ANESTHESIA TECHNOLOGY
ULTRASOUND PHYSICS

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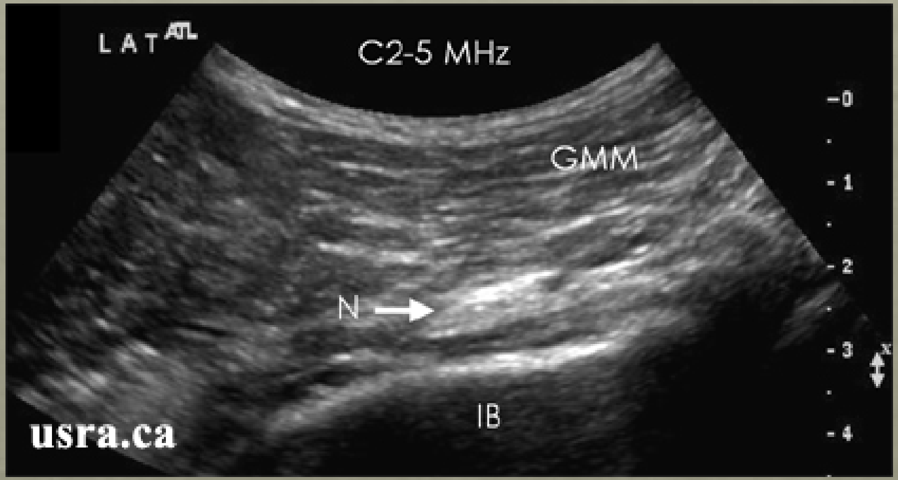
OBJECTIVES

Ultrasound Physics

- Physics
- Probe Orientation
- Descriptive Terms
- Knobology
- Optimization
  - Patient positioning
  - Ultrasound

ULTRASOUND GUIDED

- Real Time
- Anatomy aware
- Aberrancy appreciated
- Local Distribution
- Identify non-motor nerves (saphenous, TAP)

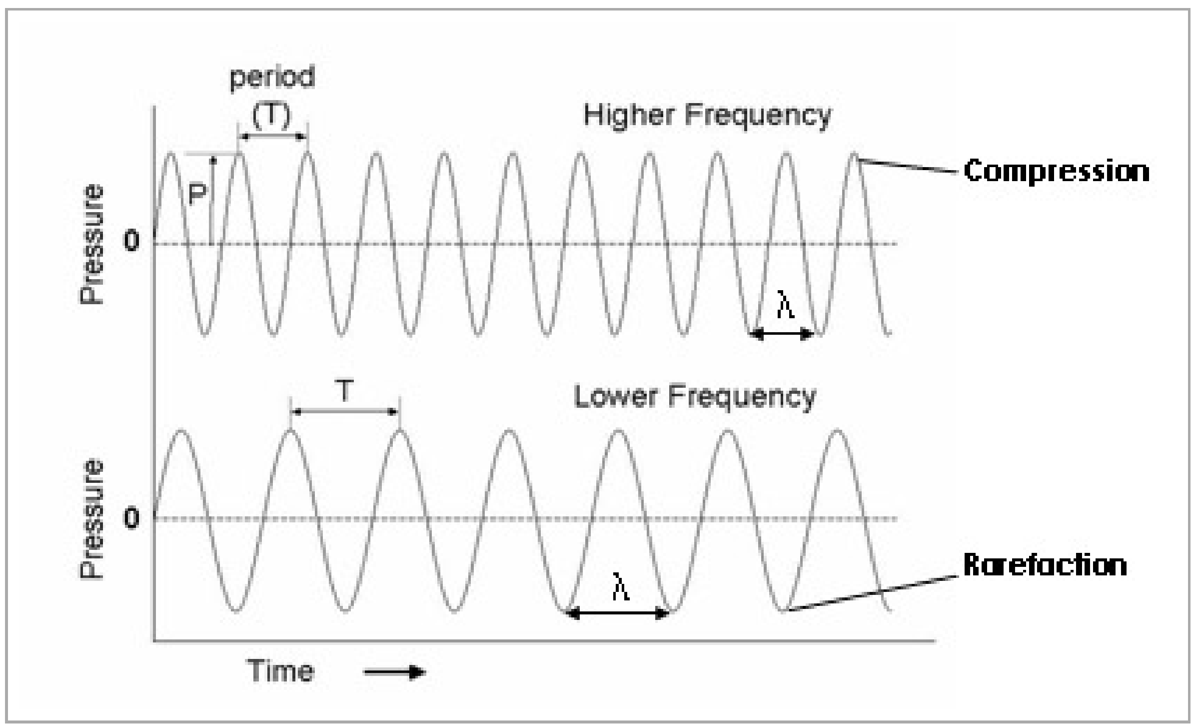


Ultrasound Physics
Seeing with Sound

Basic Principles:

Ultrasound is form of mechanical sound energy that travels through a conducting medium (e.g., tissue) and then gets reflected back to form an image.

ULTRASOUND PHYSICS

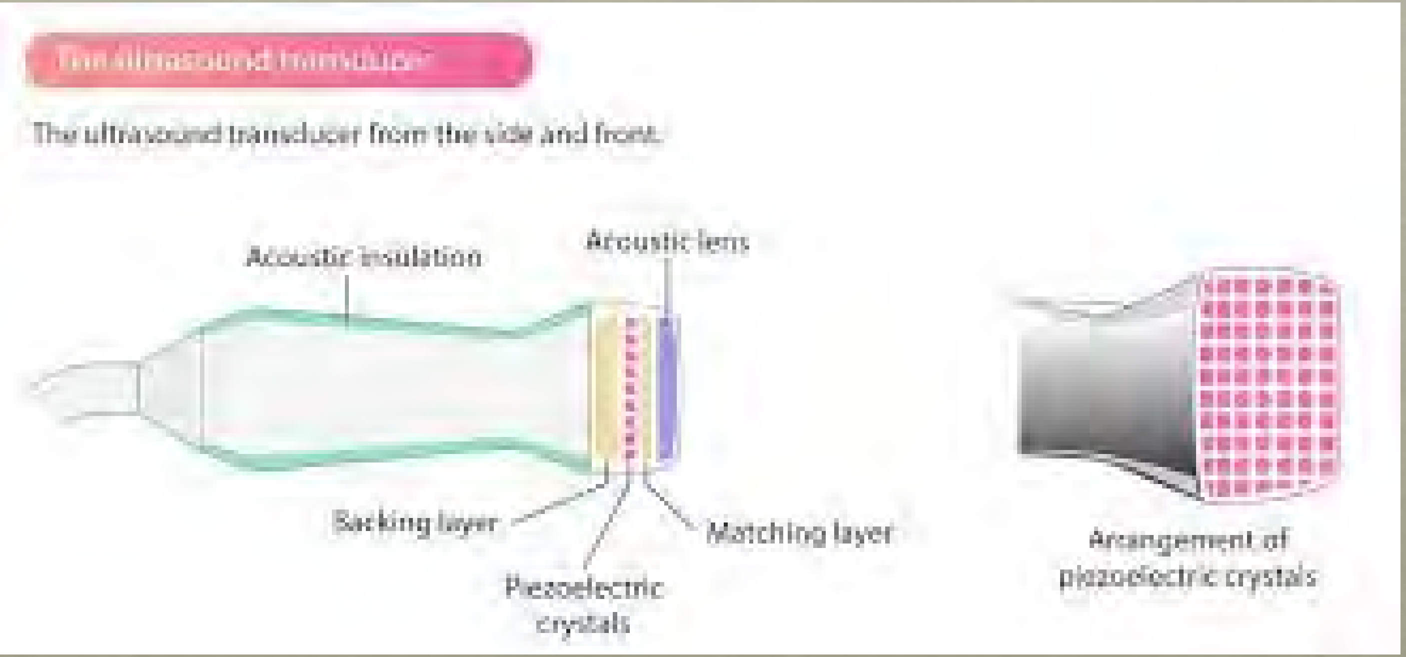


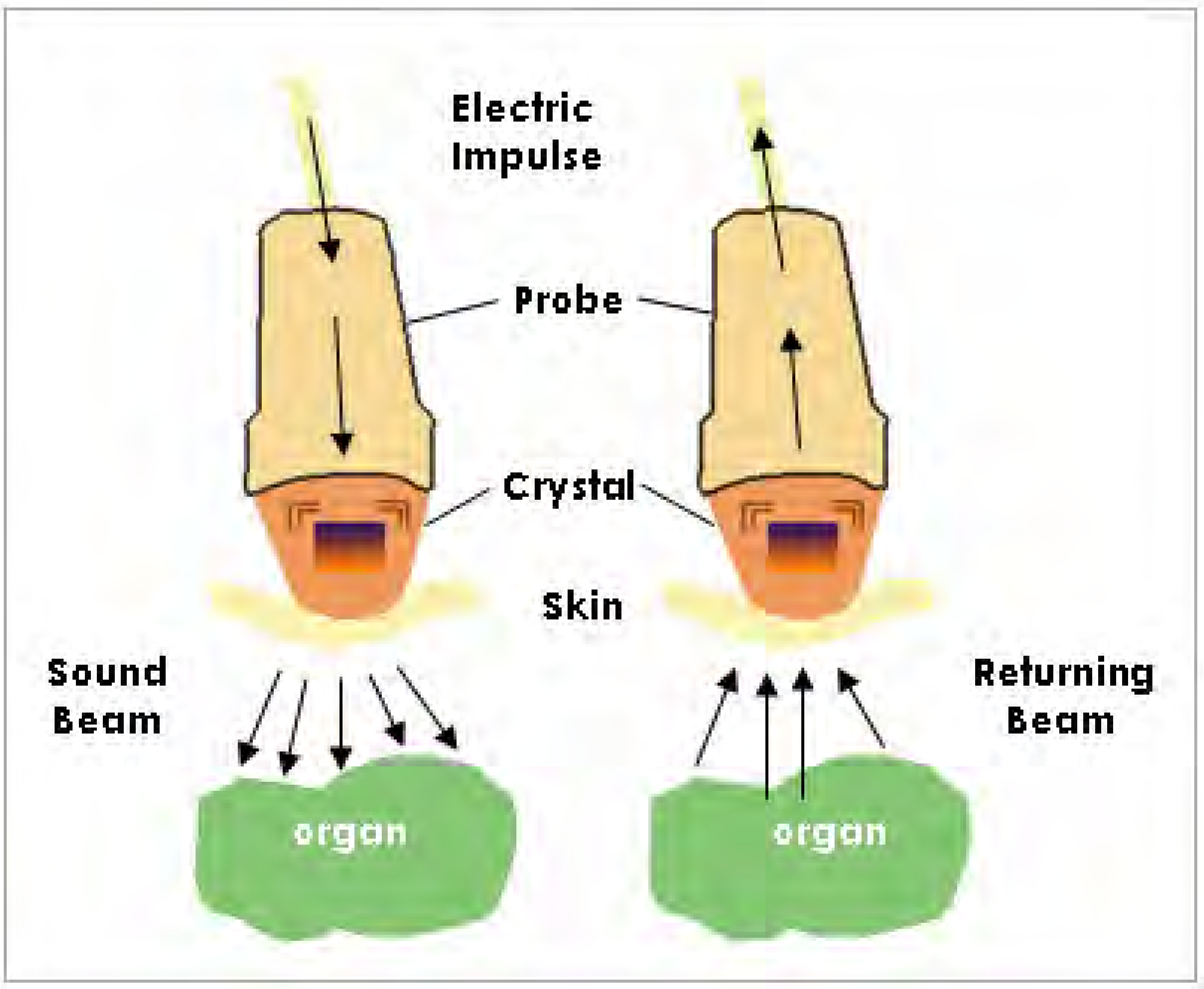
- A sound sinusoidal waveform
- Characteristic
  - Pressure, wavelength, frequency, and velocity

ULTRASOUND PHYSICS

- Electrical energy gets transmitted to pizoelectric crystals that forms the ultrasound wave.

- Waves are generated in pulses



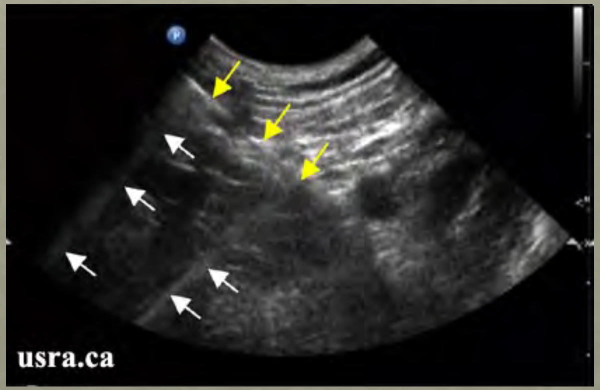

Electric
Impulse
Probe
Crystal
Skin
Sound
Beam
Returning
Beam
organ
organ

ULTRASOUND PHYSICS

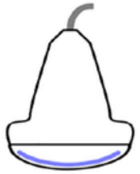
- As the ultrasound beam travels through tissue layers, the amplitude of the original signal becomes attenuated as the depth of penetration increases. **Attenuation** (energy loss) is due to:
  - Absorption
  - Reflection
  - Scattering

- High frequency is associated with high attenuation – therefore, limited tissue penetrations.
  - High freq for superficial structures.
  - Increased resolution.

- Low frequency
  - Deep structures.



ULTRASOUND PROBES

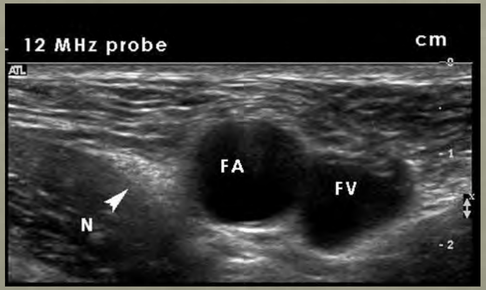
Appearance	Type	Depth (cm)	Description and use cases
	Linear array 7-15 MHz	2-7	Very high spatial resolution but limited penetration. Creates a rectangular field of view with less artifact compared to convex arrays. Typically large foot-print so limited to large craniotomies.
	Convex array 2-10 MHz	10-30	High spatial resolution with good penetration. Fan shaped large field of view. Large foot-print so limited to large craniotomies.
	Micro-convex 4-13 MHz	6-10	High spatial resolution with good penetration. Fan shaped large field of view. Smaller foot-print so more adaptable and usable in smaller craniotomies with potential for intracavitary use depending on resection size.
	Sector array 4-10 MHz	4-8	Small foot-print. Produces trapezoid image allowing wide field of view from a small craniotomy. Resolution lower at depth. Can be used for burr-hole guided surgery for instance for VP shunt placement.
	Matrix phased array 1-8 MHz	5-20	Type of sector array and often used in neurosurgery. Allows direct easy acquisition of a pyramidal 3D US image allowing volumetric reconstruction in any axis and facilitating visualization of adjacent structures. Produces relatively large field of view but resolution and contrast between different structures is poorer versus linear and convex array probes.
	Small linear “Hockey-stick” 6-15 MHz	2-5	Small foot-print, very high resolution but limited penetration. Can be placed directly into the resection cavity for high resolution assessment of superficial residual disease at the resection margin.

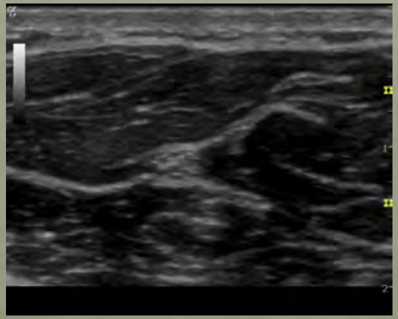
Ultrasound Probes

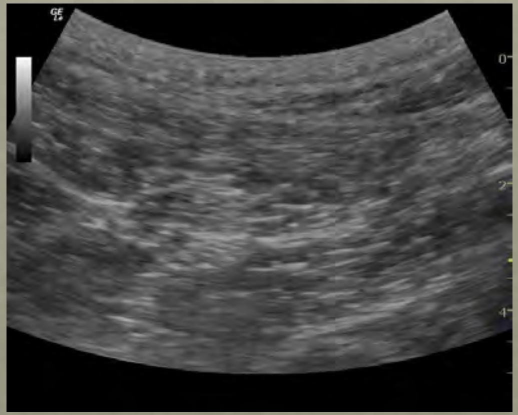
Linear

Hockey Stick Linear

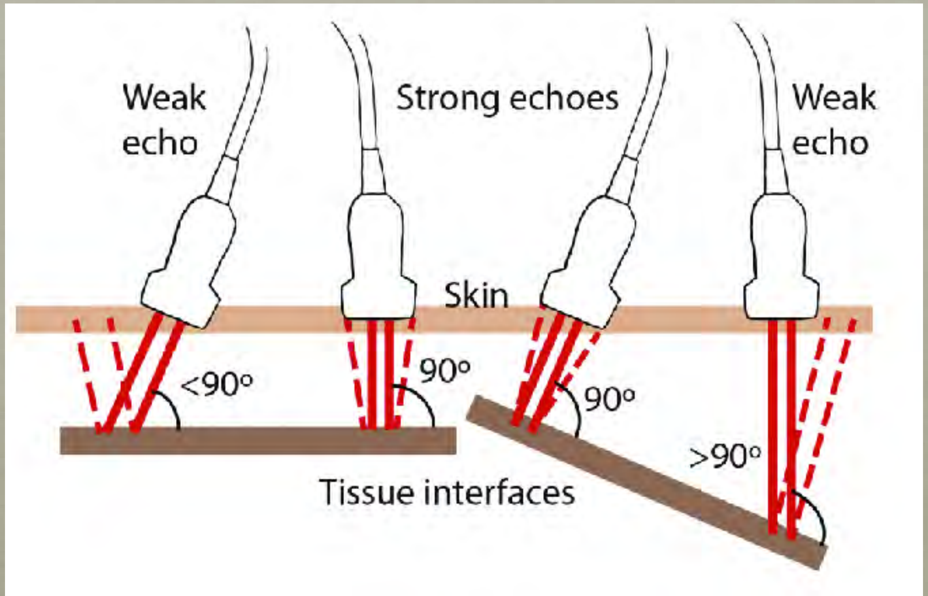
Curved Array

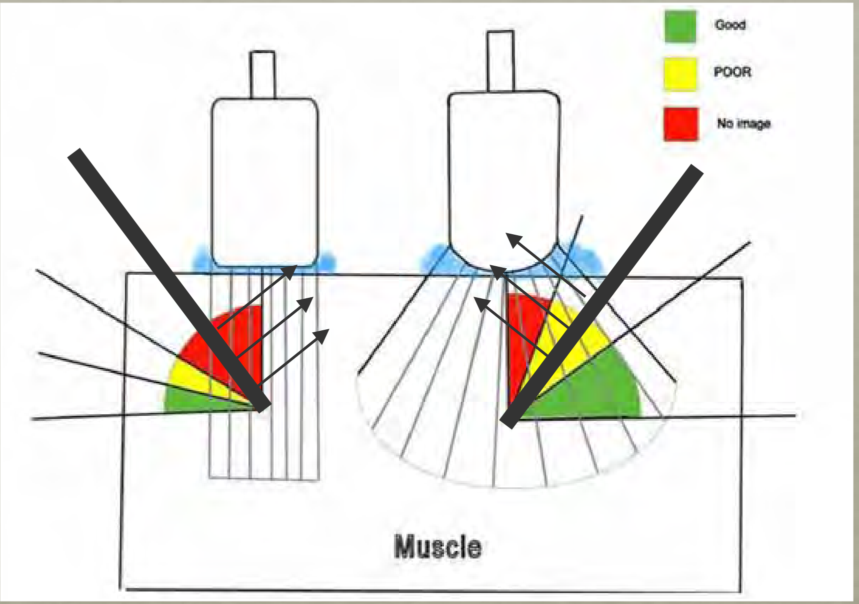






PROBES AND THE ANGLE OF INCIDENCE

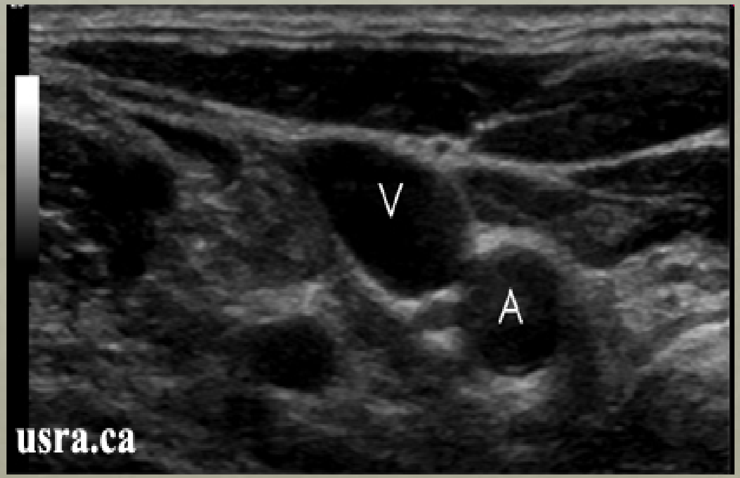




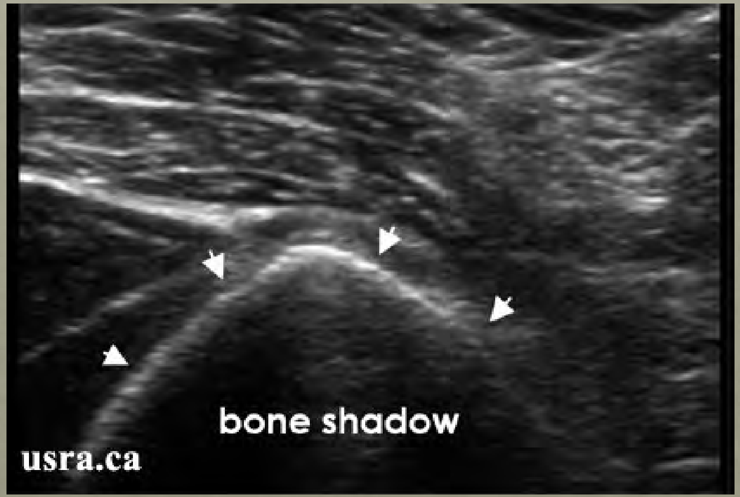
Angle of insonation is defined as the angle of the ultrasound beam relative to the tissue or organ of interest. The strongest echoes are produced when the angles of incidence approach the angle of reflection.

