SNS COLLEGE OF ALLIED HEALTH SCIENCES

SNS Kalvi Nagar, Coimbatore - 35

Affiliated to Dr MGR Medical University, Chennai

DEPARTMENT OF CARDIO PULMONARY PERFUSION CARE TECHNOLOGY

COURSE NAME : PRINCIPLES OF PERFUSION 1

2ND YEAR

TOPIC : OXYGENATOR

OXYGENATORS

- The oxygenator is designed to add oxygen, and remove carbon dioxide from the venous blood.

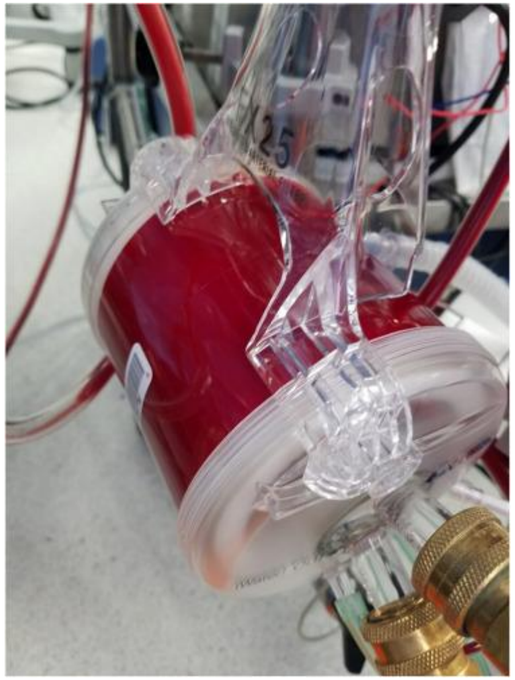
- It used in two principal modes:

  – in cardiopulmonary bypass (CPB) : shorter term < 6hours

  – in extracorporeal membrane oxygenation(ECMO) to oxygenate blood : longer term life support > 6 hours

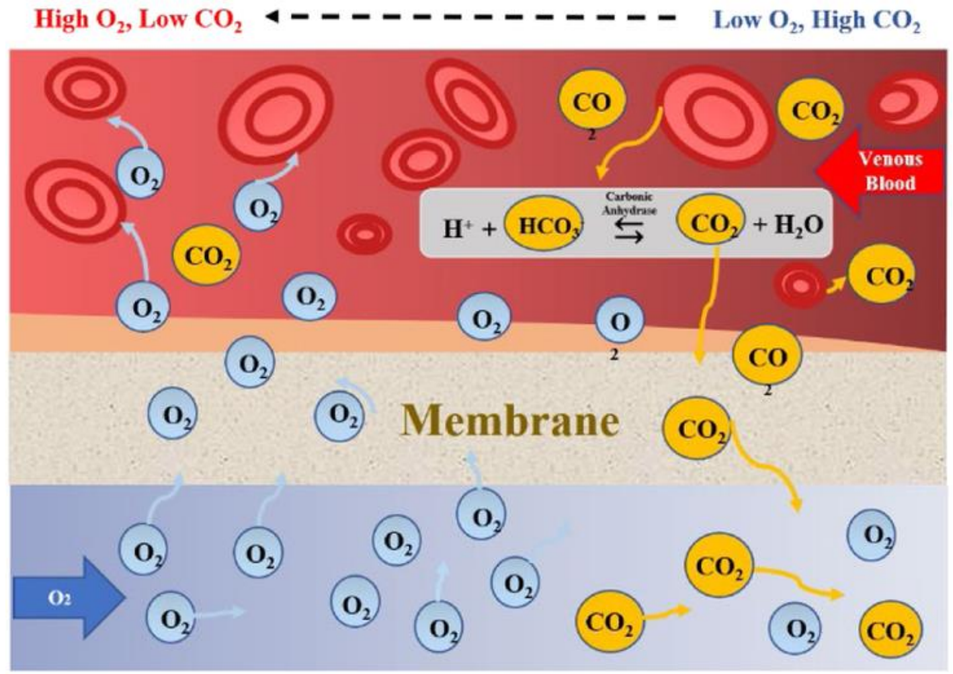
The Ideal oxygenator

- Oxygenation of venous blood
- Carbon dioxide elimination (Excellent gas exchange).
- Minimum blood trauma (Soft wall, Bio-compatibility, Minimize Inflammatory reaction).
- Small priming volume (Minimize hemodilution).
- Easily assembled and safety.
- Minimal failure incidents
- Easy to replace during Cardiopulmonary bypass in the event of oxygenation failure.
- Ease of use – Transparent to visualization of air, easily changeable in case of emergency



Main functions of oxygenator

- Reservoir functions : Defoaming, filtration and contain the blood.
- Membrane (oxygenator) functions: Gas exchange and heat exchange.

