

FYS 4250

Lecture 5

Image: www.Dräger.com

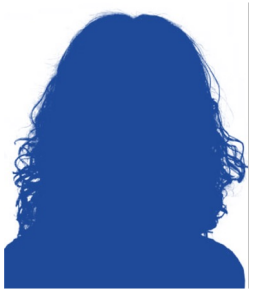
Case 5



Illustrasjonsbildehttp://www.mlive.com/news/saginaw/index.ssf/2011/04/dispatchers_report_injury_acci.html

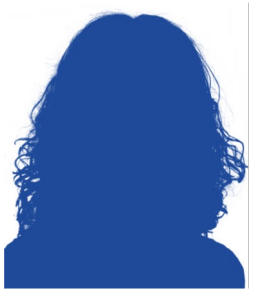
- 29 year old woman, victim of a severe car accident outside a middle sized city. When the car is found, she is confused but conscious, able to talk coherently but only two or three words. She needs help to get out of the car and finds it difficult to stand upright.

Case 5



- The accident appears to be somewhat mysterious, her car swerved up in the ditch at a straight part of the road with no other cars in sight. She is brought to the emergency department (ED), complaining of difficulty breathing and severe headache. In the ambulance, she is treated with a nonrebreather mask on 100-percent oxygen, only able to say a couple of words at a time. She denies any chest pain. Her temperature is 38.7°C, the blood pressure is 110 systolic and 66 mmHg diastolic, the heart rate is 121 beats per minute, respiratory rate is 28 breaths per minute and the oxygen saturation is 92%. The chest X-ray seems normal.

Case 5

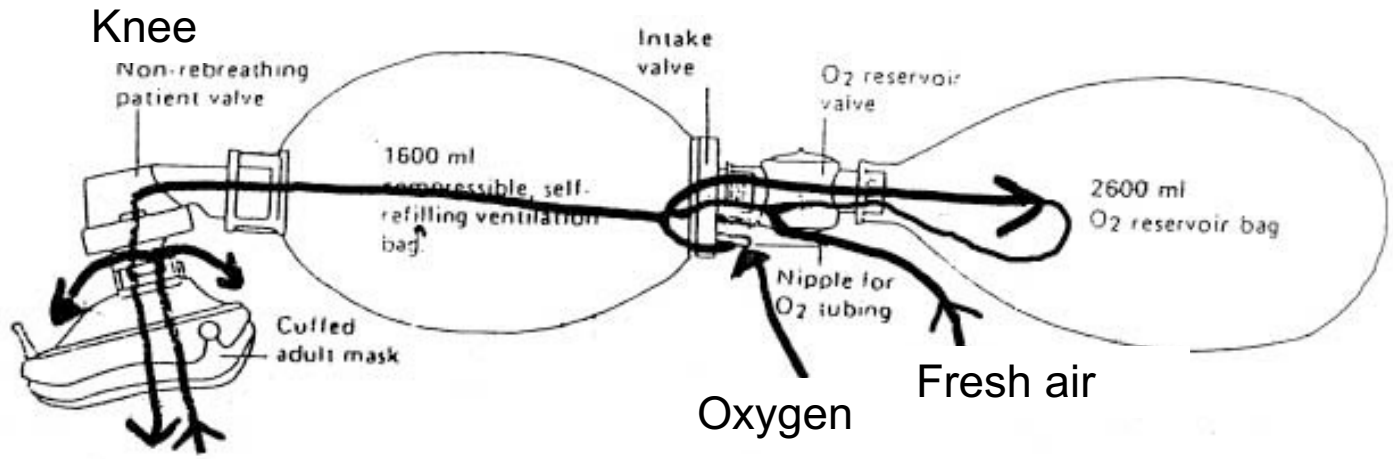


- Stabilization of ABC
  A – Airways
  B – Breathing
  C – Circulation

- Afterwards, take CT/X-ray scans/visual observations to reveal other injuries and take care of the total physiological status. For the next hour, try to fix as much of the problems as possible, then close it up and wait for the next day.

How do you stabilize the airways?

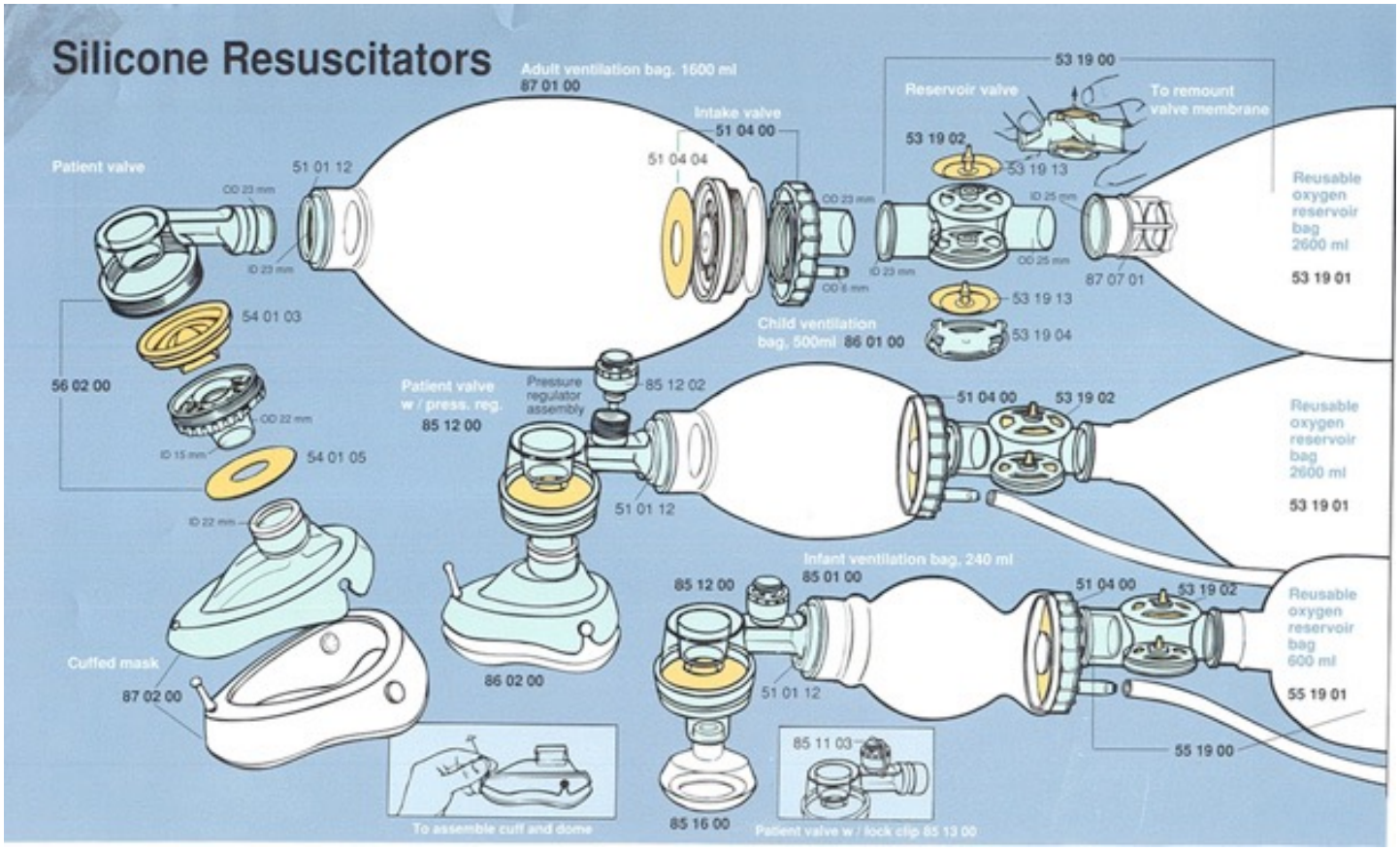
Ventilation, the Lærdal bag



http://www.akuttmedisin.uib.no/kurspakke/gjenoppliving/teori/gjenoppliving/figur21.jpg

Intubation is common for long time ventilated patients in order to maximize ventilation outcome and minimize strain on mouth

Ventilation



http://www.neann.com/images/Products2/bvm_laerdal_parts.jpg

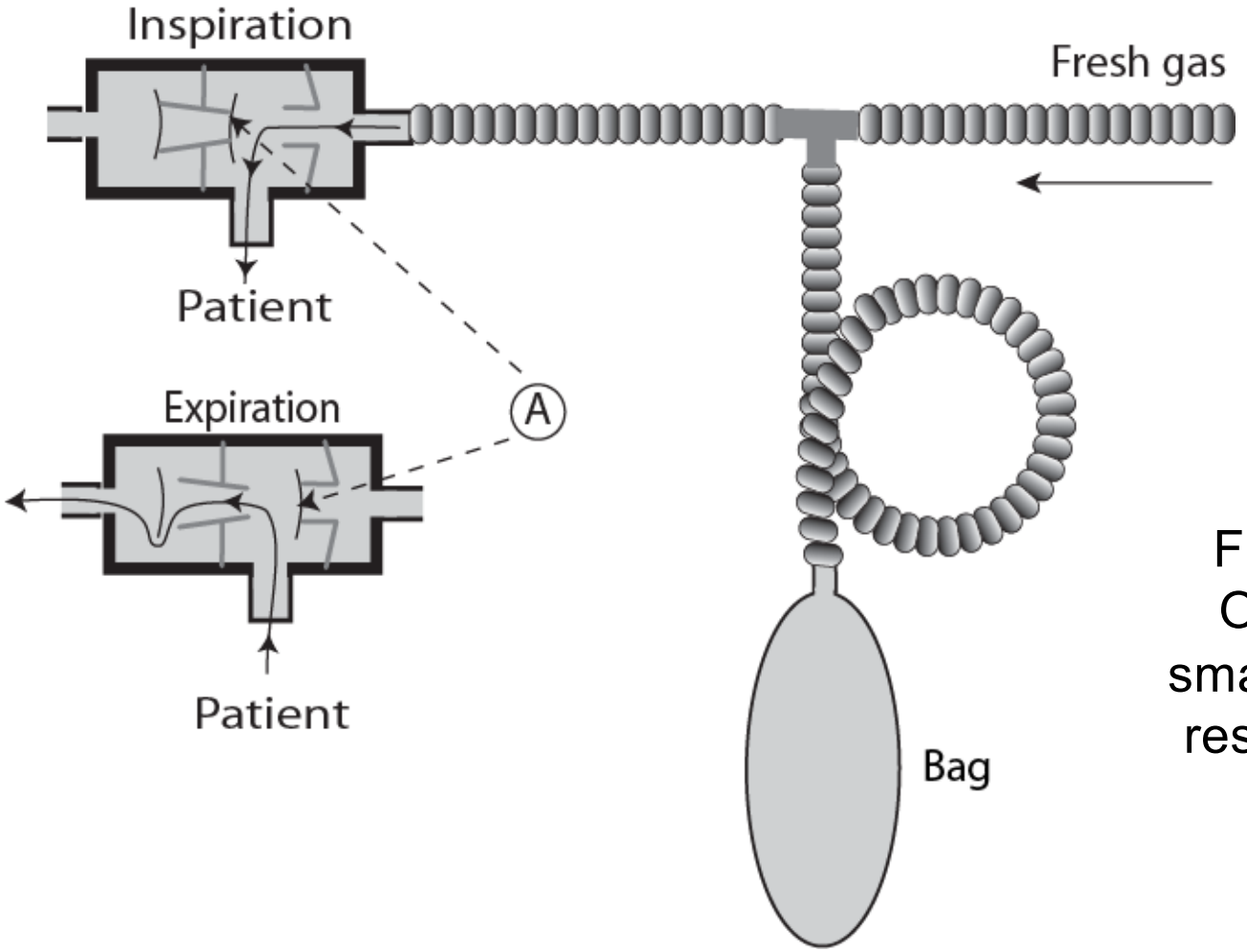
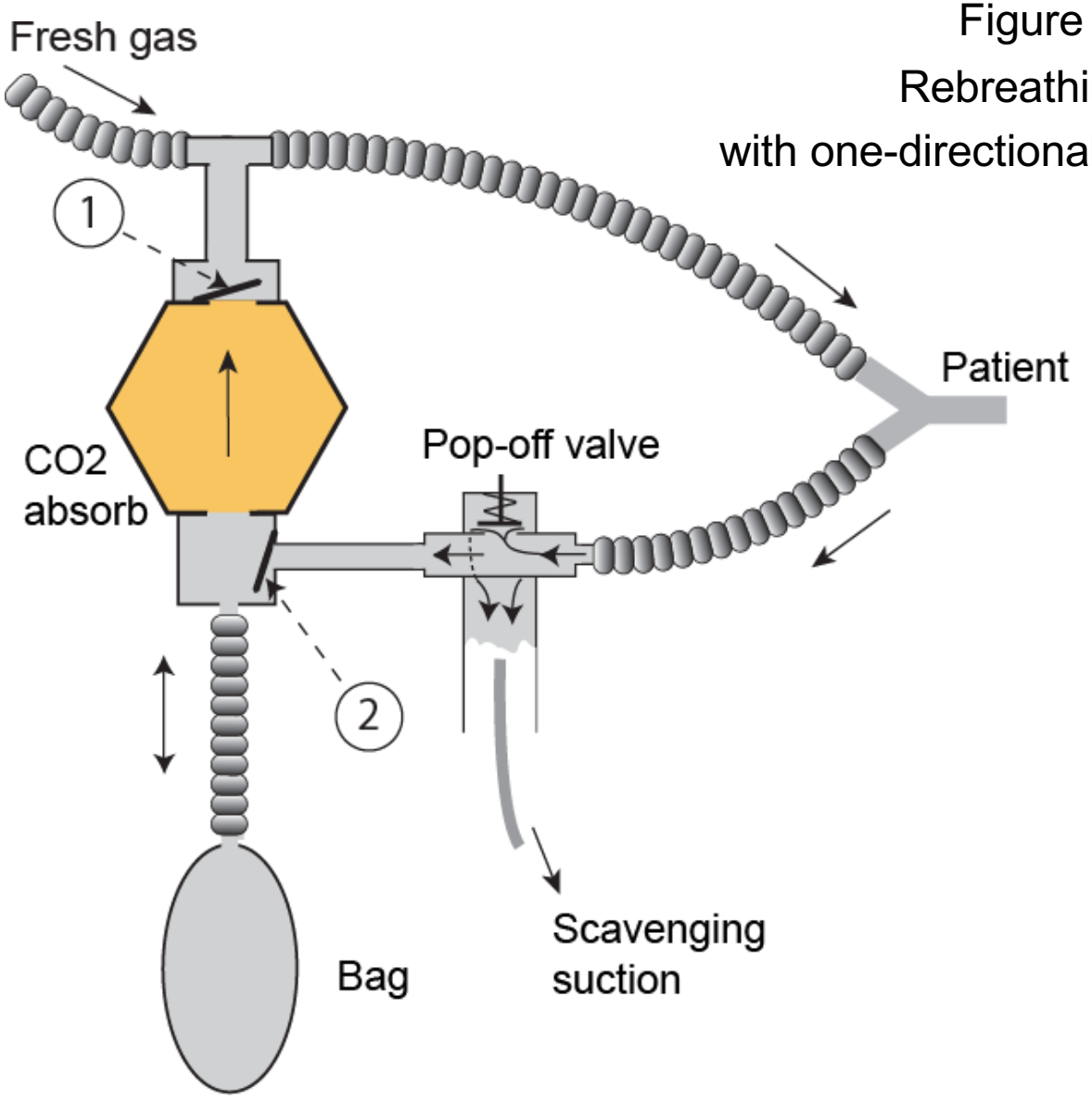


Figure 9
One-way small portable resuscitation system

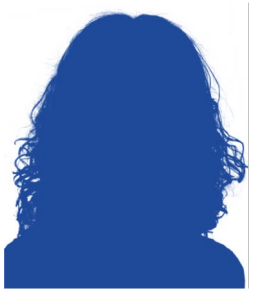
Figure 10

Rebreathing circle

with one-directional valves 1 and 2

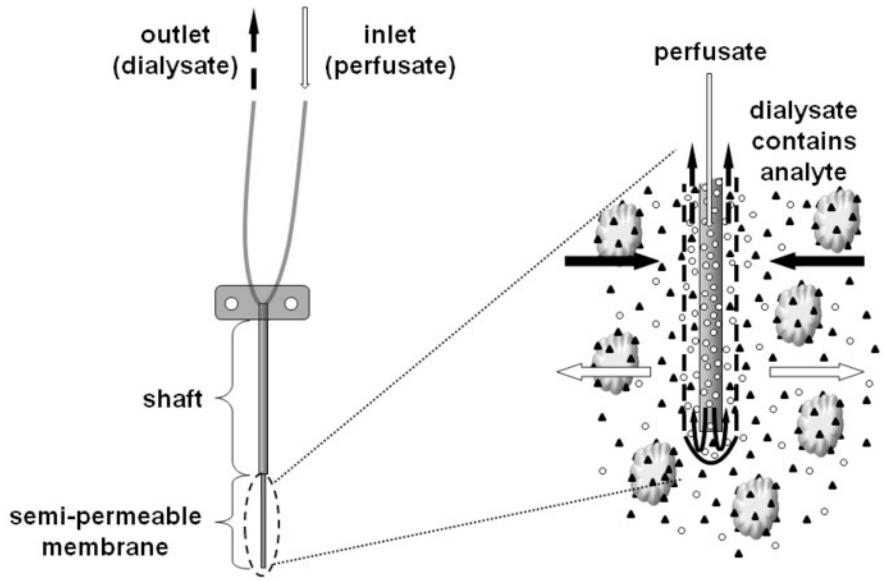


Case 5



- No signs of any internal injuries except for signs of a traumatic brain injury due to a skull fracture. In order to monitor the degree of cerebral injury, the doctors decide to monitor extracellular lactate and glucose levels as a measure of the possible impaired brain metabolism.