IMAGING

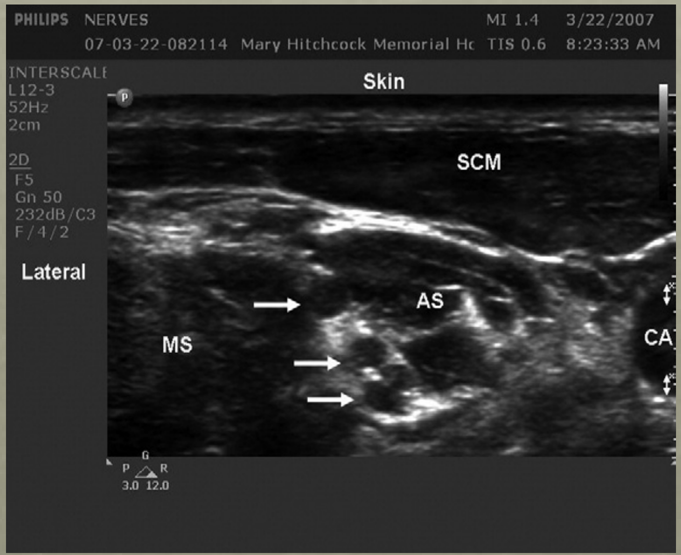
- Structures that allow for sound wave transmission cause no reflection = BLACK (Anechoic)

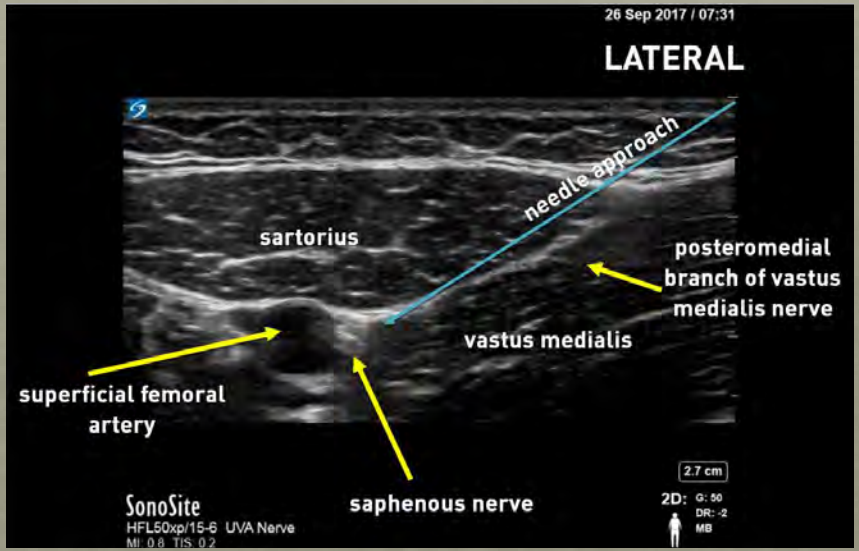


- Little to no transmission cause reflection = White (Hyperechoic)



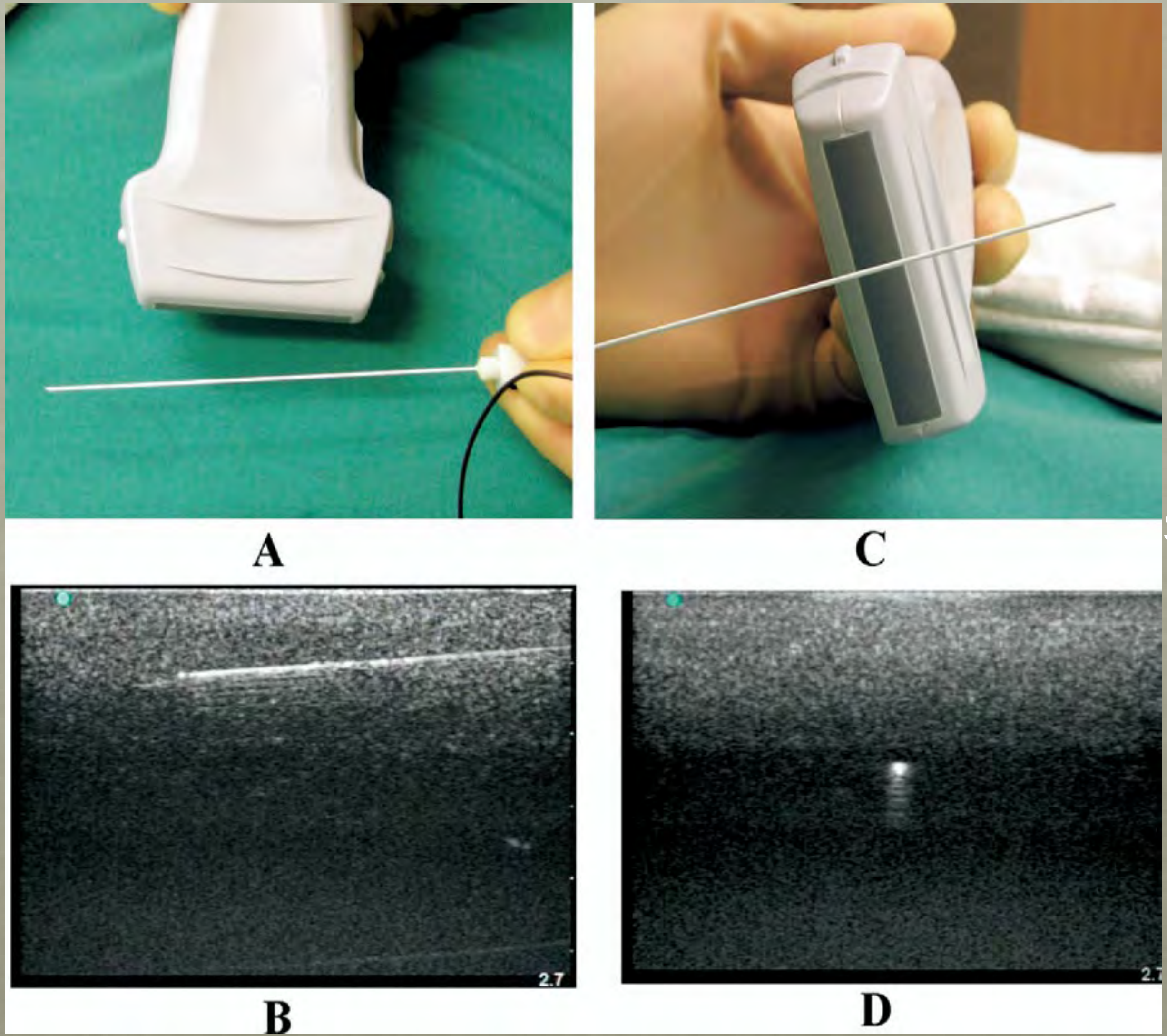
TISSUE	ULTRASOUND IMAGE FOR REGIONAL ANESTHESIA
Veins	anechoic (compressible)
Arteries	anechoic (pulsatile)
Fat	hypoechoic with irregular hyperechoic lines
Muscles	heterogeneous (mixture of hyperechoic lines within a hypoechoic tissue background)
Tendons	predominantly hyperechoic technical artifact (hypoechoic)
Bone	++ hyperechoic lines with a hypoechoic shadow
Nerves	hyperechoic / hypoechoic technical artifact (hypoechoic)





ORIENTATION

Long Axis



Short Axis

SHORT AND LONG AXIS

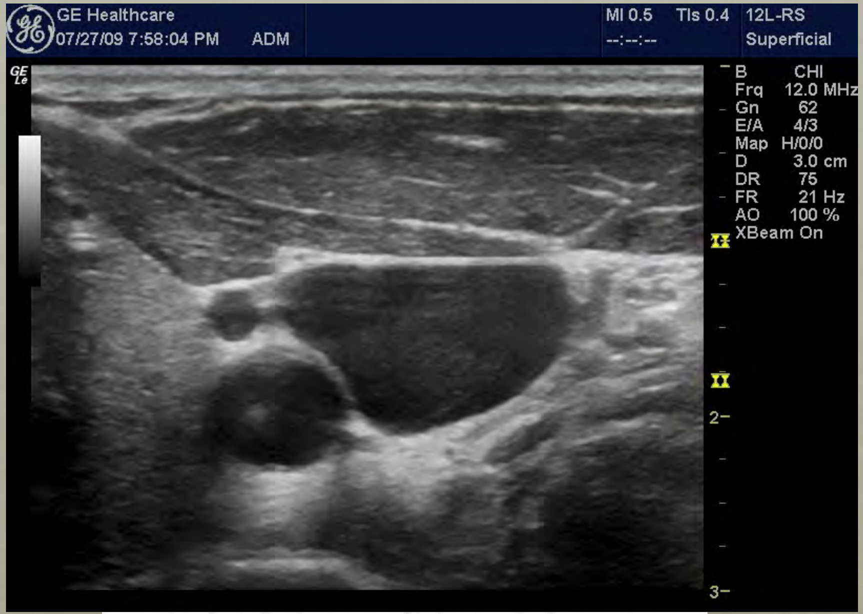
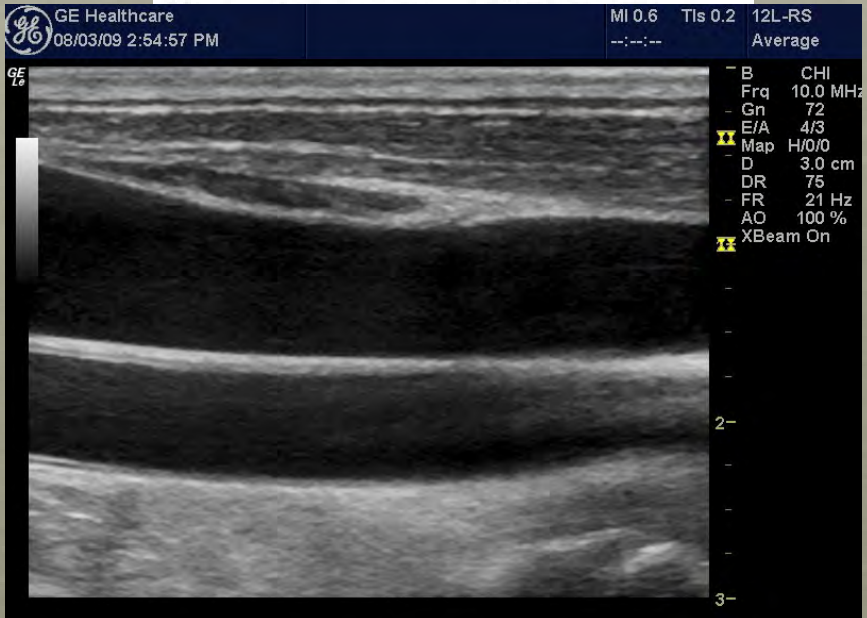
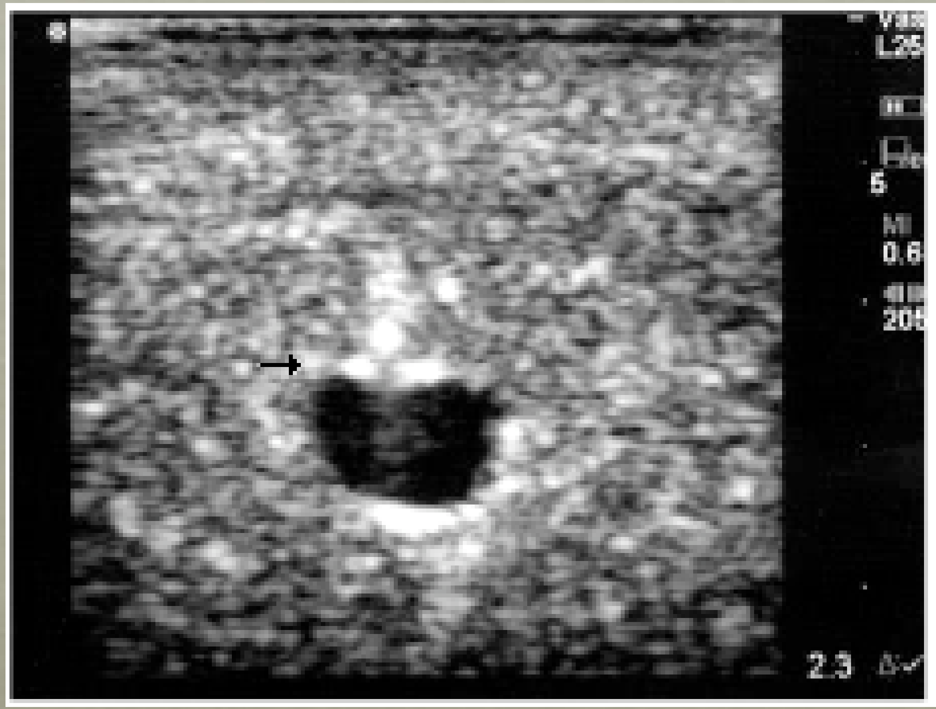


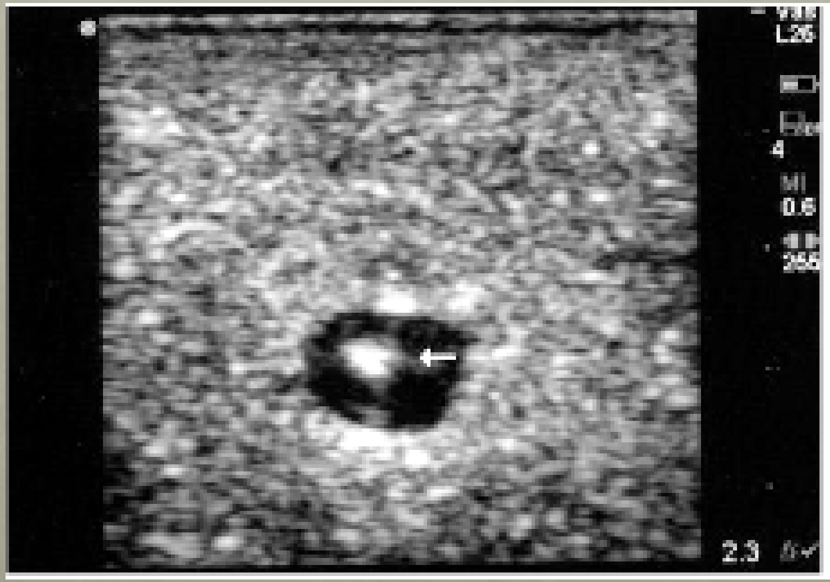
Figure 5. Needle orientation in short-axis approach.

Figure 9. Needle orientation in long-axis approach.

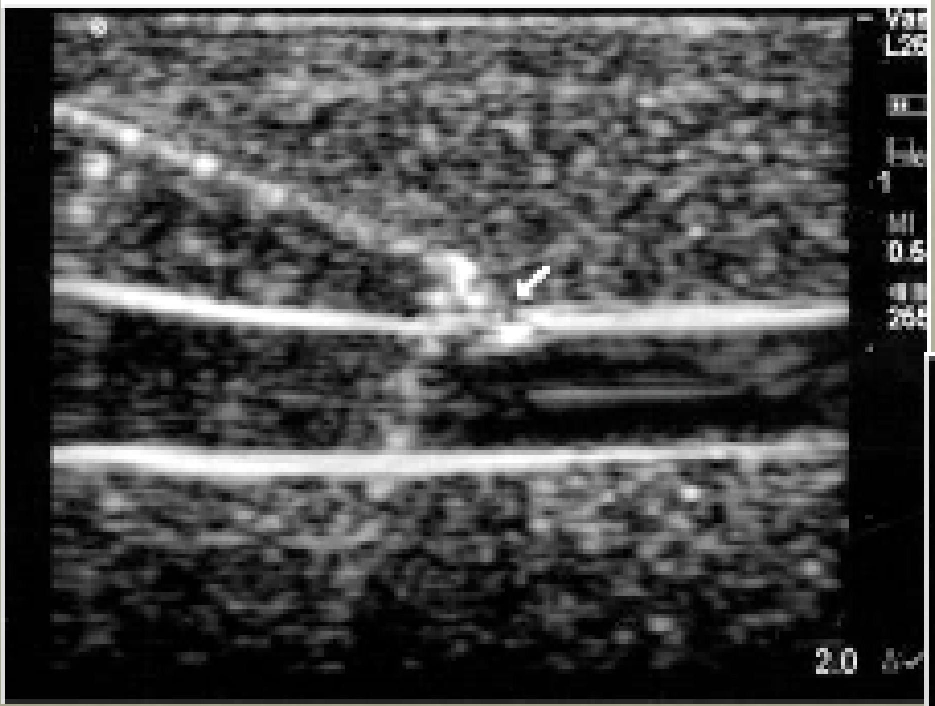


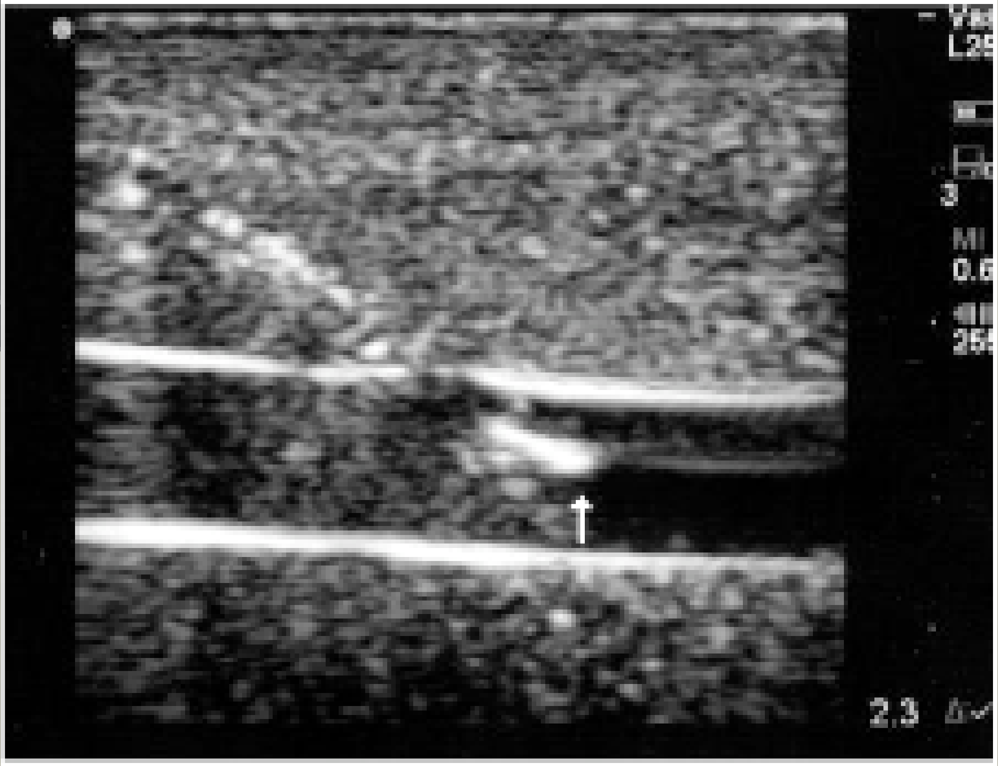
Short Axis





LONG AXIS





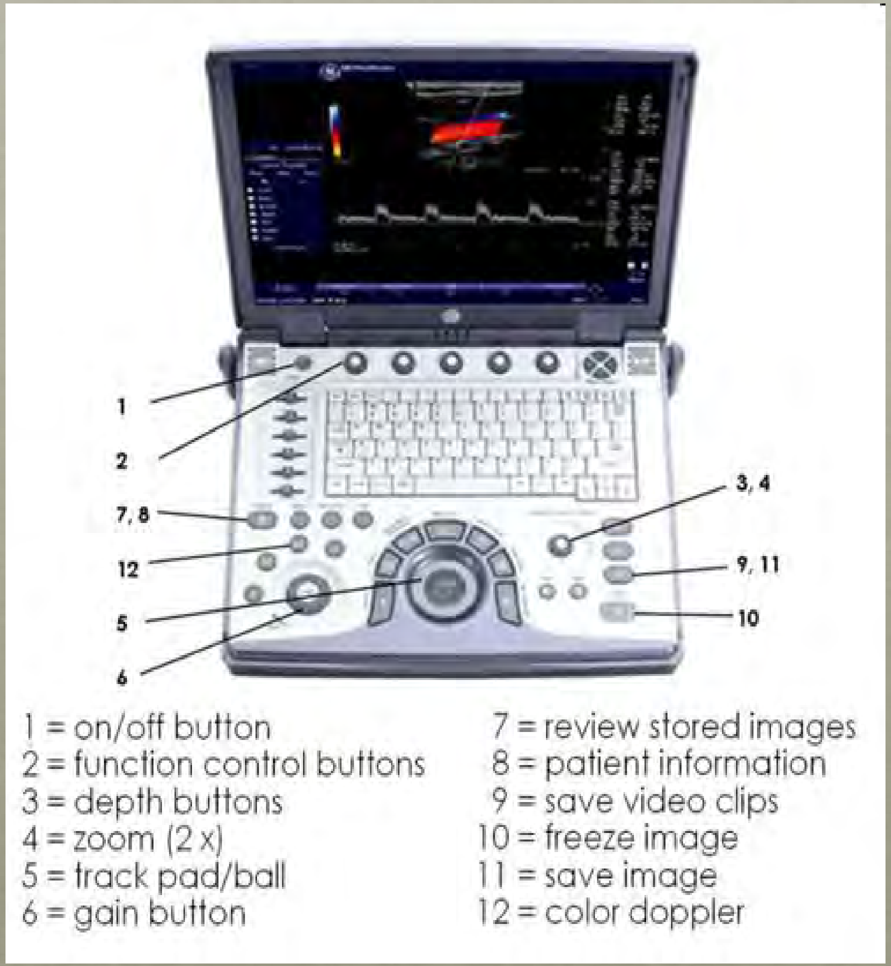
ULTRASOUND MACHINES

Components: 1) A pulser, 2) A transducer, 3) Receiver, 4) Display (B-mode, M-mode, A-mode), 5) Memory

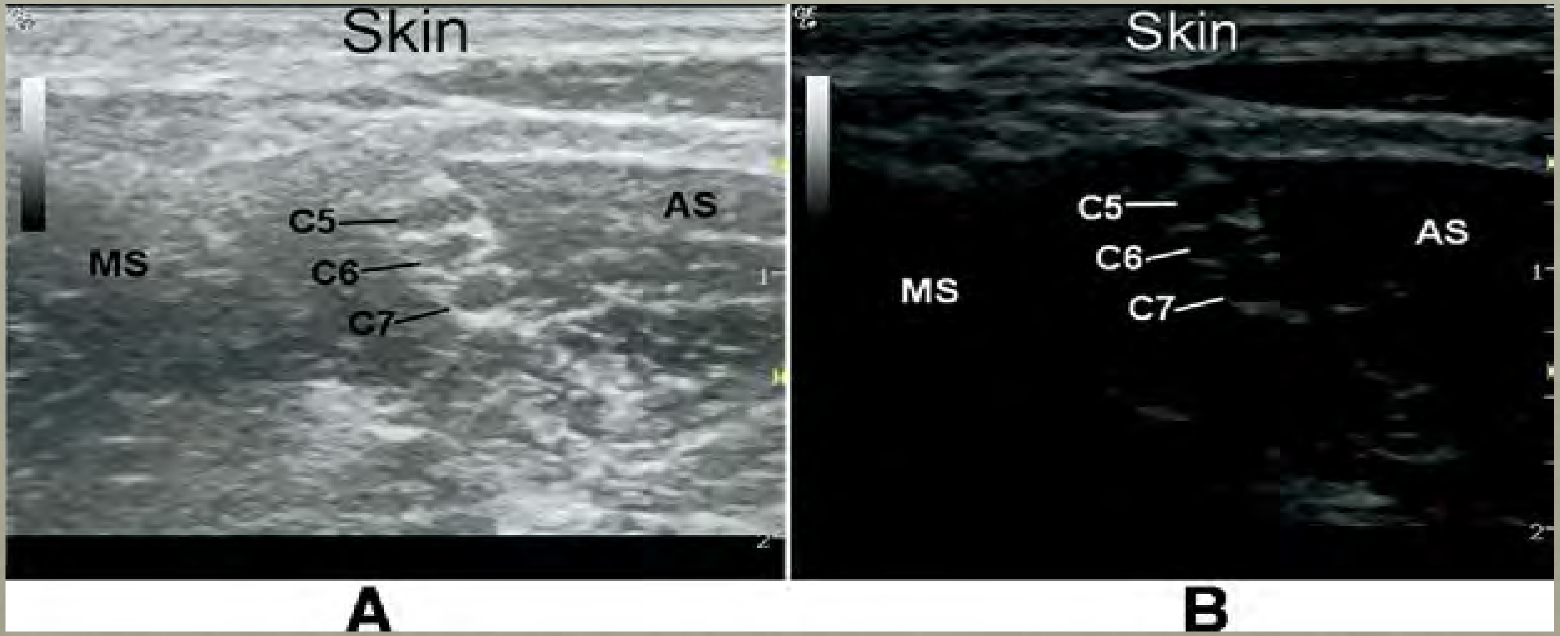
Features: 1) Compound Imaging, 2) Color Flow Doppler, 3) Contrast adjustment.

