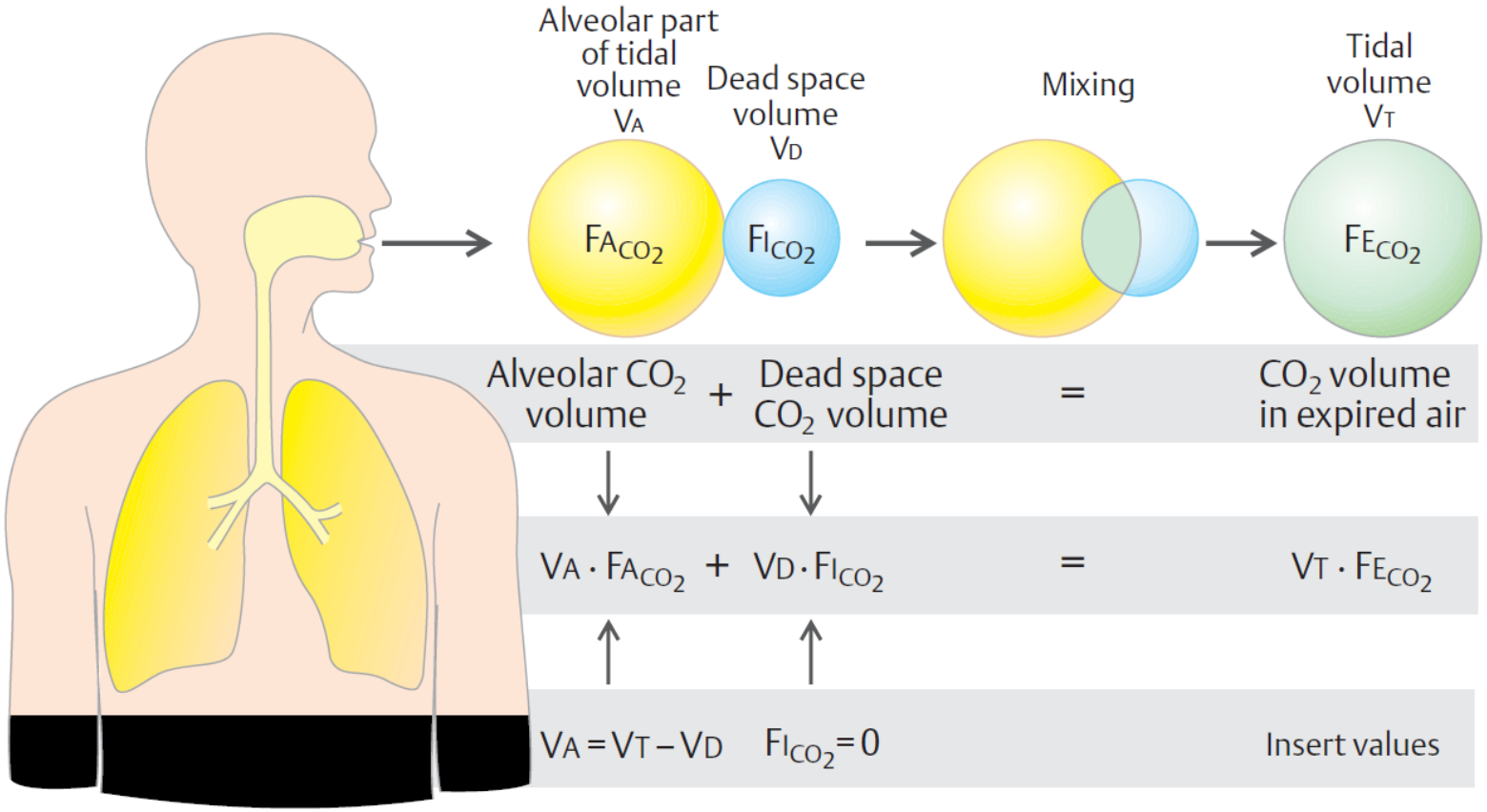
A26: Dead space, measurement



Bohr equation

$$\text{Dead space } V_D = \frac{V_T (F_{A_{CO_2}} - F_{E_{CO_2}})}{F_{A_{CO_2}}}$$

Using normal values:

$$V_D = \frac{0.5\,(0.056 - 0.040)}{0.056}$$

Dead space V_D = 143 mL

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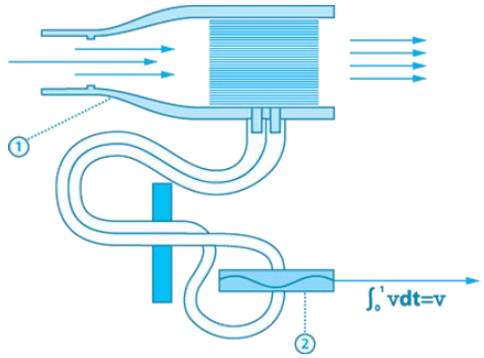
A27: Resistance of airways, measurement

Pneumotachograph:

- tubes of the same diameter, parallel arranged
- measures the differences in air pressure at the beginning and end of the pneumotachograph in proportion to the velocity of the inhaled or exhaled air