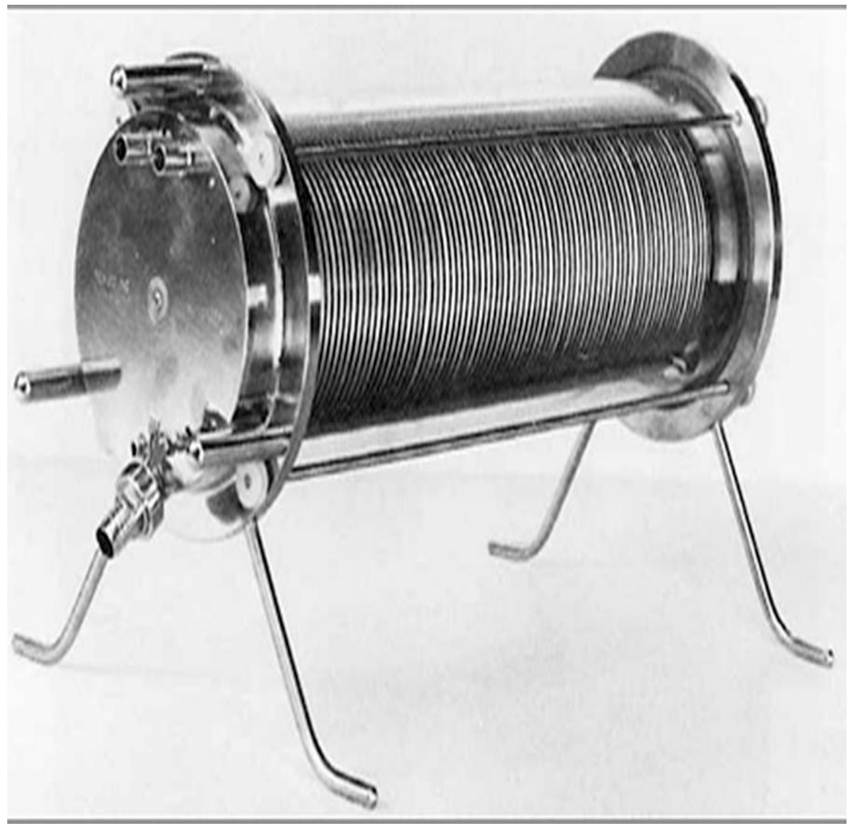


TYPES OF OXYGENATOR

- Film oxygenator
  - Rotating disc oxygenator
  - Vertical screen oxygenator
- Bubble oxygenator
- Membrane oxygenator

Rotating Disc Film Oxygenator

- Introduced by Kay Cross
- It is a **horizontal pyrex glass cylinder** with stainless steel end plates.
- A **central axel** is rotated in a bearing set.
- It contains **stainless steel discs** with spaces between them, flat and convoluted.
- There is a direct contact of **blood and gas** in it
- It had multiple vertical discs placed on a horizontal axis that rotated, with the discs dipping into a pool of venous blood, creating a film on the discs in an atmosphere of oxygen.
- It was capable of good oxygenation
- But it was nondisposable, cumbersome to use, large priming volumes, very difficult and tedious to clean and sterilize, and rapid loss of efficiency if hemodilution was attempted.



Vertical screen oxygenator

- Cabinets containing a series of upright screen in an atmospheric oxygen.

- In this type of oxygenators, venous blood is introduced by the way of slits at the top of the cabinet