KNOBOLOGY

- Most important
  - Gain
  - Frequency
  - Depth
  - Focal Length Button
  - Time Gain Toggle



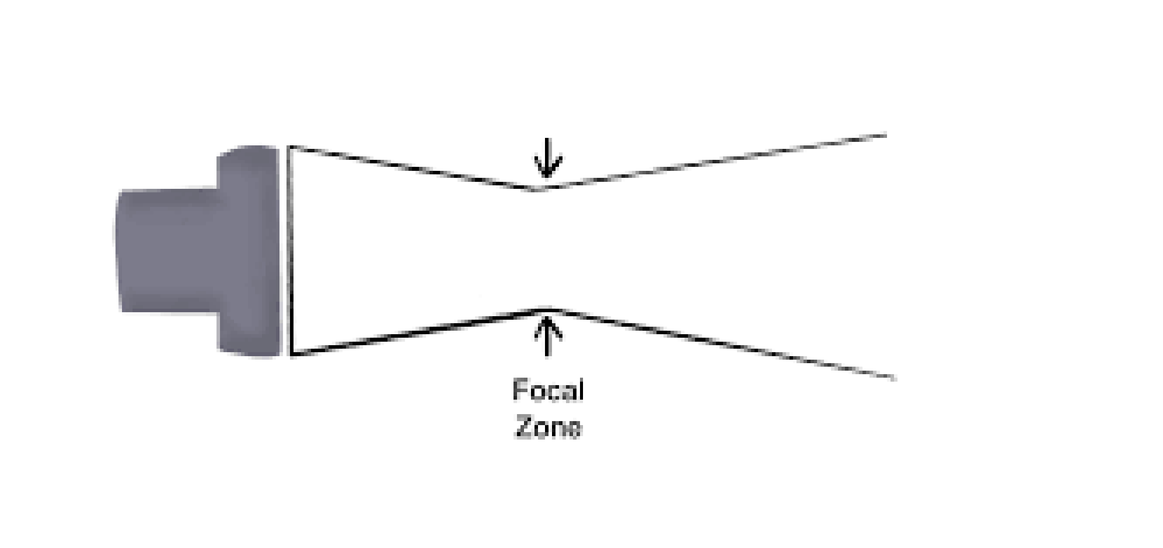
GAIN

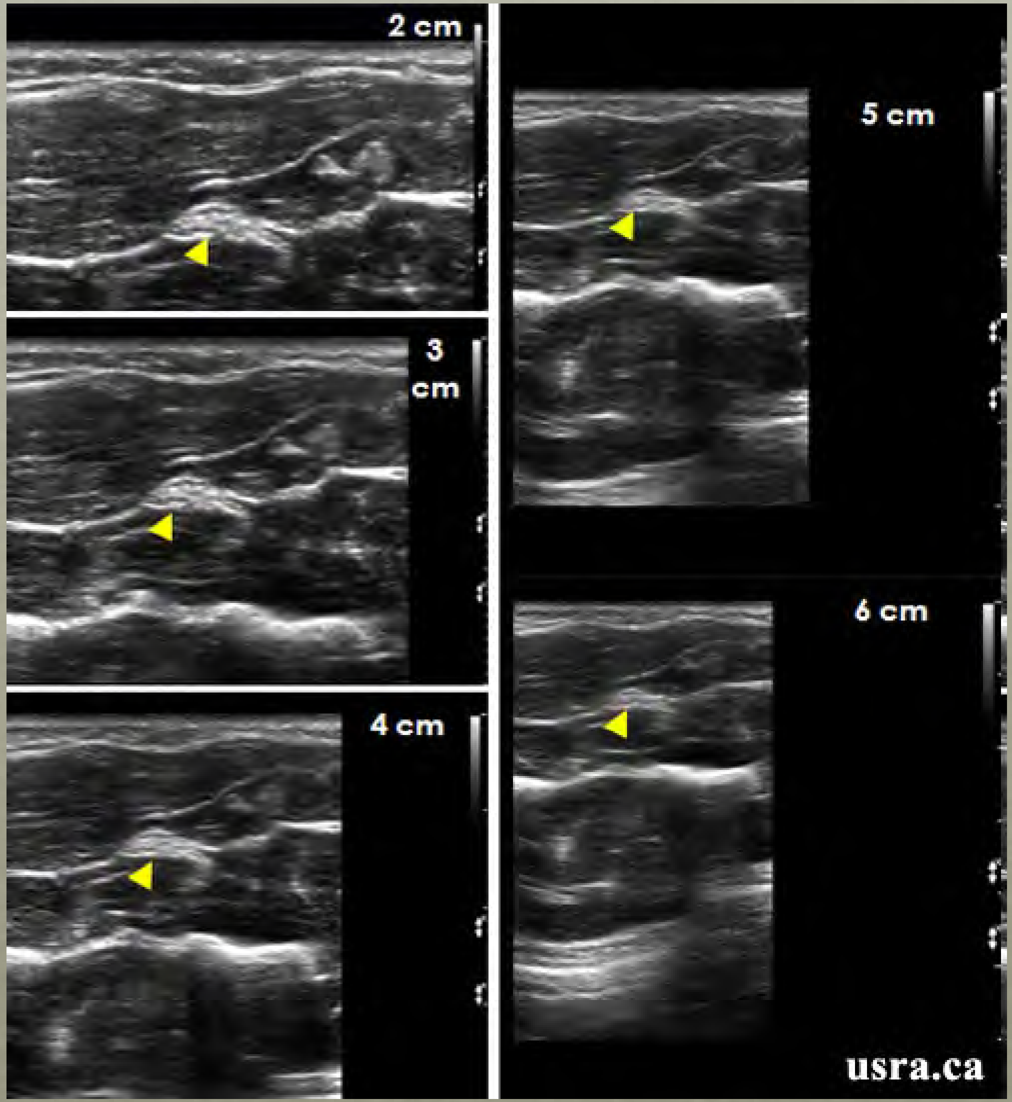


Too much

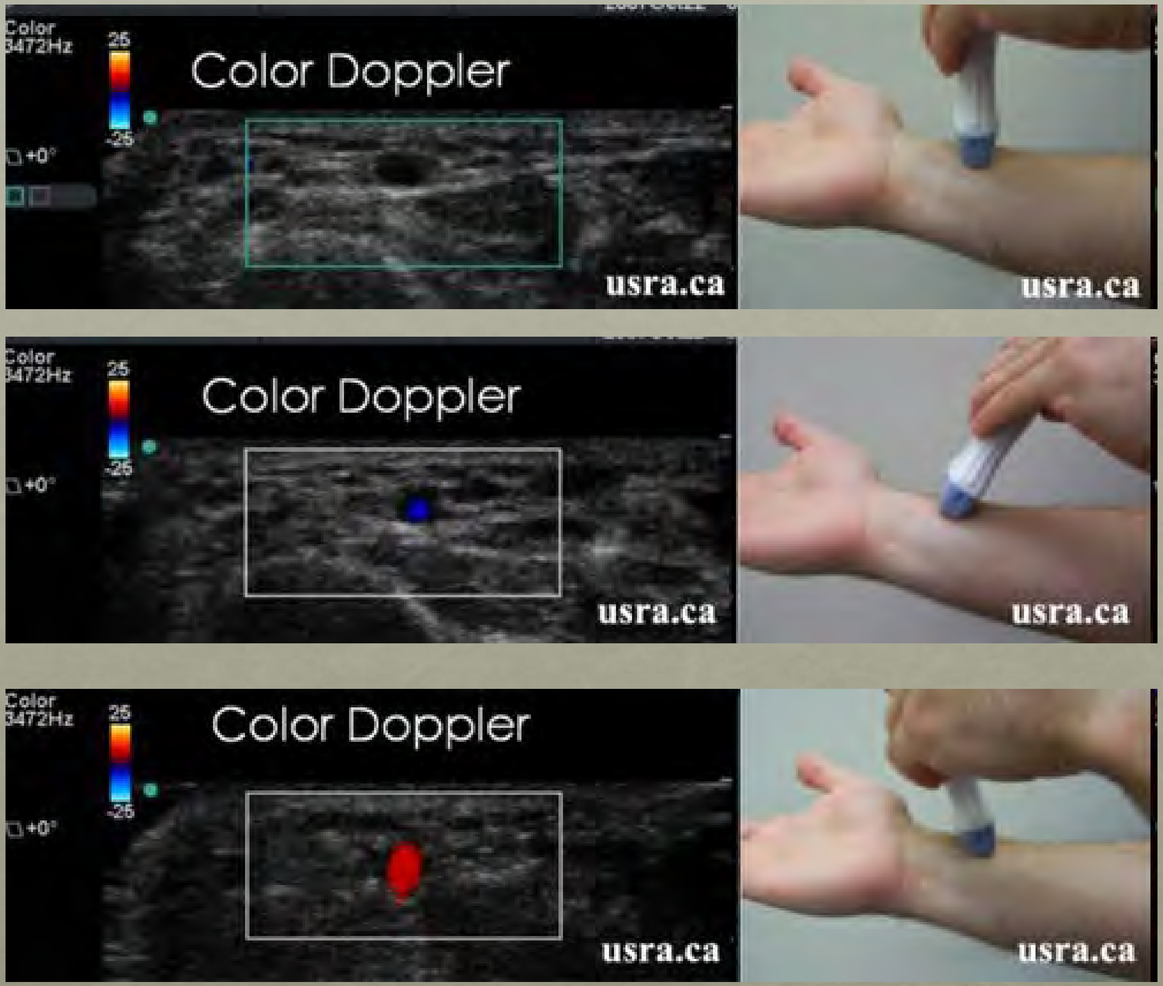
Too Little

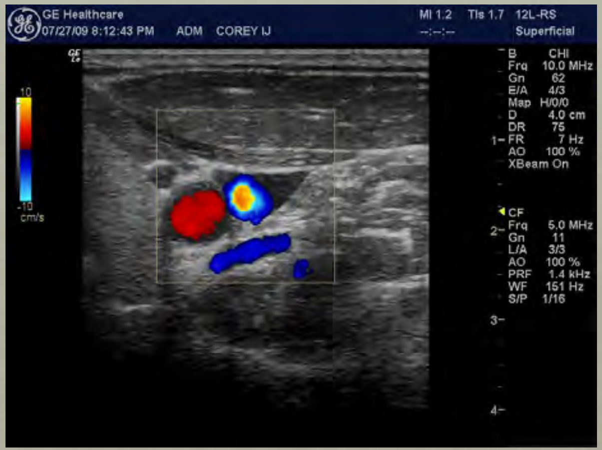
DEPTH





COLOR DOPPLER





Patient Positioning and Ergonomics

- Comfortable for the patient and the operator
- Sit, stand, but ensure you are comfortable
  - Not leaning, arms 90 degrees at elbows
- I like to align my needle, US probe and US machine along the same line.
  - Many have needle and US probe perpendicular to US machine – the important thing is to have your hands in front of you and able to see the screen without turning your body.


Patriots

Tips for Success

- Practice Practice Practice
  - Scan yourself, your patient, your loved one
  - Study anatomy
  - Needle control (Blue Phantom, meat)
- Do sonographic scan before block
  - Look deep for orientation and then decrease depth
- Hold needle with index finger and thumb, dominant hand
- Secure probe anchored to patient
- Consider adding stimulation to identify nerve structures
  - Hydrodissection
- Beware of common pitfalls

Tips for Success

- Start with easier, superficial blocks, and then progress.

  - Basic level blocks: Femoral, interscalene, and popliteal.

  - Advanced: Higher sciatic (infragluteal, parasacral,), anterior sciatic, TAP, infraclavicular, supraclavicular, PENG.

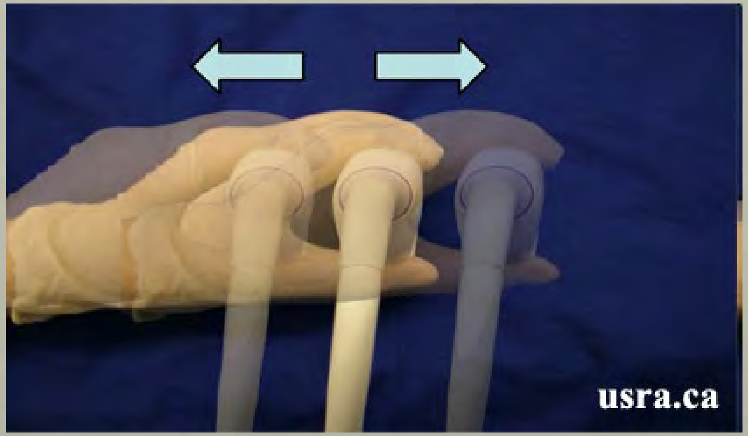
COMMON MISTAKES

- Remember
  - Specular image
  - If you don't, tip may not be where you think

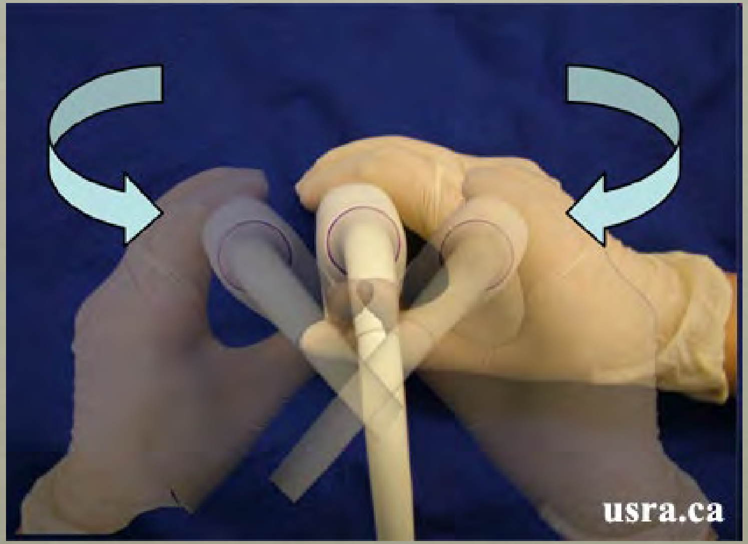
COMMON MISTAKES

- If you don’t see the entire shaft, you may not have needle tip in view.

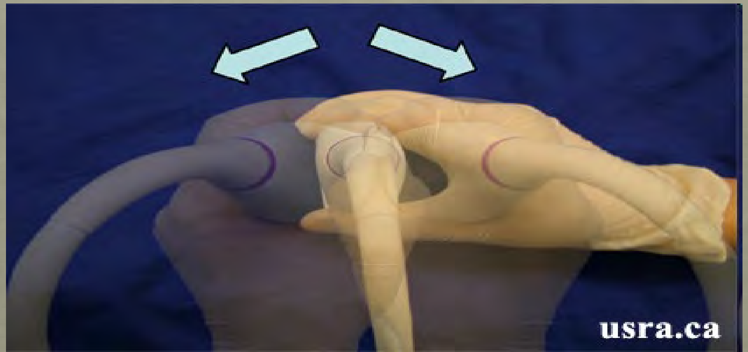
- Think “ART”
  - Alignment
  - Rotation
  - Tilt



