XVII. Pneumography
XX. Pneumotachography

Physiology I – practice

Autumn, weeks 10-12

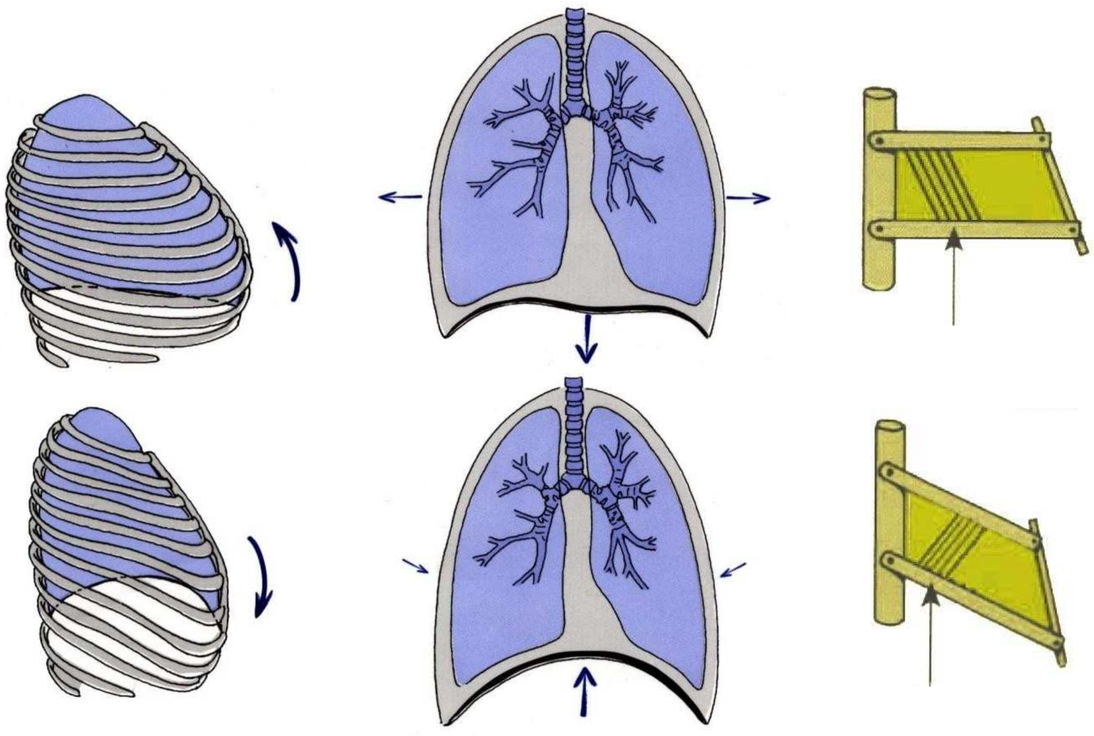
Pneumography

- = a method for registration of respiratory movements
- Respiratory muscles
  - Main inspiratory muscles: diaphragm and external intercostal muscles
  - Accessory inspiratory muscles: sternocleidomastoid musculus and a group of scalene muscles
  - Expiratory muscles: internal intercostal muscles and anterior abdominal wall muscles
- Inspiration – active process (contraction of respiratory muscles)
- Expiration – a passive process at rest (elasticity of the lungs pulls the chest wall back to the expiratory position), and forced exhalation is an active process (use of expiratory muscles)

Pneumography

inspiration

expiration



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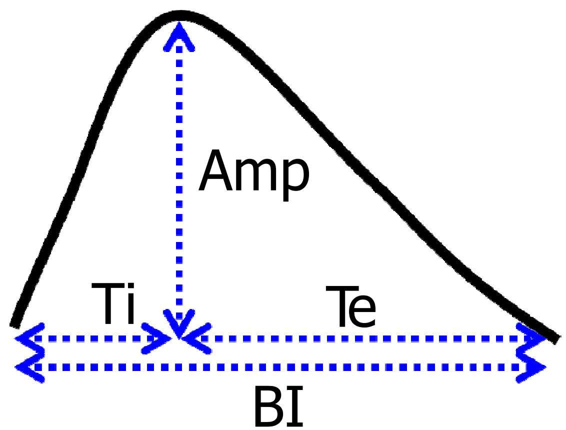
Chemical regulation of ventilation