- Oxygenated blood collects at the bottom of the cabinet

Bubble oxygenator

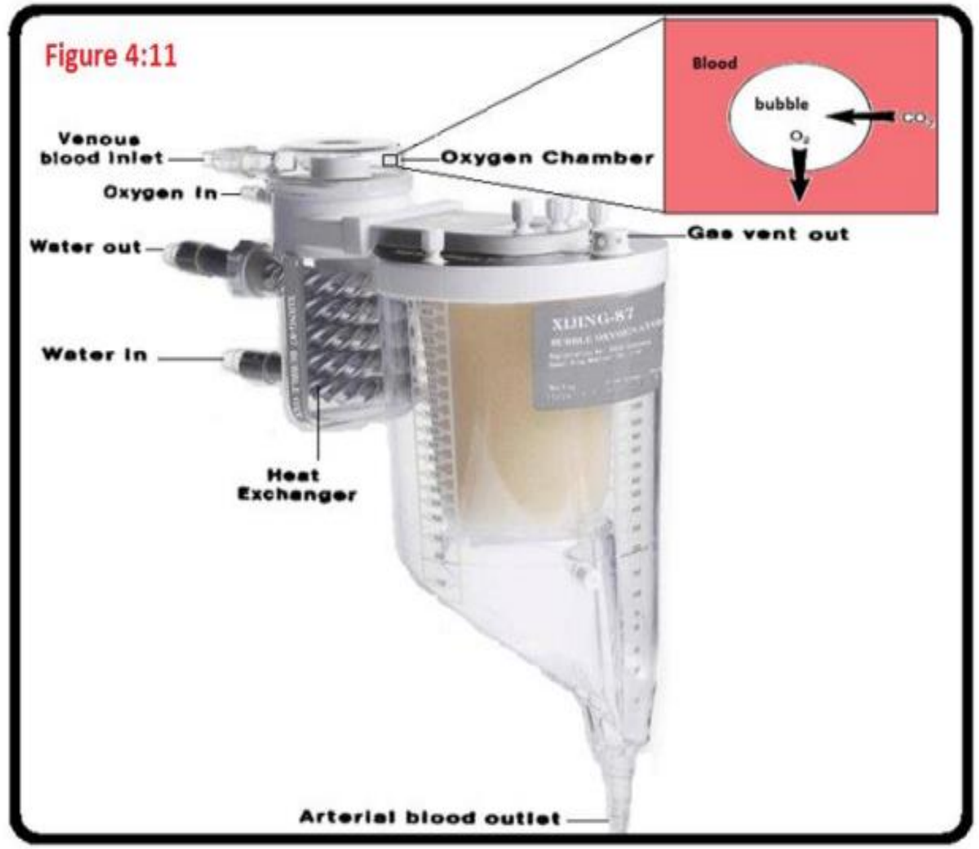
- It is introduced by De wall & Lillehei

Principle

- The blood enters in a venous inlet and crosses a heat exchanger, oxygen is then bubbled through this venous blood and gas exchange occurs.
- The oxygenated blood then flows through a defoamer and into the arterial reservoir.
- The arterial blood return to patient
- Bubble size is important for adequate gas transfer
- Small bubbles carries O_2
- Large bubbles removes CO_2
- Ideal bubble size for gas transfer is 3mm to 7mm.