- A = Alignment



- R = Rotation

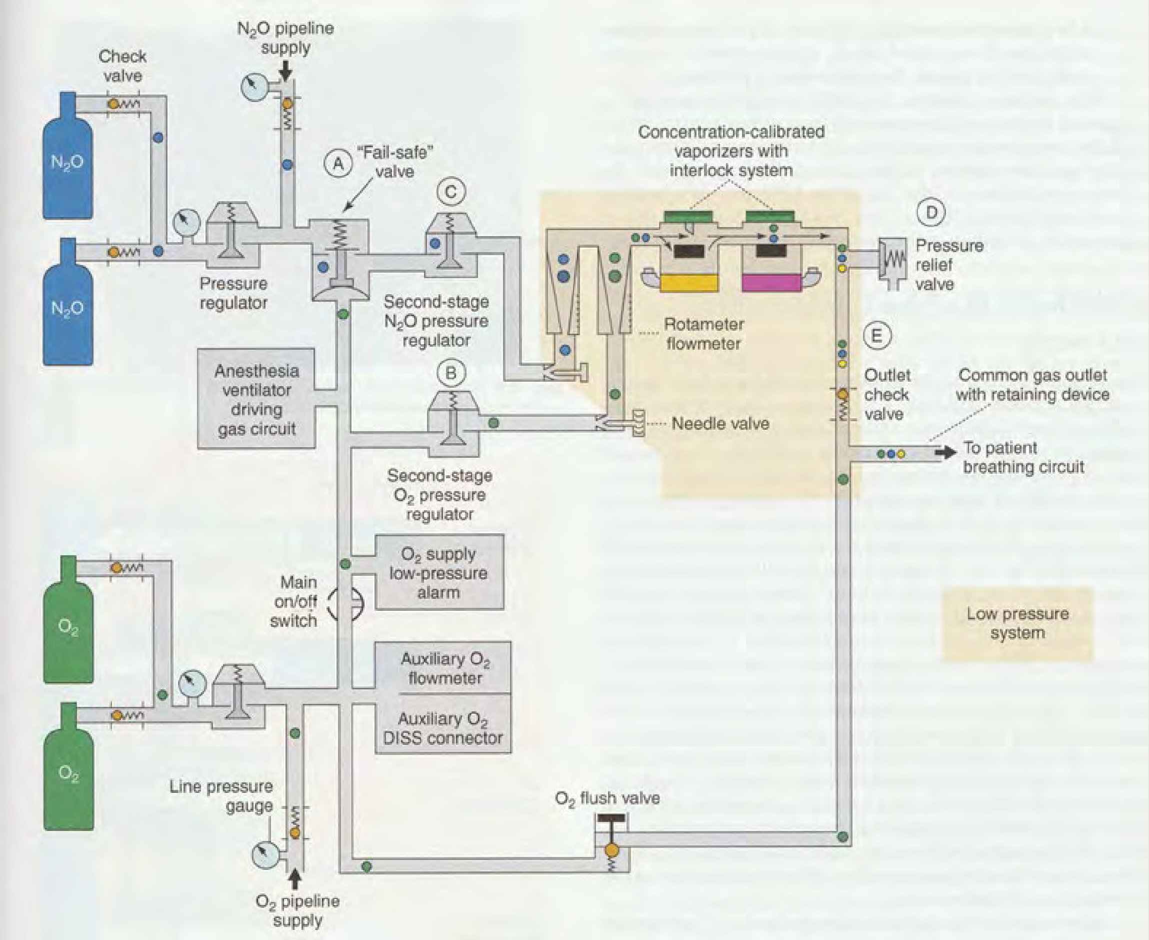


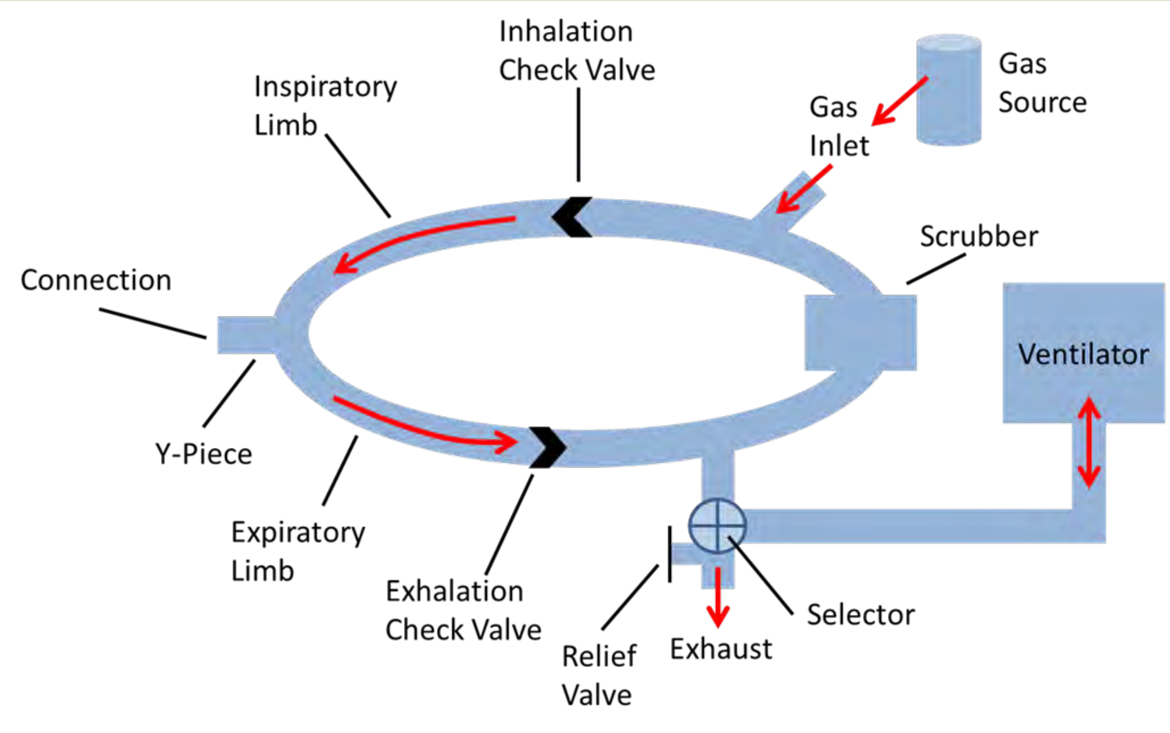
- T = Tilt

ANESTHESIA TECHNOLOGY

Derek Owens DrAP, CRNA

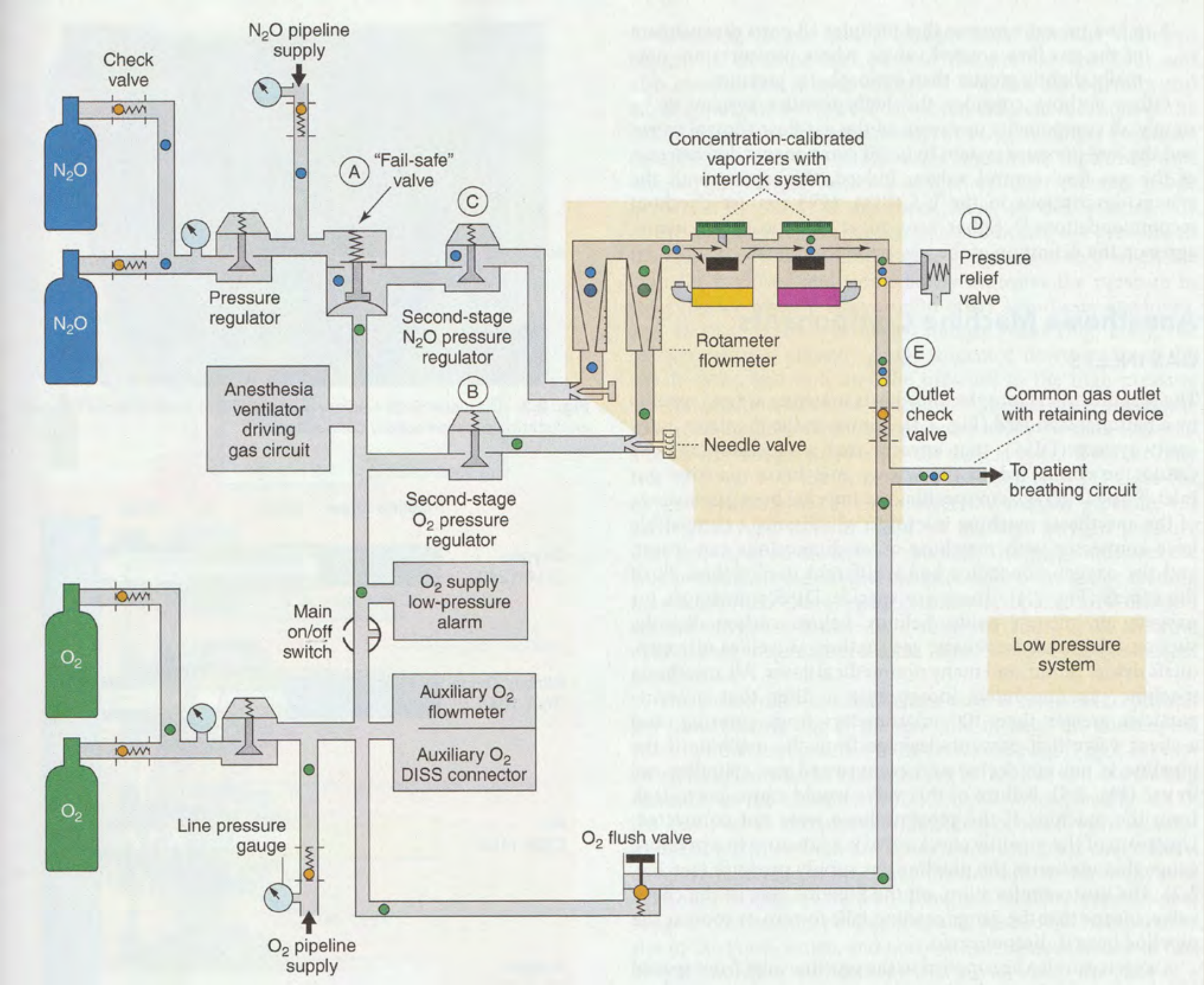
Anesthesia Machine





Gas flow

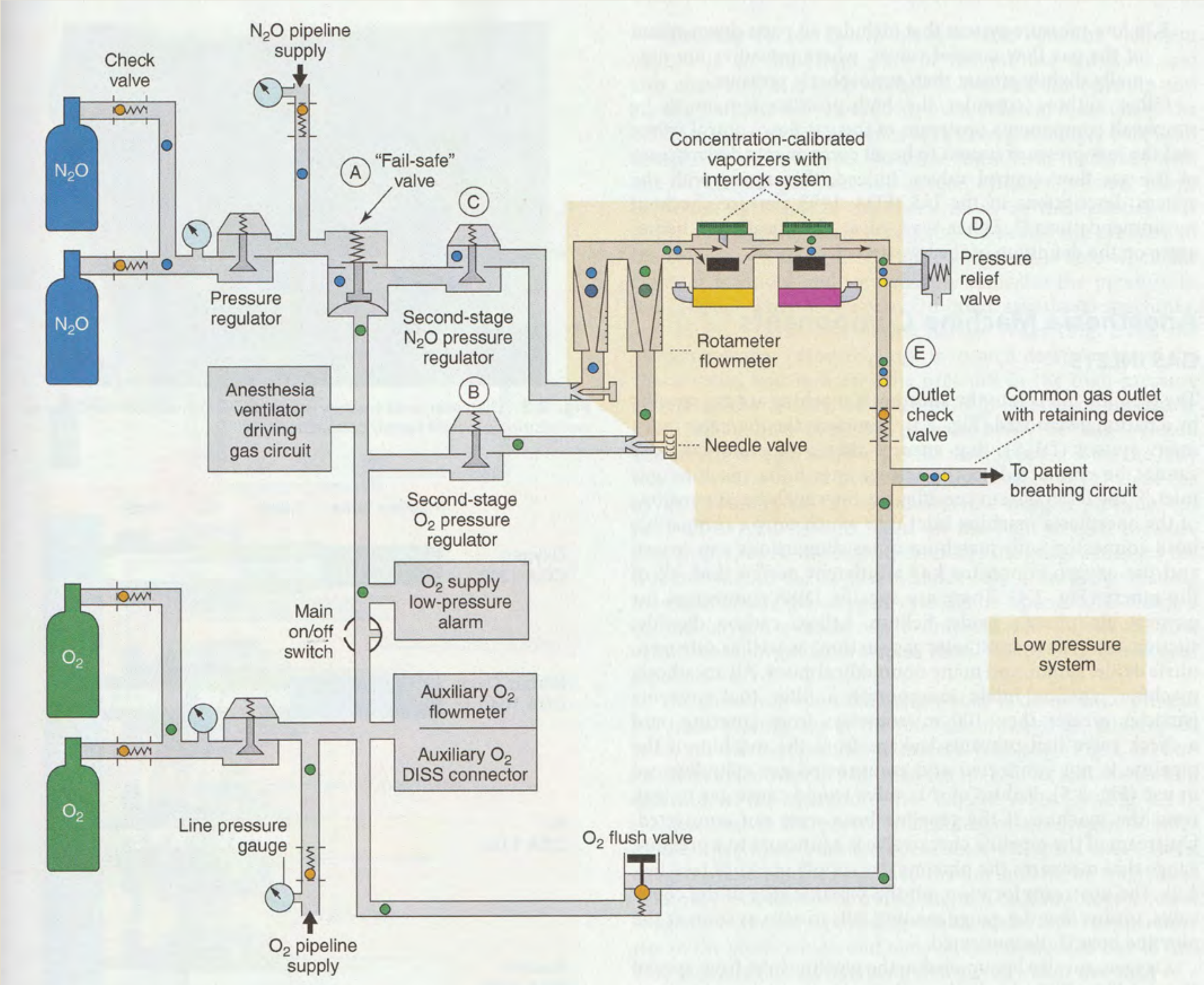
- Wall pipeline
  - 50-55 psi
- Cylinder pressure
  - 40-45 psi



Gas Flow

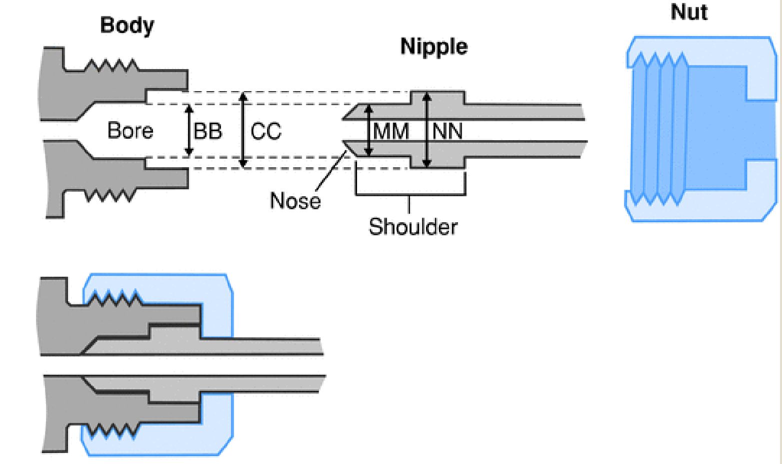
- Flow = $\dfrac{Pressure}{Resistance}$

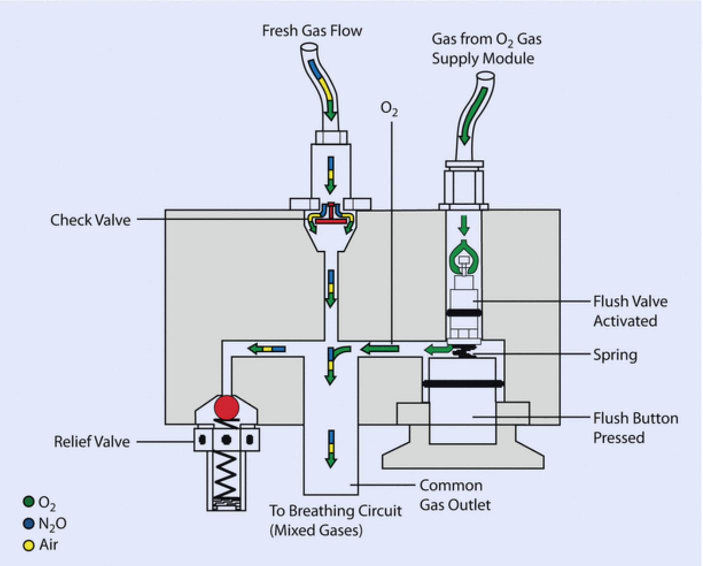
- High Pressure
  - 55-2200 psi
- Intermediate Pressure
  - 16-55 psi
- Low Pressure
  - Slightly greater than atmospheric psi