- Ventilation = tidal volume * respiratory rate
  - The volume of air ventilated over time (l/min)
  - Respiratory rate in pneumography – determined by the duration of the whole respiratory cycle (breathing interval, BI), duration of inspiration (T_i) and expiration (T_e)
  - Depth of breathing in pneumography – amplitude of breathing movements (Amp)
- Chemical control of ventilation leads to a change in depth and frequency of breathing based on chemoreceptor information
- Chemoreceptors
  - Central – cells in the medulla oblongata near the respiratory centre
  - Peripheral – carotid and aortic

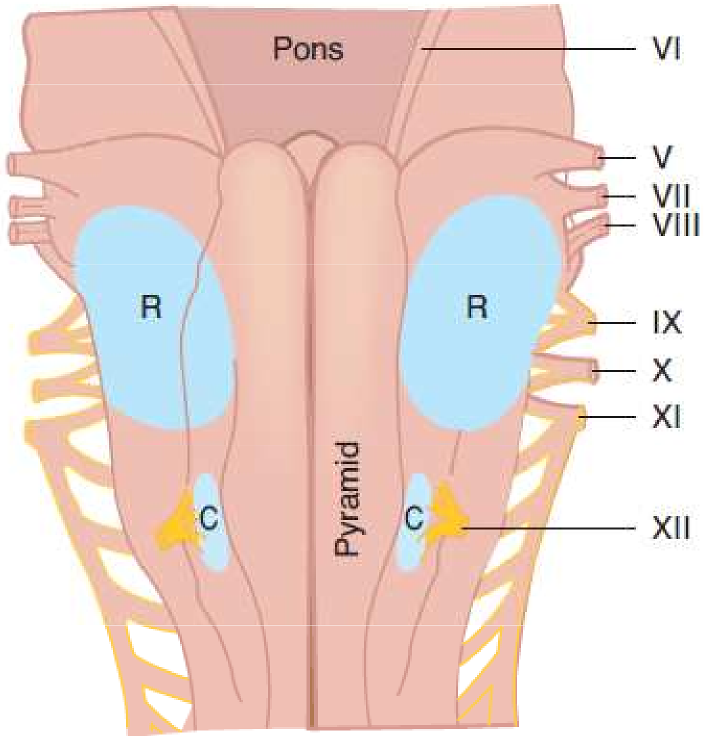


Central chemoreceptors

– Located near the respiratory centre in the medulla oblongata
– CO_2 passes the blood-brain barrier into the cerebrospinal and intercellular fluids of the brain

$$CO_2 + H_2O \rightarrow CHO_3^- + H^+$$

– Increased concentration of H_+ in cerebrospinal fluid stimulates chemoreceptors → increased ventilation



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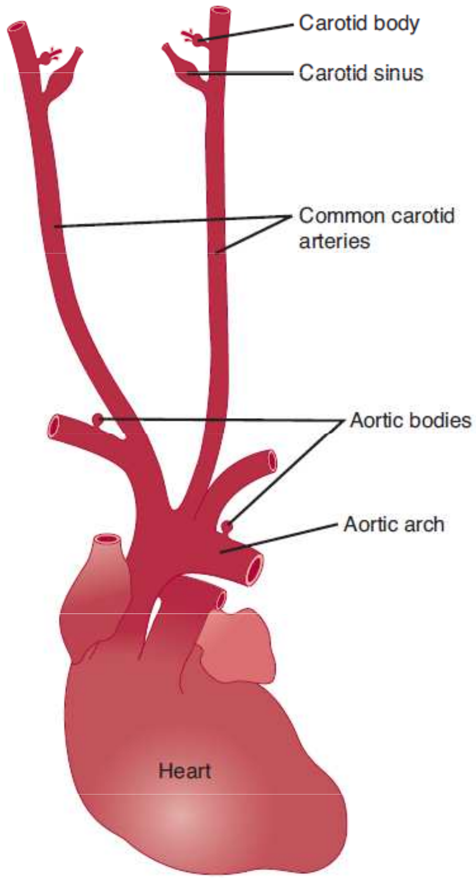
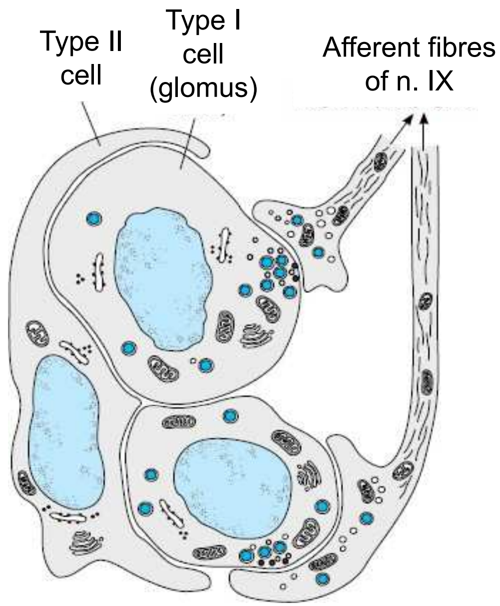
Peripheral chemoreceptors