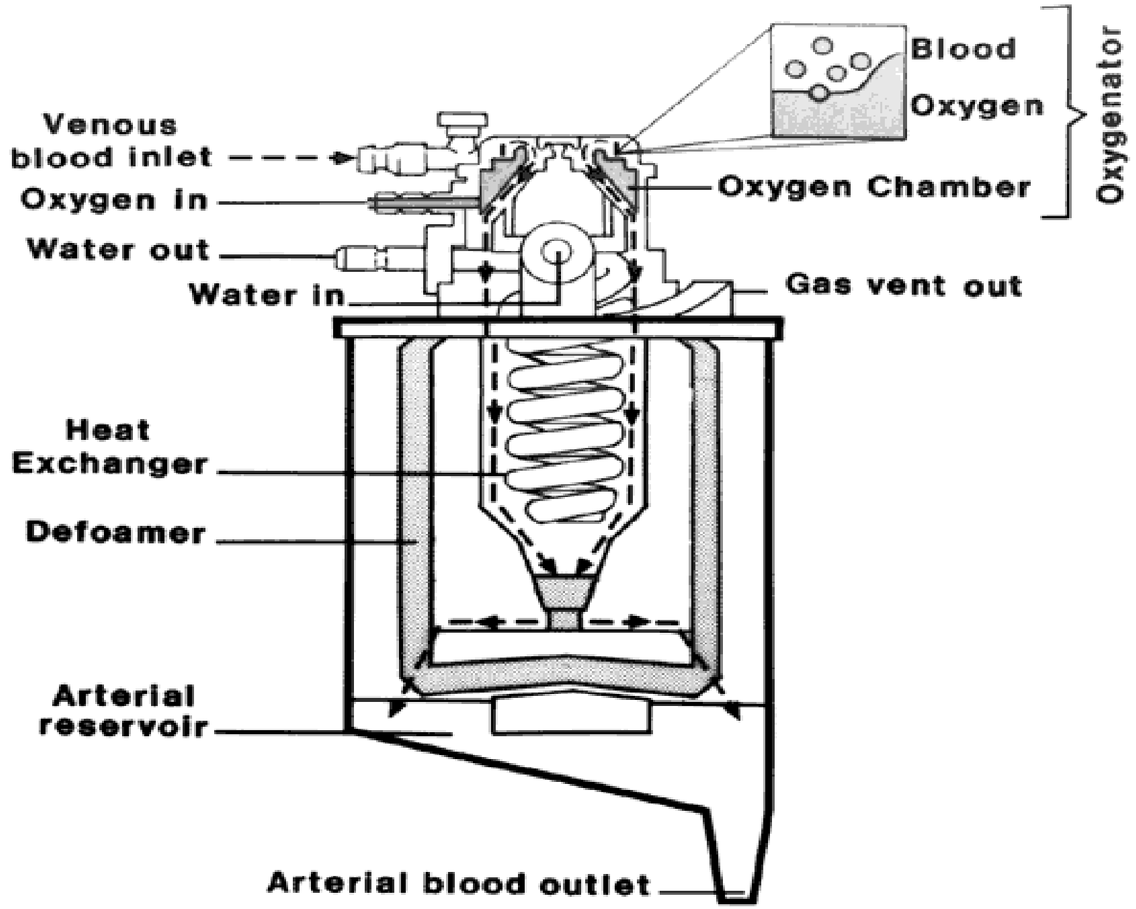
Bubble oxygenator

- The typical bubble oxygenator is divided into two sections.
- The first section is the mixing chamber (oxygen chamber), where fresh gas flows into the blood through a screen, which causes small bubbles to form.
- The oxygen is transferred from the bubbles into the blood, and carbon dioxide is transferred from the blood into the bubbles.
- The second section is the reservoir, where blood is defoaming and contain in it.



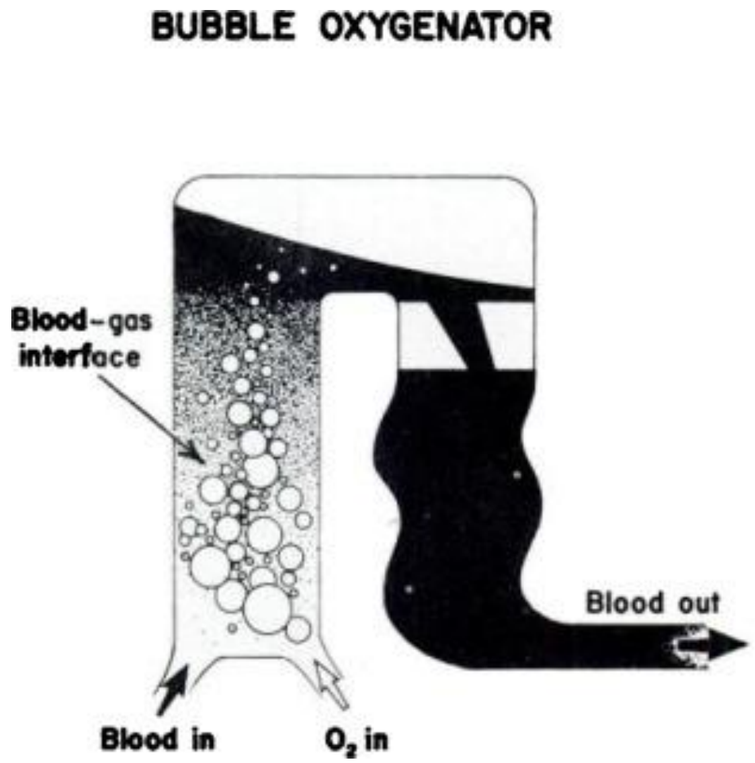
ADVANTAGES OF BUBBLE OXYGENATOR

- Easy to assemble
- Relatively small priming volume
- Adequate oxygenating capacity
- Lower cost
- Low resistance to flow



DISADVANTAGES OF BUBBLE OXYGENATOR

- Micro emboli
- Blood cell trauma
- Excessive removal of CO_2
- Destruction of plasma protein due to gas interface
- Defoaming capacity may get exhausted with time



ASSESSMENT - 1

- What are the peculiarities of an ideal oxygenator?
- Principle of bubble oxygenator
- Advantages and disadvantages of bubble oxygenator