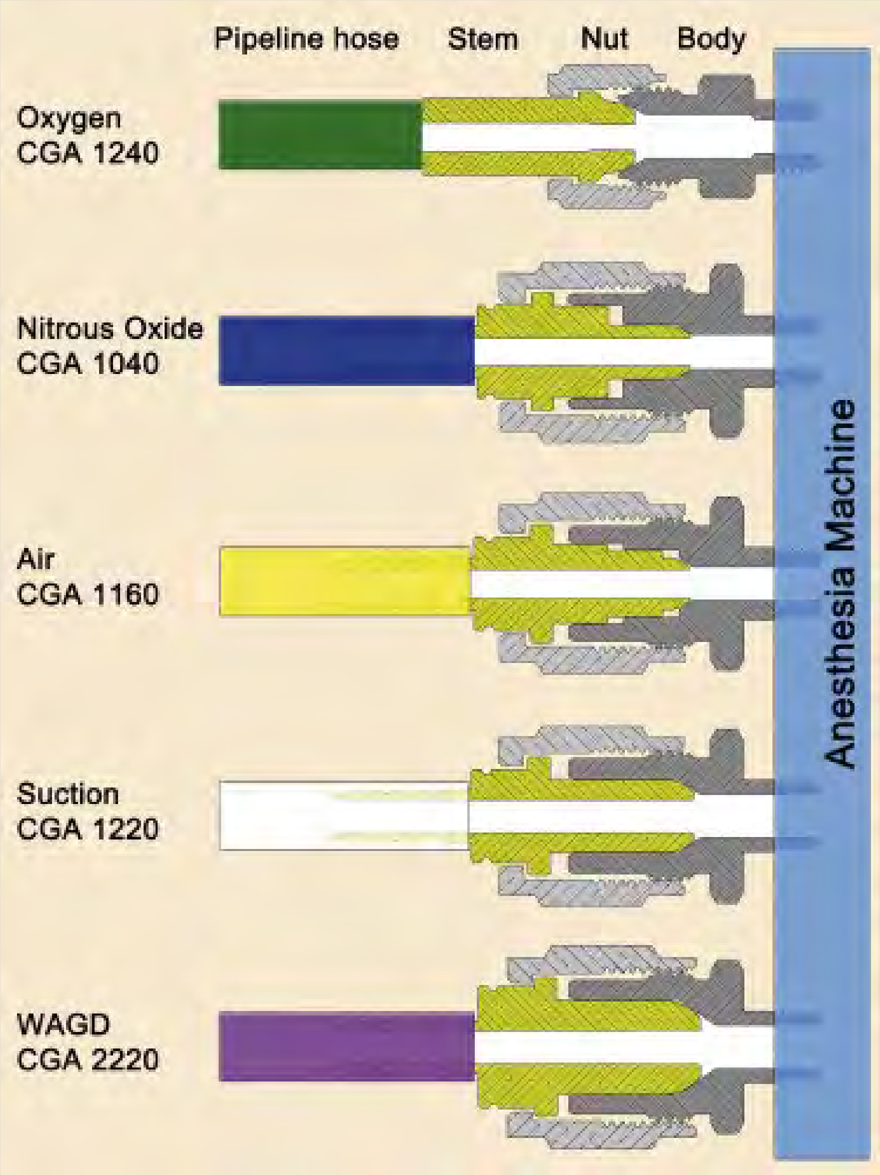


Gas inlets

- DISS

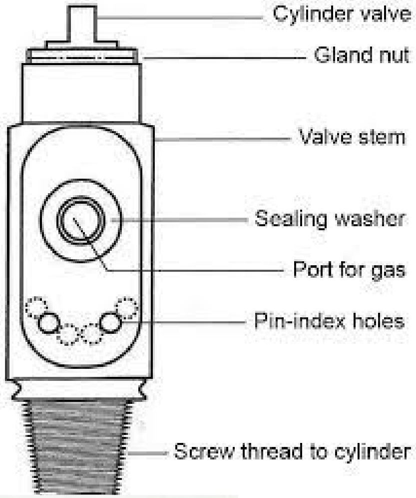


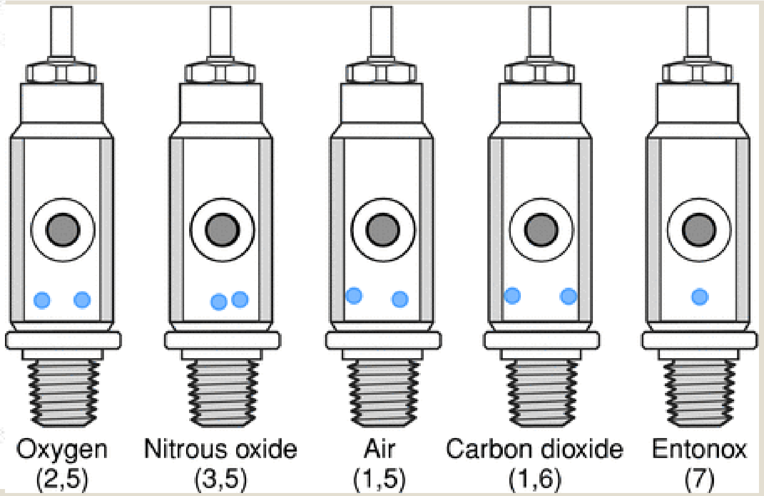


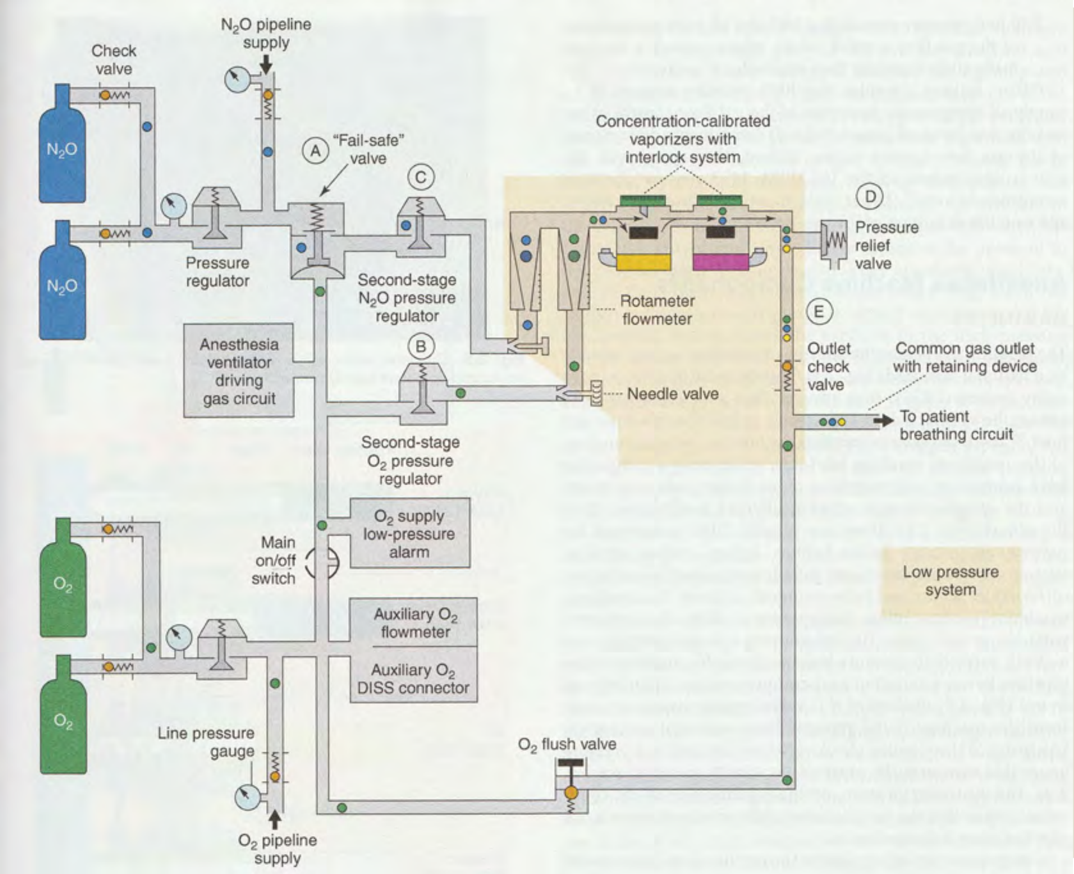


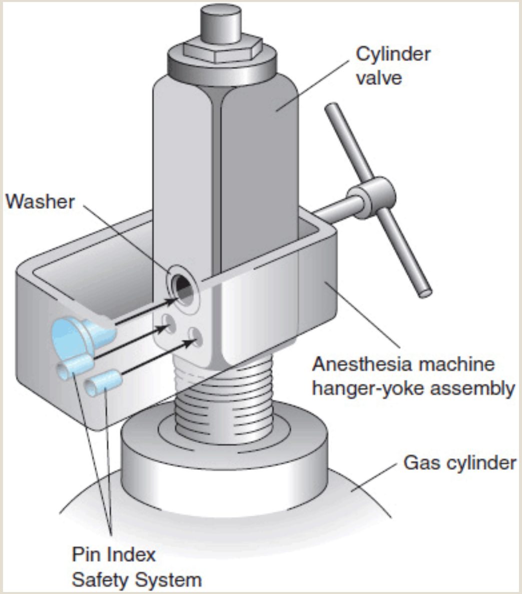
Gas inlets

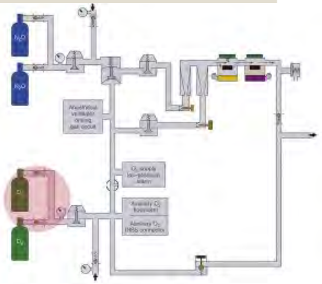
- PISS

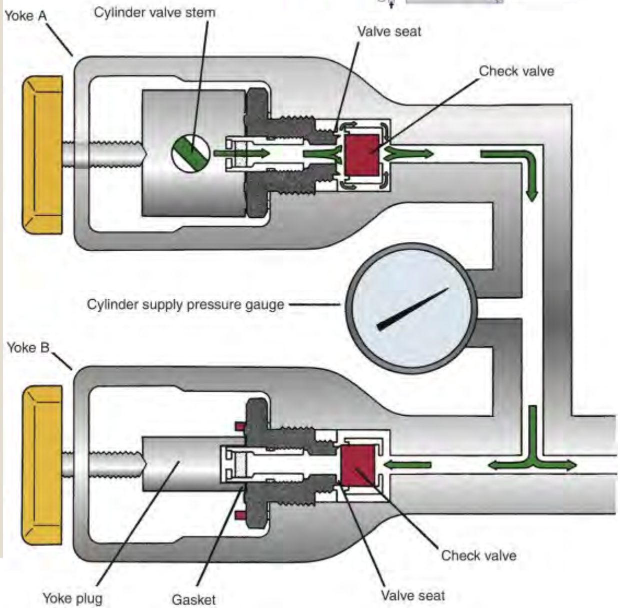






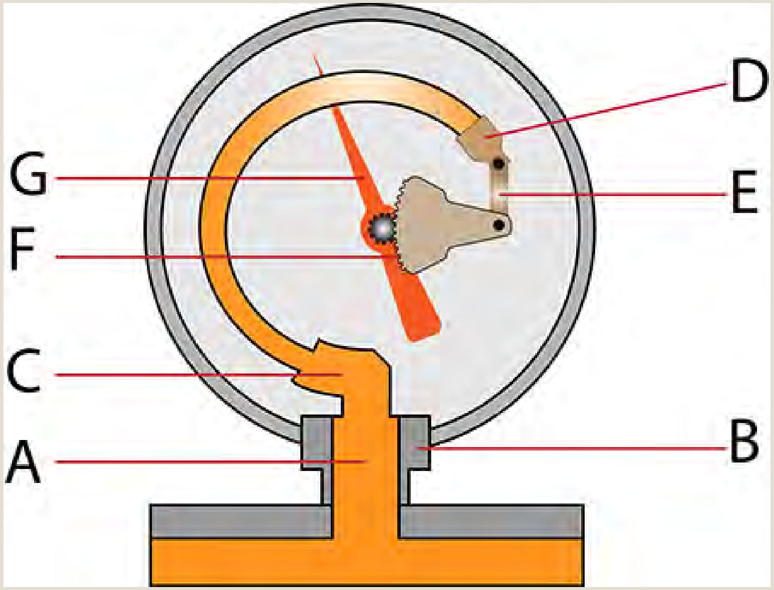


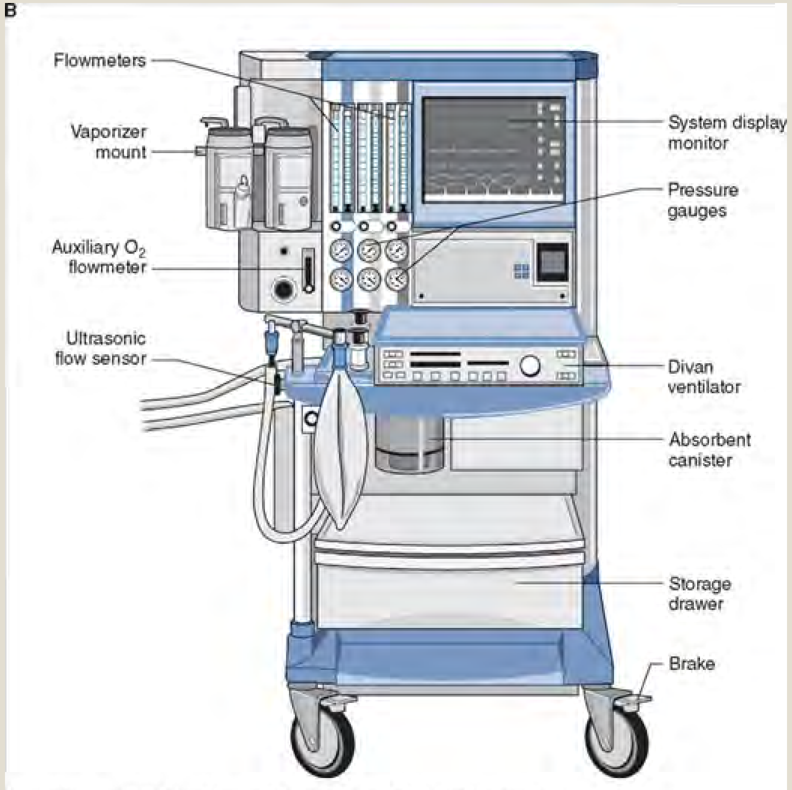




Gauges

◦ Bourbon tube

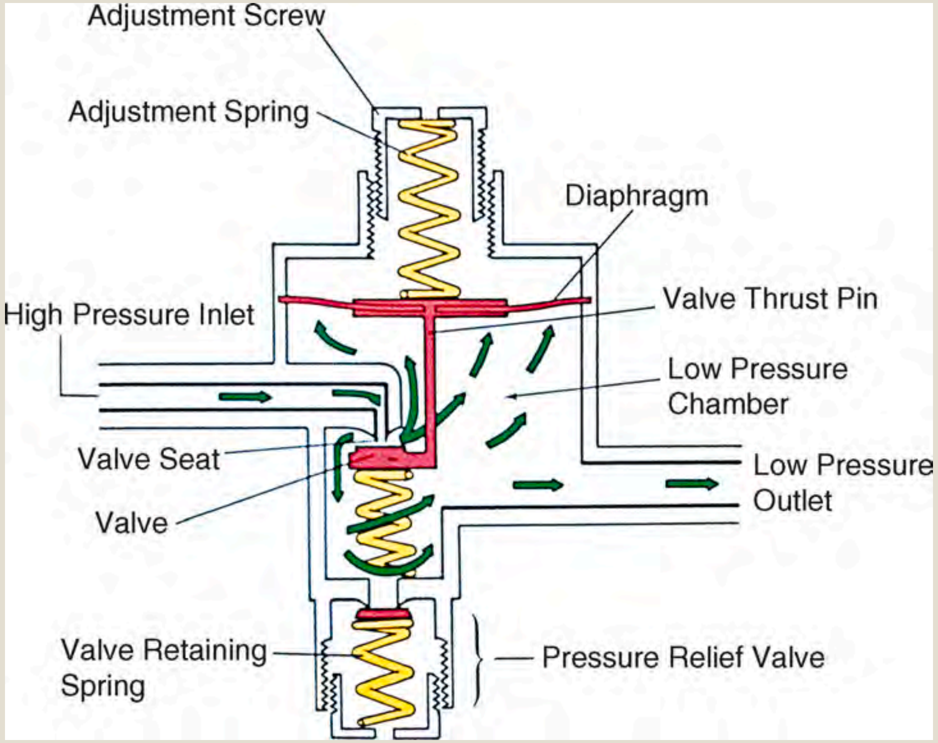


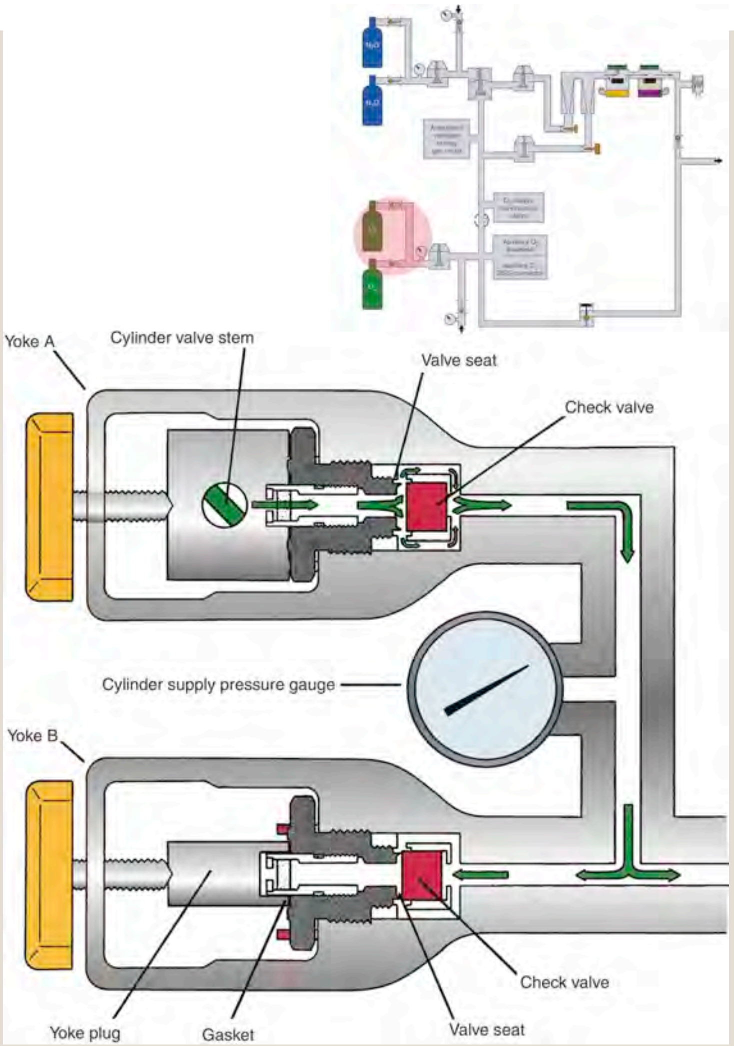


Source: Butterworth JF, Mackey DC, Wasnick JD: *Morgan & Mikhail's Clinical Anesthesiology*, 5th Edition: www.accessmedicine.com

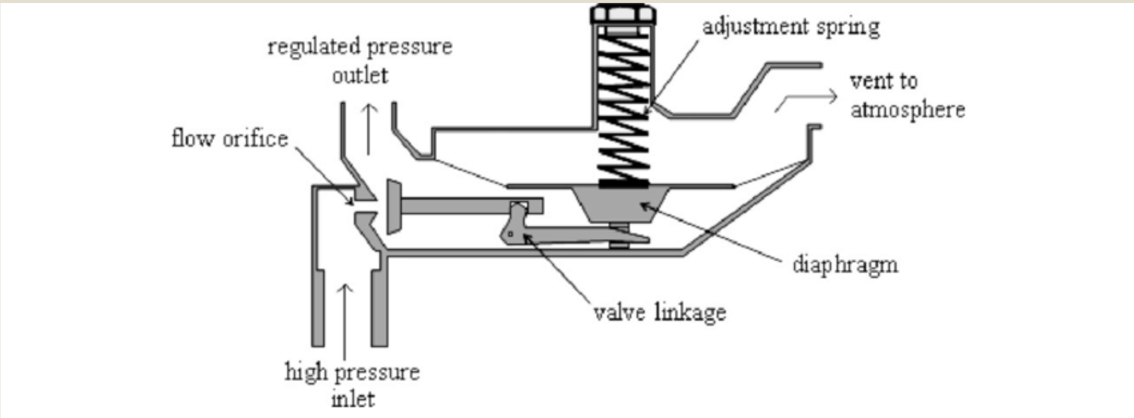
Cylinder supply

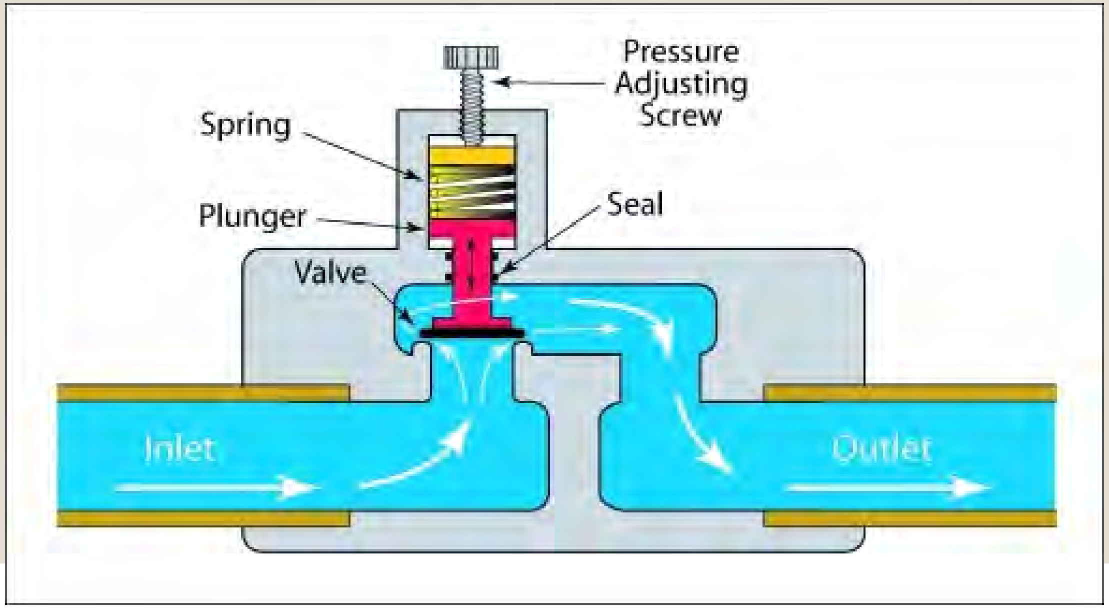
- Hanger yoke





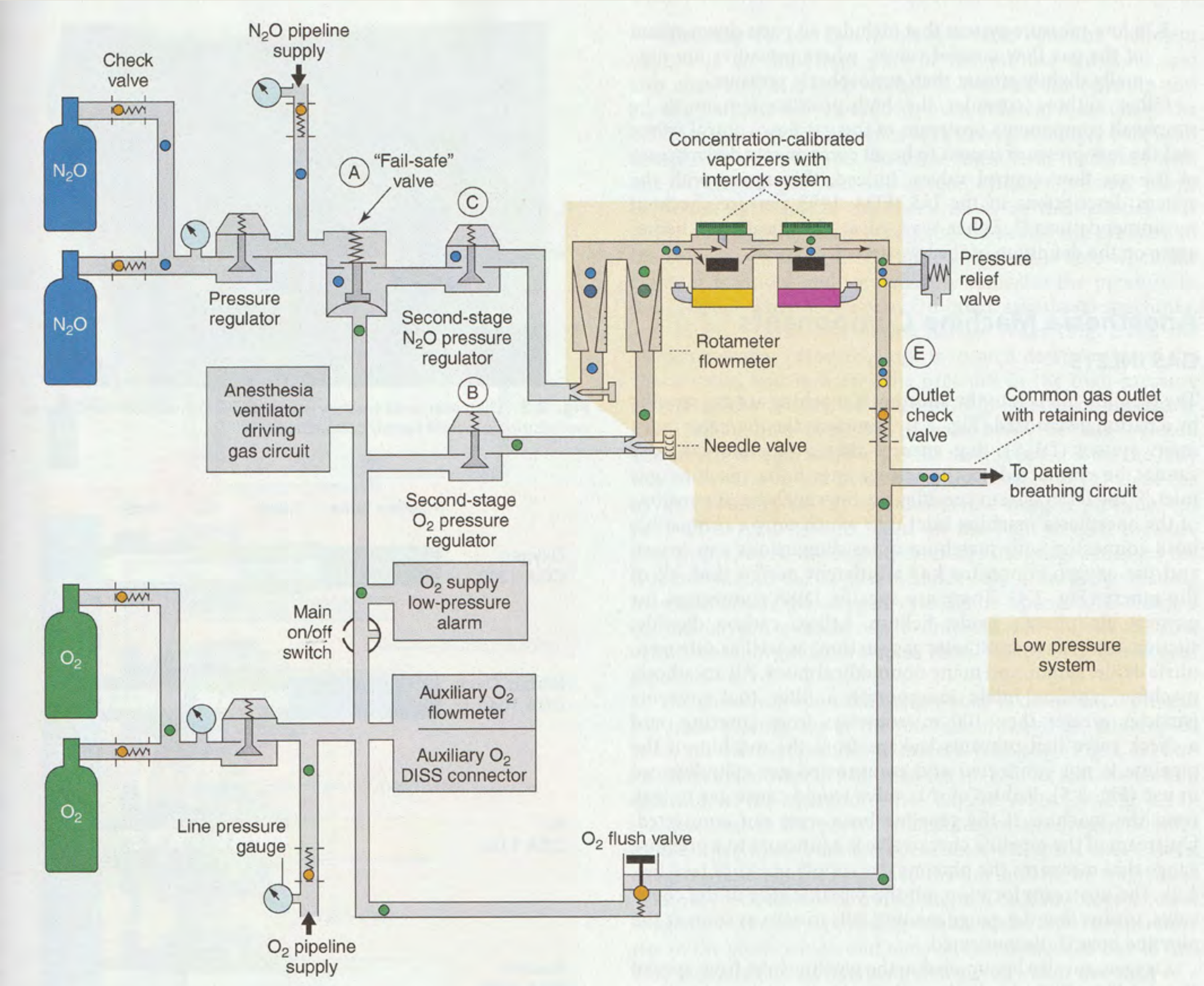
Pressure regulators





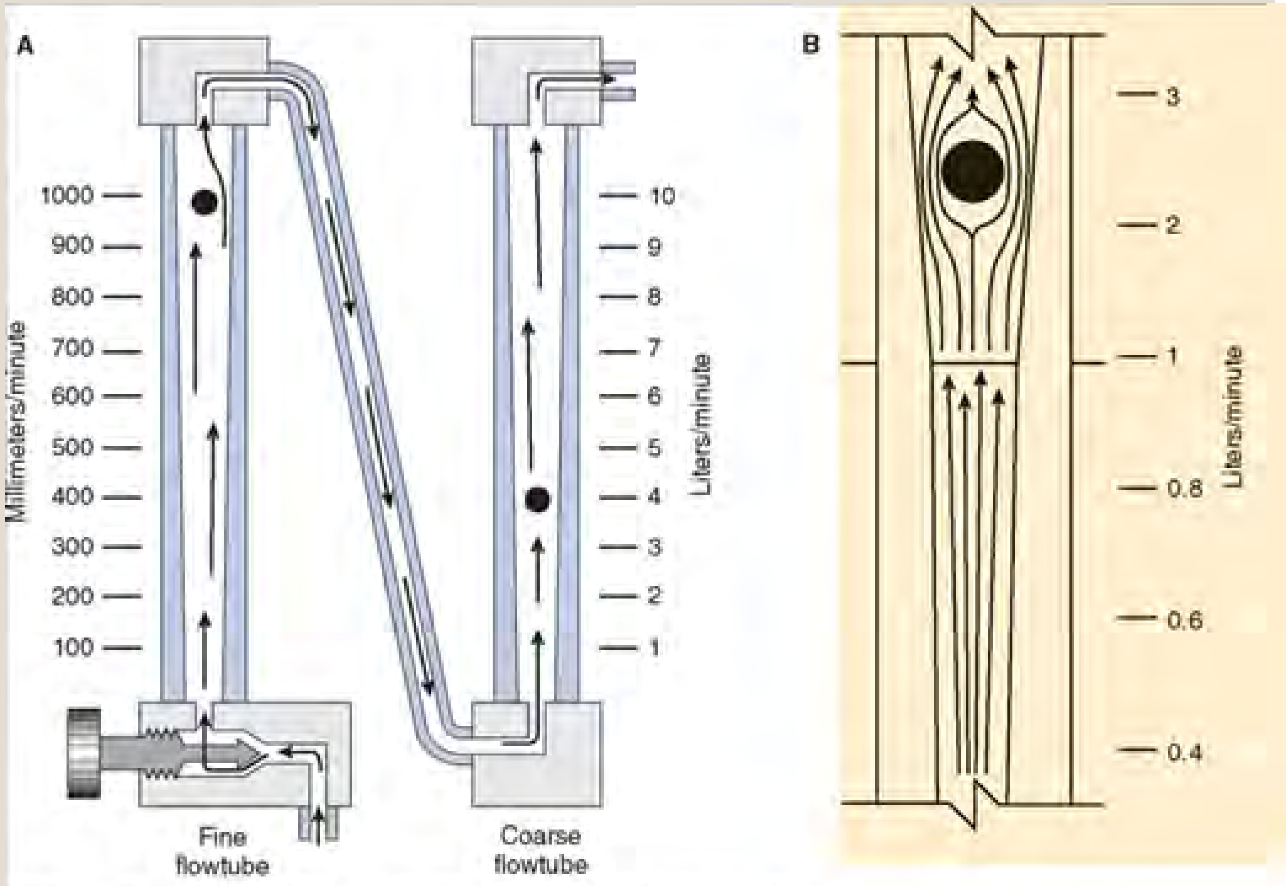
Intermediate

- High Pressure
  - 55-2200 psi
- Intermediate Pressure
  - 16-55 psi
- Low Pressure
  - Slightly greater than atmospheric psi



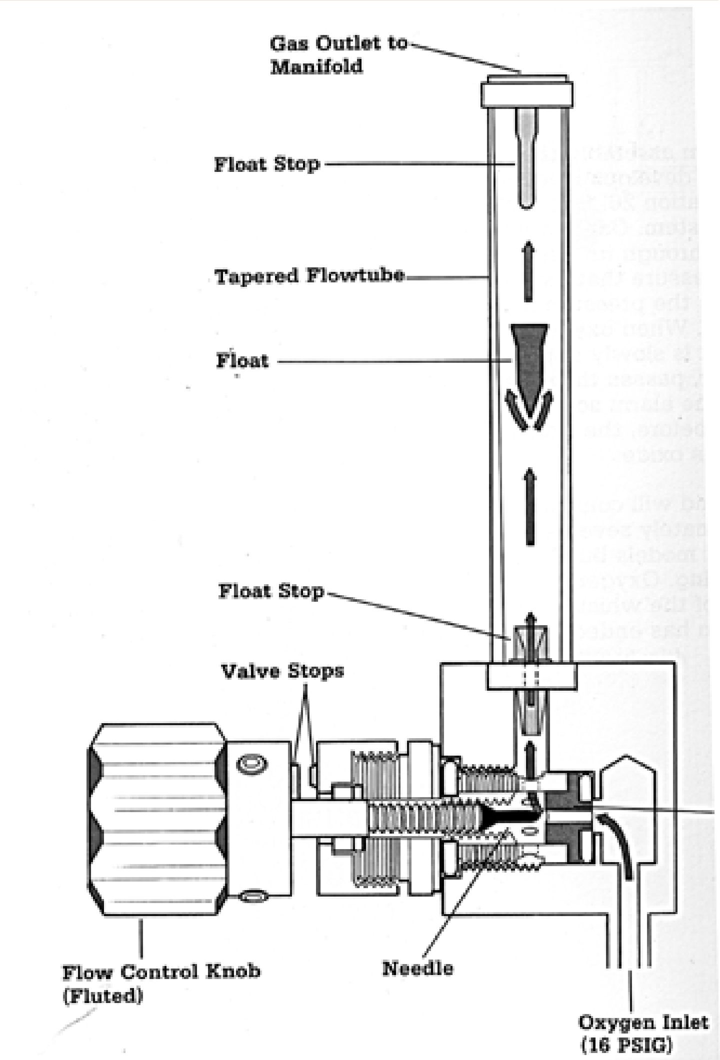
Mechanical flowmeters

- Calibrated for a single gas

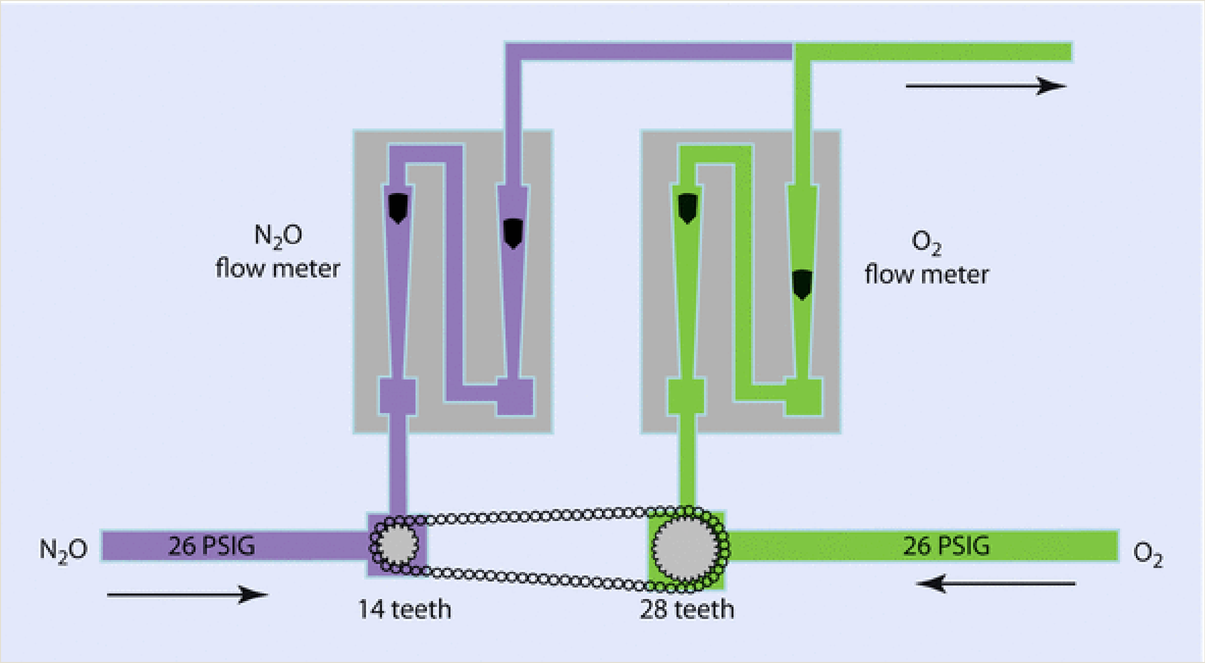


Source: Butterworth JF, Mackey DC, Wasnick JD: *Morgan & Mikhail's Clinical Anesthesiology*, 5th Edition: www.accessmedicine.com