Microdialysis



- Probe is continuously perfused with an especially designed perfusate at a rate of 0.1 – 5uL
- Works by passive diffusion at the end of the microdialysis catheter, small samples are collected and returned for analysis

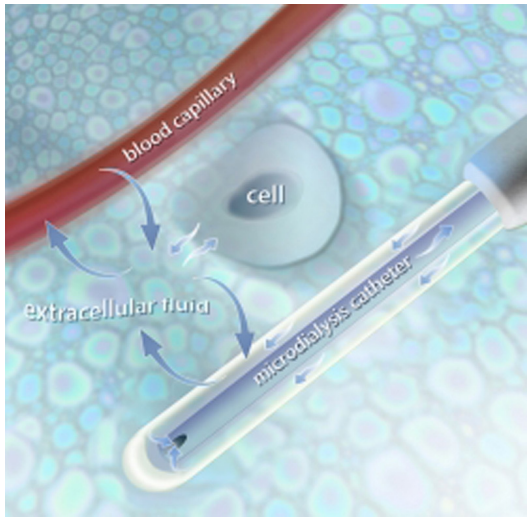
http://upload.wikimedia.org/wikipedia/en/thumb/3/3a/Schematic_illustration_of_a_microdialysis_probe.png/800px-Schematic_illustration_of_a_microdialysis_probe.png

Microdialysis

- Constant flow of fresh perfusate precludes a stable equilibrium = lower concentrations close to the probe than distant to the sampling site. The calibration described as the rate at which an analyte is exchanged across the membrane (extraction efficiency). The extraction efficiency is the ratio between the loss/gain of analyte during the passage through the probe and the difference in concentration between the proximal and distant sampling site. This can be determined by:
  1. Changing drug concentrations, keeping flow rate constant
  2. Changing flow rate, keeping drug concentrations constant

- The low-flow rate method is a common method. Probe is perfused with blank perfusate at different flow rates, determining the concentration at the sampling site for the different rates and then extrapolate the curve. Time consuming

- An alternative method is the no-net-flux method. When concentration in and out is equal, there is no net flux. Repeated for several concentrations, and a linear regression line is calculated.



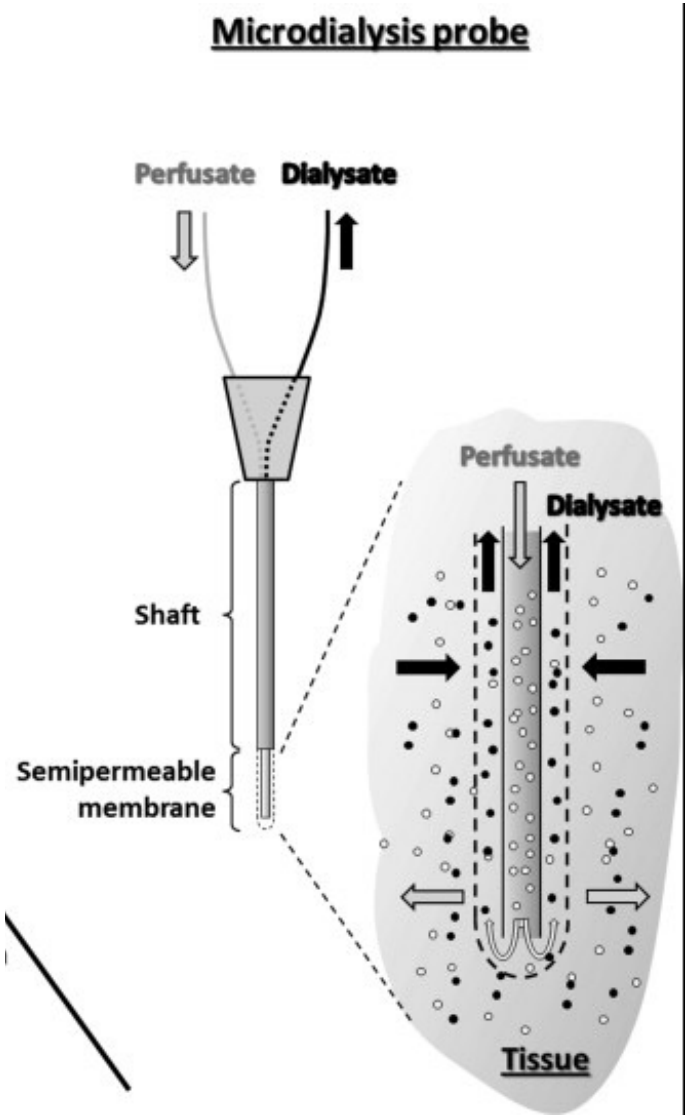
https://www.mdialysis.com/about/the-basis-of-microdialysis/

http://upload.wikimedia.org/wikipedia/en/thumb/3/3a/Schematic_illustration_of_a_microdialysis_probe.png/800px-Schematic_illustration_of_a_microdialysis_probe.png

Microdialysis

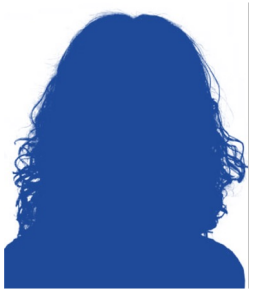
Advantages
- Any soluble substance can be measured
- Small catheter, the probe displaces a smaller area of tissue
- The microdialysis membrane provides a physical barrier between the perfusate and tissue that protects the tissue from turbulent flow and bacteria because big molecules cannot cross the membrane
- Flow rate is lower than other perfusion techniques, reduced analyte depletion
- Can infuse drugs or known compounds through the probe
- Evenly distributed area of tissue is impacted by the probe due to the probe geometry

Disadvantages
- Limited time resolution
- Invasive technique, can damage the tissue
- Depleted area around the probe



https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/microdialysis

Case 5



- The brain injury is stabilized, no increased intracranial pressure (ICP), low extracellular lactate and high glucose indicate, together with the clinical findings in the CT-scan images, that the brain trauma is under control.

- However, the patient is still short breathed and after a while she loose consciousness and is transported to the intensive care unit (ICU) and connected to a mechanical ventilator

Case 5



1. Syringe and infusion pumps
2. Infusion and nutrition
3. Patient monitor
4. Hemodialyzer
5. Mechanical ventilator

Short history of mechanical ventilation



Neil MacIntyre, “Mechanical Ventilation” SCCM Board

History of mechanical ventilation

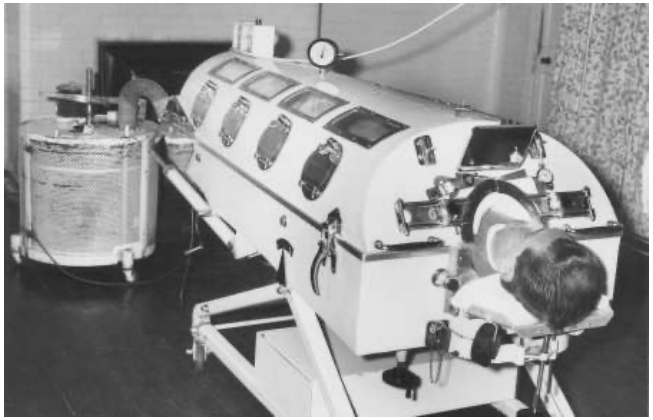




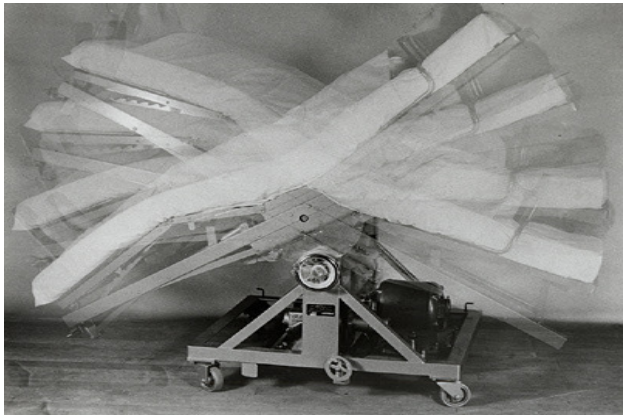
Bharat Awsare, Thomas Jefferson Hospital

The iron-lung used in a polio epidemic in the 1950's
-Creating a negative pressure inside the iron-tank, thus creating an air flow into the patient's lung
-Gentle way of ventilate the lungs

Need for ventilation suppert –
Early days: Intermittent negative pressure ventilation



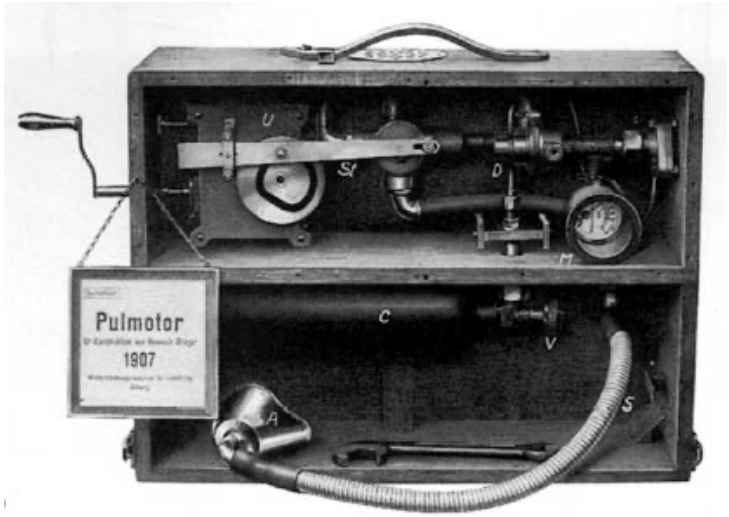
Ironlung – intermitterent negative pressure to »suck» air into the lungs



«Vipping bed» – amplified effect of diaphragma with gravity being in sync with spontaneous respiration

Source: Andreas Espinoza

Positive pressure ventilation



From the 1960's
-Breakthrough in the 1952 Polio epidemic in Copenhagen, medical students was bagging patients manually
-A positive pressure is generated outside the body, actively pushing air into the lungs

Overpressure ventilation with traceal tube

- Developments of techniques with intermittent posiitive pressure ventilation (IPPV)