MEMBRANE OXYGENATOR

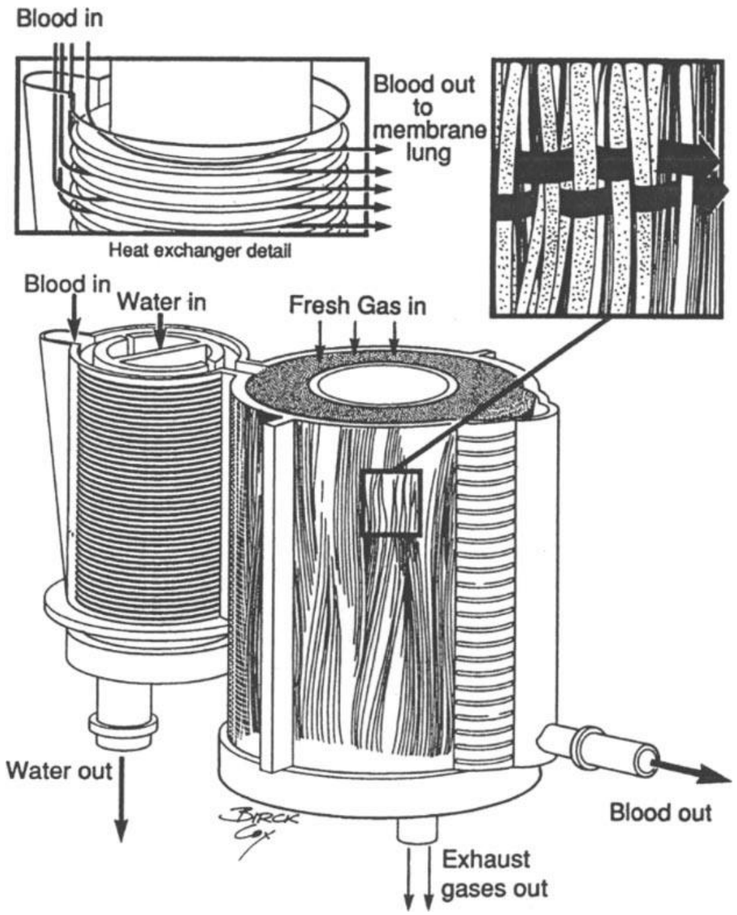
Natural lung	Membrane oxygenator
More surface area It has a surface area of 70m2	Less surface area It has a surface area of 0.5- 4.0 m2
O2 transfer 2000ml/min	O2 transfer 200 – 600 ml/min
Length 200µ m	Length of blood path increases to get fully oxygenation, so it is 2,50,000 µ m
Membrane thickness 0.5 µ m Blood path width 8 µ m	Membrane thickness 150 µ m Blood path width 200 µ m

MEMBRANE OXYGENATOR

- It physically separates the blood from gas with the gas permeable membrane material

- Membrane materials have been used for gas transfer includes cellophane, nylon, polyethylene, ethyl cellulose, Teflon, butyl rubber, silicon, polypropylene, and polymethyl pentene.

- The best gas transfer characteristics with minimal cellular trauma have been silicone and polypropylene, and have become the standard materials used for oxygenators currently



Types of Membrane material

Membrane material

Silicone rubber

Polypropylene

It is Homogenous

Non Porous material (True membrane)

Used in ECMO

It is Heterogenous

Microporous hydrophobic membrane

Used in CPB

Parts of Membrane oxygenator

1. Cardiotomy Reservoir.

   There are two type of reservoir:

   – Flexible venous reservoirs (Soft shell reservoir).

   – Hard-shell Venous Reservoirs.

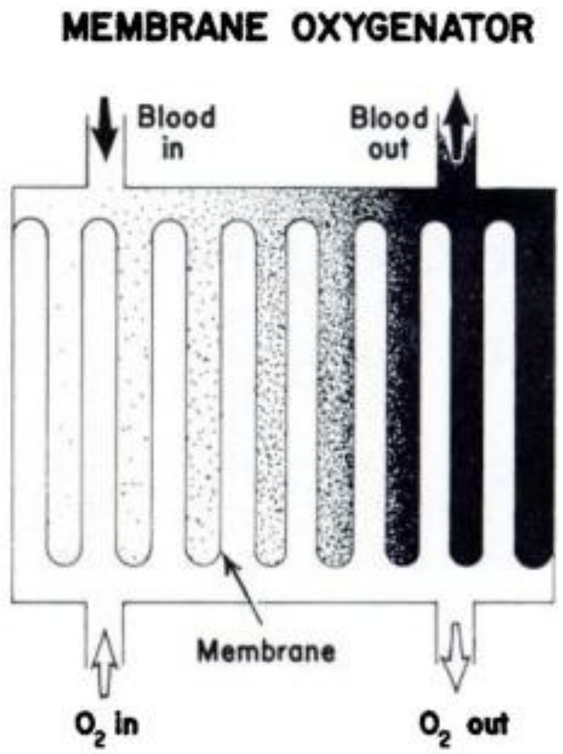
2. Membrane (oxygenator).