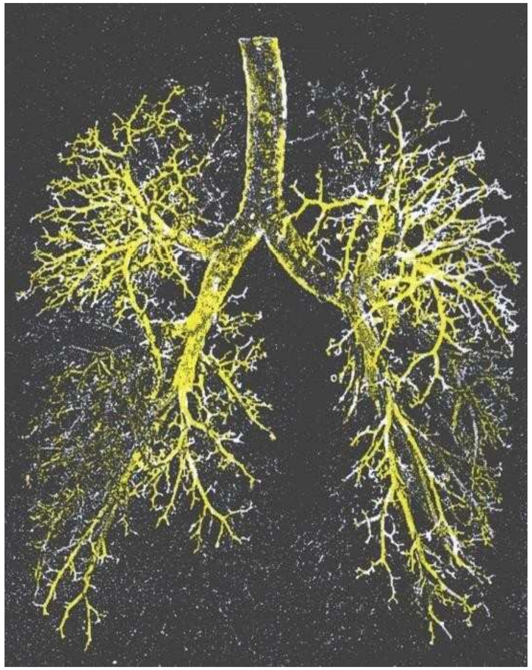
- They contain two types of cells
  - Type I: located beside nerve fibres
  - Type II: glia (each one surrounds 4-6 type I cells)
- Registration of pO_2 levels dissolved in the blood plasma over time
  - Stimulation by a decrease in pO_2 or by a decrease in blood flow
- Peripheral receptors also register pCO_2 and pH





Dead space

- Air volume in the conductive airway area where no gas exchange with blood occurs
  - Anatomical DS: volume of the respiratory system outside the alveoli (150-200 mL)
  - Functional (physiological) DS: the volume of air that does not participate in gas exchange with the blood – includes non-perfused alveoli
- In healthy individuals, both dead spaces are the same