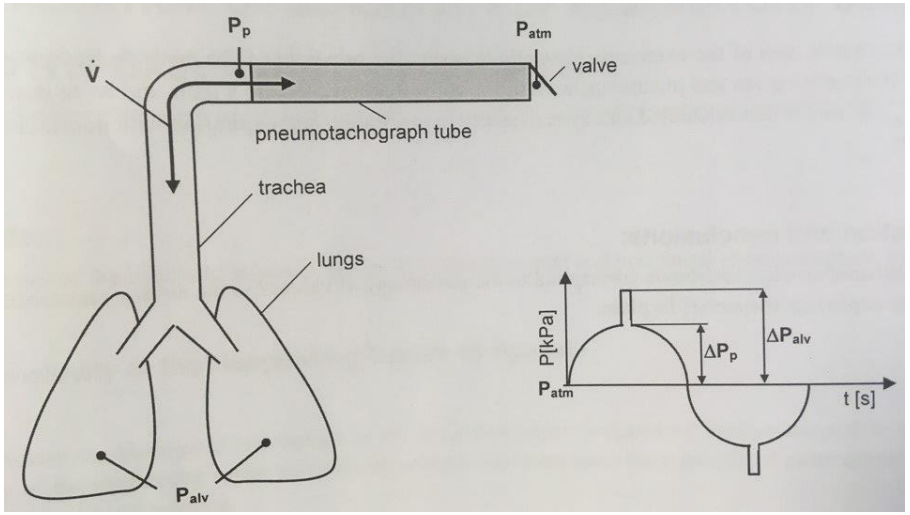
$$\dot{V} = \frac{\Delta P}{R}$$

$$\Delta P_p = P_p - P_{atm}$$

$$\Delta P_{alv} = P_{alv} - P_{atm}$$

$$R_d = R_p \cdot \left(\frac{\Delta P_{alv}}{\Delta P_p} - 1 \right)$$

$$\frac{P_p - P_{atm}}{R_p} = \dot{V} = \frac{P_{alv} - P_p}{R_d}$$



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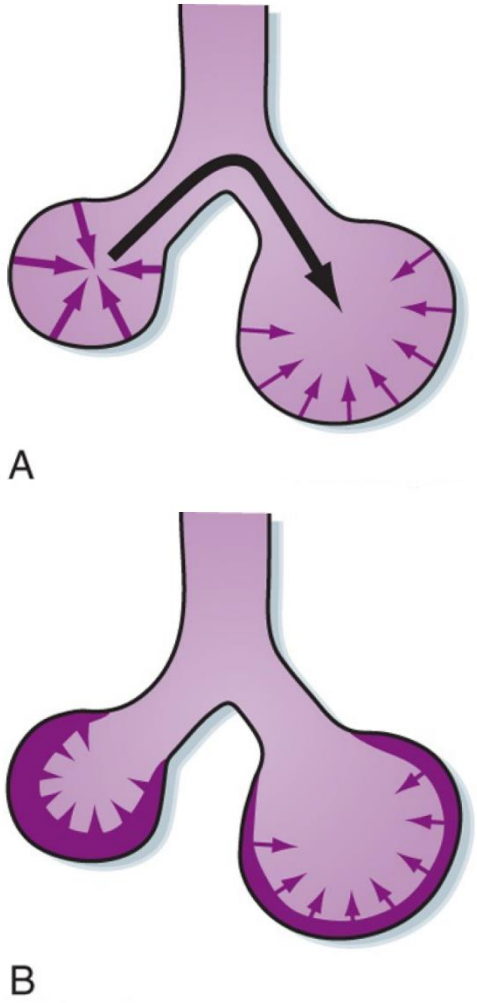
A45: Alveolar surface tension. Surfactant



- pneumocytes typ II
- reduces the surface tension depending on the size of the alveolus
- increases lung compliance, reduces breathing work

The Laplace law (in constant tension):
the alveolus with bigger radius has lower pressure
→ the air would move from a smaller alveolus to a bigger one
→ collapse of smaller alveoli

$$P = \frac{2T}{r}$$

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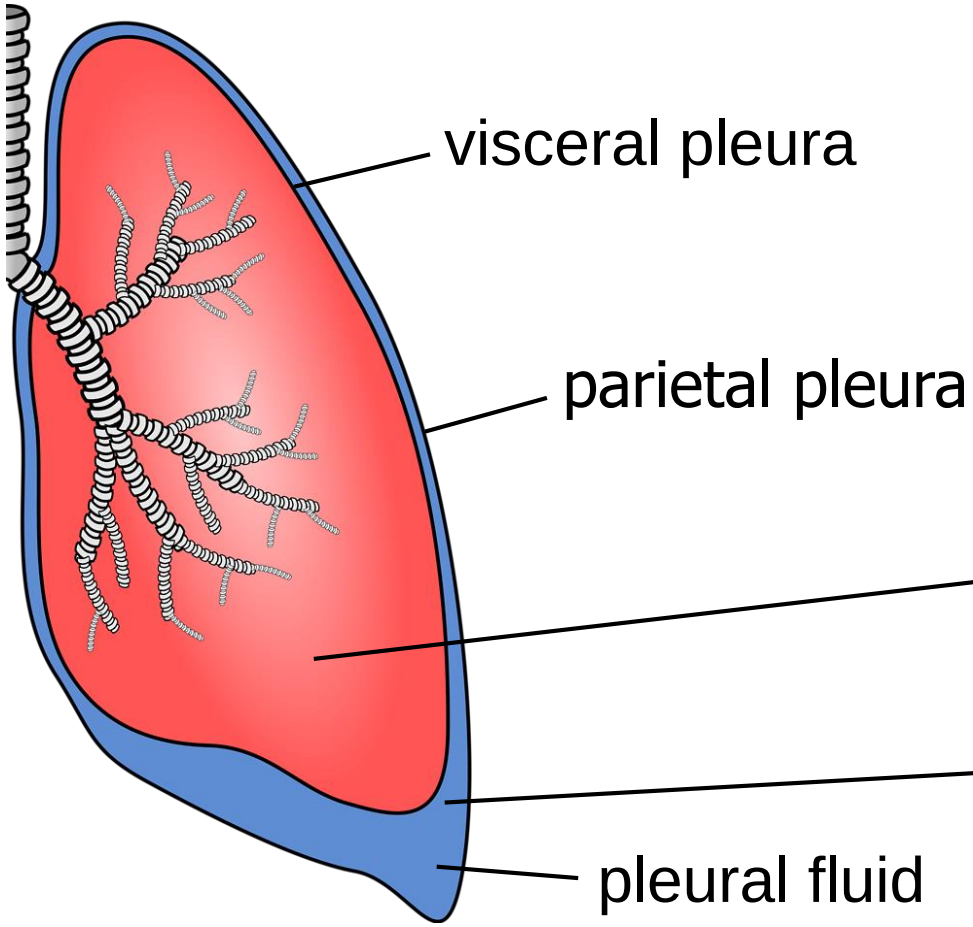
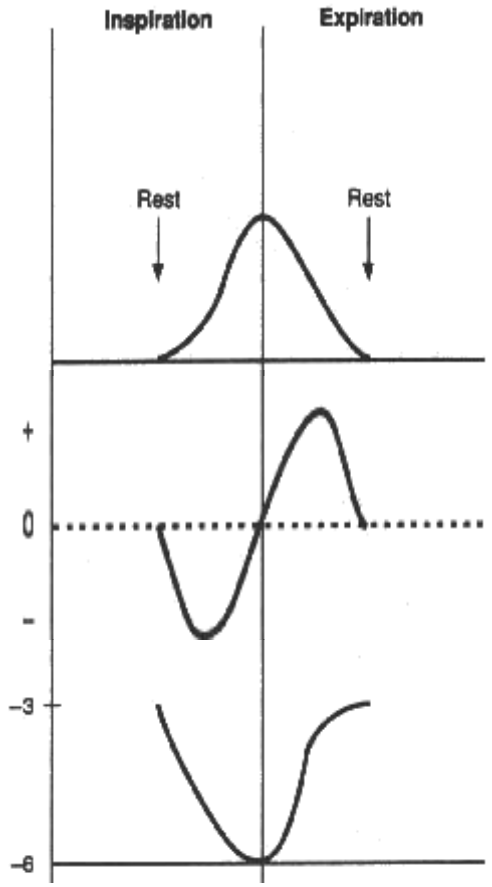
A46: Compliance of lungs. Respiratory work. Pneumothorax





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A46: Compliance of lungs. Respiratory work. Pneumothorax