- 1952 polioepidemic in Copenhagen
- Not enough tank-ventilatiors

  ⇒Trach + IPPV

  ⇒Mortality dropped from 85% til 40%

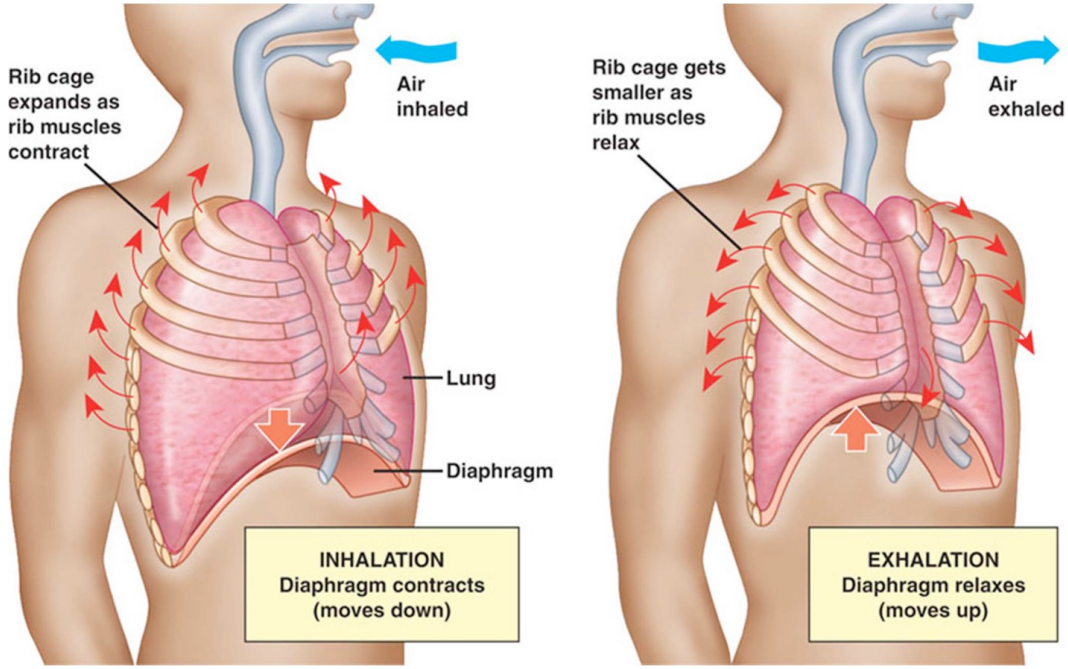


Source: Andreas Espinoza

Mechanical ventilation

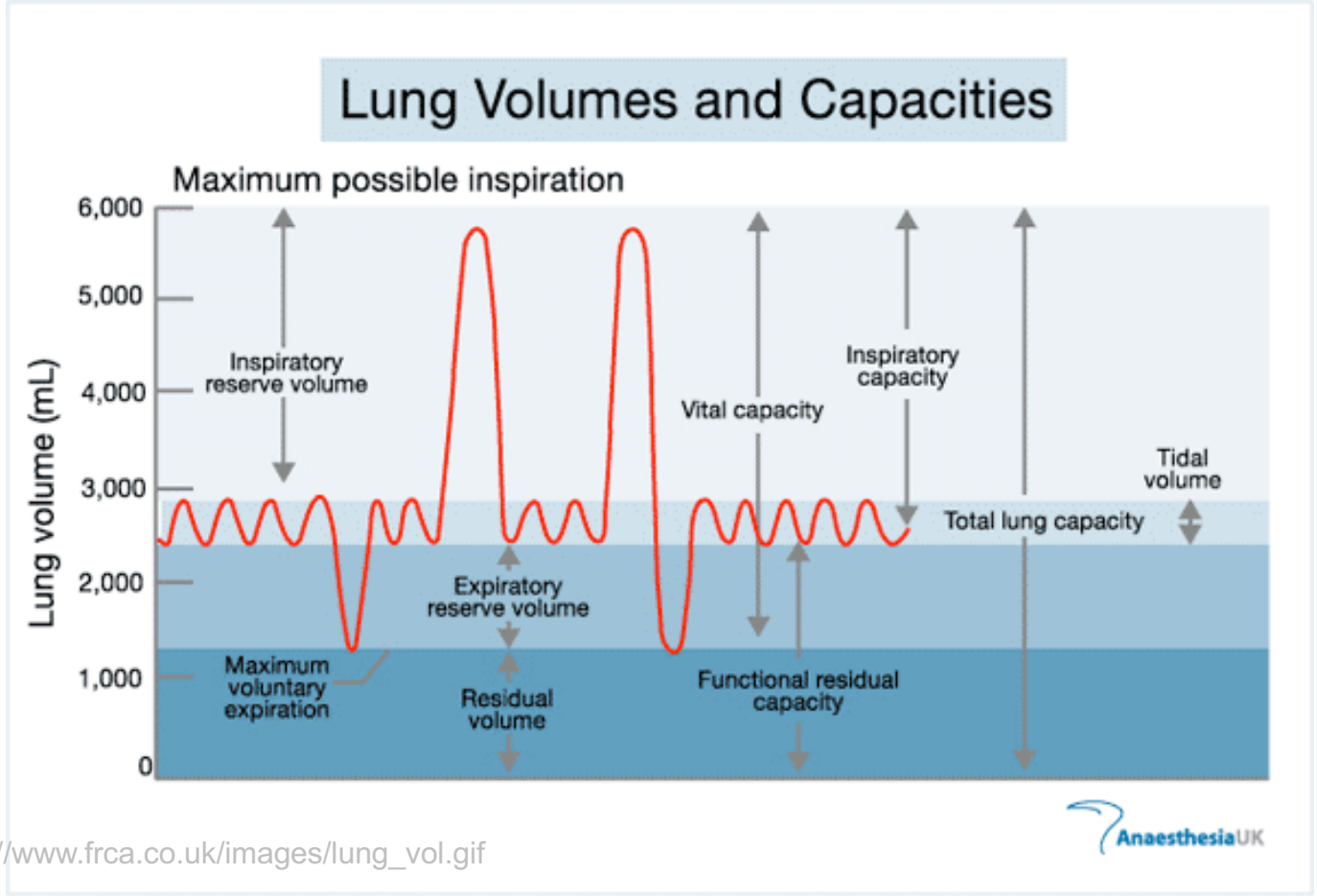


Ventilation



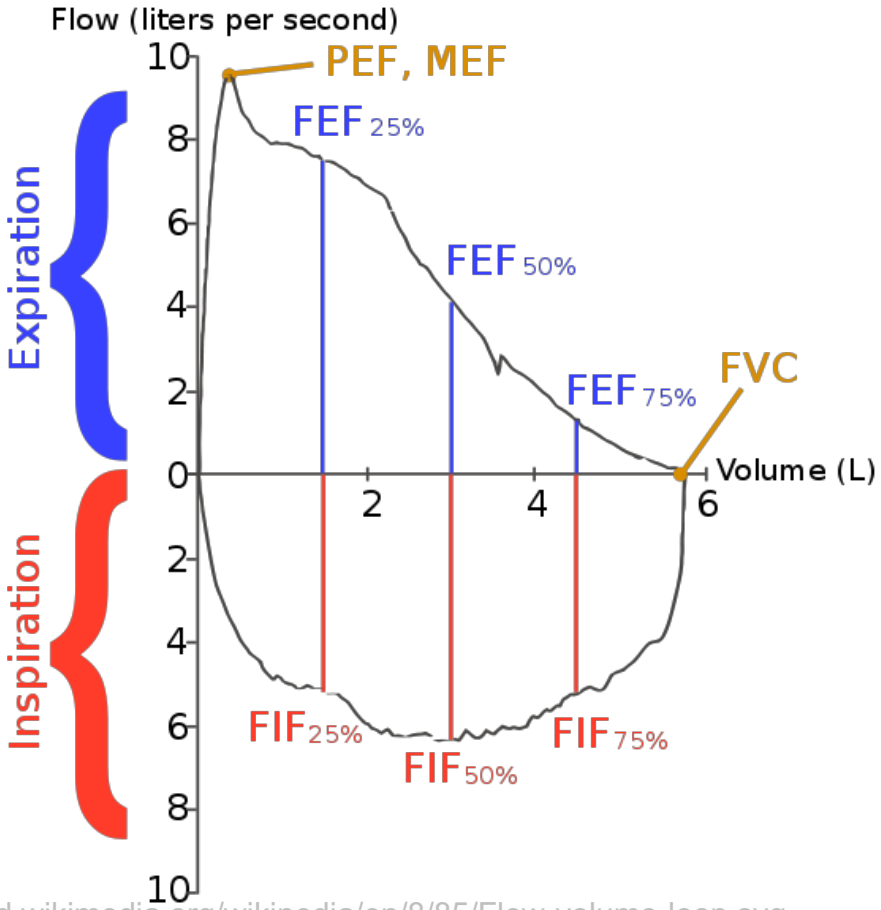
www.studyblue.com

Lung volumes



http://www.frca.co.uk/images/lung_vol.gif

Positive pressure ventilation



http://upload.wikimedia.org/wikipedia/en/8/85/Flow-volume-loop.svg

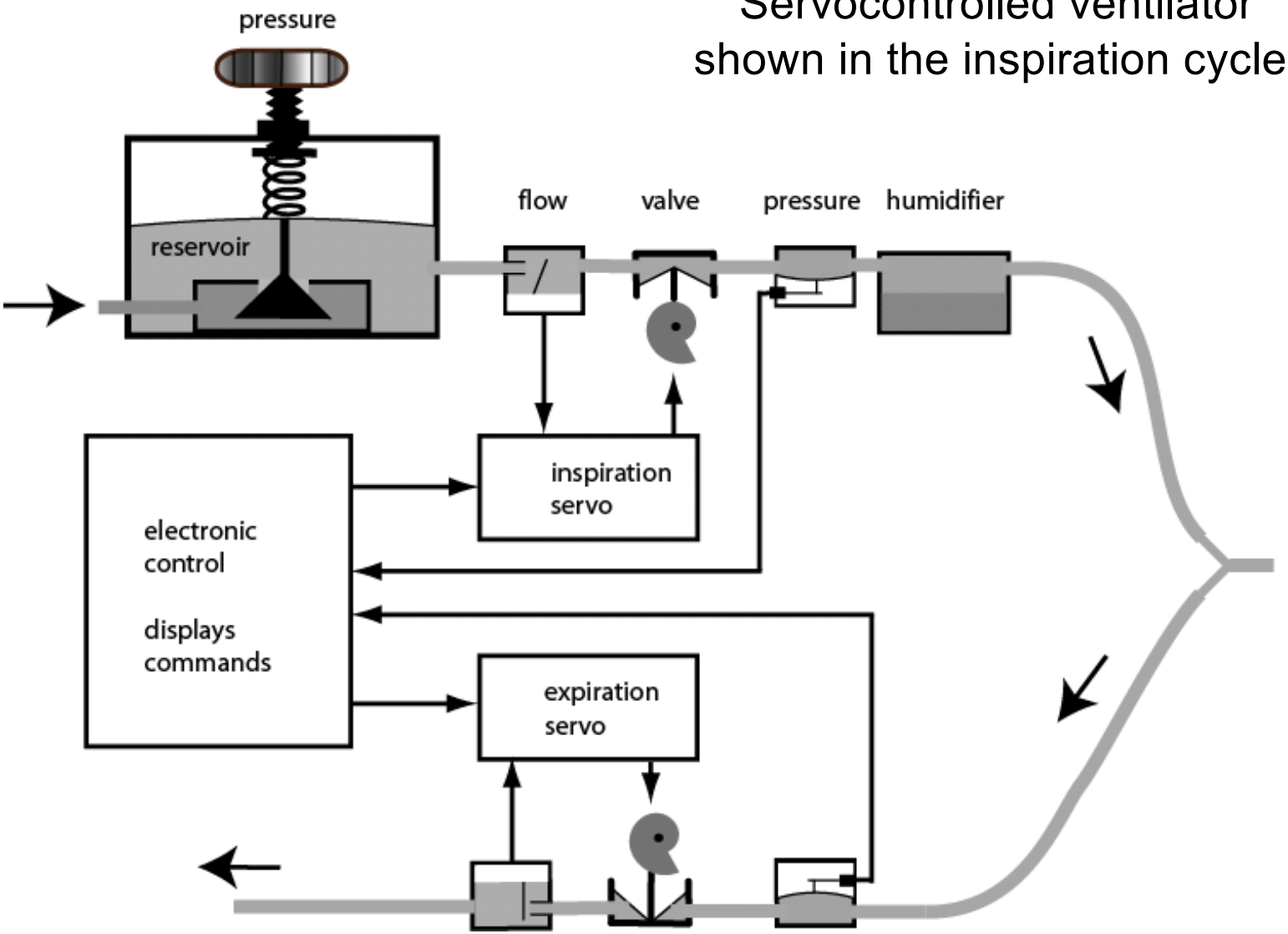
Ventilator

- Two main types, assisted and controlled
  - Assisted, the ventilator provides an additional amount of air during the patients individual inspiration
  - Controlled, the ventilator takes control of the ventilation regardless of the patients individual inspiration

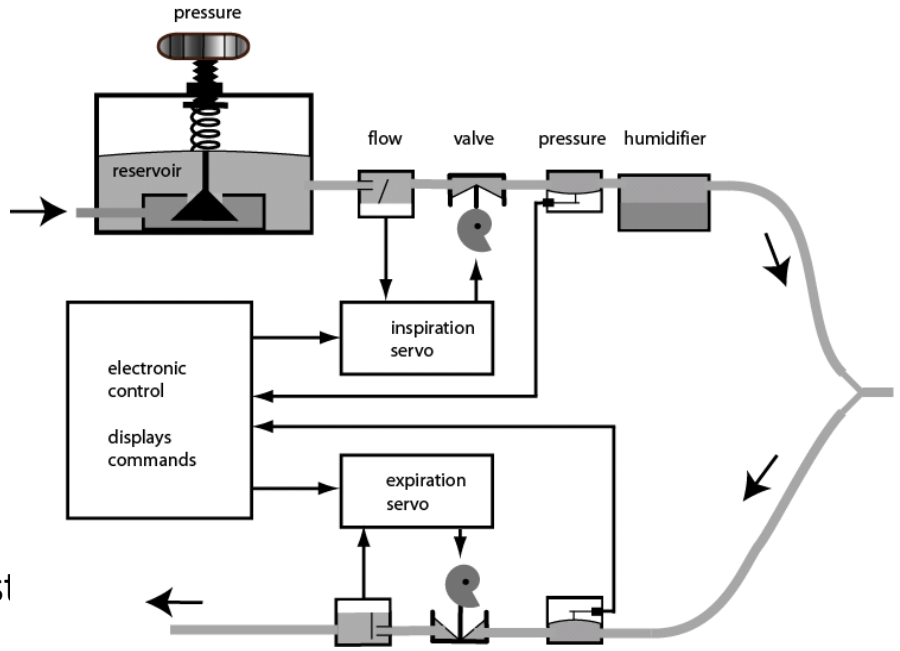
In order to avoid drying out the mucosa, humidity has to be introduced in the circuit. Typically a filter absorbing and releasing humidity during inspiration and exhalation

Air is pumped into the lungs during inspiration by means of an increased pressure, and the pressure is released during exhalation to let the air flow passively out of the lungs.

Figure 23
Servocontrolled ventilator
shown in the inspiration cycle



Exercise



Form groups of 2 or 3 st

a. Have a look at the servo ventilator, and explain what will happen if you remove each component, one by one



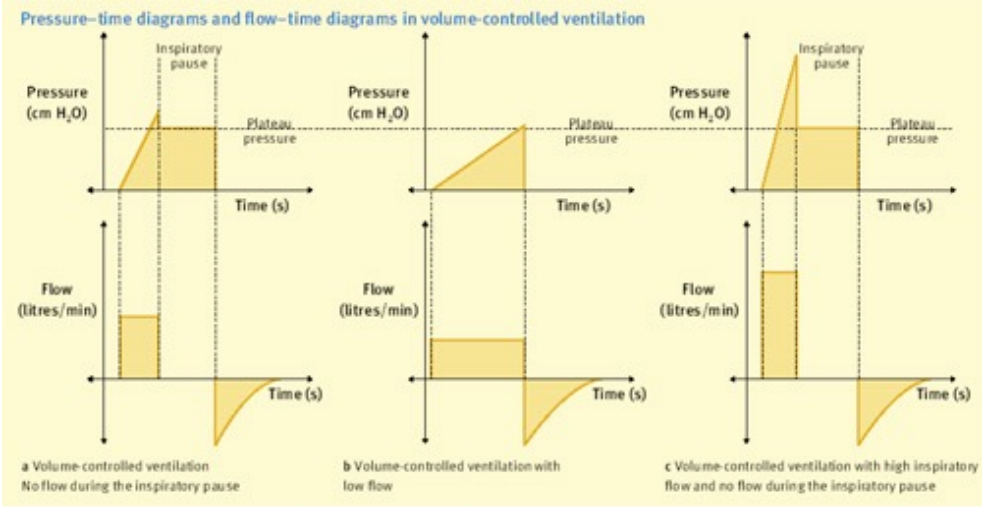
http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

PEEP, BiPAP and CPAP



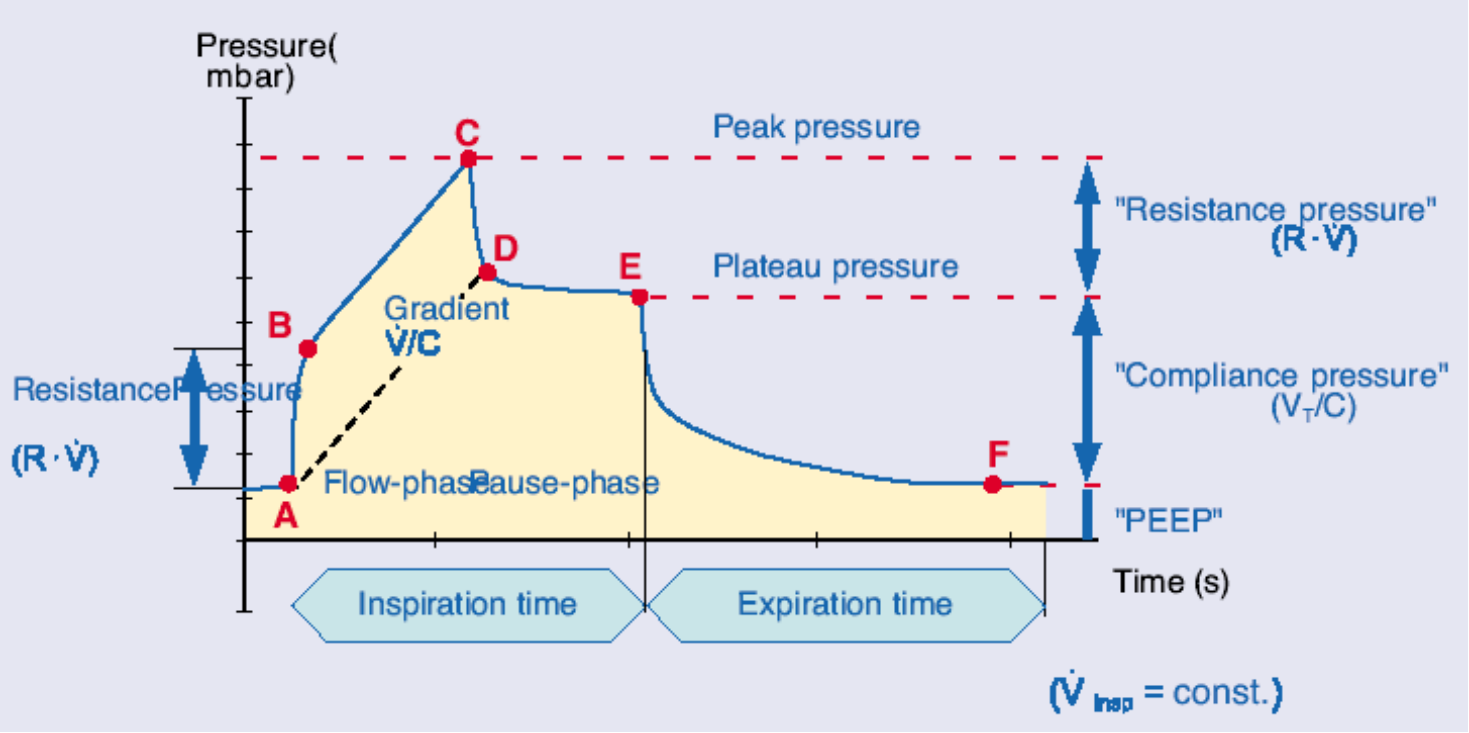
Ventilator Volume controlled

- A constant air volume is delivered to the patient each respiratory cycle
- A balloon is filled with the desired volume and then exposed to an external pressure
- If the desired volume has been delivered, the pressure drops below the peak inspiratory pressure and an inspiratory pause occurs.