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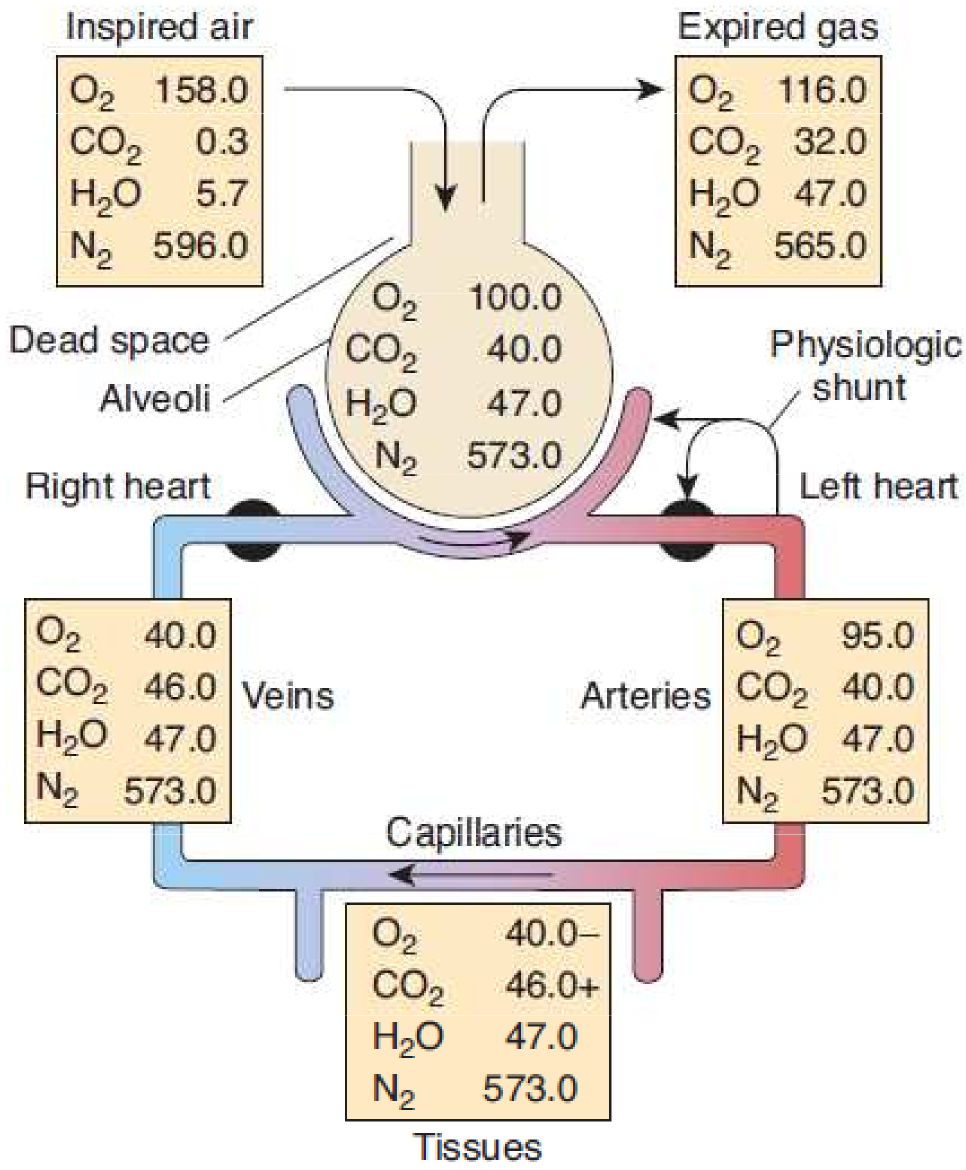
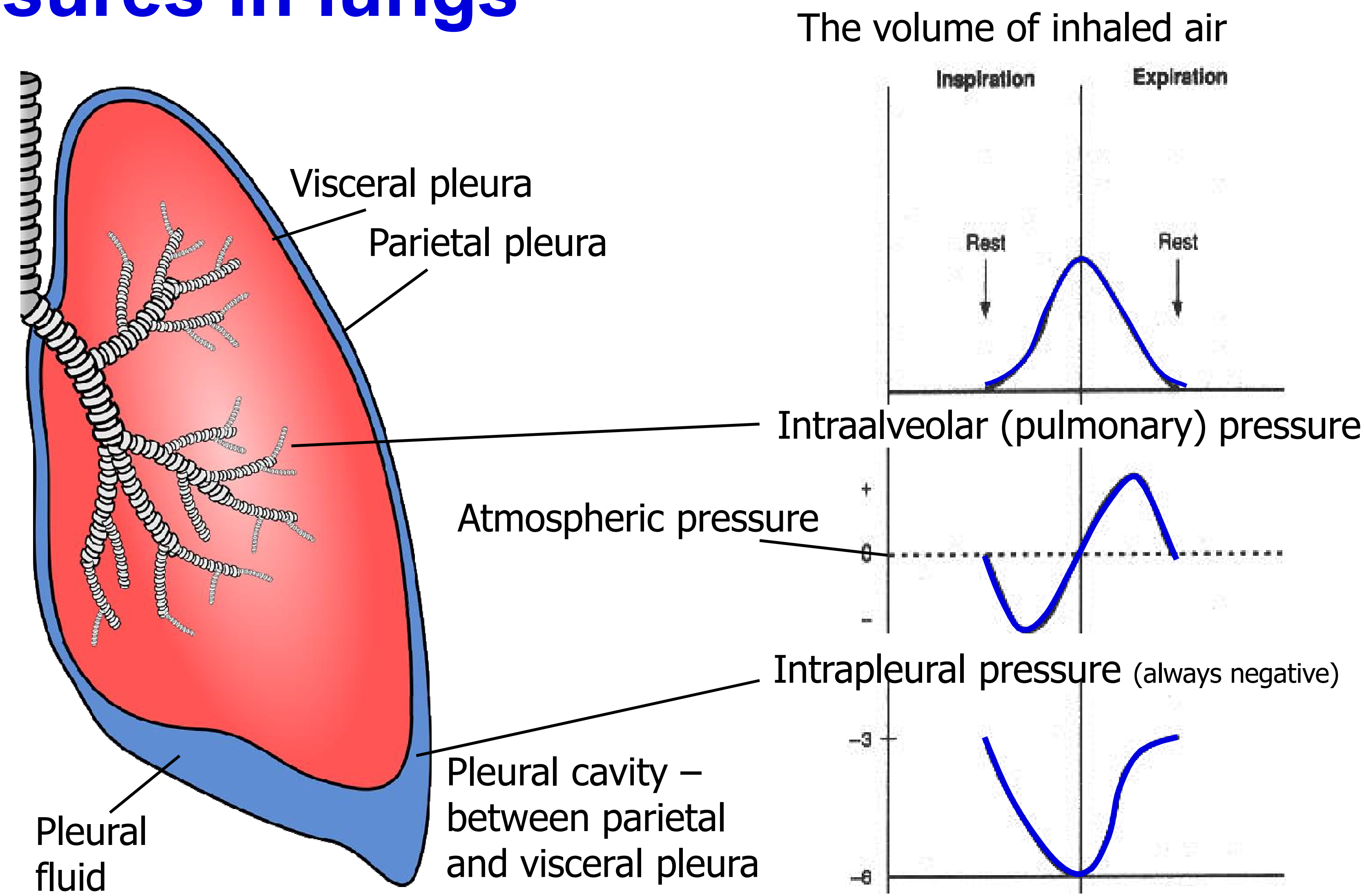
Partial pressures of gases (mmHg)