- According to etiology:
  - **traumatic** pneumothorax (due to an injury) occurs if the chest wall is perforated or during an injury of the esophagus, bronchi, and during rib fractures.
  - **spontaneous** pneumothorax
  - **primary** idiopathic pneumothorax (without any known cause) may occur in tall healthy young men with an incidence of pneumothoraxes in the family,
  - **secondary** pneumothorax arises as a consequence of lung diseases (such as COPD or cystic fibrosis),
  - **iatrogenic** pneumothorax (due to medical procedures) occurs during invasive medical examinations such as transparietal aspiration biopsy, subclavian vein catheterization, or mechanical ventilation with positive pressure.
  - **artificially induced** (deliberate) pneumothorax is used during thoracoscopy, an endoscopic examination the thoracic cavity.
- According to the communication of the pleural space with its surroundings
  - **open pneumothorax** (when the hole in the pleural space remains open, the air in the pleural cavity moves back and forth with each breath of the patient)
  - **closed pneumothorax** (when a small opening through which air enters the pleural cavity closes)
  - **valvular pneumothorax** (the tissue of the lungs or the chest wall covers the hole in such a way that a valve emerges, this valve allows air to flow inside during inspiration, but it prevents the air from leaving the pleural cavity during exhalation).

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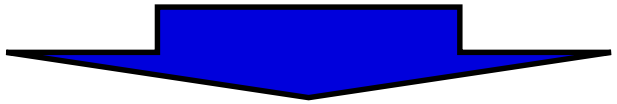
A46: Compliance of lungs. Respiratory work. Pneumothorax

Respiratory system resistance

- Elastic resistance:
  - elastic fibers
  - alveolar surface tension
- Nonelastic resistance:
  - viskose resistance
  - airway resistance



Respiratory work:

- Elastic
- Viskose
- Work of airway resistance

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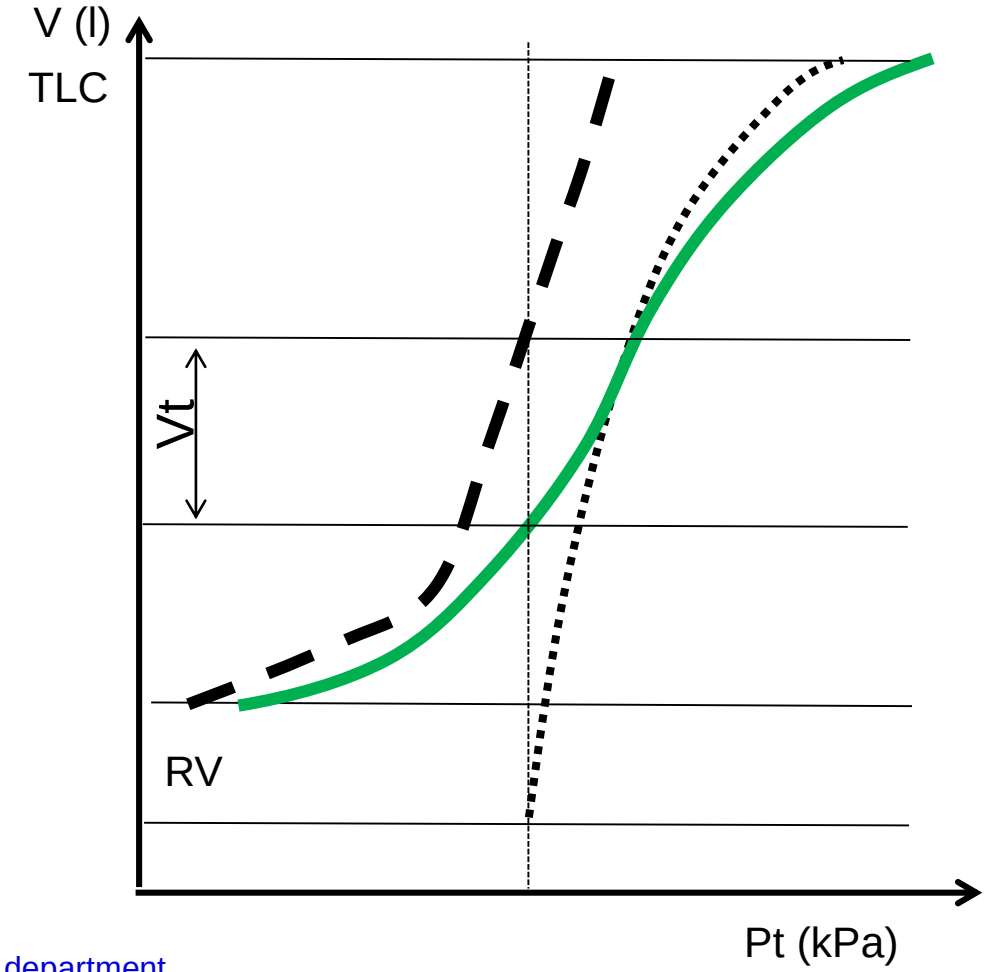
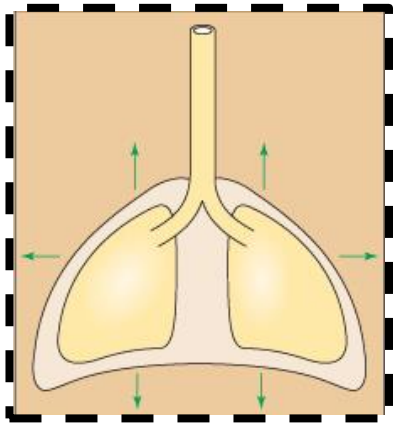
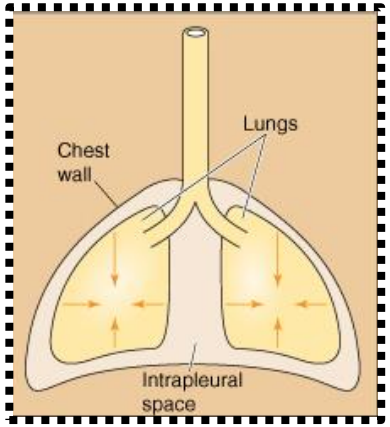
A46: Compliance of lungs. Respiratory work. Pneumothorax