http://www.frca.co.uk/images/vent-fig1.jpg

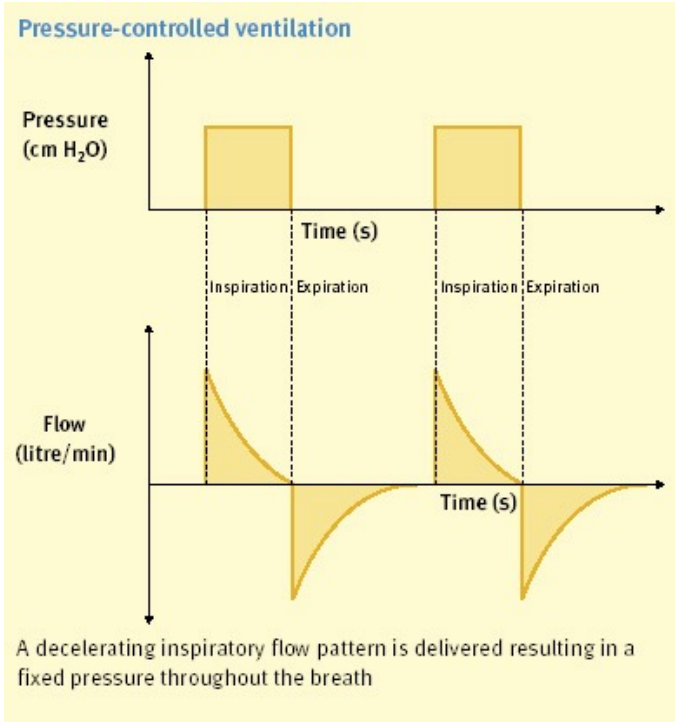
Ventilator Volume controlled



Source: Andreas Espinoza

Ventilator Pressure controlled

- Inspiration stops when a defined pressure is achieved, The result is a tidal volume that depends on the resistance and the lung compliance (stiffness). An increased resistance will decrease the air flow
- Driven by the pressurized gas (air) used for airsupply for the patient, this means a simple and robust design
- Due to the uncertainties regarding airway resistance, there is a risk of underventilation
- Can be combined with flowsensors so that the insufflation can be stopped when the airflow is zero



http://www.frca.co.uk/images/vent-fig3.jpg

Pressure vs Volume controlled ventilation

Pressure controlled	Volume controlled
Advantages	
Reduction of peak pressure and risk of barotrauma	Maintains constant tidal volume
Improved gas exchange due to decelerating flow	Better control of partial pressure of carbon dioxide in arterial blood
More homogeneous ventilation in cases of distribution disorders	
Compensates for system leaks	
Disadvantages	
Hypoventilation secondary to changes in lung compliance and resistance	Potential for high airway pressures and acute lung injury
	Inability to compensate for leaks

http://www.frca.co.uk/images/vent-fig4.jpg

There are 3 ventilation modi: Pressure control, Volume control and pressure support. All others are kombinations of these

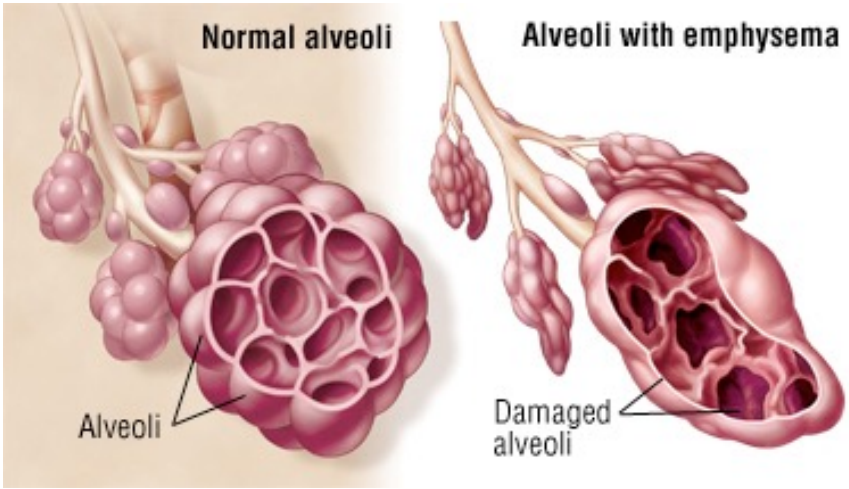
Compliance

$$C = \Delta V / \Delta P$$

$$C_{stat} = V_{Tidal} / P_{plat} - PEEP$$

$$C_{dyn} = V_{Tidal} / PIP - PEEP$$

PIP = Peak inspiratory pressure

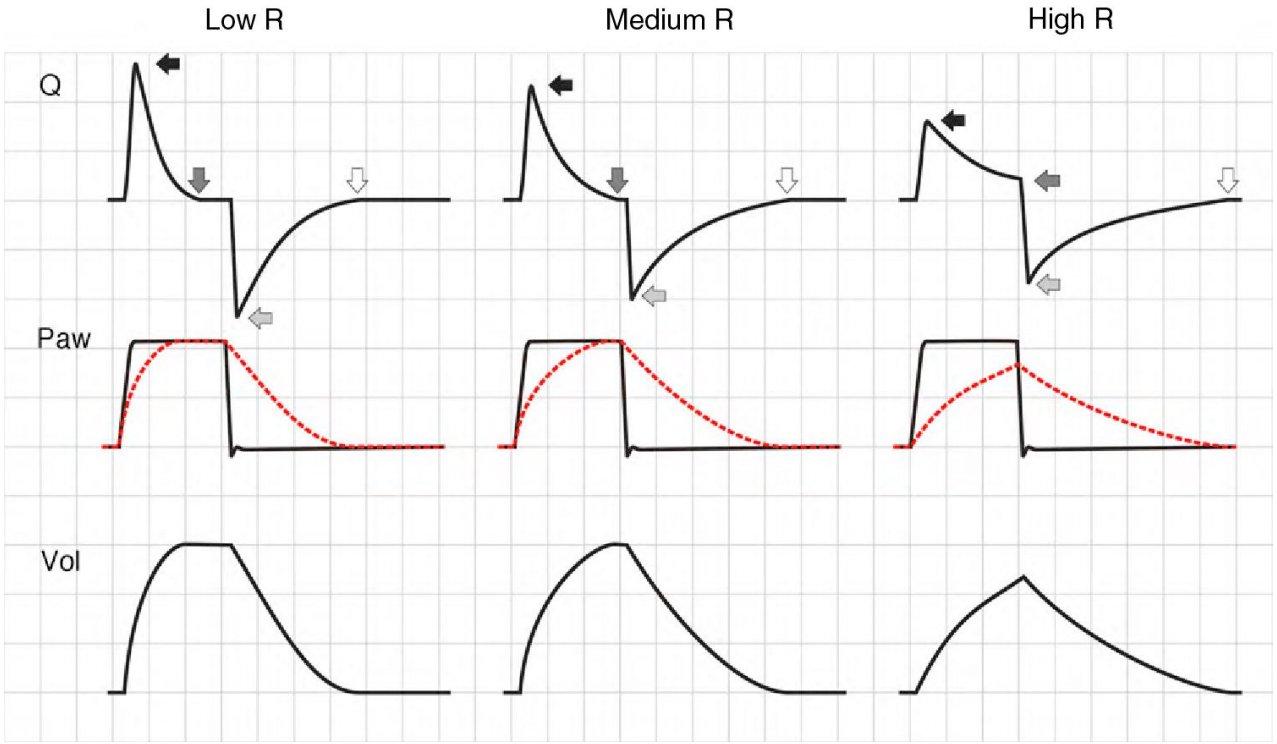


http://www.drugs.com/health-guide/images/205041.jpg

Pulmonary compliance is a measure of the ability of the lungs to stretch and expand. Two types of compliance: Static and dynamic. Static is the compliance when the lungs are not moving, while the dynamic compliance can be measured at the end of expiration when the lungs are moving.

Compliance is a good indicator for lung issues, like fibrosis or emphysema. Increased compliance is a sign of diseases where a degeneration of the tissue leads to increased stiffness and more work to expand the lungs.

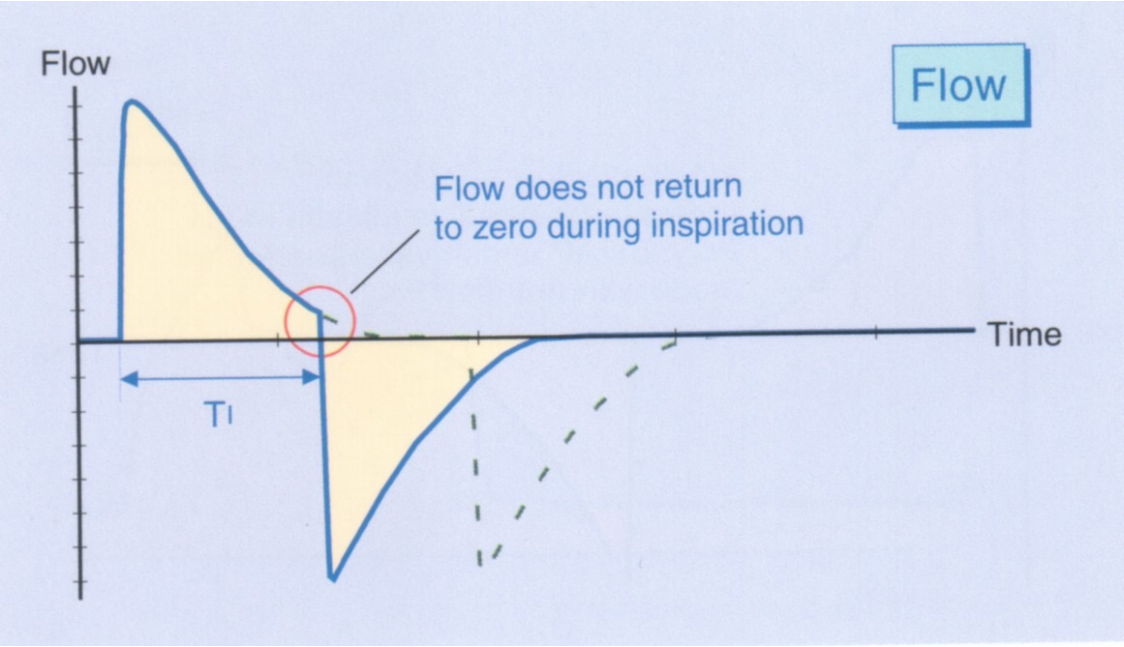
Flow curve vs Resistance



Paw = mean airway pressure

Source: Andreas Espinoza

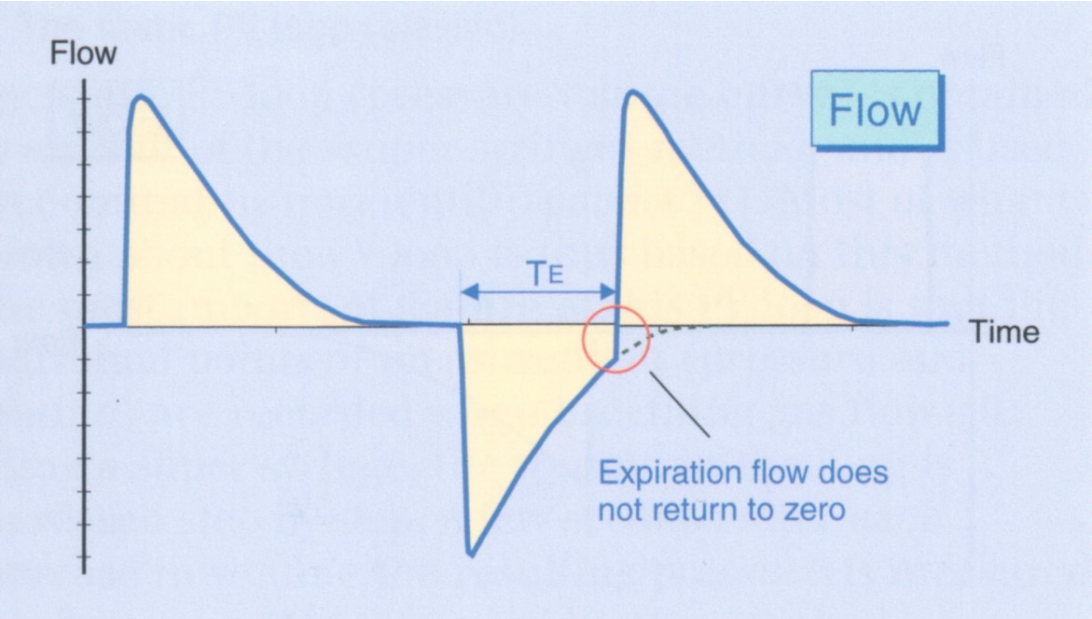
Too short inspiration time with pressure controlled modi



Source: Andreas Espinoza

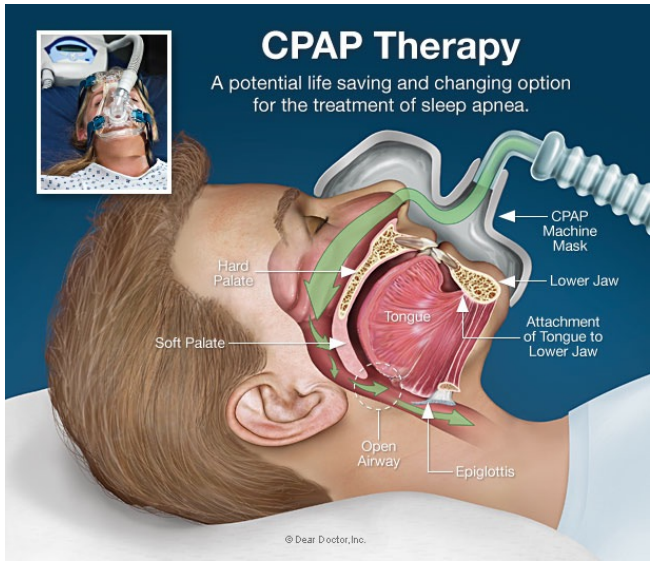
Source: Andreas Espinoza

Too short expiration time with pressure controlled modi



= Intrinsic PEEP (Positive end expiratory pressure)

PEEP, BiPAP and CPAP



http://www.deardoctor.com/images/ddwc/features/sleep-disorders/cpap-therapy-thumb.jpg

CPAP (Continous positive airway pressure) is the same as PEEP, mainly used for sleep apnea. The pressure keeps the airways open, not the air flow.