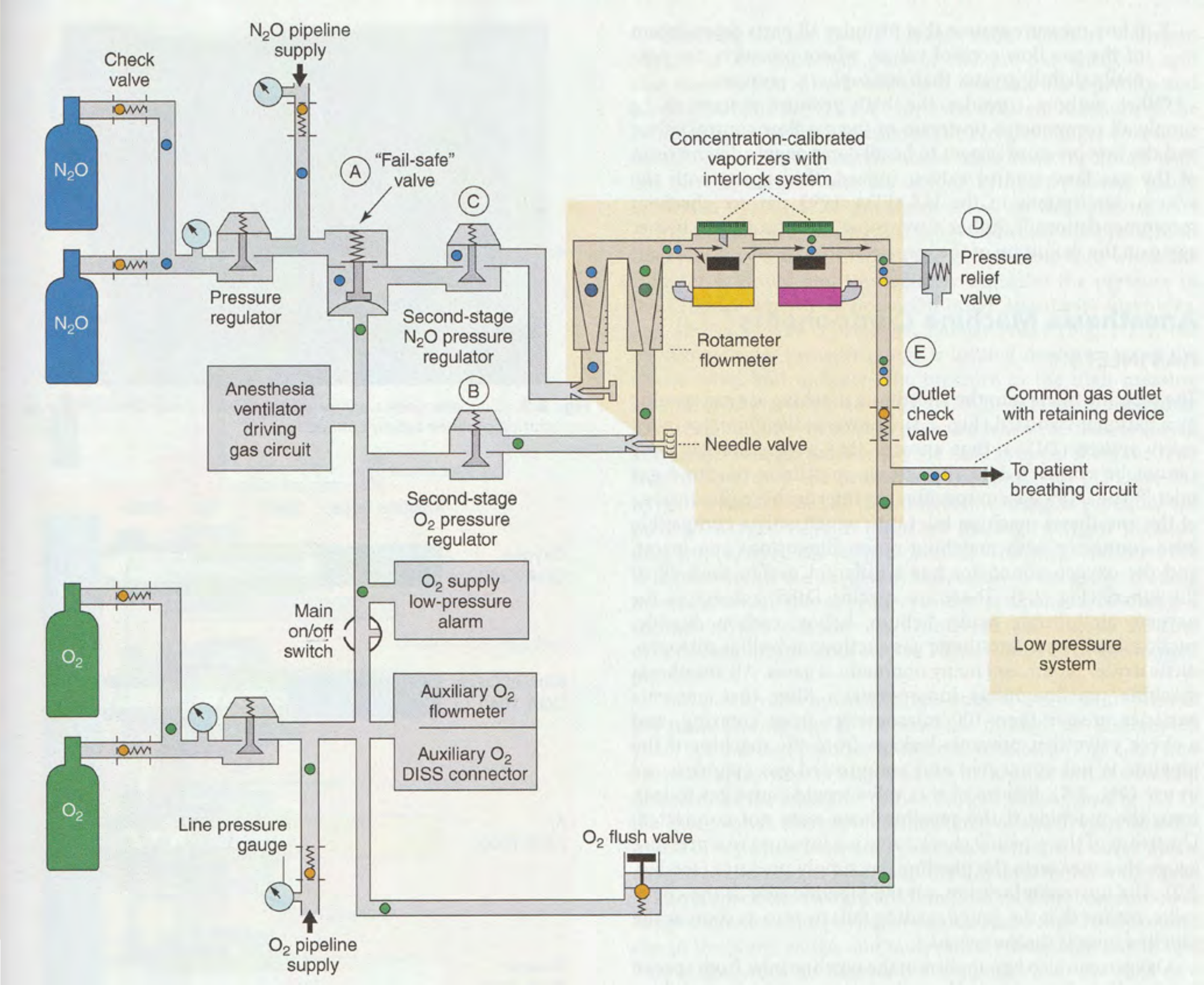
Mechanical flow control valves



Oxygen ratio proportioning system

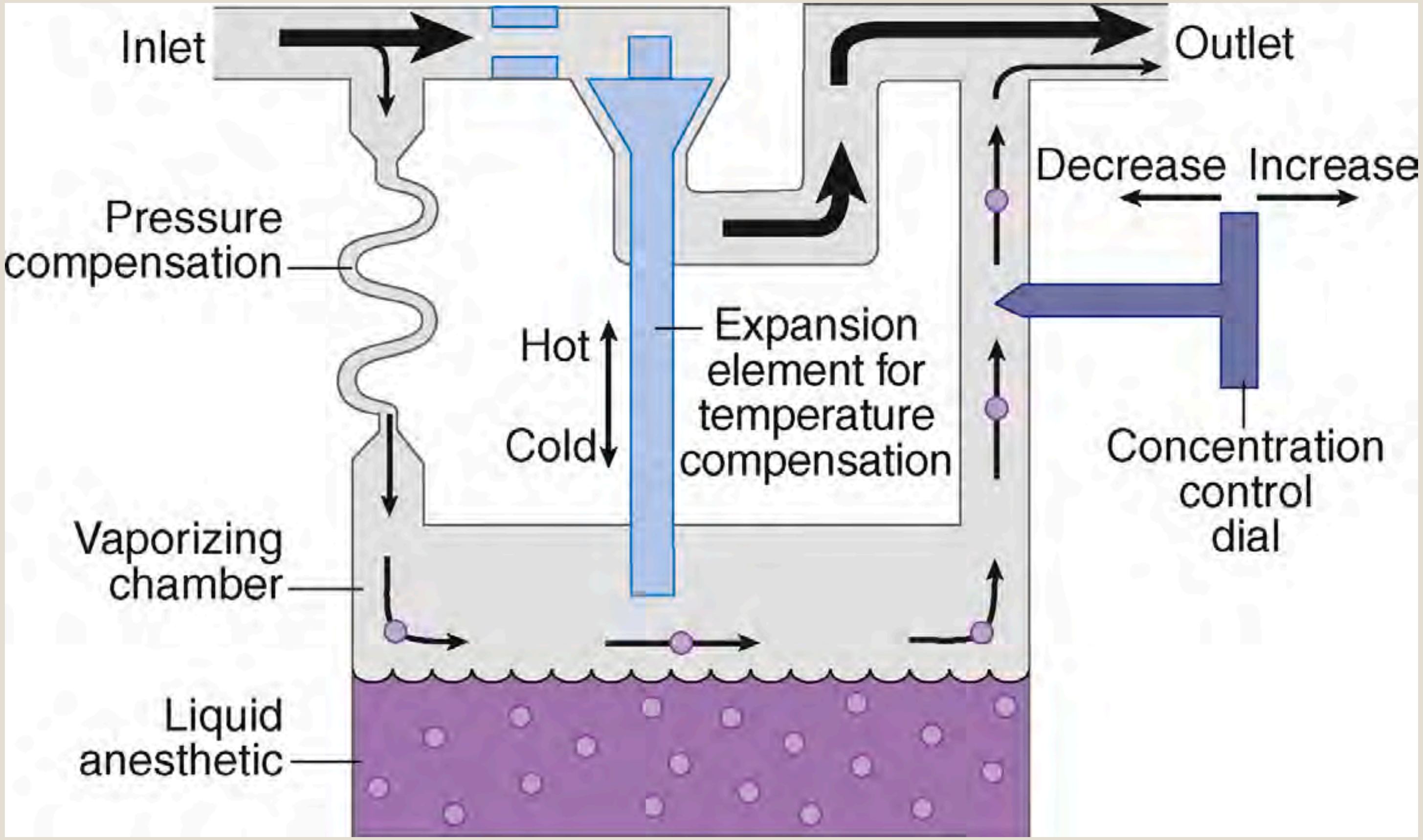


Alarms

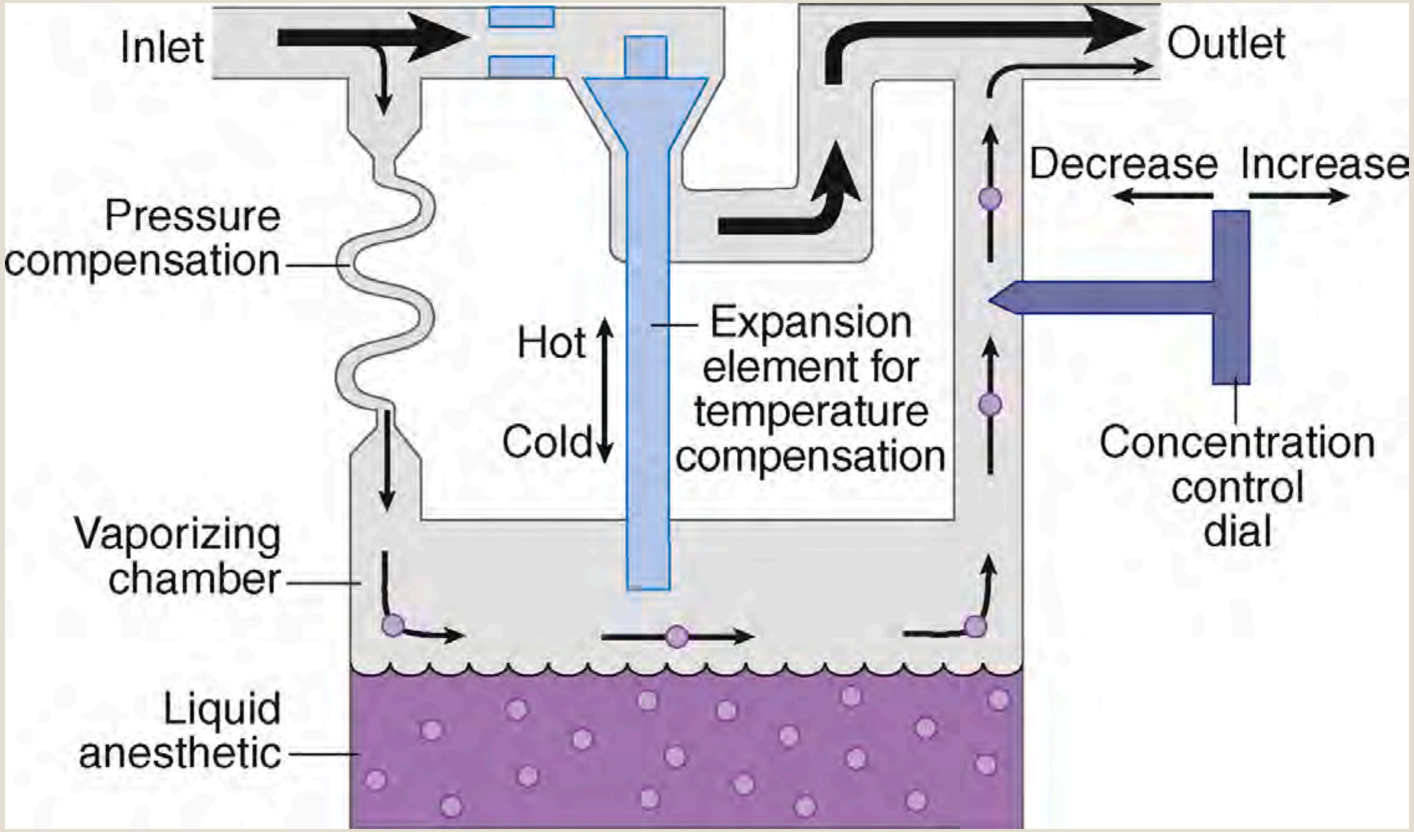

N_2O pipeline supply
Check valve
N_2O
N_2O
"Fail-safe" valve
A
C
B
D
E
Pressure regulator
Second-stage N_2O pressure regulator
Concentration-calibrated vaporizers with interlock system
Pressure relief valve
Rotameter flowmeter
Anesthesia ventilator driving gas circuit
Outlet check valve
Common gas outlet with retaining device
Needle valve
To patient breathing circuit
Second-stage O_2 pressure regulator
O_2 supply low-pressure alarm
Main on/off switch
Low pressure system
Auxiliary O_2 flowmeter
Auxiliary O_2 DISS connector
O_2
O_2
Line pressure gauge
O_2 flush valve
O_2 pipeline supply

Vaporizers

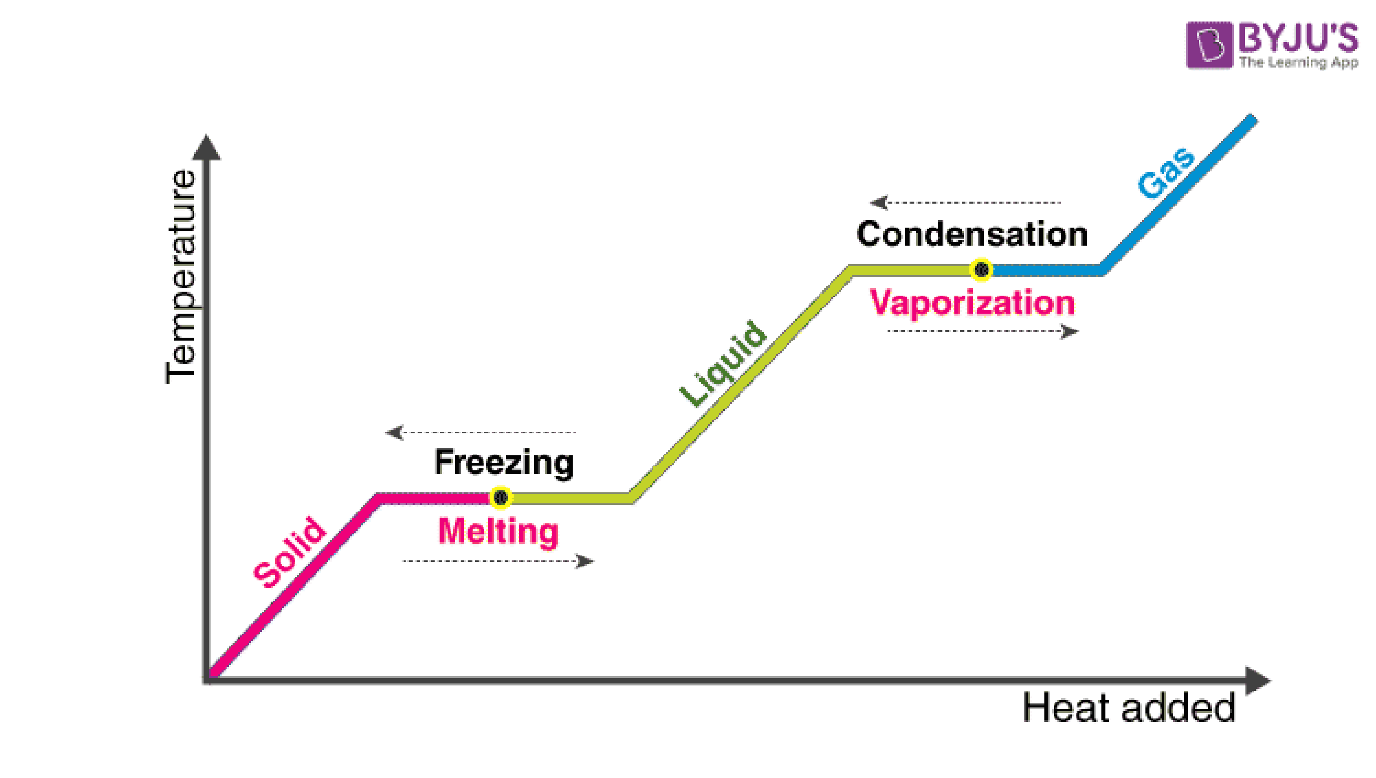
◦ Variable bypass



Vaporizers

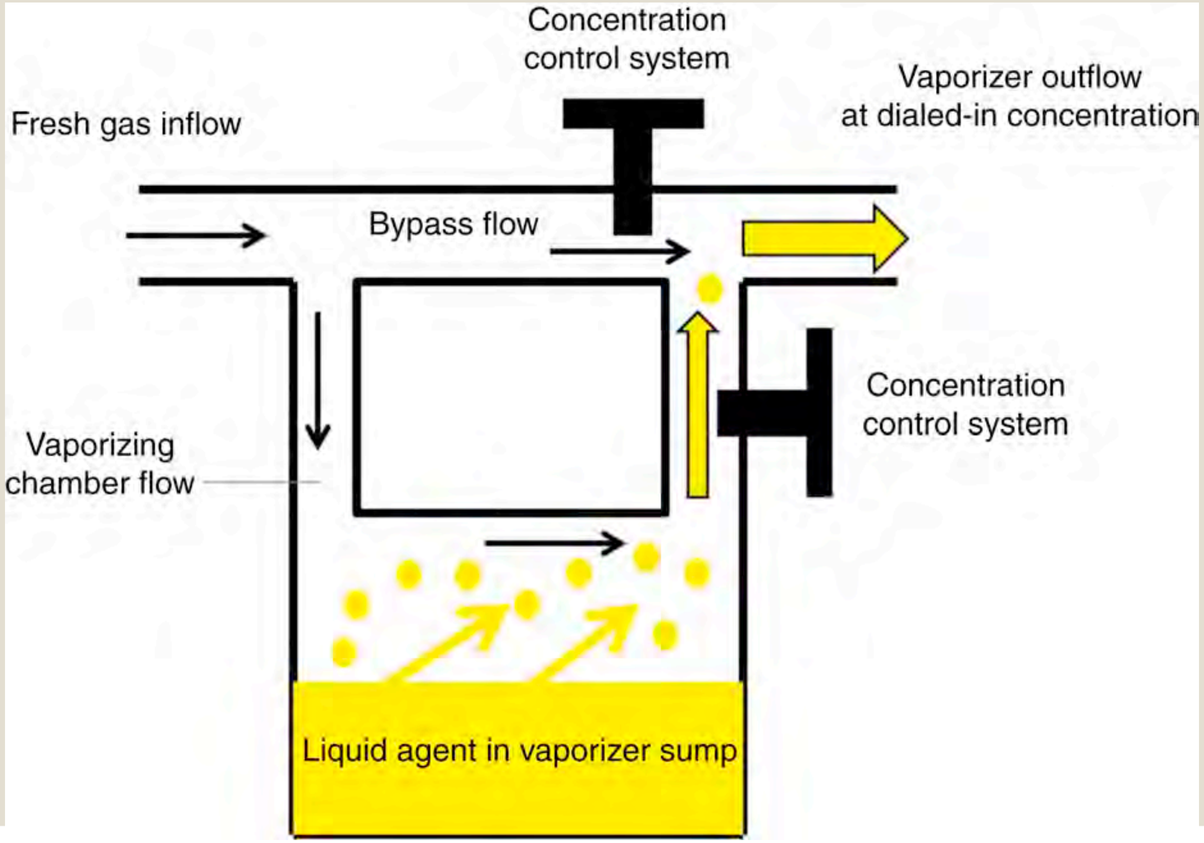

Inlet
Outlet
Decrease
Increase
Pressure compensation
Hot
Cold
Expansion element for temperature compensation
Concentration control dial
Vaporizing chamber
Liquid anesthetic

Latent heat of vaporization

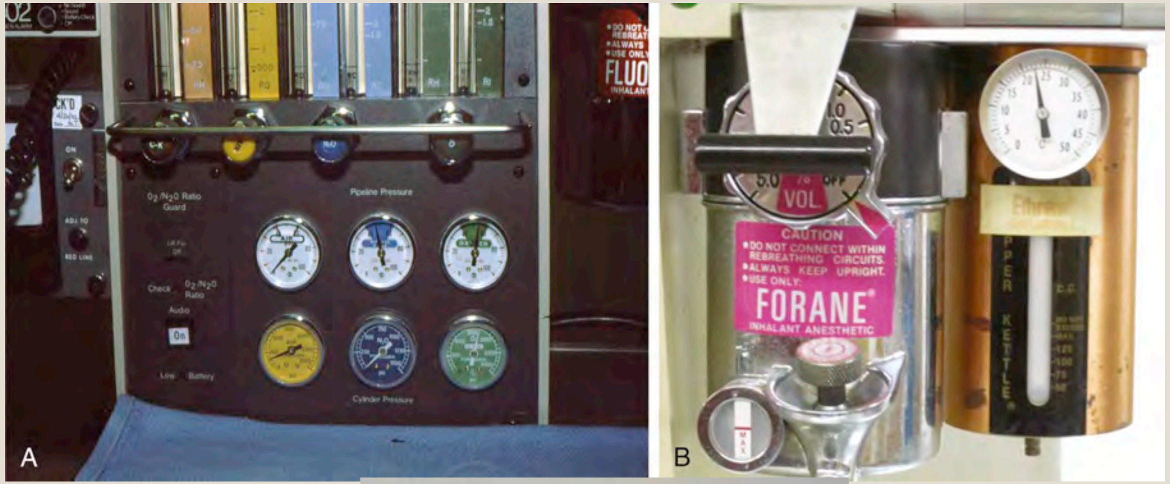


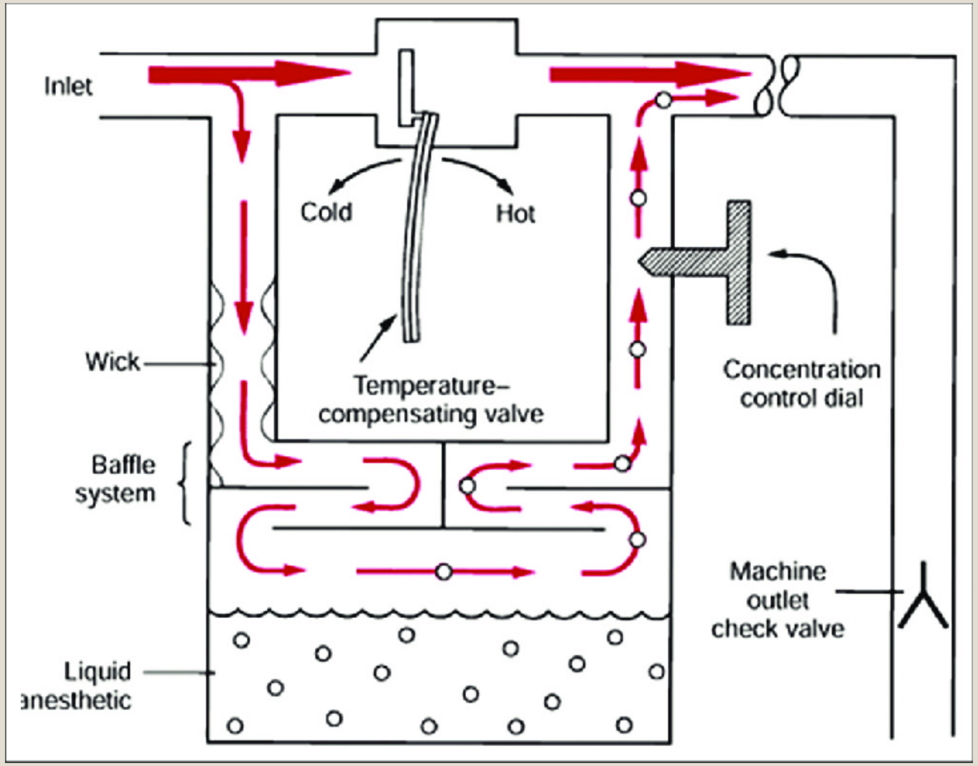
Regulating output

- Concentration calibrated variable bypass



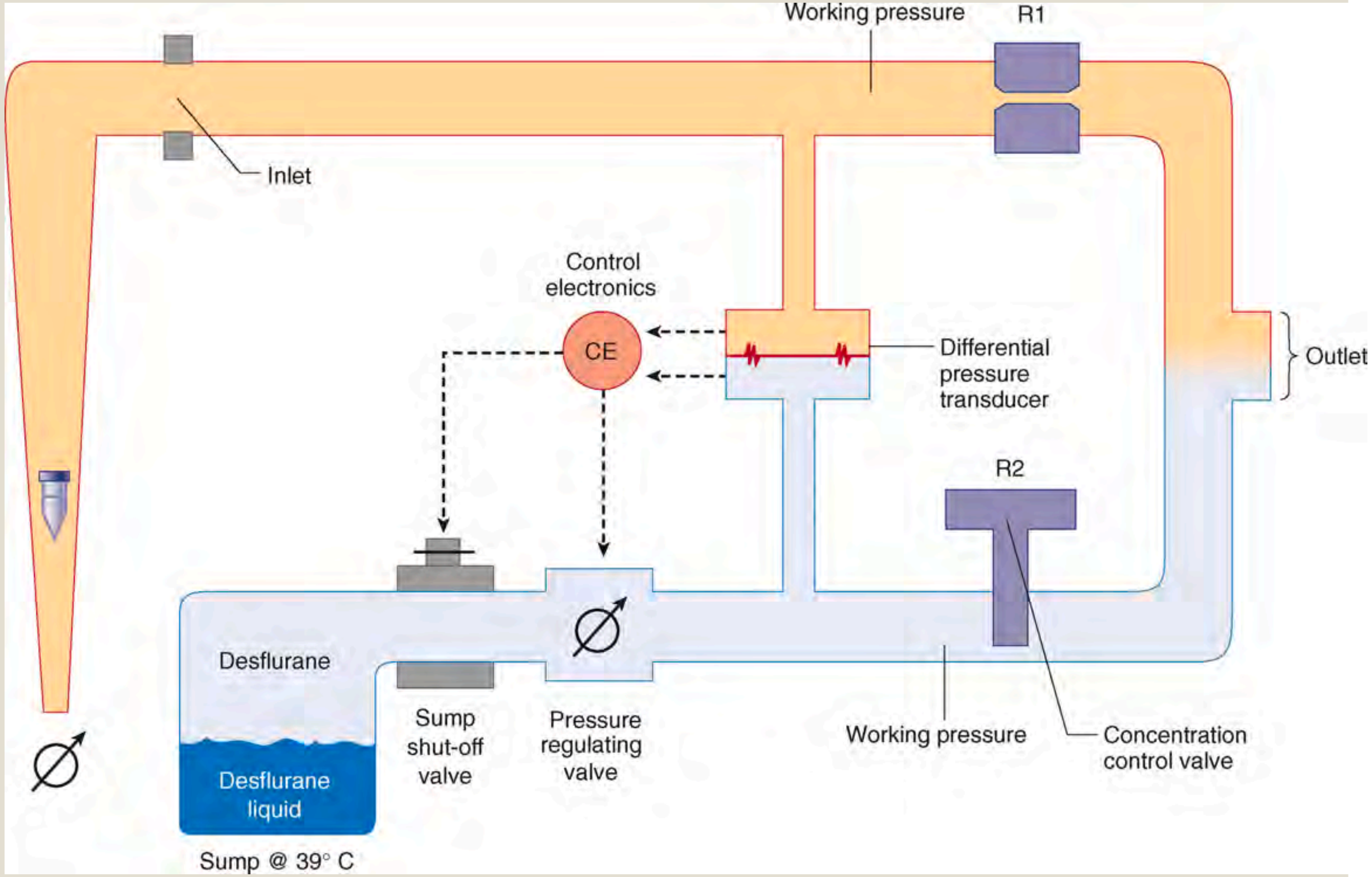
Temperature compensation



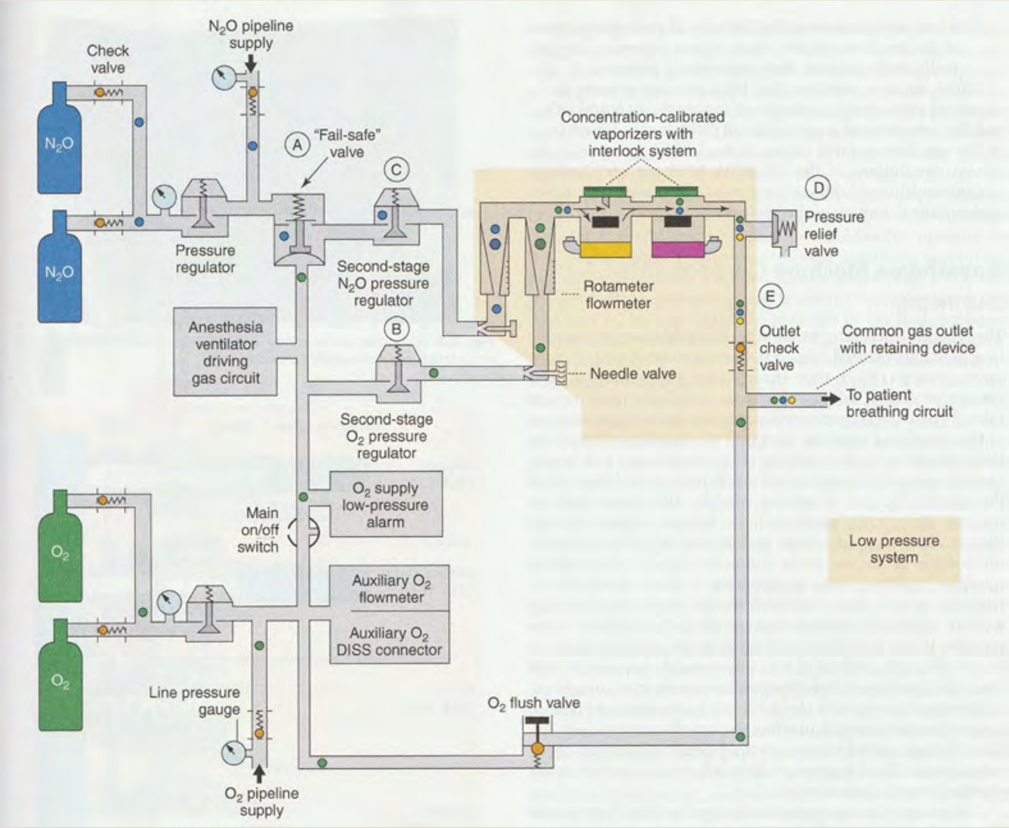


Vaporizer classification and design

- Tec 6
  - Control points
    - Concentration dial
    - Differential pressure transducer