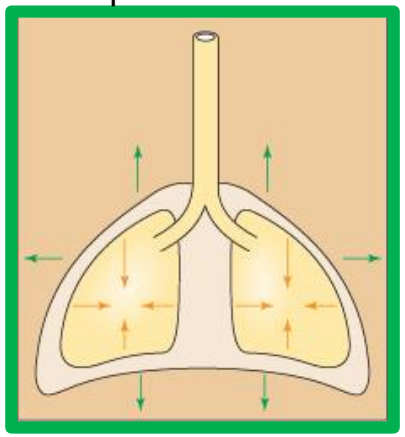




Pt: P_{atm} and P_{pl}



Pt: P_{alv} and P_{pl}



Pt: P_{atm} and P_{alv}

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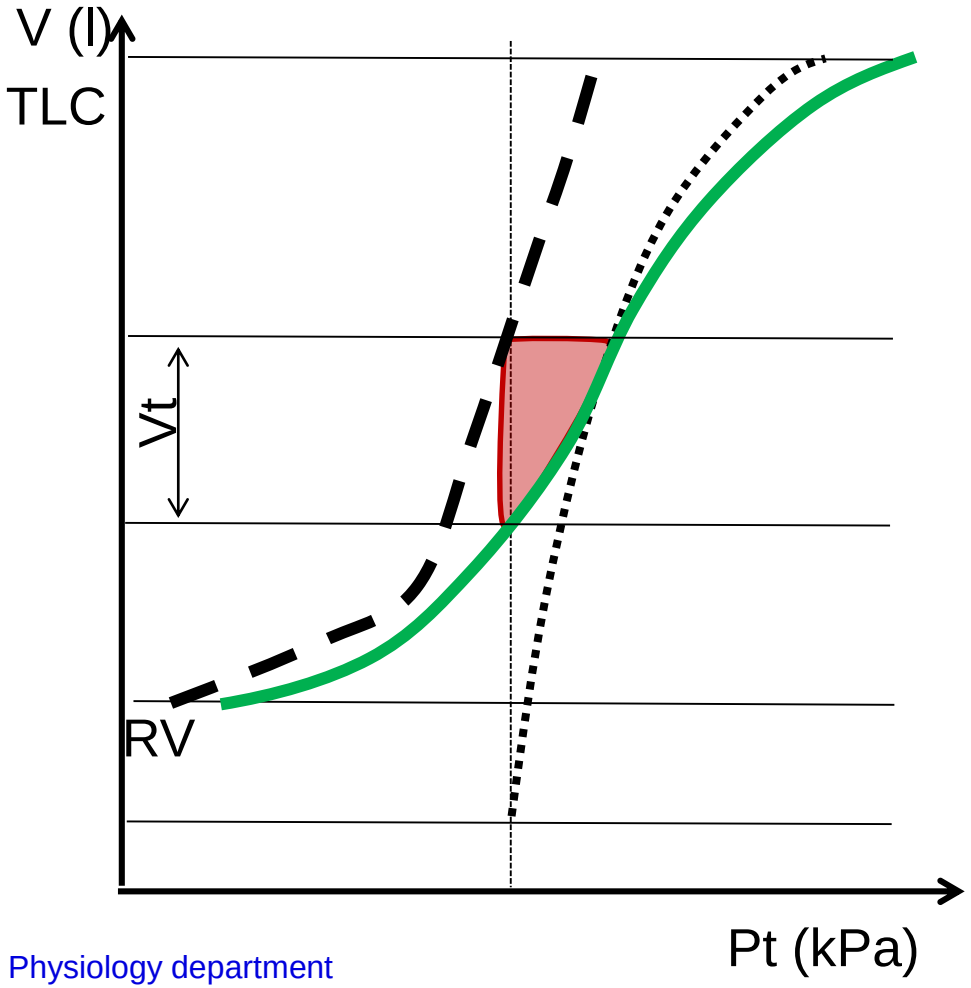
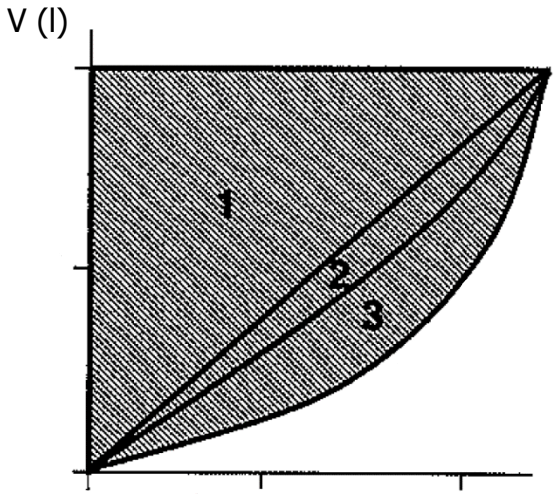
A46: Compliance of lungs. Respiratory work. Pneumothorax





Respiratory work:
1 – elastic
2 – viscos
3 – airway resistance

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A47: Composition of atmospheric and alveolar air. Gas exchange in lungs and tissues.

COMPOSITION OF DRY ATMOSPHERIC AIR

O_2	20.95 %	$F_{O2} \cong 0,21$
N_2	78.09 %	$F_{N2} \cong 0,78$
CO_2	0.03 %	$F_{CO2} \cong 0,0004$

BAROMETRIC PRESSURE IN SEA LEVEL

1 atmosphere = 760 mm Hg

PARTIAL PRESSURE OF DRY AIR IN SEA LEVEL

P_{O2}	= 760 x 0,21	=	~160 mm Hg
P_{N2}	= 760 x 0,78	=	~593 mm Hg
P_{CO2}	= 760 x 0,0004	=	~ 0,3 mm Hg