There are two type of membrane according to materials that are made of:

– 1) Microporous Polypropylene:

- (a) Hollow Fiber Structure .
- (b) Flat-Sheets Membrane (Microporous Sheets).
- (c) Integrated Arterial Filter With Self-Venting Technology.

– 2) True Membrane (Diffusion membrane)



CARDIOTOMY RESERVOIR

Blood reservoir is a device used in cardiopulmonary bypass for contain the volume of blood that displacement out of the human circulation during the operation.

TYPE OF CARDIOTOMY RESERVOIR

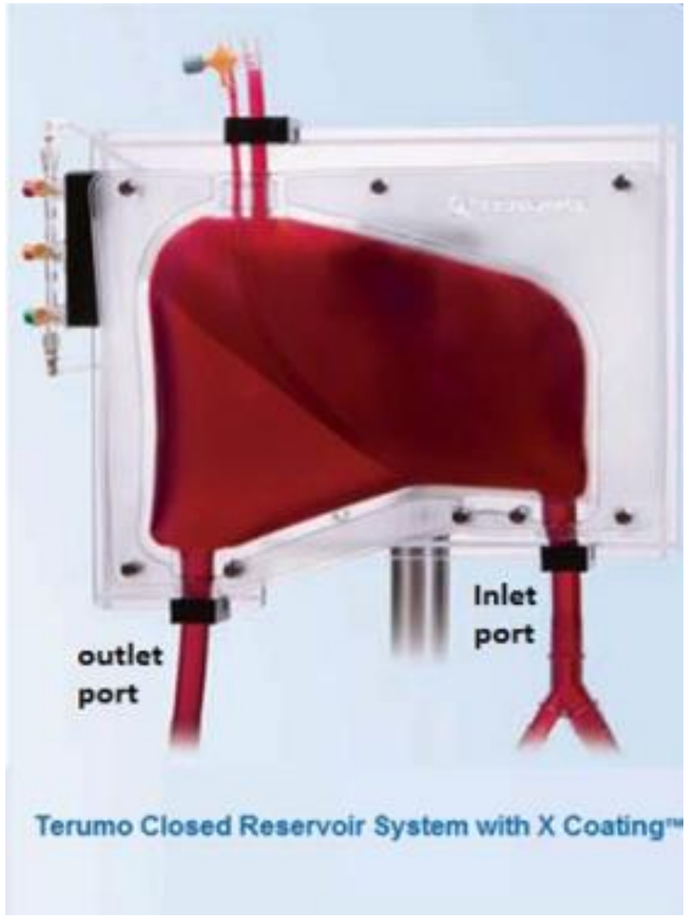
A- Soft shell reservoir:

- The soft-shell reservoirs (Flexible venous reservoirs) have the advantage of increase and reduce its size according to the amount of blood that they contain
- They are not have airspace, that prevent the accidental delivery of air to patient.

CARDIOTOMY RESERVOIR (cont)

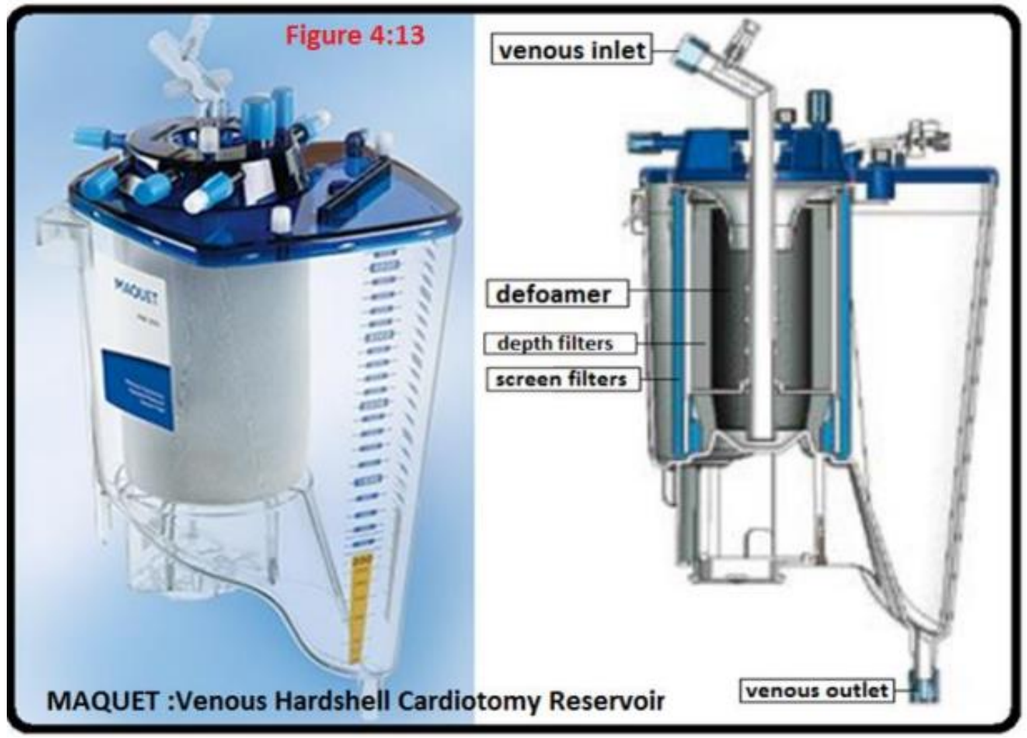
- The venous blood enter in the reservoir through the inlet port, and passes through micro screen and aspirate from the outlet port by head pump to oxygenator inlet.