Freestanding vaporizer



Common gas outlet

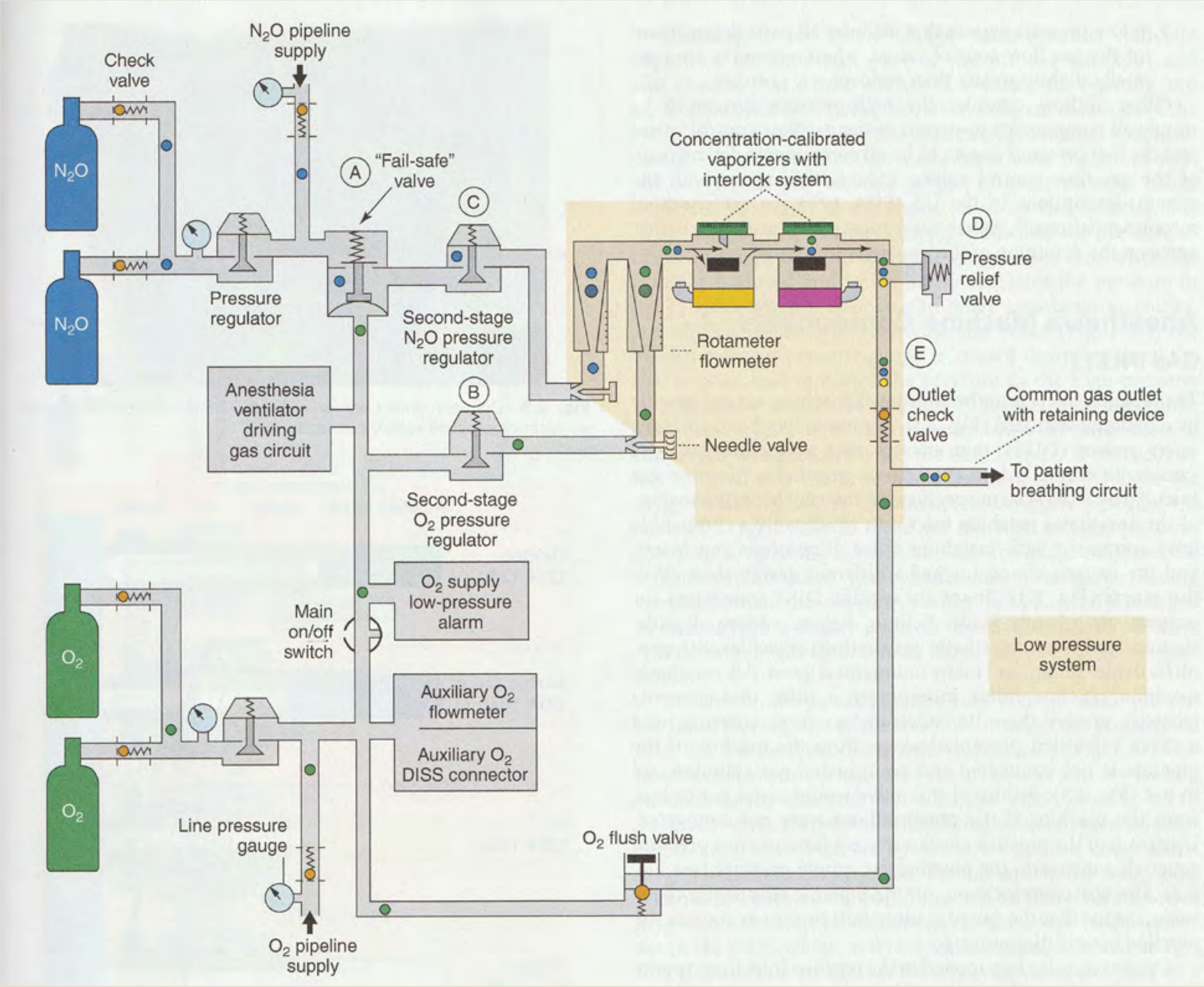
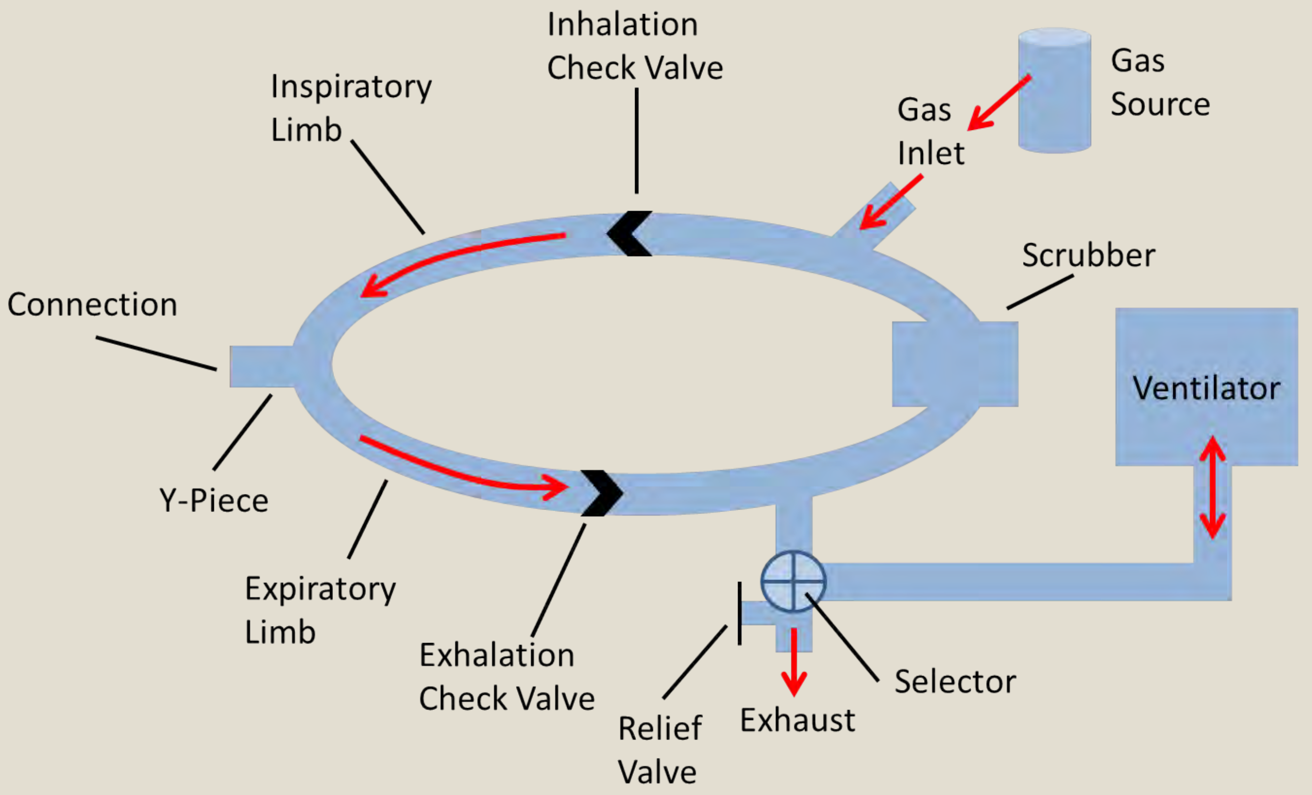


Fig 2 Connector of common gas outlet of an ana

The breathing circuit

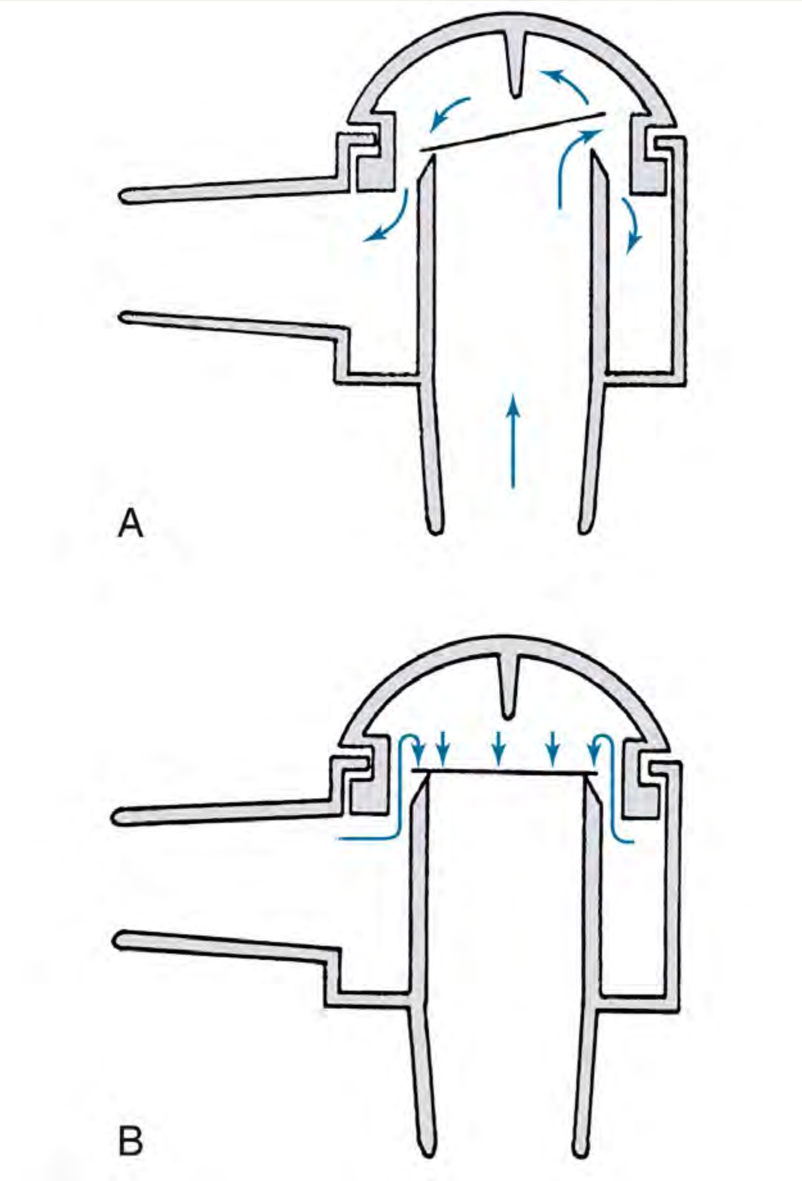
- Low resistance
- Minimal re-breathing
- Removal of carbon dioxide
- Gas composition changes
- Warmed humidification
- Disposal of waste gases

Chemical absorption of carbon dioxide

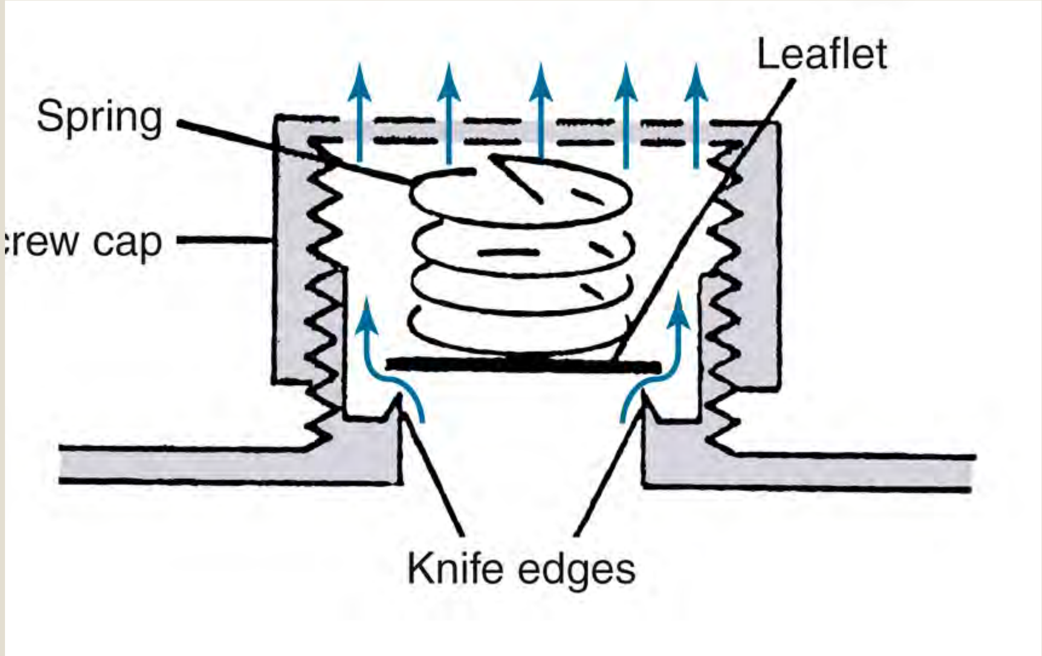


Unidirectional valves

- Inspiratory valve
- Expiratory valve



Pop-off valve



Carbon dioxide absorption

$$CO_2 + H_2O \rightarrow H_2CO_3$$

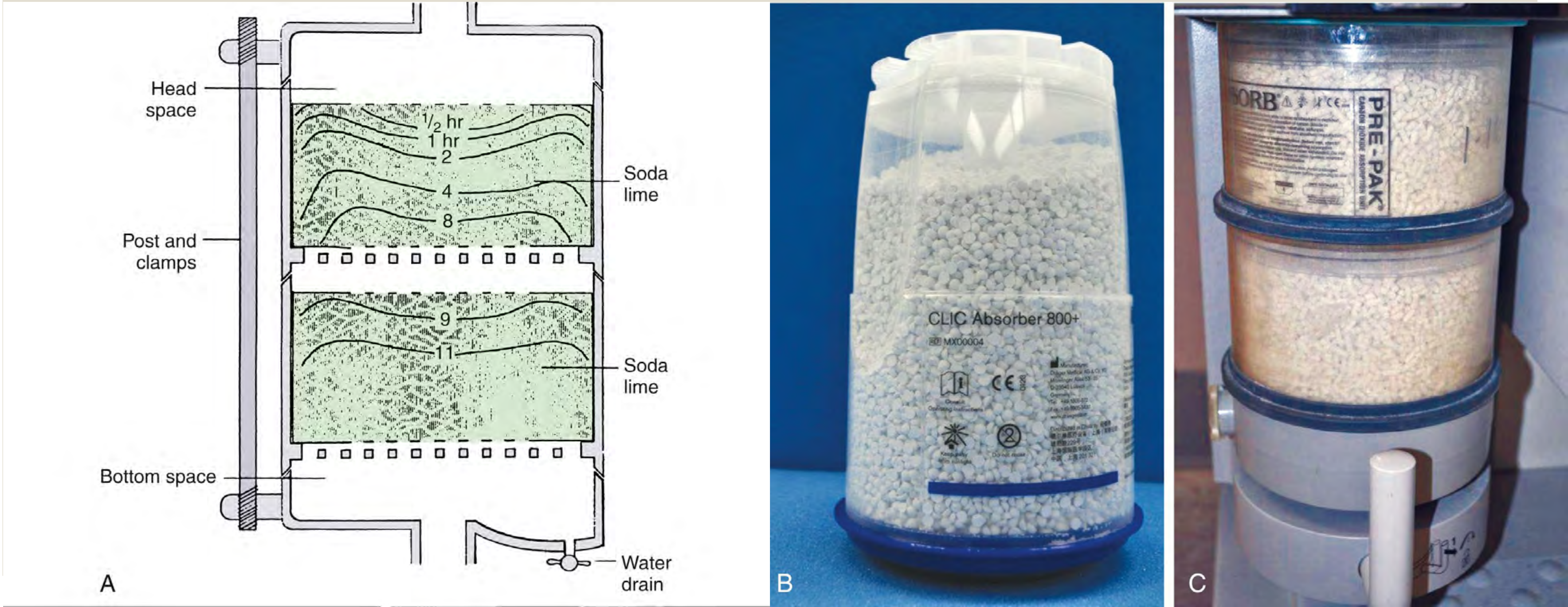
$$H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$$

$$H_2CO_3 + 2KOH \rightarrow K_2CO_3 + 2H_2O$$

$$Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$$

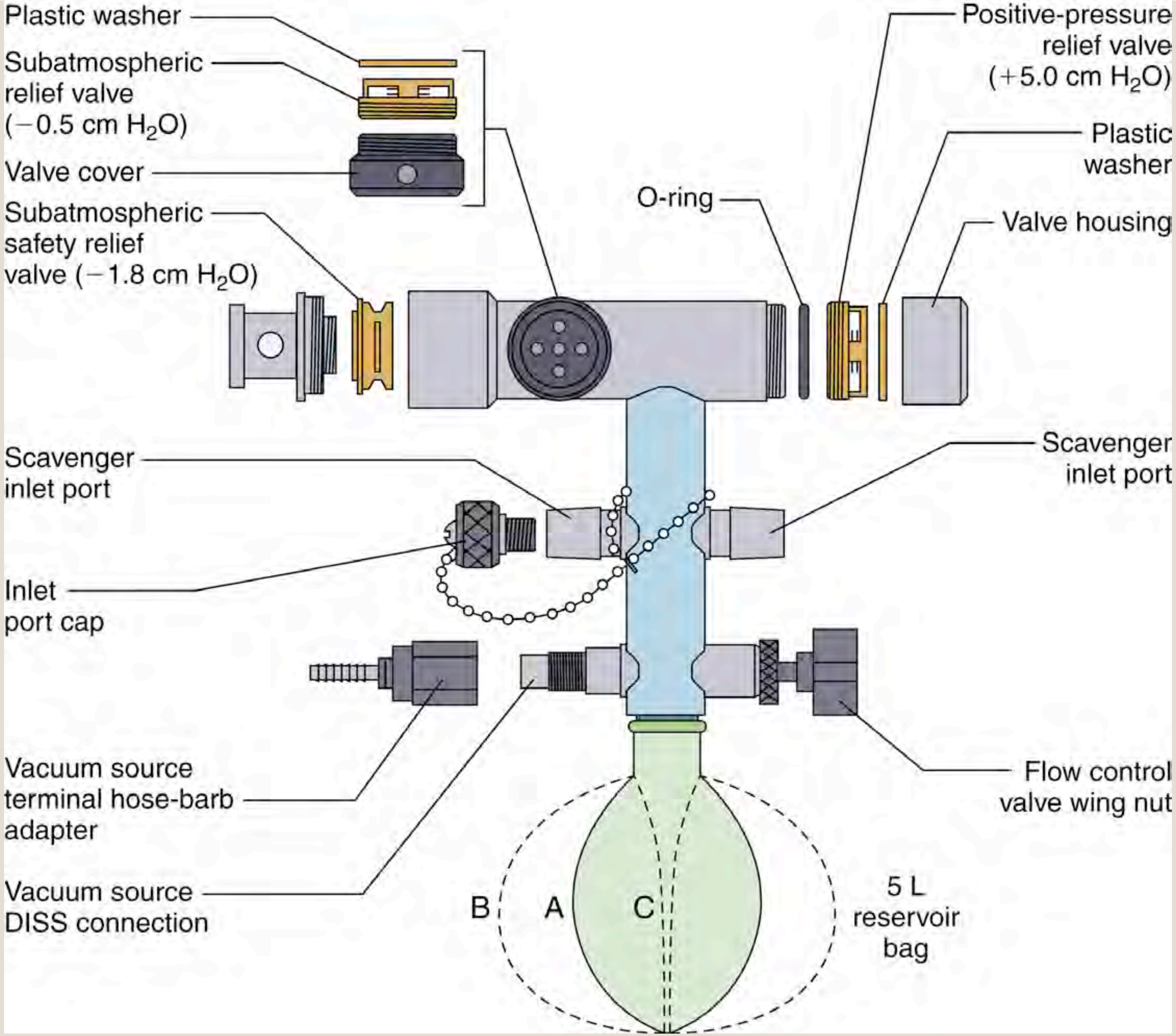
(or K_2CO_3) (or 2KOH)