1 *kPa* = 7,5 *mm Hg (torr)*

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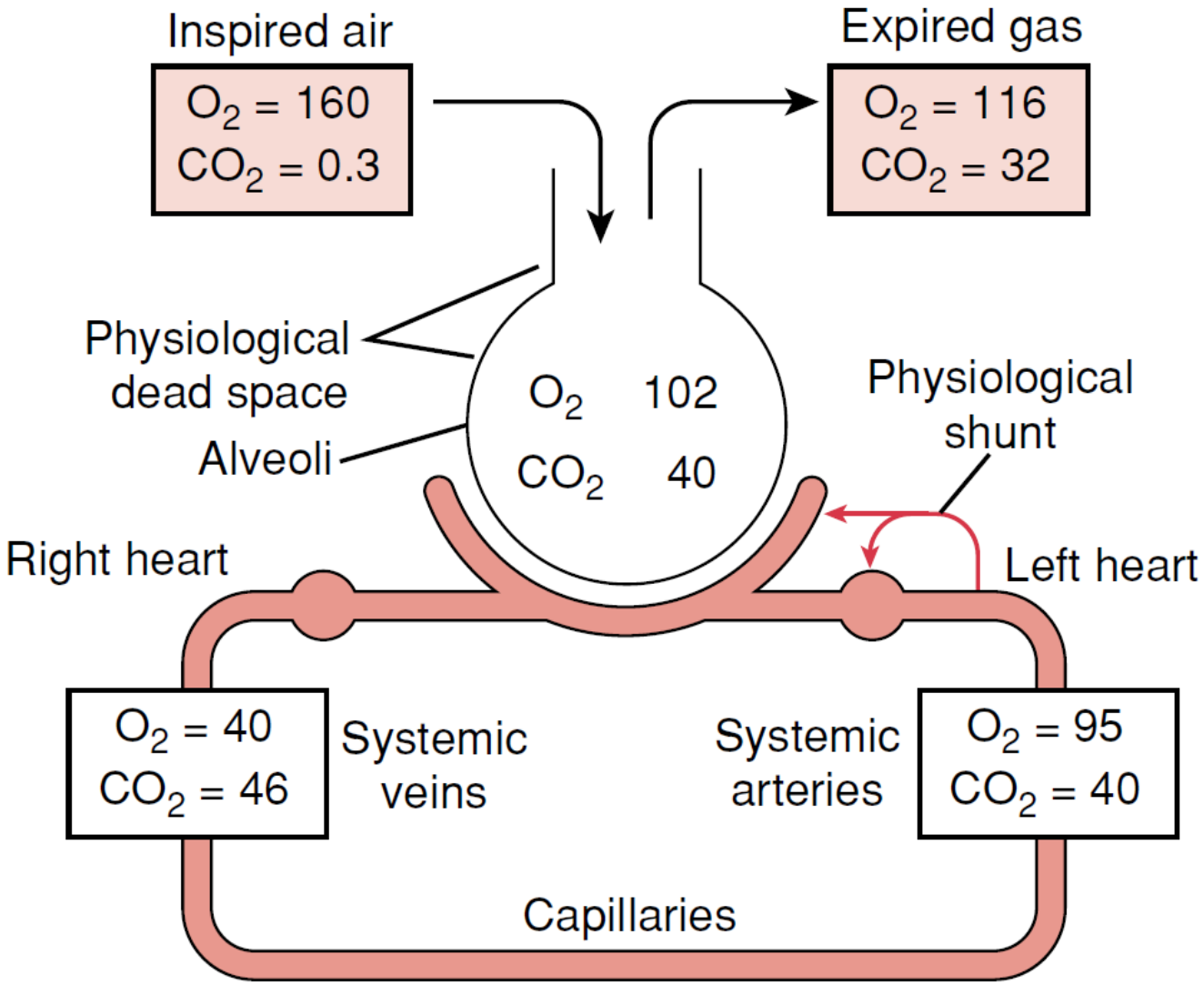
A47: Composition of atmospheric and alveolar air. Gas exchange in lungs and tissues.



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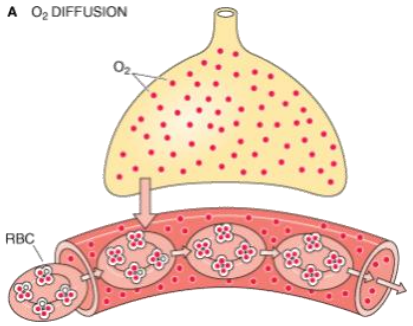
A48: Transport of O2. Oxygen - haemoglobin dissociation curve. Transport of CO2



O_2 is transported in two forms :

- physically dissolved(1%)
- in chemical bond with Hb (99%)

- Fetal hemoglobin(2α, 2γ)
- Methemoglobin (Fe^{3+})
- Carboxyhemoglobin (CO)
- Carbaminohemoglobin (CO_2)
- Oxyhemoglobin (O_2)
- Deoxyhemoglobin (without any gases)

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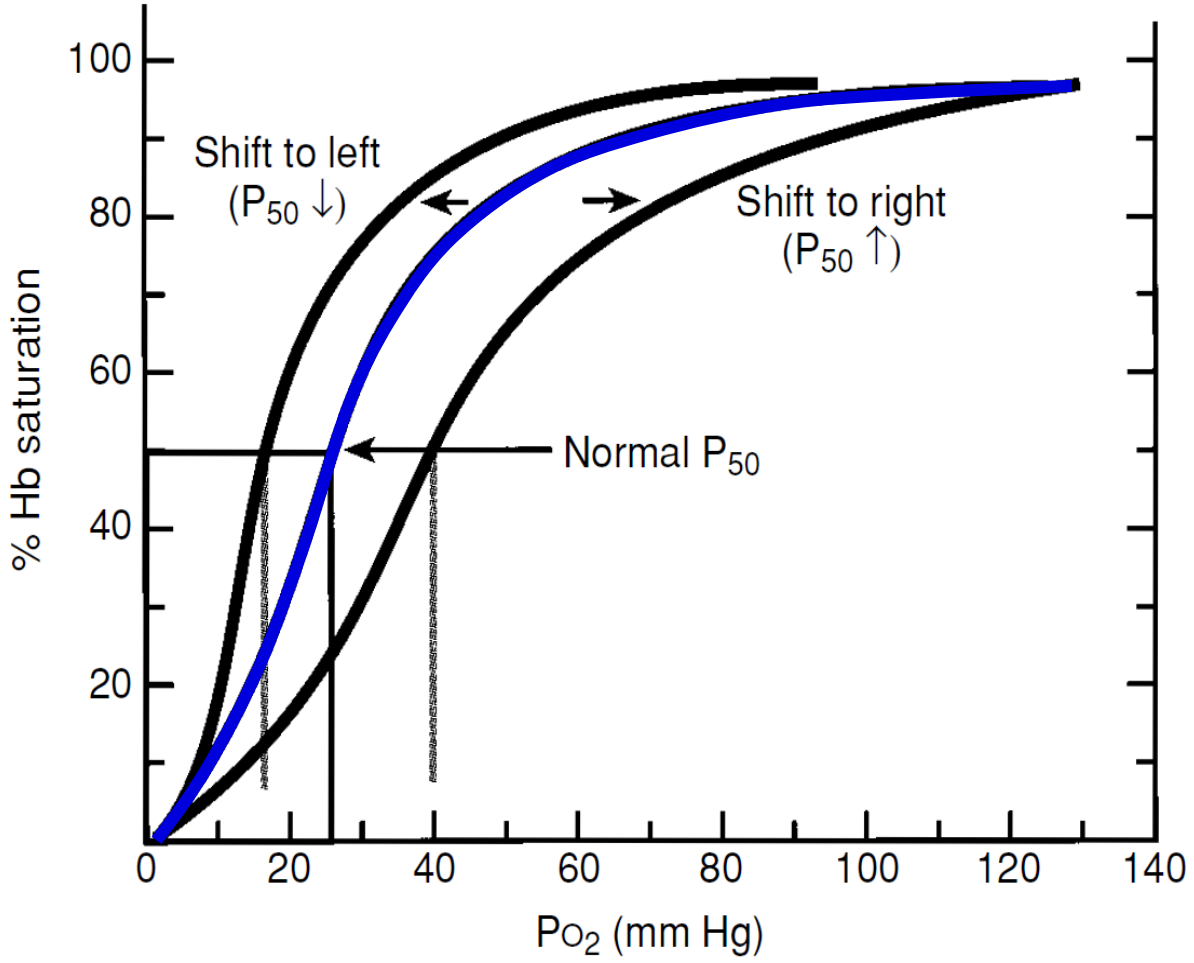
A48: Transport of O2. Oxygen - haemoglobin dissociation curve. Transport of CO2



Dissociation curve of Hb is influenced by:

- pH of blood
- pCO_2 of blood
- Temperature
- Concentration of 2,3 - BPG

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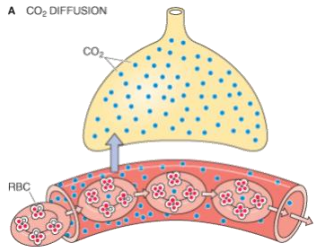
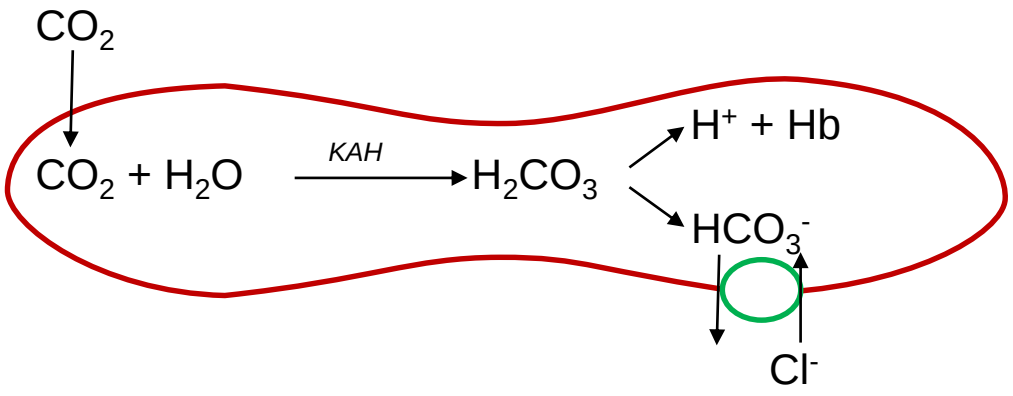
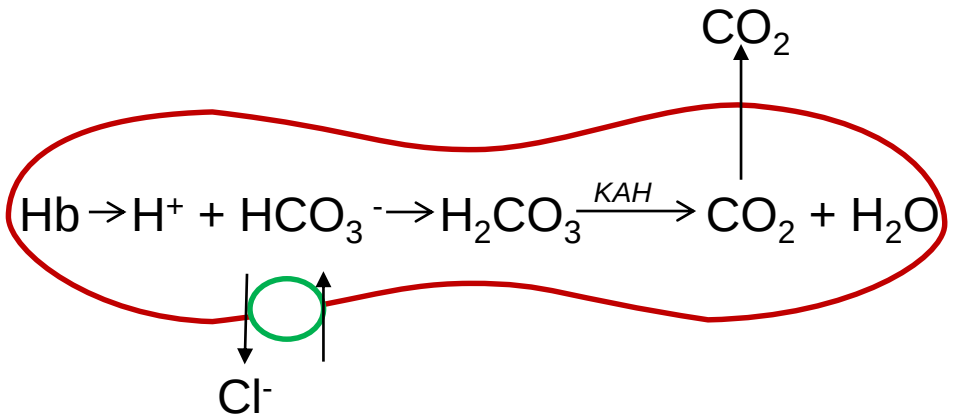
A48: Transport of O2. Oxygen - haemoglobin dissociation curve. Transport of CO2



CO_2 is transported in next forms :

- physically dissolved(5 %)
- in the form of bicarbonate anions (85%)
- in chemical bond with Hb (10%)





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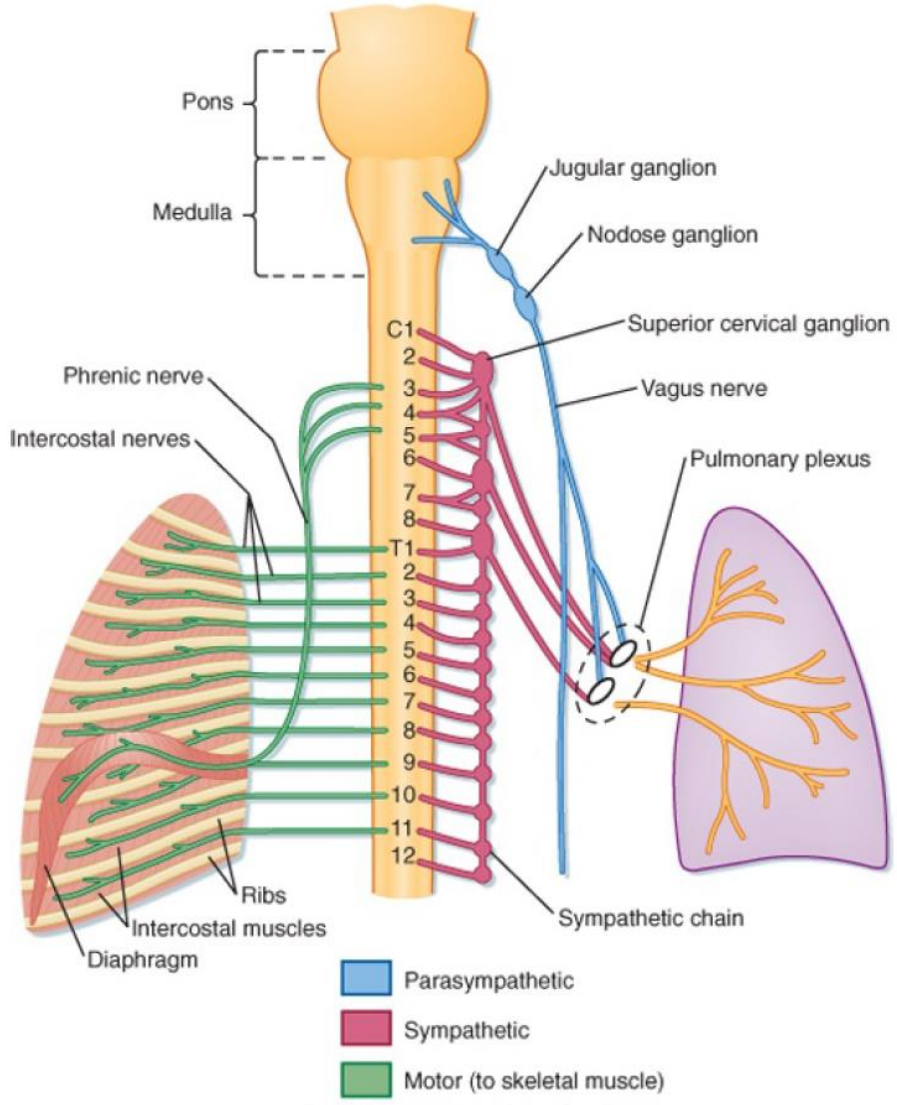
A49: Regulation of ventilation