- The inlet port position is above the outlet port which puts a larger volume above the outlet port which promotes mixing, prevent vortex, optimize air removal, and promotes low venous resistance



Hard shell cardiotomy reservoir

- Hard plastic container (rigid walls) made of polycarbonate
- Contains an integral filter mechanism
- The venous blood enter from the venous inlet port and passes through a defoamer, depth filters and screen filters which result to filtration the blood from particulate materials (clots, blood cell aggregates, fat emboli, fibrin and surgical contamination) before leaving the venous outlet of cardiotomy.



Advantages & Disadvantages of hard shell reservoir

ADVANTAGES

- Easy volume measurements
- Management of venous air
- Larger capacity
- Easier to prime
- Permit suction for vacuum-assisted venous drainage.

DISADVANTAGES

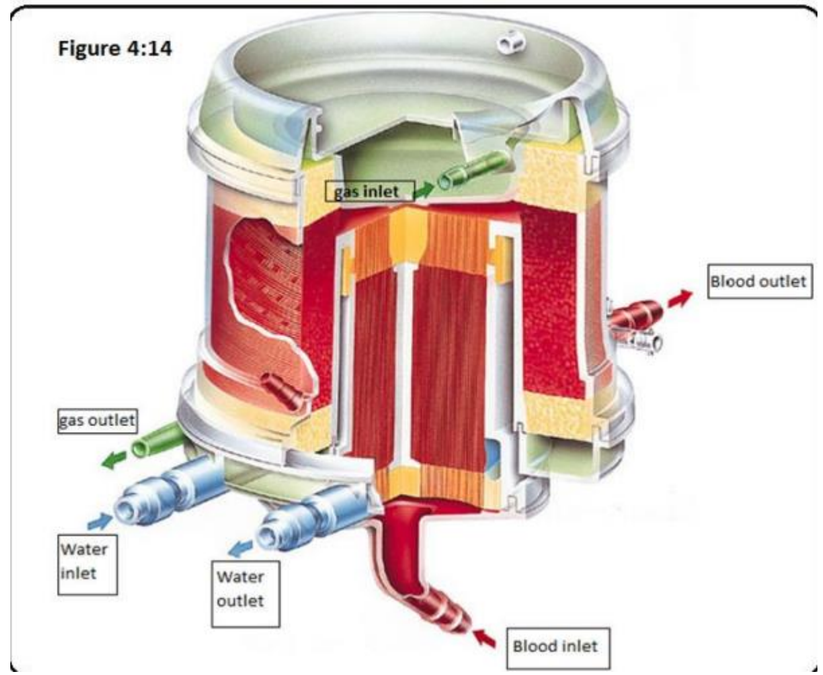
- Micro air bubbles due to the possibility to form the vortex
- Increased activation of blood elements.

MEMBRANE OXYGENATOR

- Consists of a plastic housing made of polycarbonate, which contains the gas exchange membranes and water circuit.