Exercise: The emergency ventilator



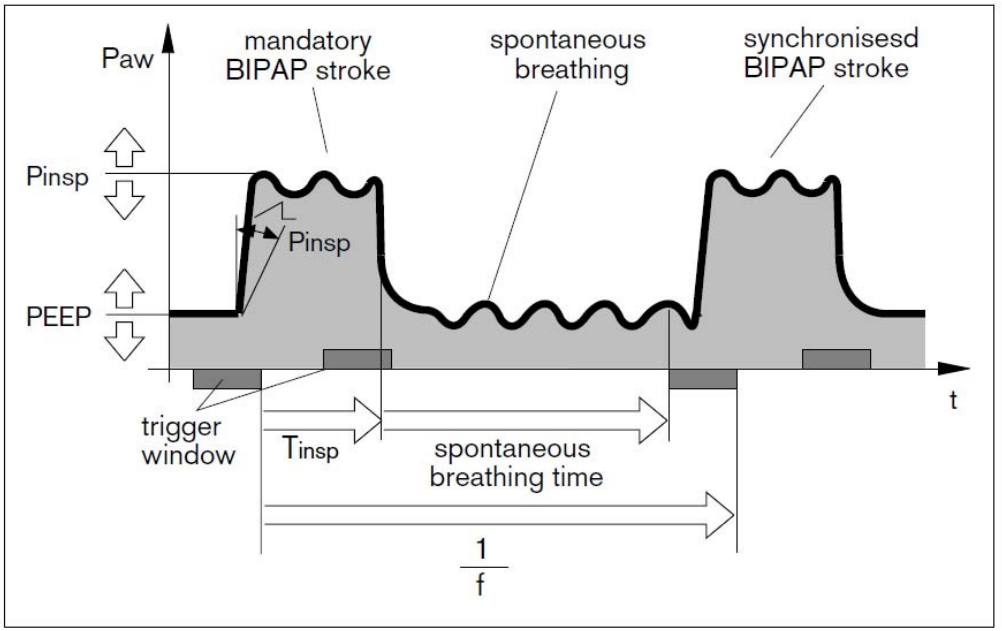
A Covid-19 patient must typically be ventilated very gently with very small volumes, high frequency, decelerating flow, a decent PEEP, high O2-levels to mention a few things

Form groups of 2 or 3 students, and discuss:

a. Is the emergency ventilator better than nothing during the Corona-pandemic?



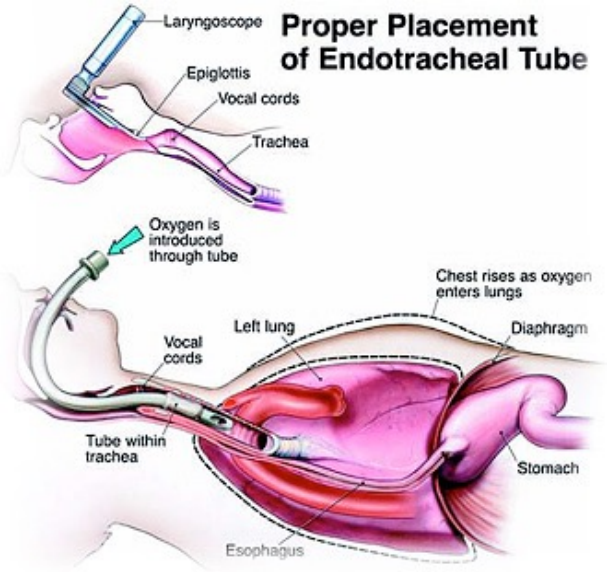
BiPAP



http://www.lungventilator.com

Bilevel positive airway pressure. More support during both inspiration and expiration aid the patient breathing. The pressure keeps the airways open, not the air flow.

Ventilation intubation

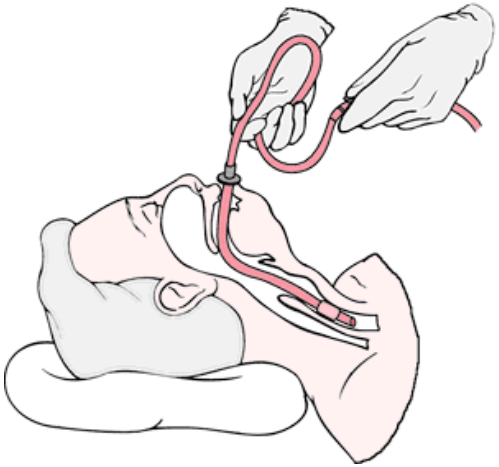


http://mpaweb1.wustl.edu/~medschool/outlookarchives/winter2008/images/tubes-ill.jpg

Intubation is common for ventilated patients in order to avoid airway obstructions and control airflow into the lungs

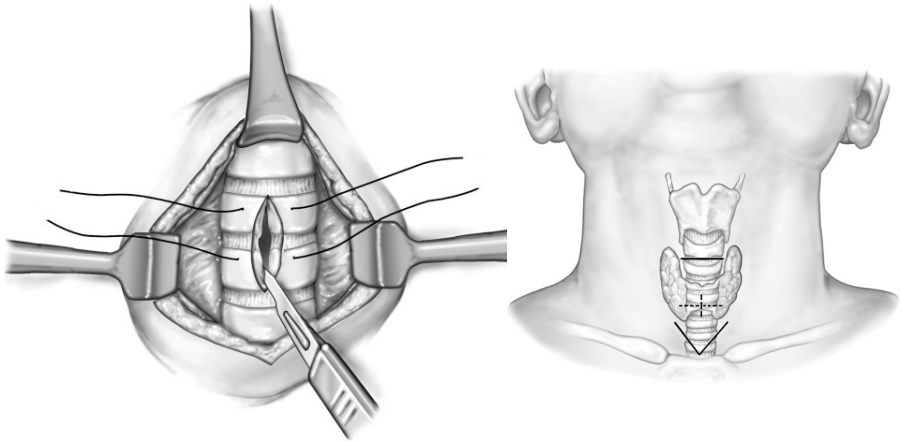
Connecting the Ventilator

Positive pressure from the ventilator demands an air-tight connection to the ***tracheal tube*** or to the ***tracheal cannula***



Placement of the tracheal tube

Medical-dictionary

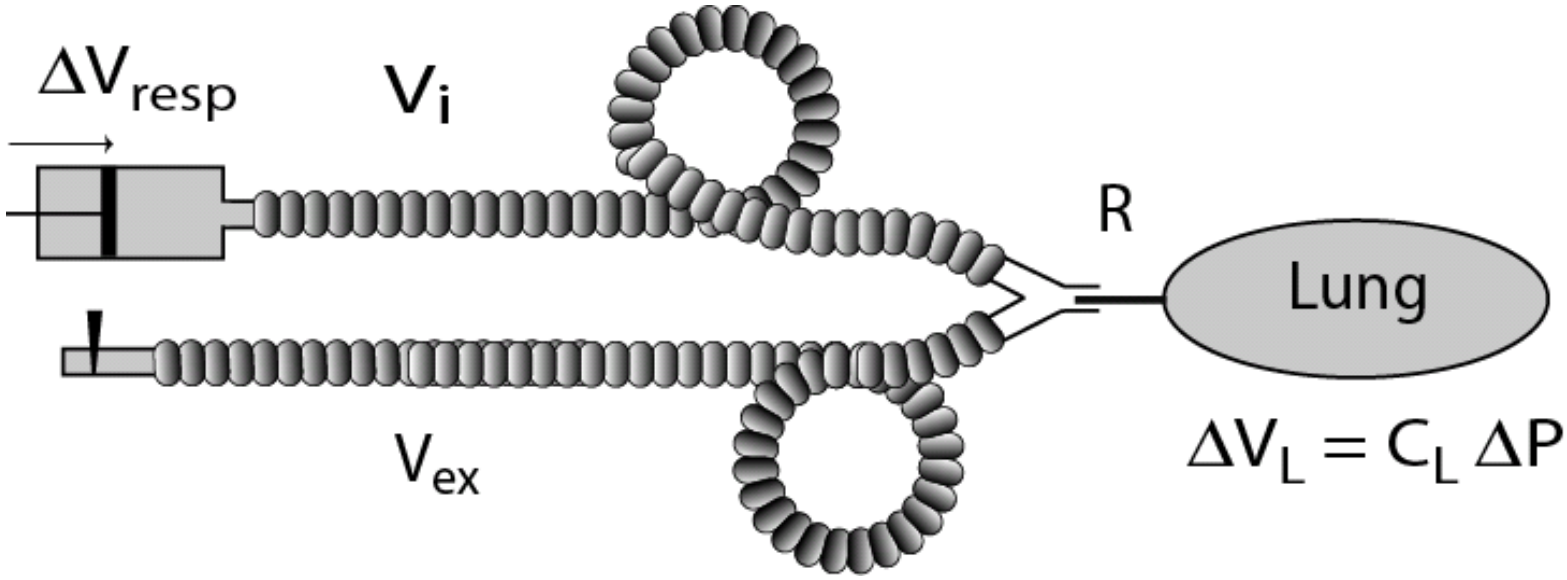


Placement of the tracheal cannula

http://ars.els-cdn.com/content/image/1-s2.0-S1043181007000590-gr3.jpg

How can you assure an air-tight system?

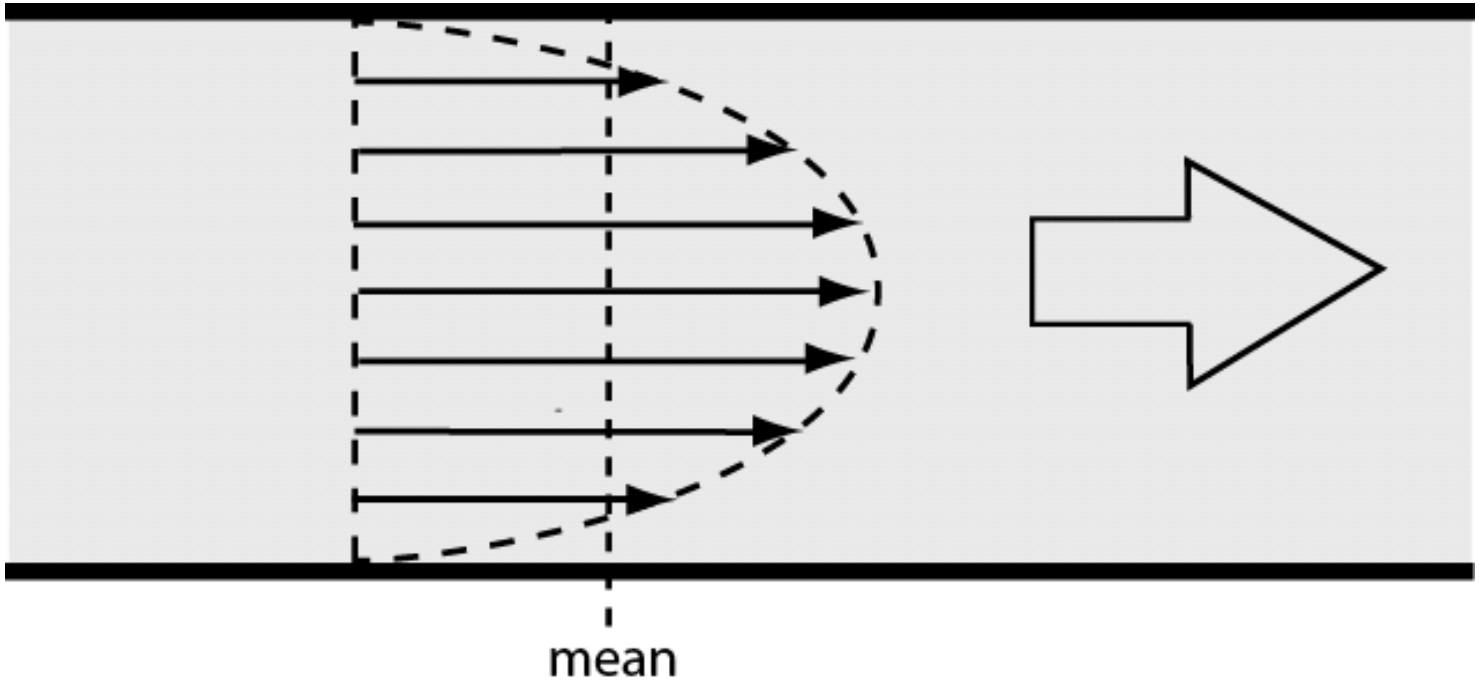
Figure 24
Compression loss model



Equation 2 *Poiseuille*

$$R = \frac{8\eta L}{\pi r^4}$$

[Pa/m^3/s = pressure / flow rate]



Gas measurement

- Important for controlling the airway-function, should be used continuously during forced ventilation to ensure proper ventilation