– in different parts of the respiratory and circulatory systems



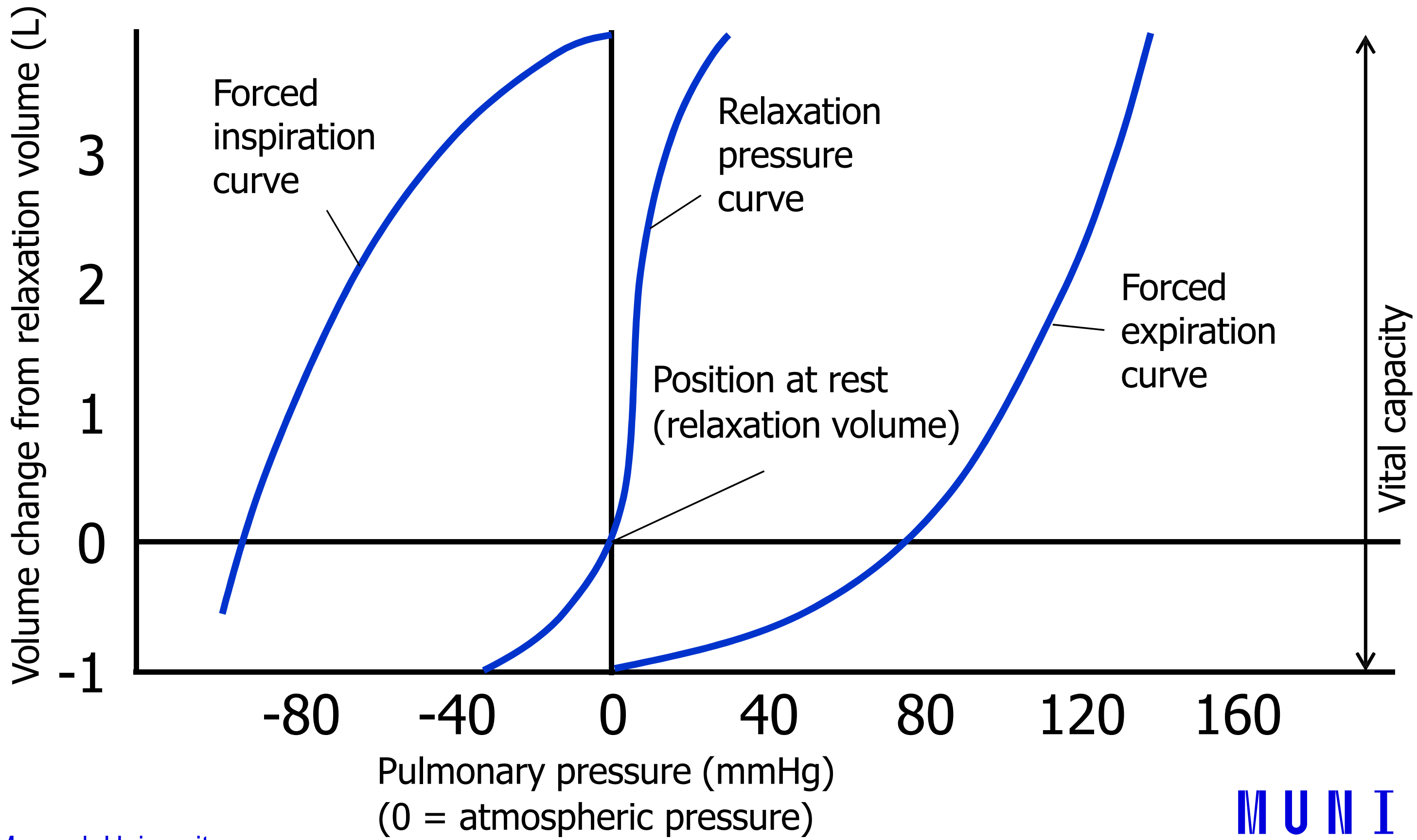
http://worldartsme.com/images/happy-lungs-clipart-1.jpg