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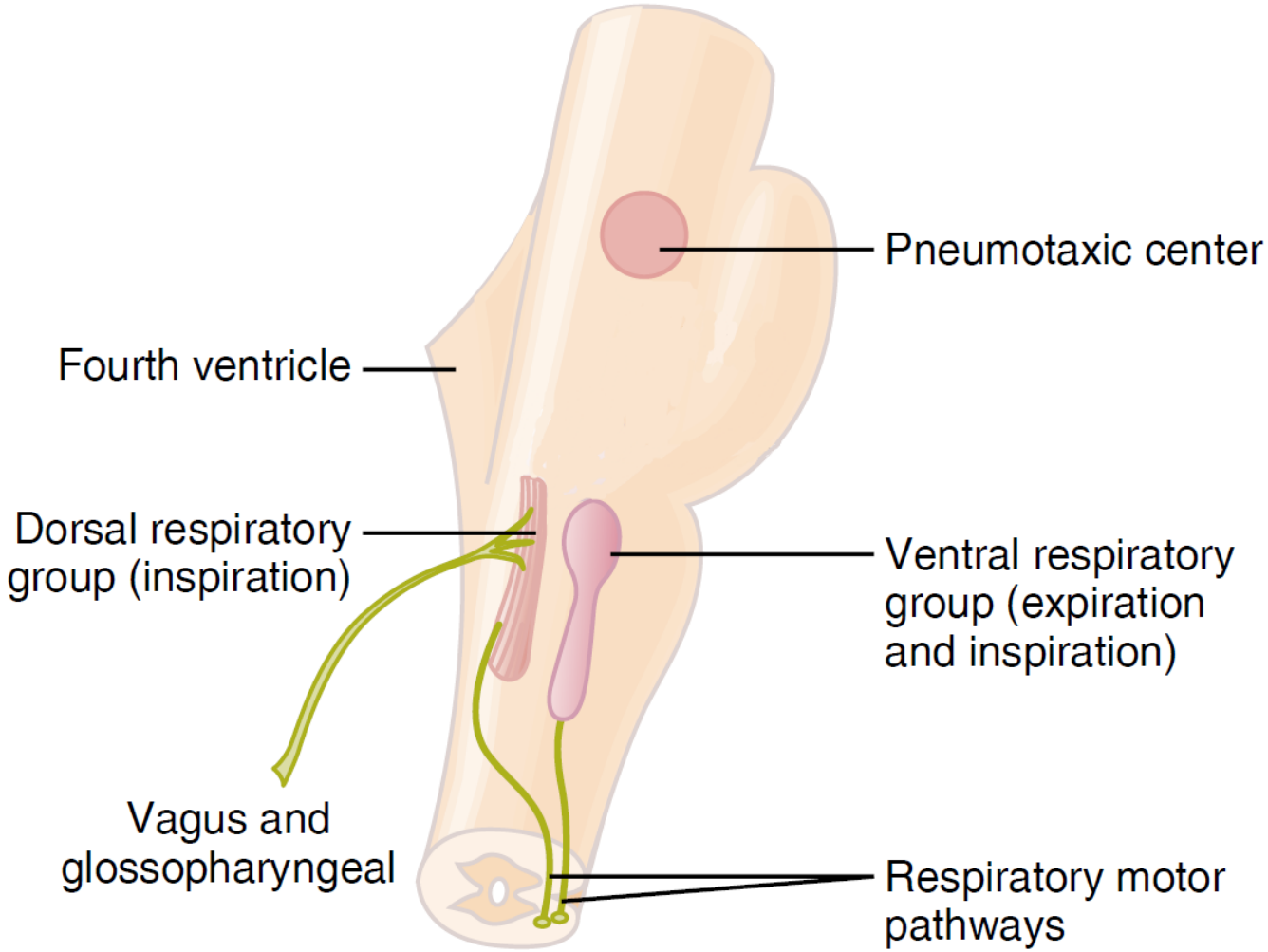
A49: Regulation of ventilation



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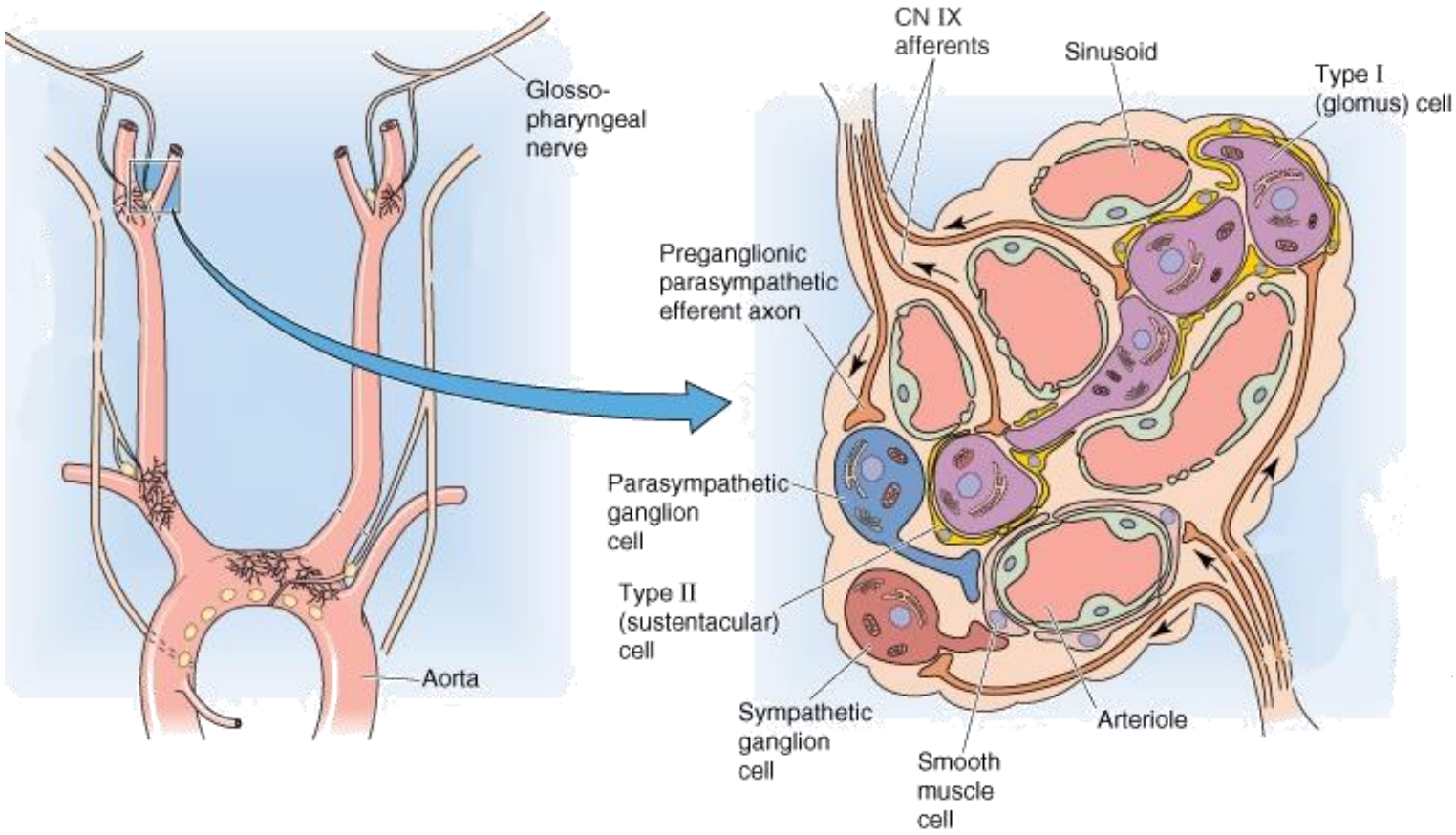
A49: Regulation of ventilation