Important properties:
1. Response time
2. Selectivity
3. Calibration

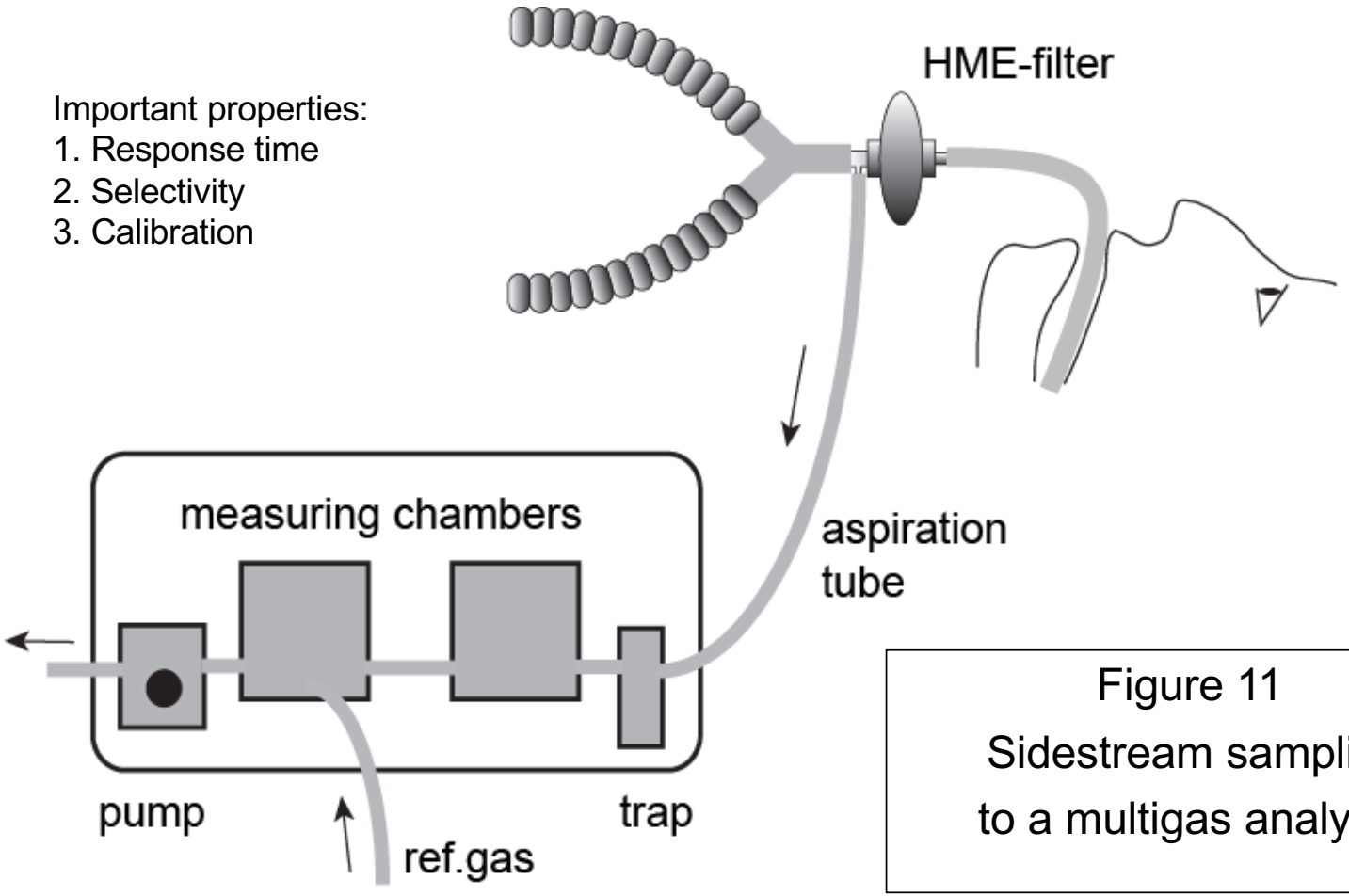
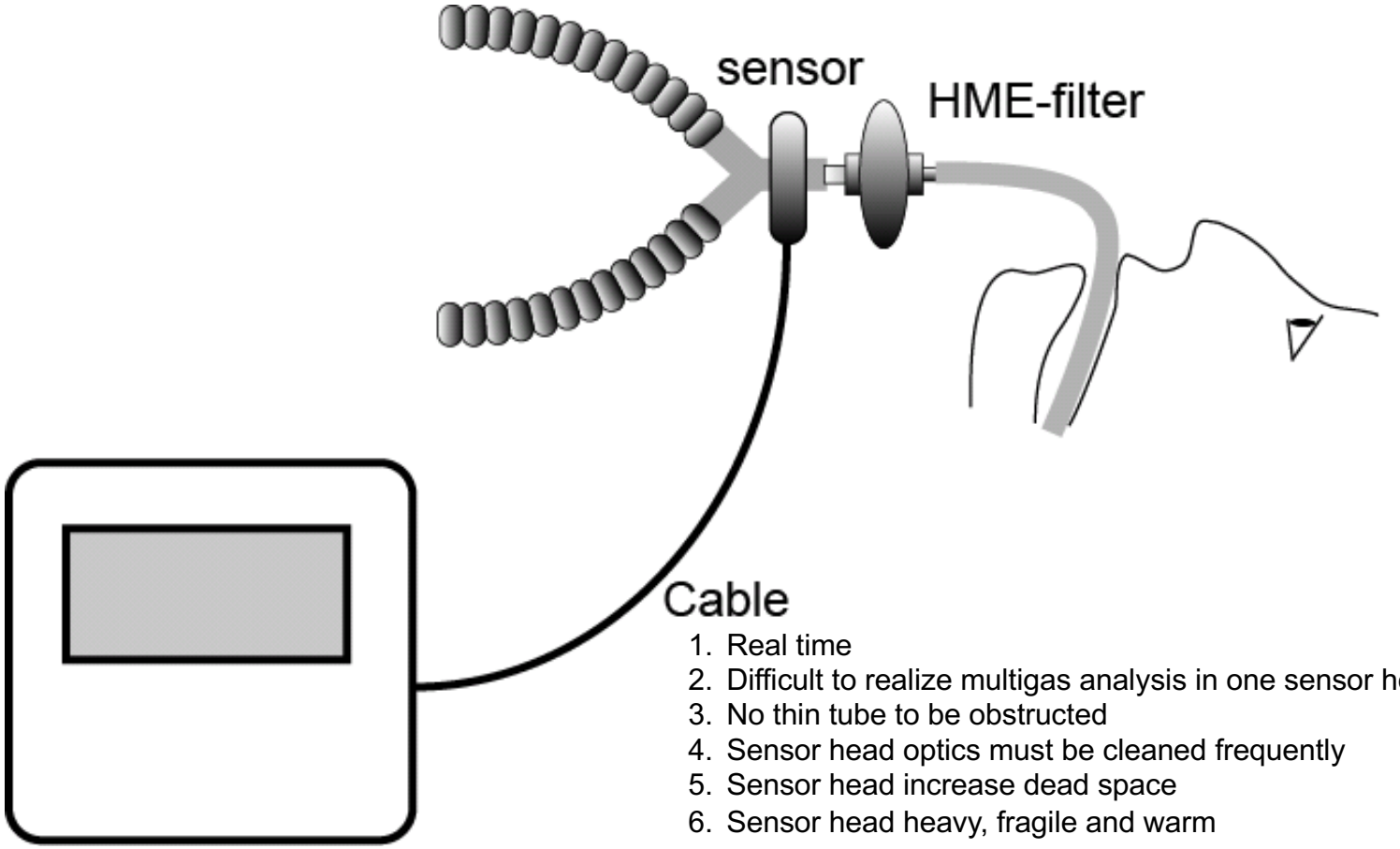


Figure 11
Sidestream sampling
to a multigas analyzer

Figure 12
Mainstream sampling

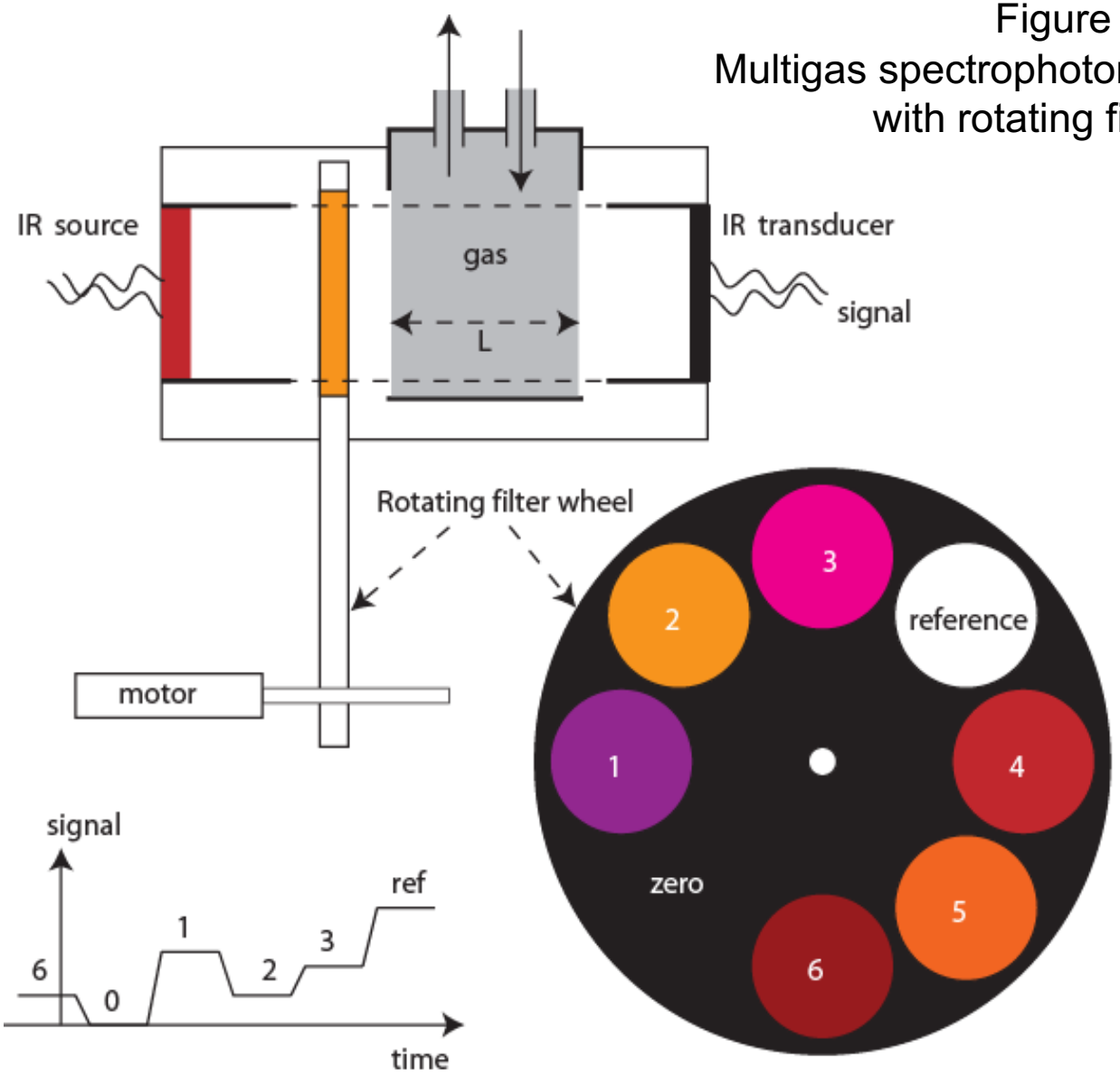


1. Real time
2. Difficult to realize multigas analysis in one sensor head
3. No thin tube to be obstructed
4. Sensor head optics must be cleaned frequently
5. Sensor head increase dead space
6. Sensor head heavy, fragile and warm

Table 4
Three measuring principles

	Measuring principle	*medium*	*variables*	*time const*	*comments*
1a	Spectrophotometric	gas	CO_2, H_2O, agent vapors	0.1s	capnography included
1b	Spectrophotometric pulsoximetry	blood	O_2	1-10s	also in-vitro cuvette-oximetry and in blood gas analyzers
2a	Paramagnetic, contin.	gas	O_2	10s	sample gas unchanged
2b	Paramagnetic, pulsed	gas	O_2	0.2s	sample gas changed
3a	El.chem. fuel cell, membrane covered	gas or liquid	O_2	30s	limited lifetime, drifts and frequent calibration, single use
3b	El.chem. polarographic membrane covered (Clark)	gas or liquid	O_2	0.1-20s	membrane & el.lyte change and reuse, used in blood gas machine
3c	El.chem. membrane covered (Severinghaus)	gas or liquid	CO2	30s	used in blood gas machine
3d	El.chem. pH and ion-selective electrodes	liquid	pH Na, K etc	10s	used in blood gas machine

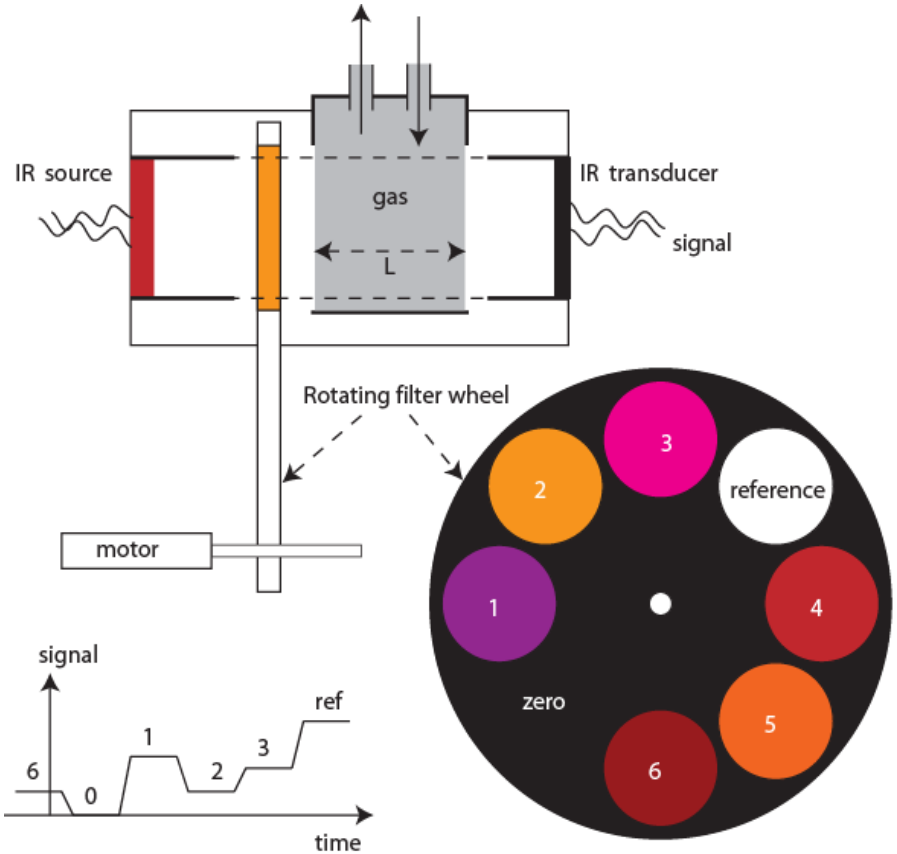
Figure 14
Multigas spectrophotometric gas analyzer with rotating filter wheel



Exercise

Form groups of 2 or 3 students, and discuss:

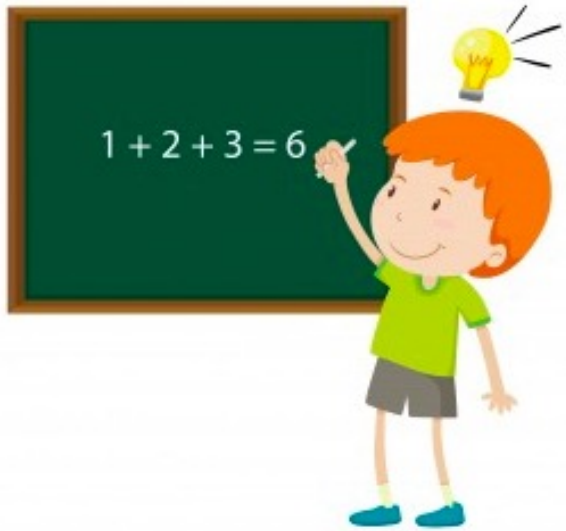
a. What are the main error sources of a multigas optical spectrophotometric system?





http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answers



The main error sources

a. Moisture (dew) (most typical)
b. Sensor drifting
c. Insufficient mixing of gases
d. Anything that will influence on the visibility of the gas
e. Lack of calibration

Source: Braun AB

Figure 16
Paramagnetic oxygen analyzer
using pulsed magnetic field.
Gray lines are tubes.

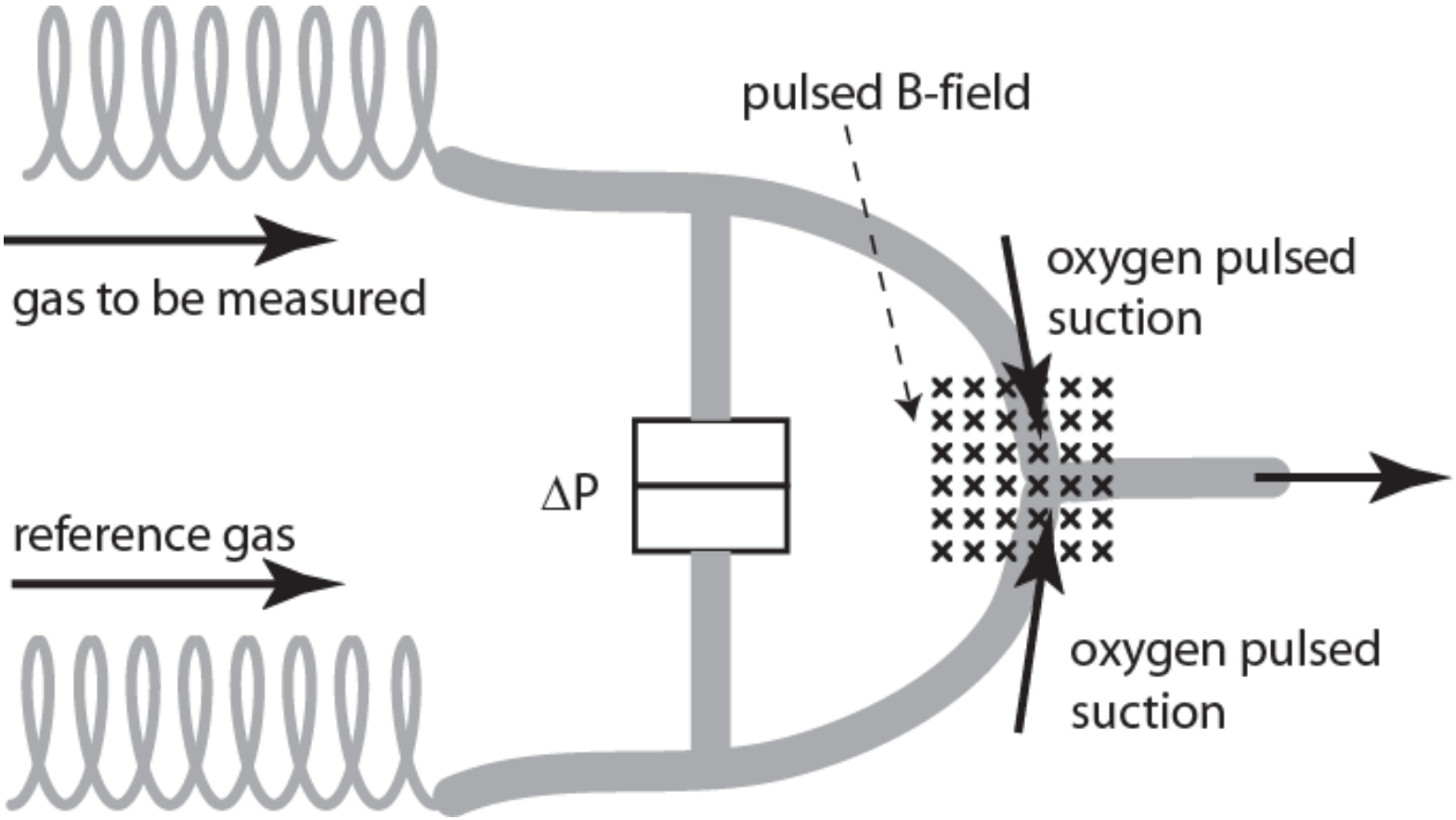


Figure 19
Hot wire flow meter with two termistors,
cross section shown to the right