Carbon dioxide absorbent mesh size and channeling

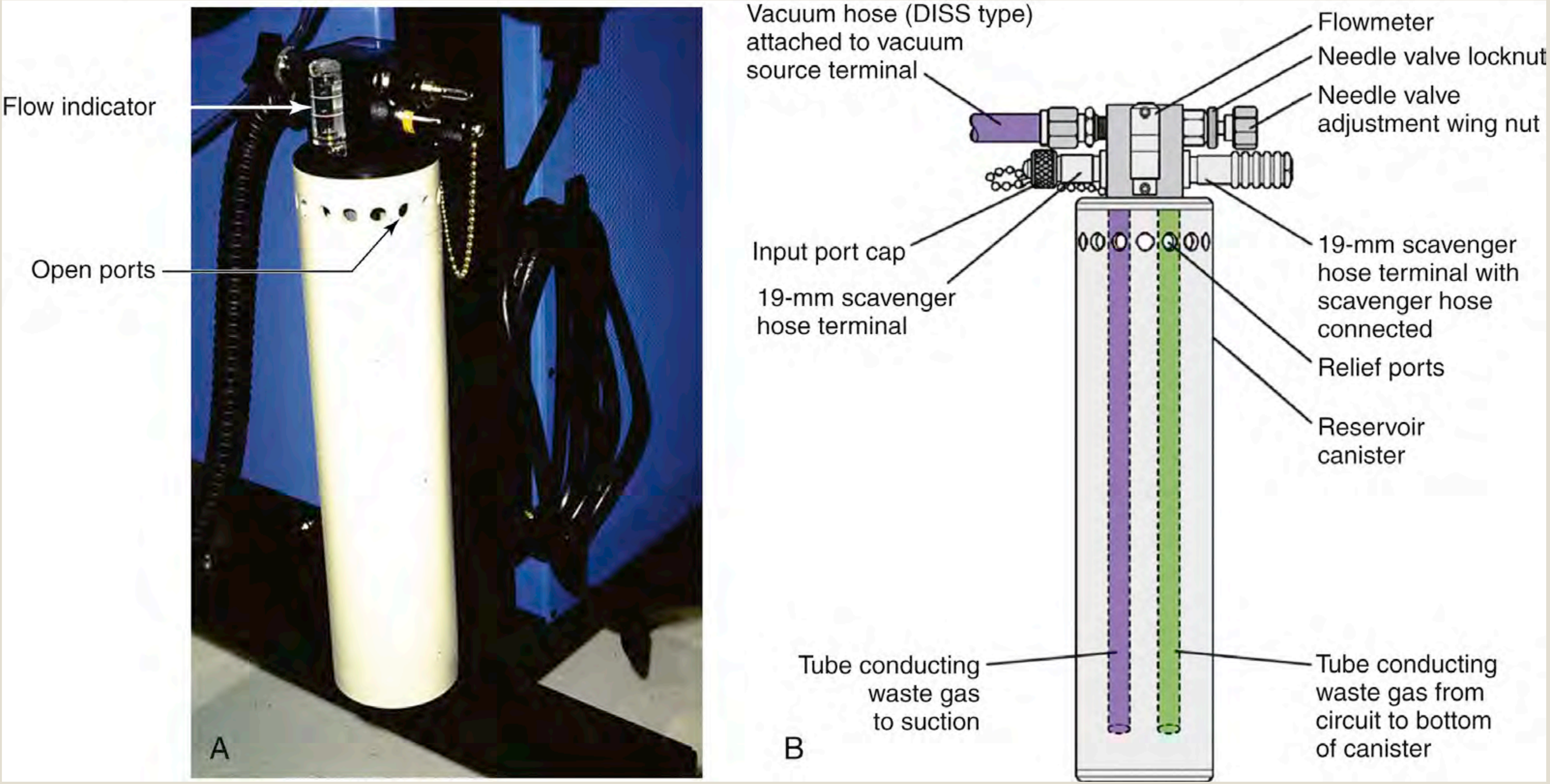


Scavenging Interface

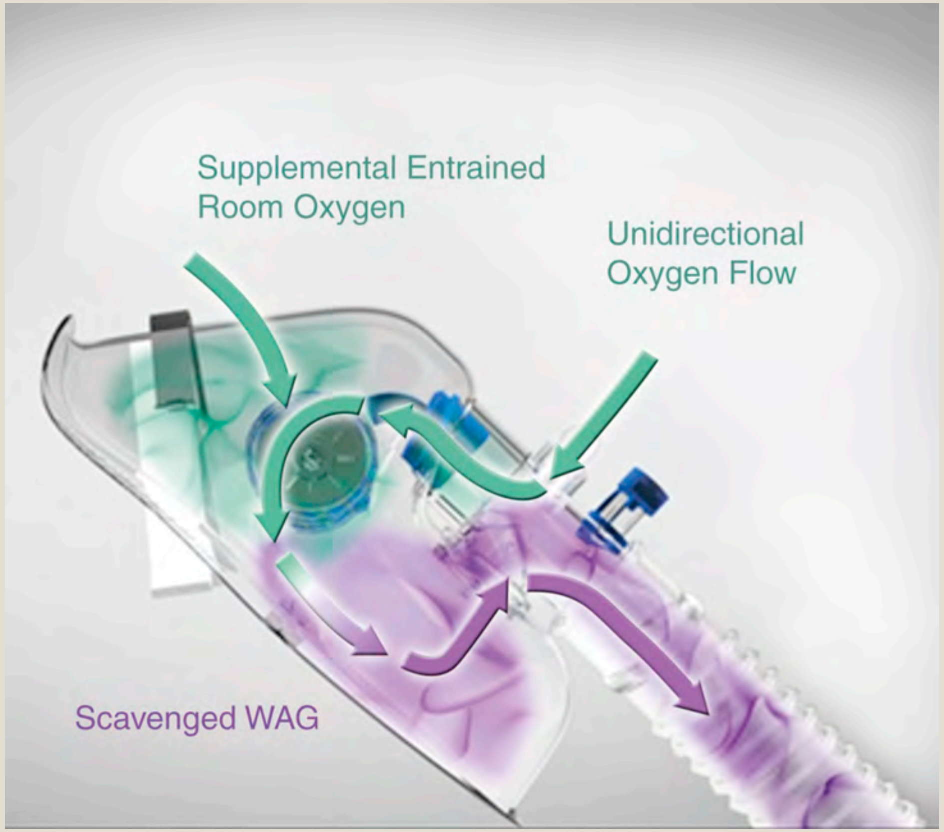
- Open
- Closed

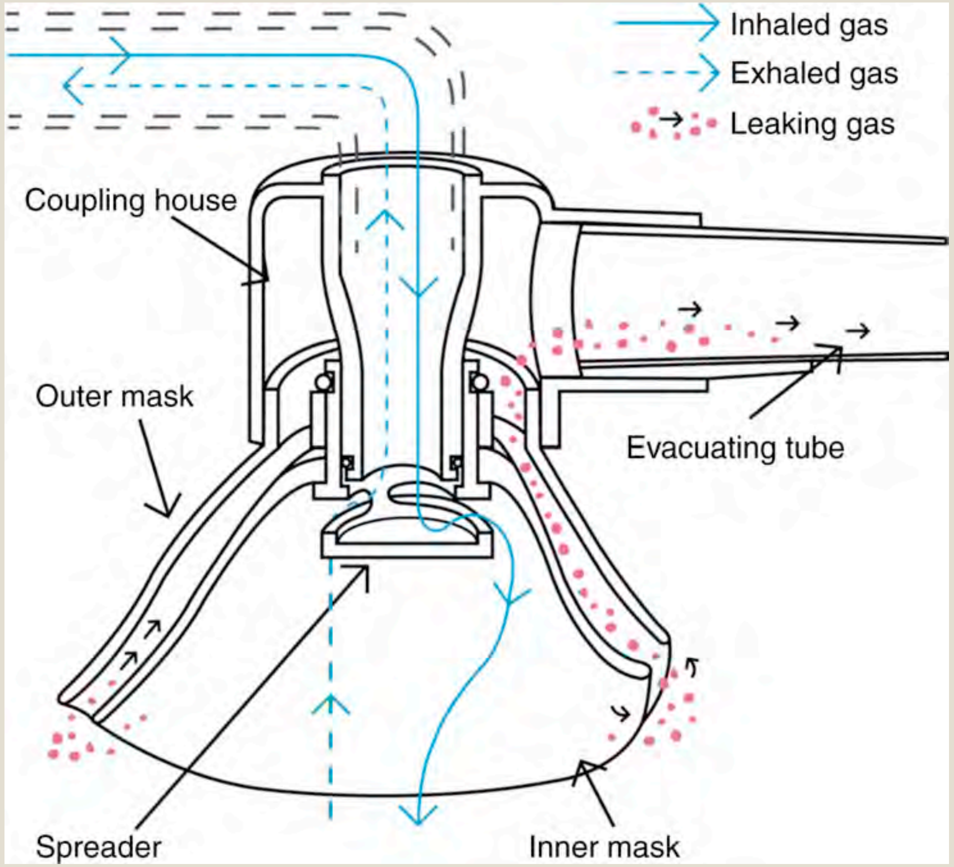


Open Reservoir scavenging system

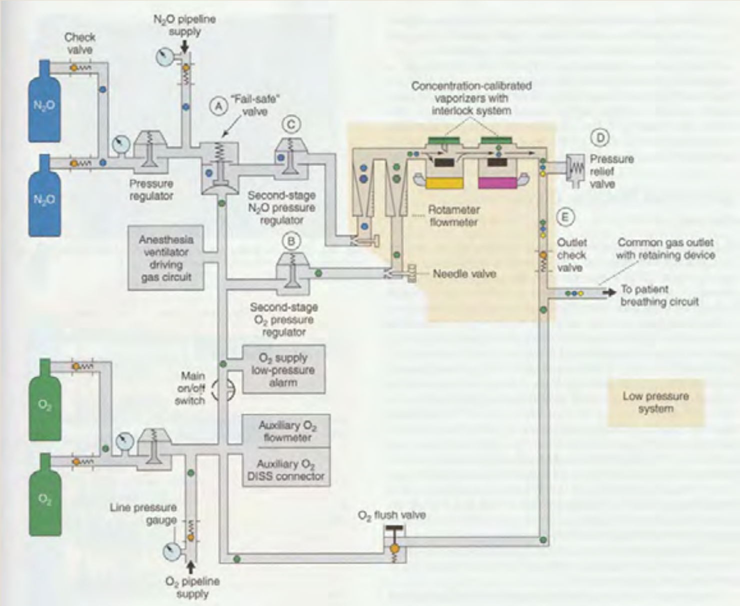


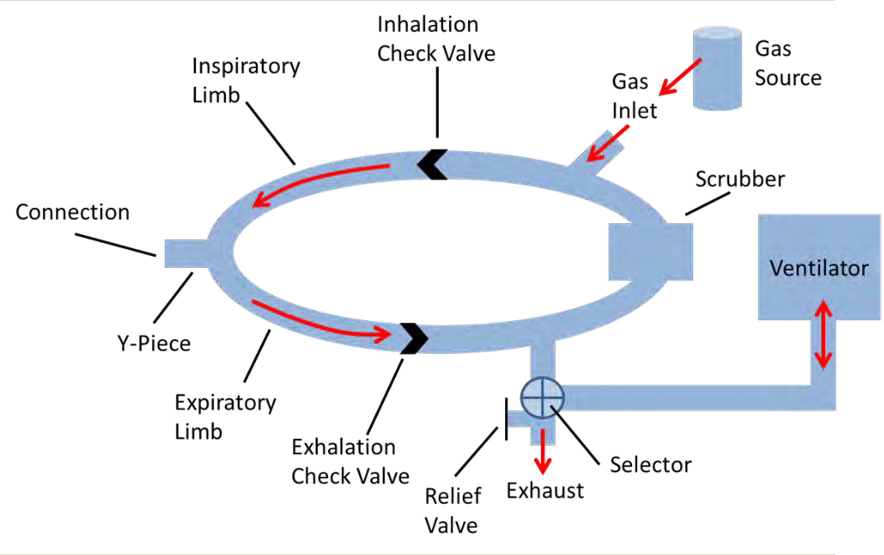
Post anesthesia care unit





Anesthesia Machine





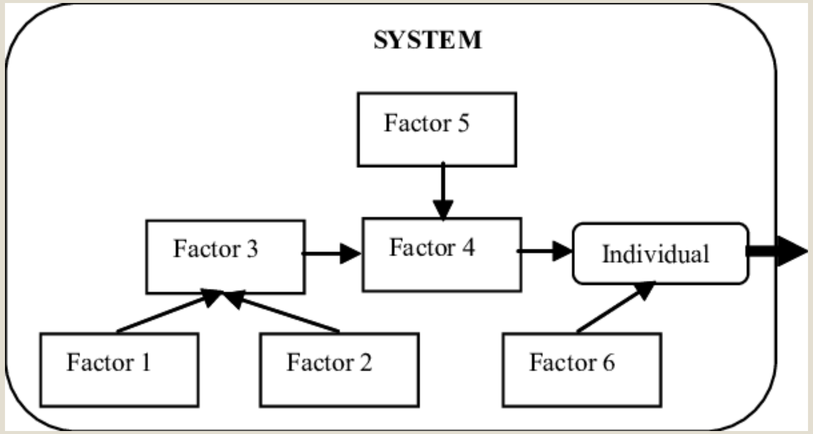
Risk management

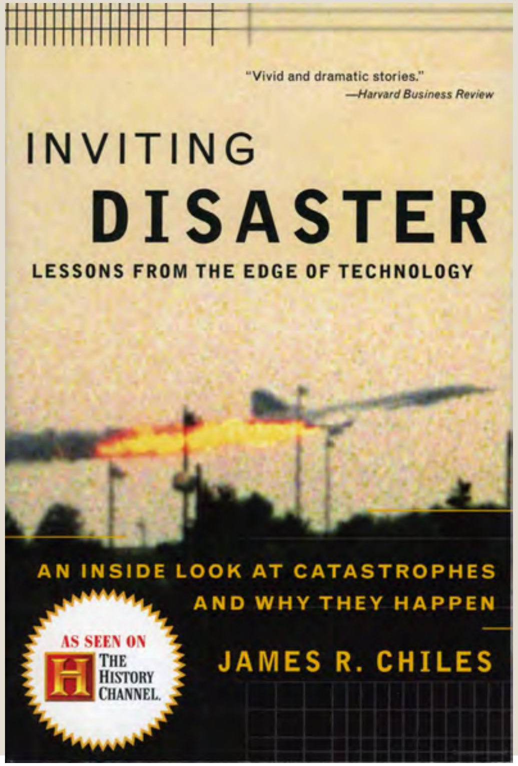
- Define potential problems
- Estimate the likelihood of occurrence
- Weight the relative benefits of expending available resources
- Apply solutions
- Monitor

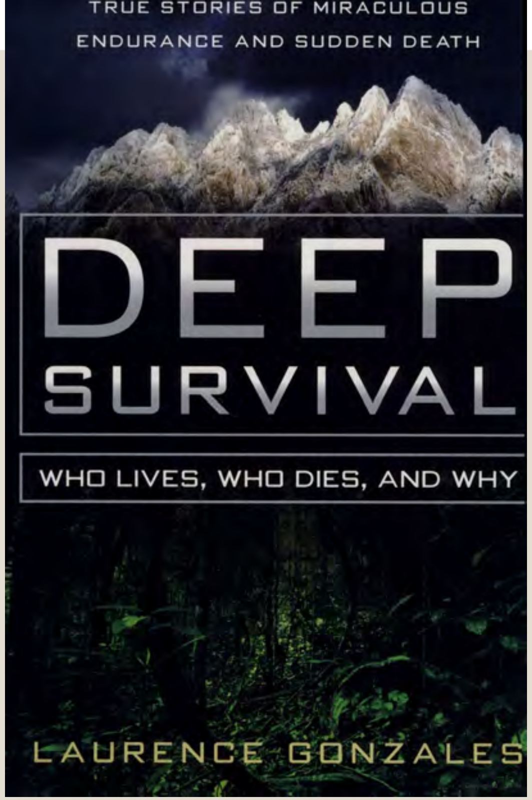
Incidence

- ASA Closed claims database
  - 115 in 6000 for gas delivery systems
  - 0.23-0.4%

Chain of events







Aggravating factors

- Failure to check equipment
- Lack of familiarity with equipment
- Inexperience
- Haste
- Inattention
- Distraction
- Fatigue

Response

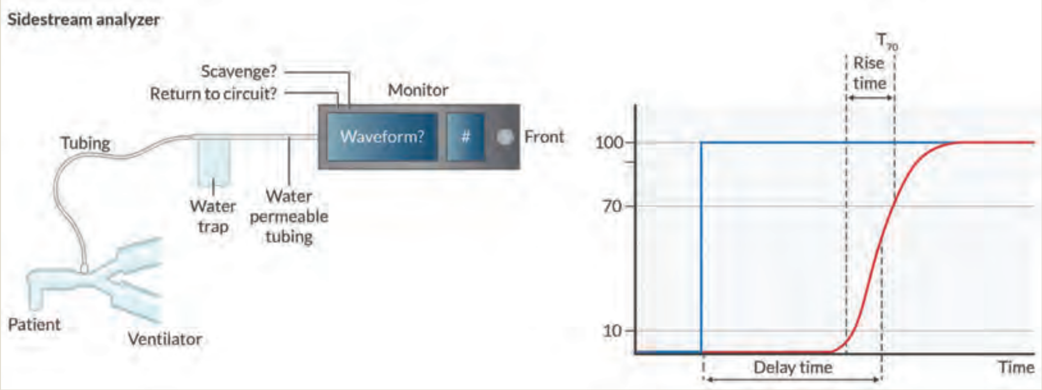

Ped
2016-09-22 11:44:01 AM
ECG
X1
Surgery
ECG
109
SpO₂
SpO2
%
100
90
100
PR
78
PI 0.96
Source SpO2
Capnograph
60
Side
CO2
mmHg
60
1
Et
31
awRR
8
Fi
0
NIBP List
77 / 40 (53)
80 / 48 (59)
81 / 48 (57)
104 / 53 (70)
85 / 49 (64)
PR
46
49
45
48
41
Time
11:41 AM
11:38 AM
11:37 AM
11:33 AM
11:29 AM
NIBP
mmHg
11:41 AM
3 min
77/40
Cuff
93
Auto Measuring...
T1 90.1
Current Configuration :MEDIUM
Alarm Setup
Main Menu

Capnography

There are two primary methods

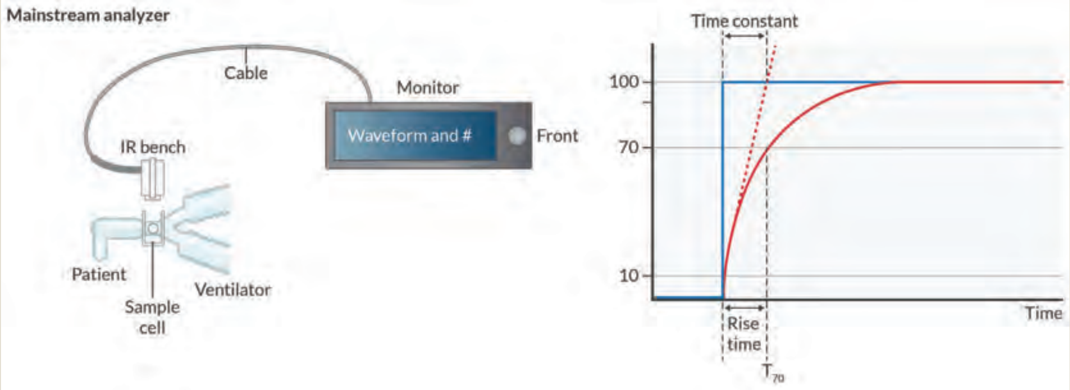
A sidestream (or diverting) system aspirates a sample from the airway and transports it to an external monitor

- Located external to the airway, and it requires a sampling line to continuously aspirate gas from the airway



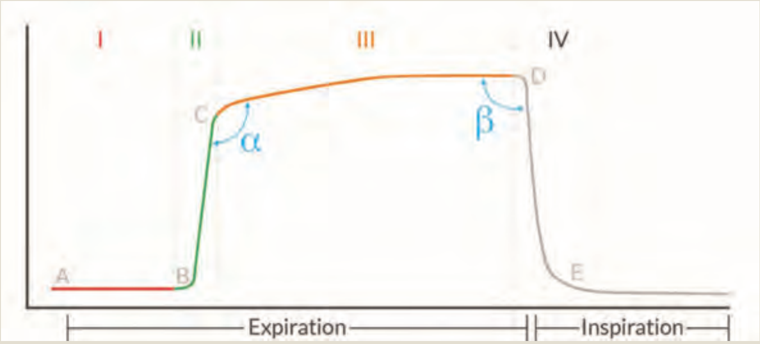
By contrast, a mainstream (or non-diverting) device is placed directly inside the airway

- An adapter is placed between the patient's airway and the breathing circuit which adds apparatus dead space



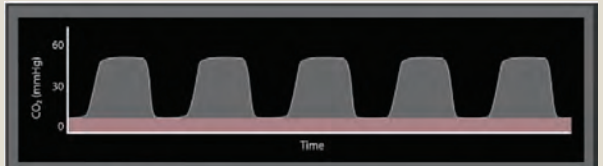
Pictures from Apex

Capnography Waveforms



Airflow obstruction:
- Increased alpha angle
- Causes: COPD, bronchospasm, kinked ETT

Esophageal intubation:
- Shows washout of CO_2 from the stomach
- Within several breaths the waveform approaches zero



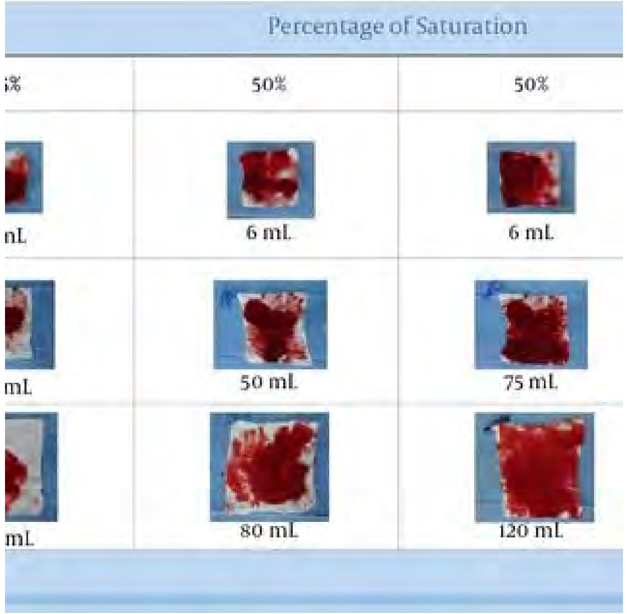
Increased $EtCO_2$ + elevated baseline:
- If baseline doesn't return to zero, then pt is rebreathing
- Causes: exhausted CO_2 absorbent, incompetent unidirectional valve, hole in inner tube of coaxial circuit

Cardiac oscillations:
- Result from heart compressing the lungs during each beat
- More common in children

Decreased $EtCO_2$:
- Causes: decreased CO_2 production, increased alveolar ventilation, increased Vd, or reduced cardiac output

Incompetent unidirectional valve:
- Increased beta angle suggests rebreathing
- Baseline elevation may or may not occur

Pictures from Apex



Measurements of EBL

The most common method of assessing blood loss relies on visual inspection of the suction canisters, sponges, surgical drapes, gowns, and the floor. Although visual estimation is the standard of care, such subjective assessments varying greatly from one provider to another, and are complicated by irrigation solutions, body fluids, body tissues that may be incorporated into a blood/tissue matrix, and intravascular volume issues such as hemodilution and hemoconcentration.

Measurements of EBL

With the Triton app you take a picture of blood-soaked sponges or a suction canister filled with blood, and then the app pushes this data to a cloud server. Here, the Triton system uses computer vision algorithms and machine learning to analyze the photographic and geometric information about the hemoglobin mass shown in the image. Finally, the server transmits the data back to the operating room, giving you a highly reliable, real-time assessment of blood loss. The entire process is completed in a matter of seconds.

Non-Invasive Hemoglobin monitoring

Non-invasive hemoglobin monitors

The technology emits multiple wavelengths of light and then calculates the hemoglobin concentration based on the adsorption of light in the blood [12]. The device uses a finger tip probe similar to a standard pulse oximeter sensor and determines the hemoglobin noninvasively.


VANS
VIRGINIA