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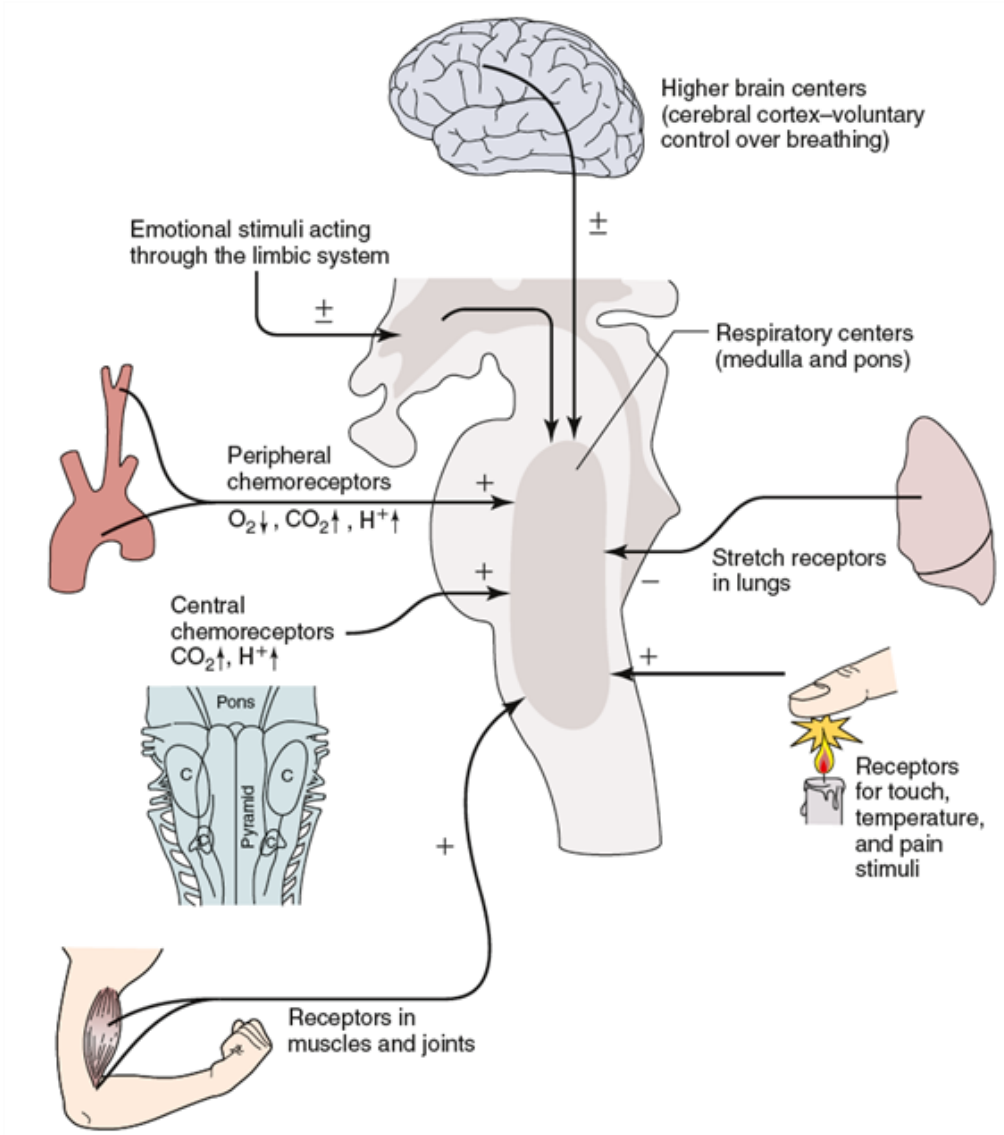
A49: Regulation of ventilation



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A50: Respiratory responses to irritants

The lungs are protected from damage by:

- presence of hair (vibrissae) in the nasal cavity (traps dust particles)
- presence of ciliary epithelium covered with mucus (cilia moving mucus in one direction - into the pharynx)
- pulmonary alveolar macrophages
- presence of antibodies in bronchial secretion (IgA)

Reflexes:

- Herring-Breuer reflexes (inflation/deflation)
- Sneeze reflex
- Cough reflex
- Hiccup
- Yawn

A50: Respiratory responses to irritants

Cough Reflex	Sneeze Reflex	Hiccup
Cough is an expulsive reflex that protects the lungs and respiratory passage from foreign bodies. *Causes of cough*: – Irritants-smokes, fumes, dusts, etc. – Diseased conditions like COPD, tumors of thorax, etc. *Pathway for cough reflex:* – Receptors in nose, paranasal sinuses, pharynx, trachea, pleura, diaphragm, perichondrium, stomach, ex.auditory canal and tymphanic membrane – V,IX,X cranial nerves and phrenic nerves – medulla – X cranial nerve, phrenic nerve, spinal motor nerve – primary and accessory respiratory muscles	Sneeze is defined as the involuntary expulsion of air containing irritants from nose. *Causes of sneeze:* – Irritation of nasal mucosa – Excess fluid in airway *Pathway for sneeze reflex:* – Olfactory receptors or V cranial nerve endings – I and V cranial nerve – medulla – nucleus solitarious and reticular formation – V, VII, IX, X cranial nerves and intercostal muscles – pharyngeal, tracheal and respiratory muscles	Hiccup is spasmodic contraction of the diaphragm which causes a sudden intake of breath that is involuntarily cut off by closure of the glottis, thus producing a characteristic sound. *Causes of hiccup:* – Eating too fast or too much – Strokes, brain tumors, damage to the vagus or phrenic nerve – Anxiety and stress *Pathway for sneeze reflex:* – Phrenic, vagus, and sympathetic nerves – Midbrain – Motor fibers of phrenic nerve and accessory nerves – Diaphragm and intercostal muscles

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A50: Respiratory responses to irritants

Herring-Breuer reflexes (inflation/deflation)

- *a. keeps the lungs from over-inflating with inspired air*
  - *pulmonary stretch R – vagus nerve – medulla – inhibition of inspiration and initiation of expiration*
- *b. serves to shorten exhalation when the lung is deflated*
  - *pulmonary stretch R – vagus nerve – the pontine center*