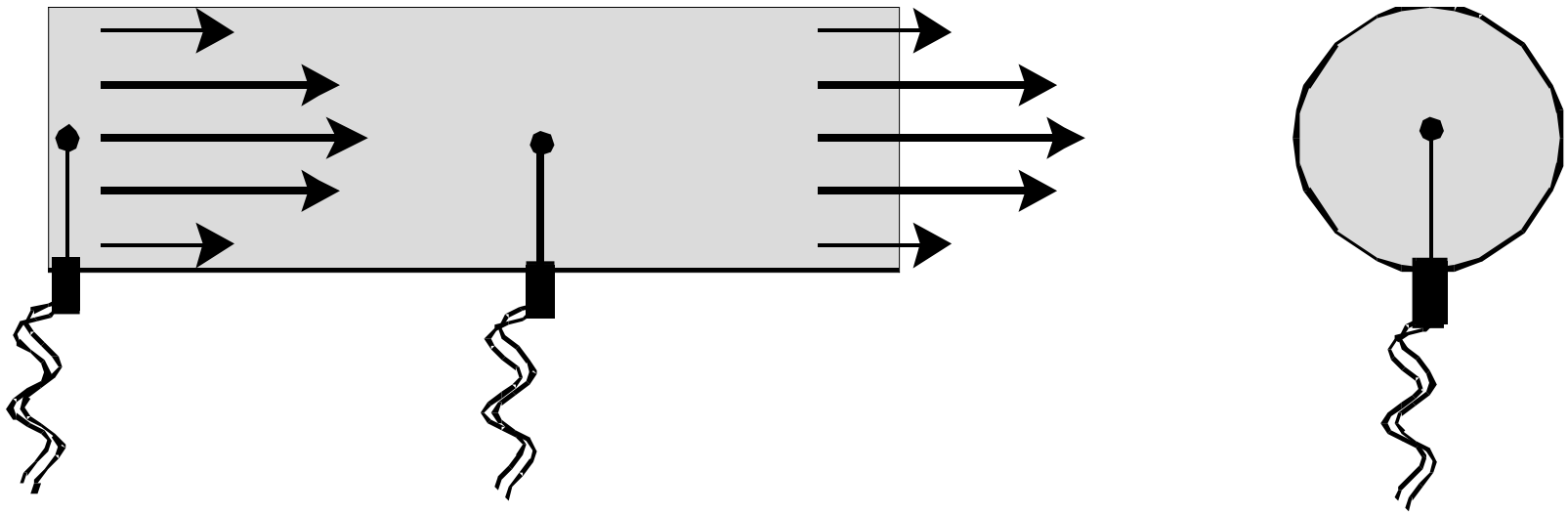


Figure 20
Vane flow sensor in a tube,
cross section shown to the right

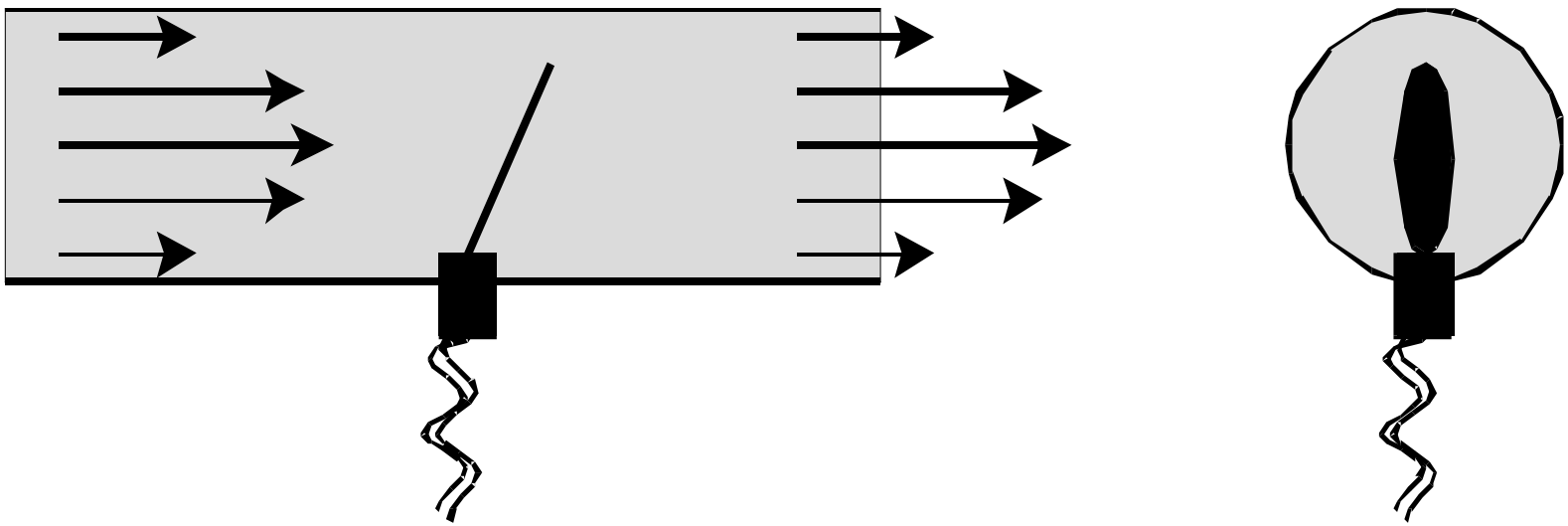


Figure 21
Pitot flow sensor in a tube,
cross section shown to the right

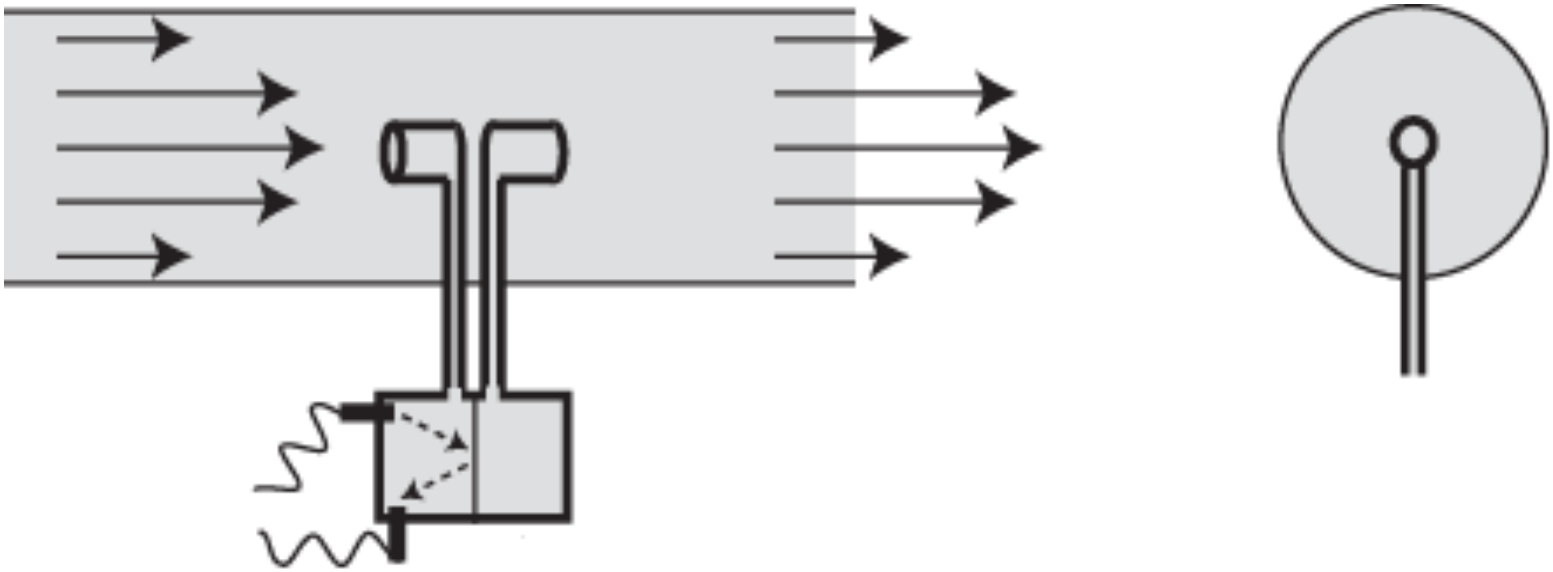
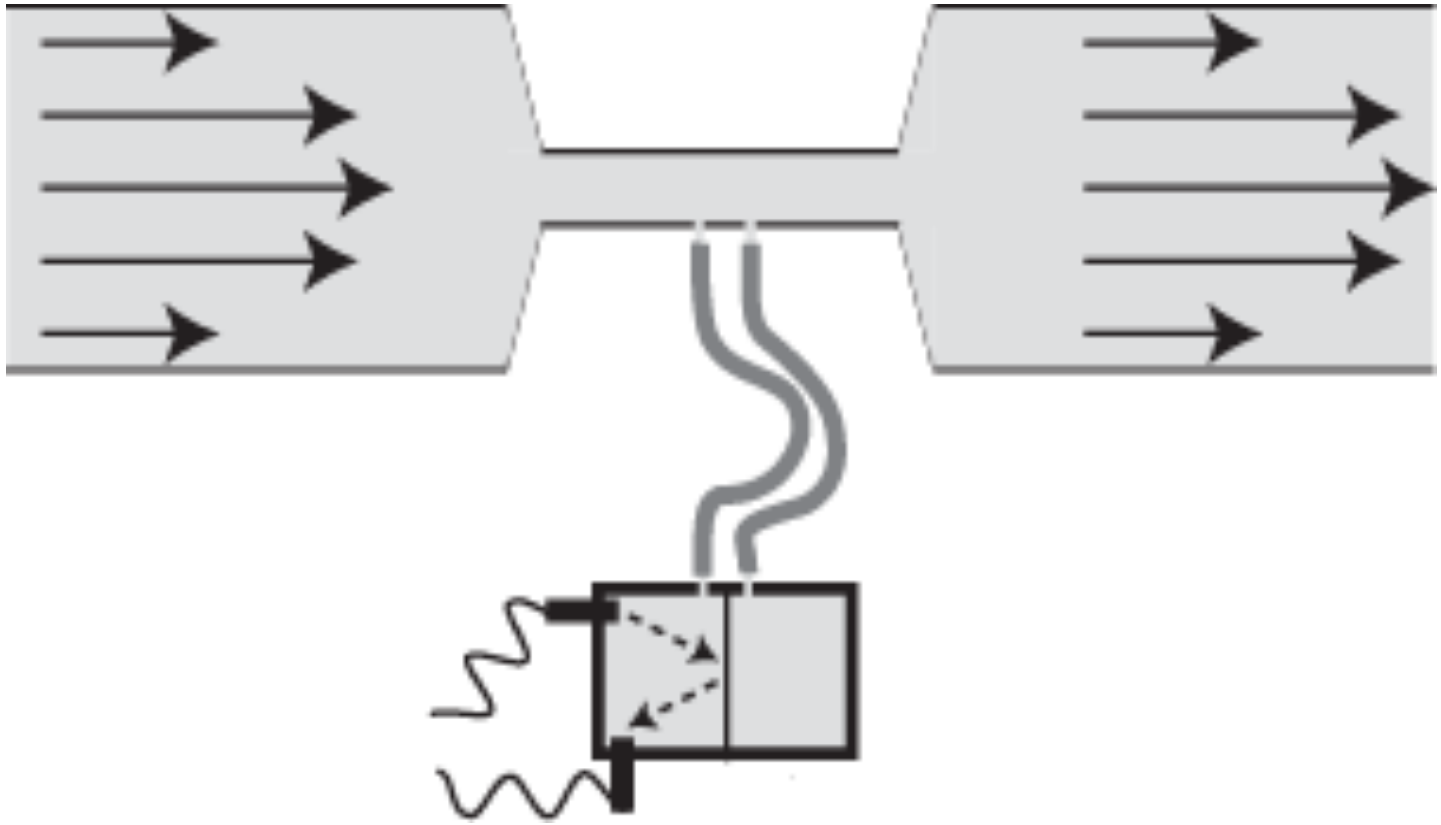


Figure 22
Poiseuille gas flow sensor
(pneumotachometer)