Pressures in lungs



Lung compliance C

- $C = \frac{\Delta V}{\Delta C}$
  - the slope of the curve on the graph
- The value of C is the highest at rest
- The value of C depends on
  - Own tissue elasticity (ensured by elastin and collagen fibres)
  - Surface tension forces (surface tension forces in the alveoli: liquid-air interface, surfactant)

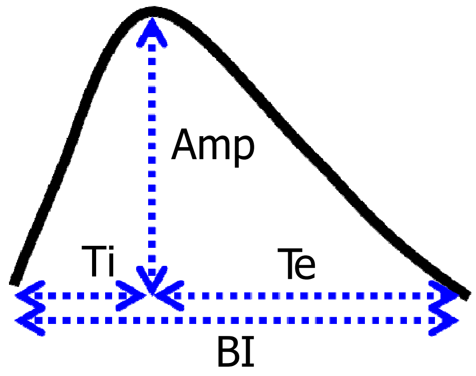


Statistical evaluation – in general

		Reality	
		H_0	H_A
Results	H_0	OK	β
	H_A	α	OK

- Mann-Whitney test
  - Nonparametric sequential test, it compares samples A and B
- Null hypothesis H_0: sample A do not differ from sample B
- Alternative hypothesis H_A: sample A is bigger or smaller than sample B
- Statistical significance of α (usually $\alpha = 0.05$ or 0.01)
  - The probability of error, in other words, that we reject H_0 based on the selection, but in reality H_0 is true
- Test results:
  - The test is not significant = confirmation of H_0: we did not confirm the difference between A and B
  - The test is significant with significance α = rejection of H_0: we confirmed that there is a difference between A and B

Statistical evaluation – an example



- Sample A: Amp at rest, sample B: Amp after exercise
- Null hypothesis H_0: Amp at rest will be the same as Amp after the exercise
- Alternative hypothesis H_A: Amp at rest is bigger or lower than Amp after exercise
- We compare T1´-T1 with the table values for α while the number of elements n = 6. Possible results:
  - T1´-T1 < 13 → we do not reject H_0 at the significance level of α = 0.01, i.e. we have not shown that Amp at rest differed from Amp after exercise
  - T1´-T1 > 13 → we reject H_0 at the significance level of α = 0.05, i.e. we have shown that Amp at rest differs from Amp after exercise (logically it should be higher after exercise)
  - T1´-T1 > 16 → we reject H_0 at the significance level of α = 0.01, i.e. we have shown that Amp at rest differs from Amp after exercise (logically it should be higher after exercise)

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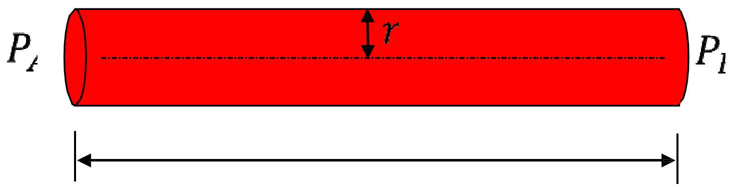
Pneumotachography

Pneumotachography

- Pneumotachography is a method enabling the estimation of airway resistance. It measures the pressure difference between two ends of a tube through which the examined person breathes.

- An increased value of airway resistance indicates obstruction of the airways.

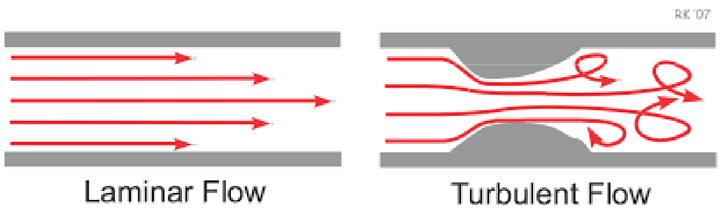
Poiseuille-Hagen law



- Volume flow (Q) in rigid tube equals directly to the pressure gradient between the beginning and end of the tube ($\Delta P = P_A - P_B$) and to the fourth power of its radius (r), and indirectly to its length (l) and viscosity of the fluid (η)

$$Q = \frac{\pi \cdot \Delta P \cdot \boldsymbol{r^4}}{8 \cdot l \cdot \eta} = \frac{\Delta P}{\boldsymbol{R}}$$

- R is tube resistance against gas flow
  - The pressure required to pass a given volume of liquid/gas through the tube
  - Valid only in laminar flow



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Airway resistance

- Airway resistence (R_d) results from inner friction between flowing gas and the airway wall.

$$R_d = \frac{\Delta P}{Q} = \frac{8 \cdot l \cdot \eta}{\pi \cdot r_d^4}$$

- A small change in the radius of the airways (r_d) causes a substantially bigger change in the airway resistance to airflow (R_d).
  - Narrowing (obstruction) of the airways occurs when the chest is compressed, the mucous membrane is swollen, vocal cords are swollen, smooth muscles of the airways are constricted when a foreign body is inhaled, asthma attack or other allergic reaction
  - Bronchioles are the main contributors to resistance: a large proportion of smooth muscle and no cartilaginous reinforcement, they contain receptors for various agents (histamine –

Principle of pneumotachography

- The airflow in the pneumotachograph is the same as the airflow in the airways:

$$\frac{P_p - P_{atm}}{R_p} = Q = \frac{P_{alv} - P_p}{\boldsymbol{R_d}}$$

Substitution:

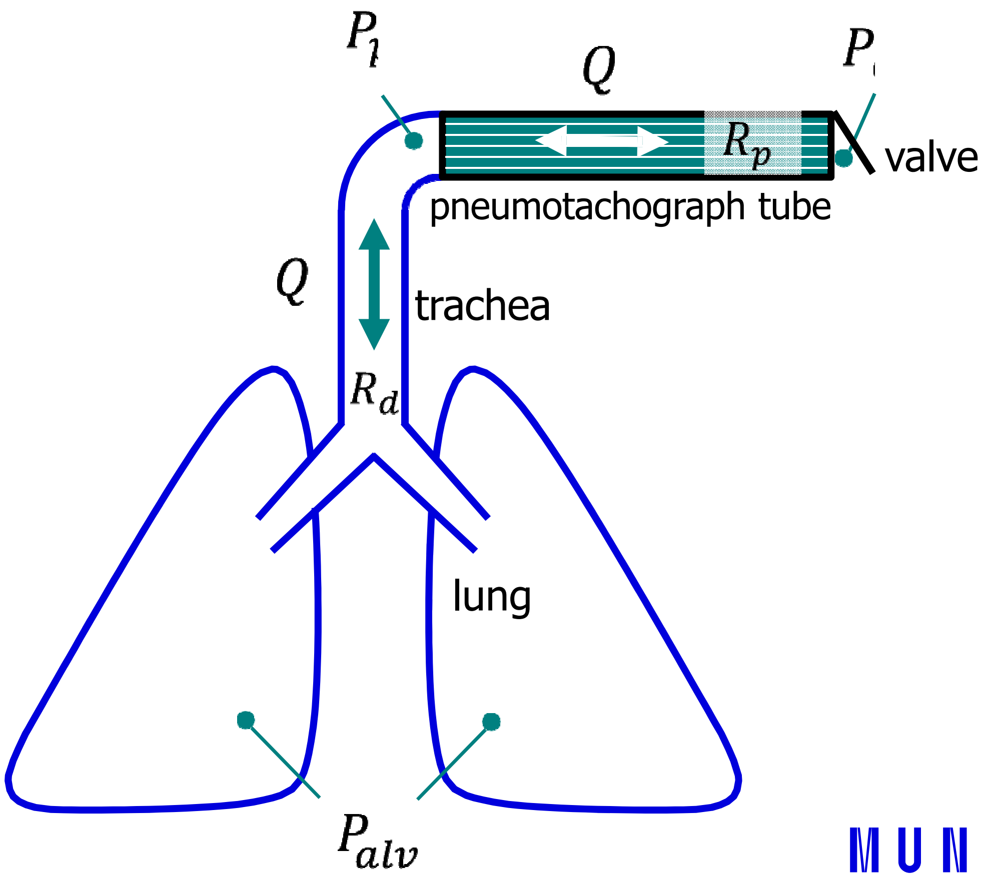
$$\Delta P_p = P_p - P_{atm}$$
$$\Delta P_{alv} = P_{alv} - P_{atm}$$

$$\boldsymbol{R_d} = R_p \cdot \left[\frac{\Delta P_{alv}}{\Delta P_p} - 1\right]$$

Pneumotachograph resistence: $R_p = 0.043\ \mathrm{kPa \cdot s/L}$

ΔP_p and ΔP_{alv} are measured

(Note: The values are in mV, not kPa, which does not matter because they are in ratio. Do not write minus for expiratory values.)