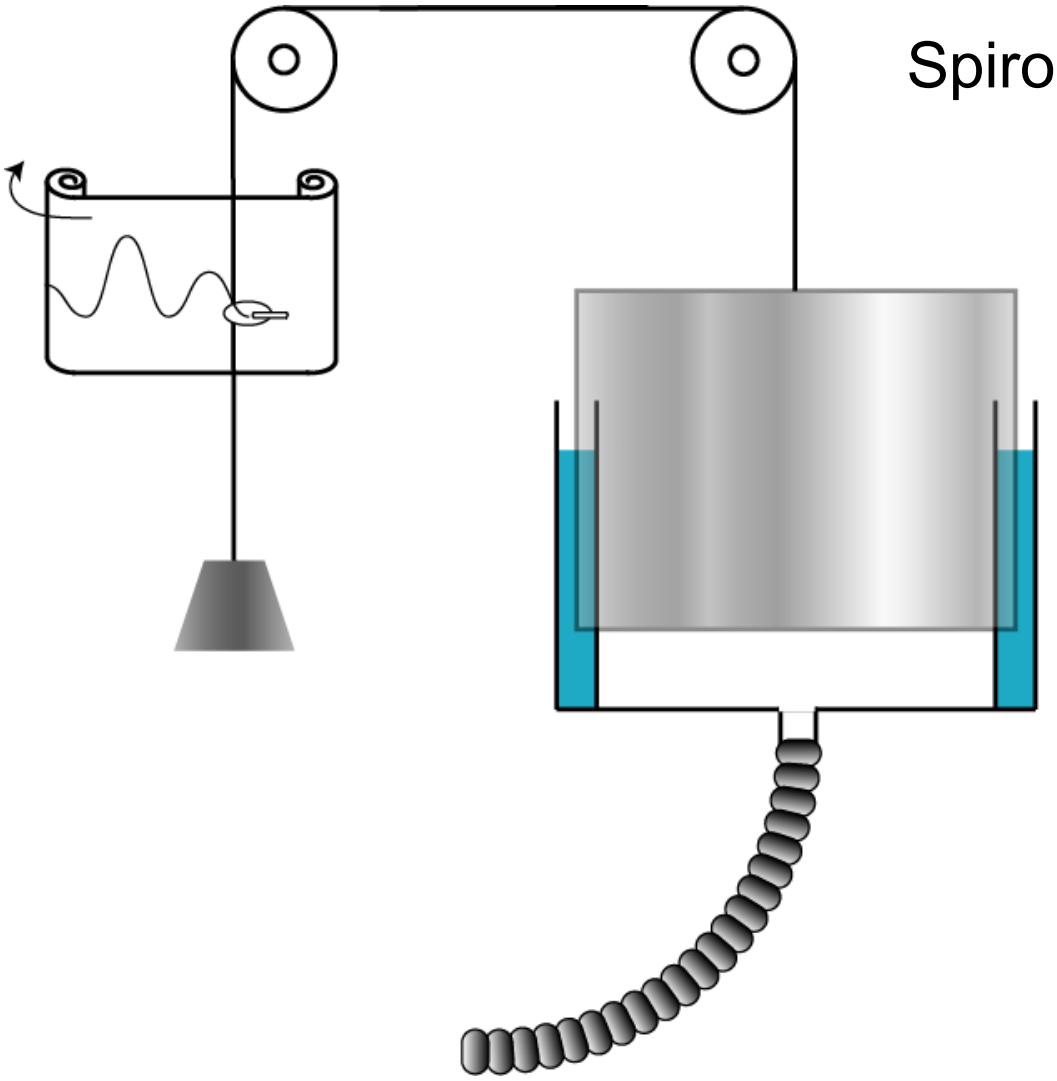


Figure 26
Spirometer, watersealed

Spirometer, electronic



$$R = \frac{8\eta L}{\pi r^4}$$

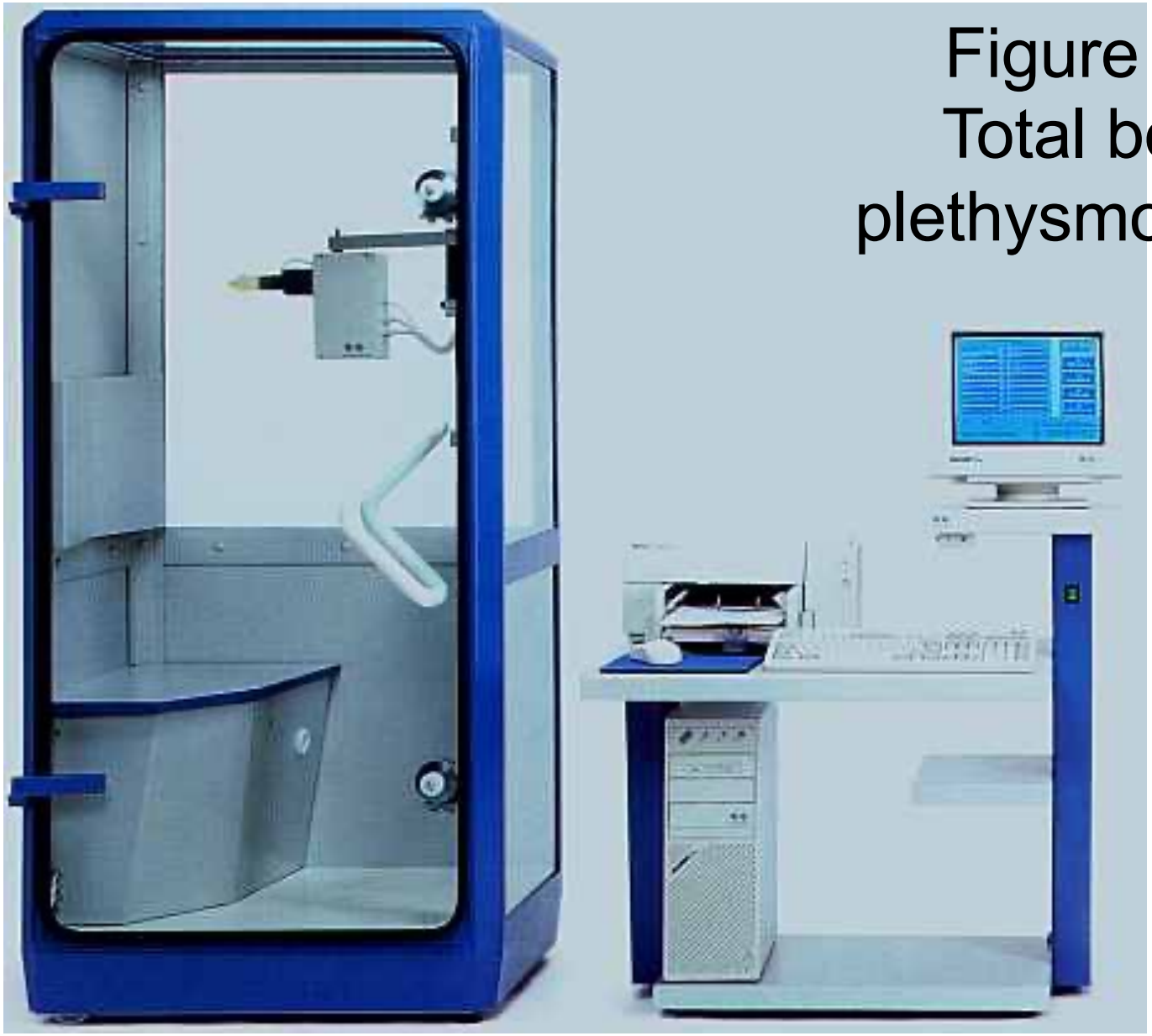


Figure 27
Total body
plethysmograph

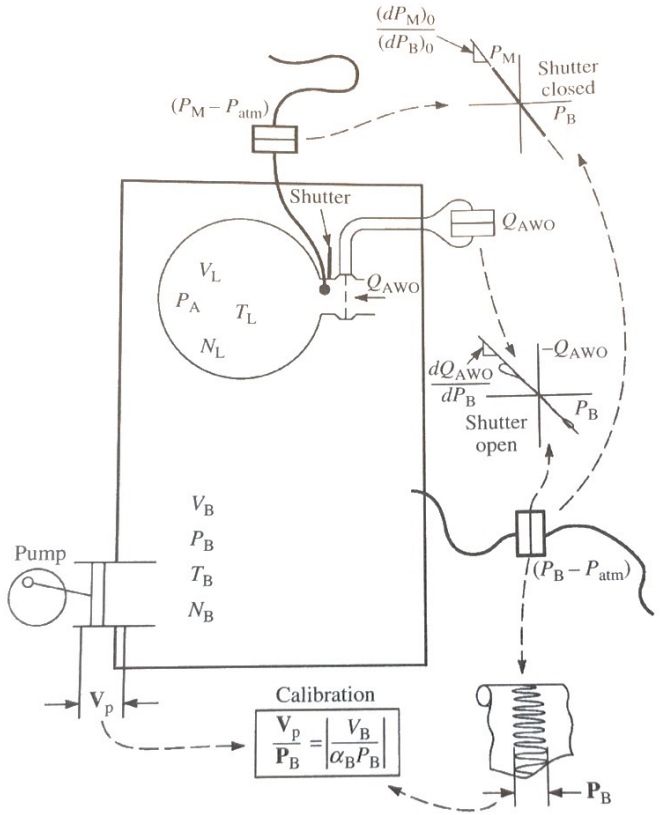


Figure 9.8 A pressure-type total-body plethysmograph is used with the shutter closed to determine lung volume and with the shutter open to determine changes in alveolar pressure. Airway resistance can also be computed if volume flow of gas is measured at the airway opening. Because atmospheric pressure is constant, changes in the pressures of interest can be obtained from measurements made relative to atmospheric pressure.

Boyles law:

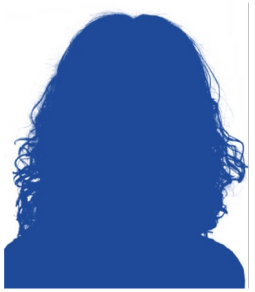
$P_1V_1 = P_2V_2$

Volume of plethysmograph
Vp=Vtissu + VL (Gas space in lungs) + VB (Gas space around the object)

Incompressible tissue, volume of plethy = constant - > dVL = - dVB

Can measure FRC (Functional residual capacity) and Specific airway resistanse

Case 5



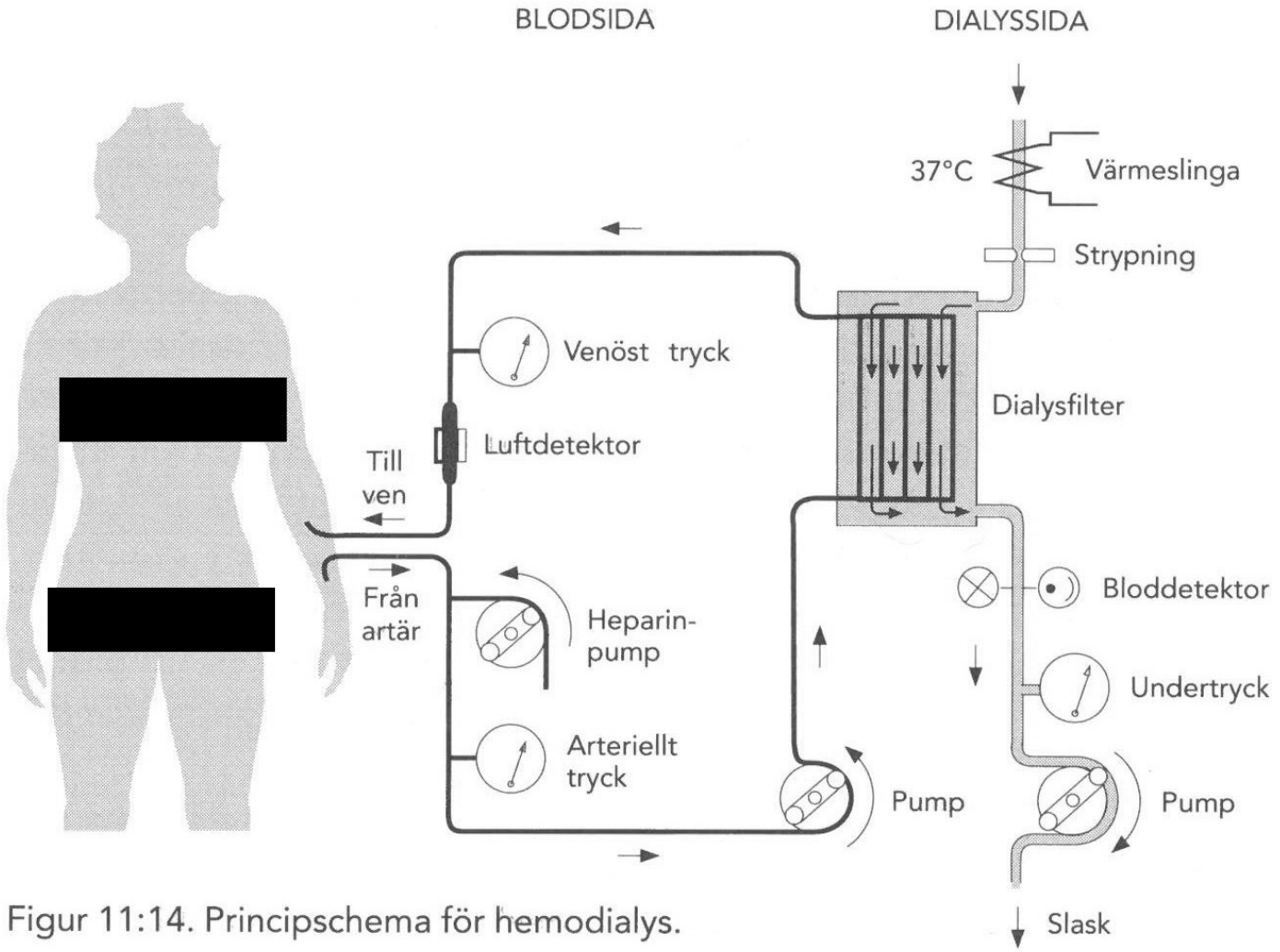
- The respiratory distress is now striking, even with a fraction of inspired oxygen (FiO2) of almost 1.0. She has high fever and pale skin, and she is constantly sweating

- Blood gases show a $PaCO_2$- level of 10.2 kPa, a PaO_2-level of 5.3 kPa, a pH of 7.36 and a saturation of 88%.

- More blood samples are taken, liver enzymes (ASAT, ALAT) show normal values, but creatinine is 12.3 mg/dL and Blood urea nitrogen (BUN) is 44 mg/dl

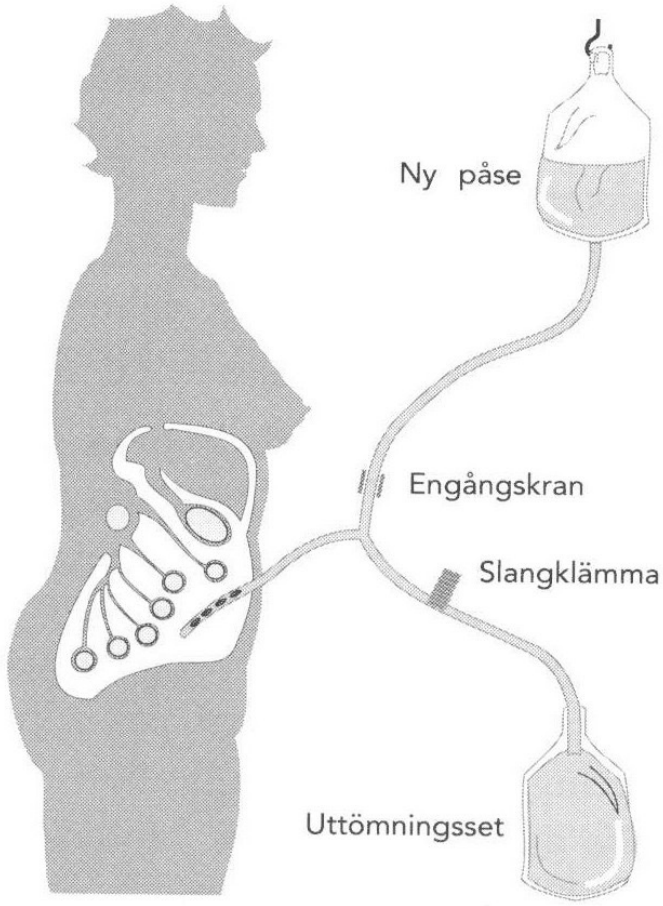
What would you do now?

Hemodialysis



Figur 11:14. Principschema för hemodialys.

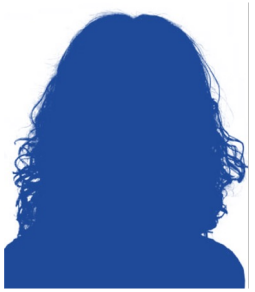
Peritoneal dialysis



Figur 11:15. Vid peritoneal-dialys utnyttjas bukhålan som konstgjord njure.

Use the abdominal cavity as a membrane

Case 5



- A bacterial sample is taken to grow in a petri dish. After a couple of days we have a positive finding of *Pneumocystis carinii pneumonia (PCP)* which seems to be a very likely cause of the respiratory failure. This disease has a mortality of up to 20%



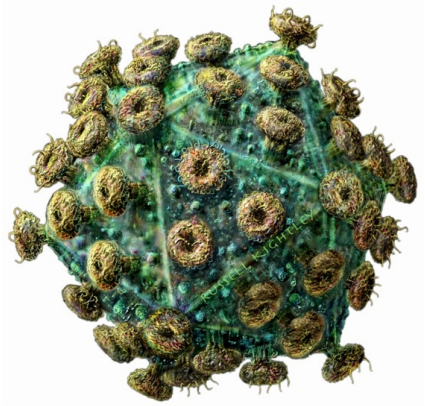
http://www.dental.temple.edu/develop1/Admissions/Images/bacteriaCulture.jpg

What is the final diagnosis then?

Case 5



- *Pneumocystis carinii pneumonia (PCP)* in young healthy persons is extremely rare. In almost all cases, an immunodeficiency syndrom is the underlying cause, and typically HIV. The patient admits to be HIV-positive and also admits to have avoided follow-up the medication for the last year. The CD4-count is below 40 cells/mm^3 and she's treated aggressively with steroids and trimethoprim-sulfamethoxazole. After almost two weeks at hospital, the patient is discharged and told to continue medication for treatment of the HIV



http://www.rkm.com.au/VIRUSES/HIV/HIV-Images/HIV-virus.jpg