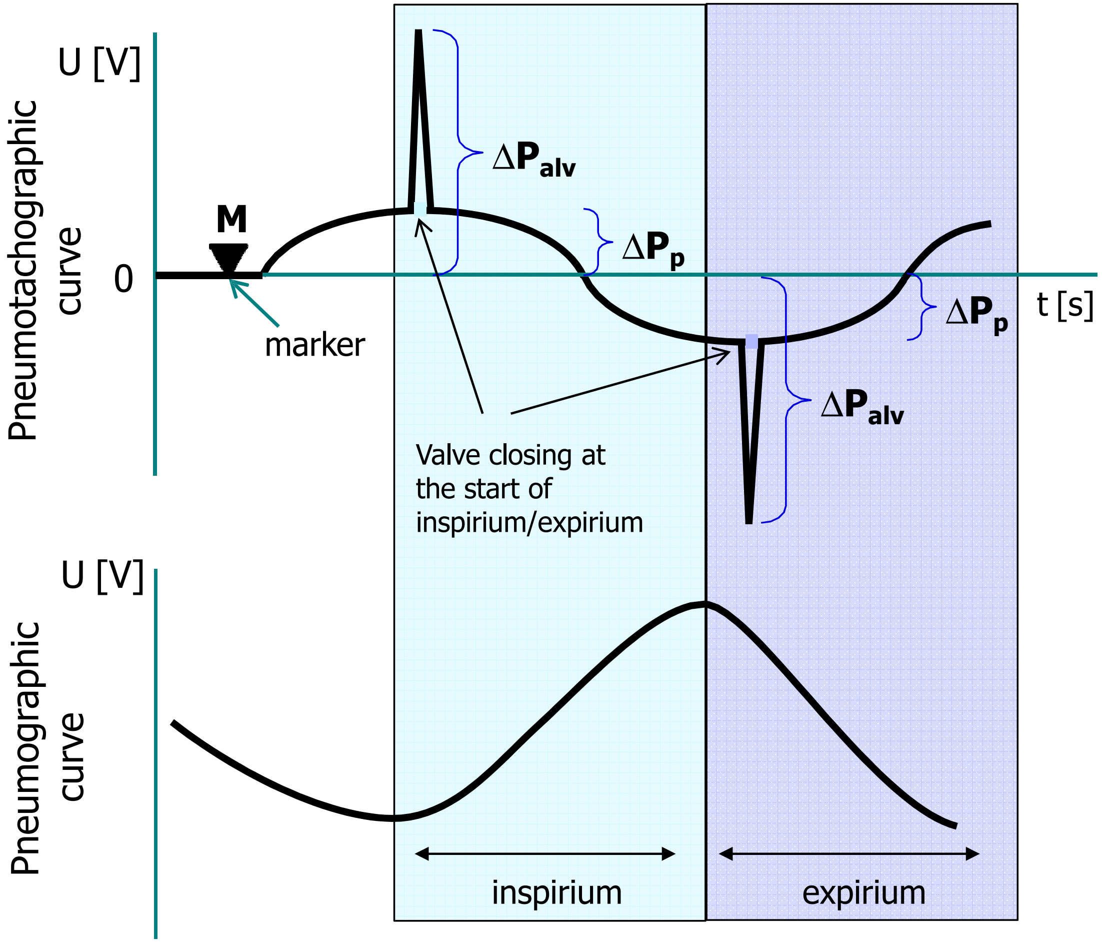


– $$\boldsymbol{R_d} = R_p \cdot \left[\frac{\Delta P_{alv}}{\Delta P_p} - 1\right]$$

– Calculation of R_d
  – During inspiration with a normal mouthpiece
  – During expiration with the normal mouthpiece
  – During inspiration with a narrowed mouthpiece
  – During expiration with the narrowed mouthpiece

  – Physiological values: $0.1 - 0.2\ \mathrm{kPa} \cdot s/\mathrm{L}$

A narrowed mouthpiece increases R



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