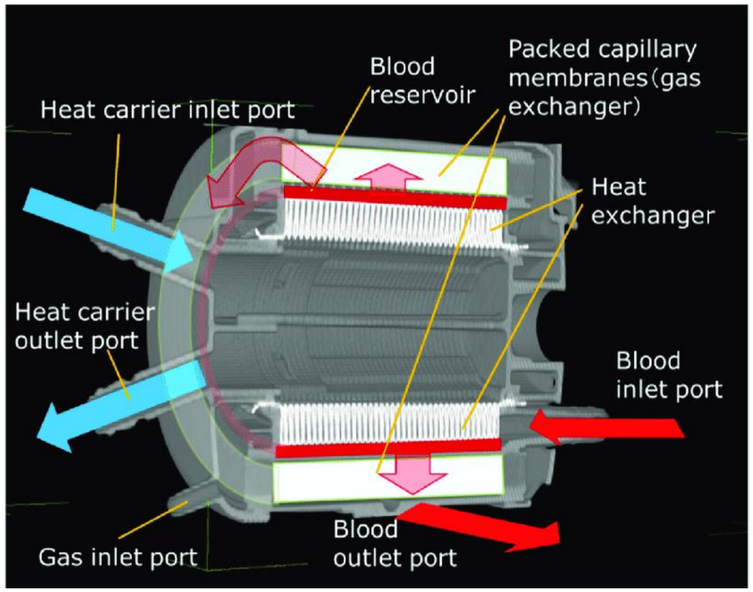
- It designed to be used to gas exchange and heat exchange.

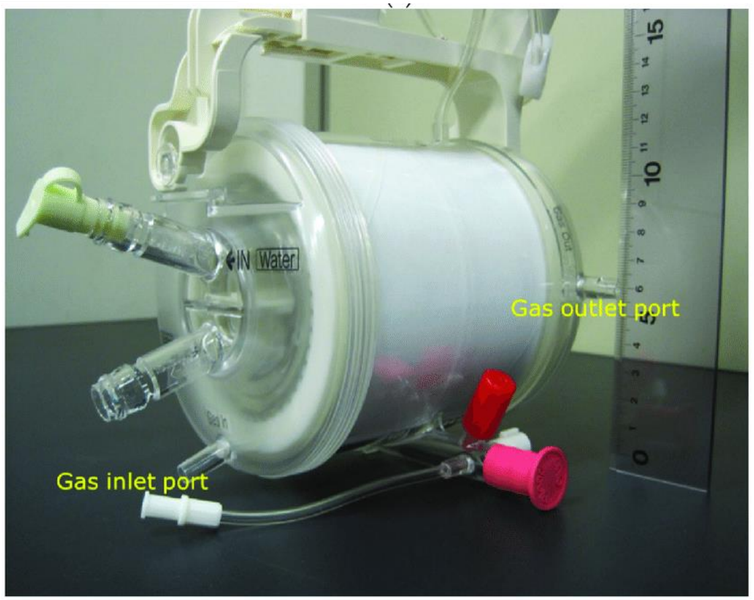
- The venous blood enter from the membrane inlet port and leaving from the membrane outlet after provided with oxygen and get rid of carbon dioxide.



MEMBRANE OXYGENATOR

- The blood temperature is control through a water circulator.
- The priming volume of the oxygenator can be adjusted by selecting different sizes and lengths of microporous polypropylene (or Silicone) fibers (Low priming volume – reduce hemodilution).
- Microporous polypropylene fibers is highly permeate to oxygen and most other common gases.





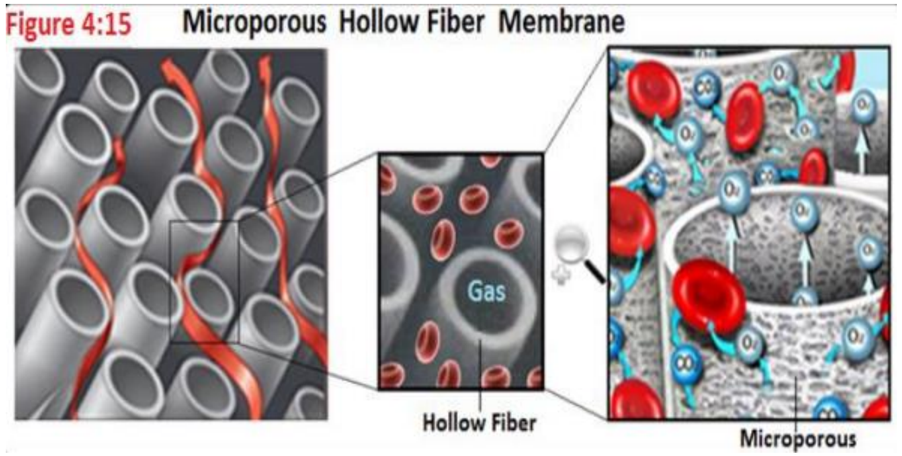
(b)

Type of Membrane Oxygenator

1. MICROPOROUS POLYPROPYLENE

(A) **Hollow Fiber Structure**:

- Gas exchange in the membrane occurs by diffusion through the membrane wall and transit via microporous (micro channels).
- The flow of gas through the hollow fibers with blood around them
- This configuration reduces blood pressure drop across the oxygenator.

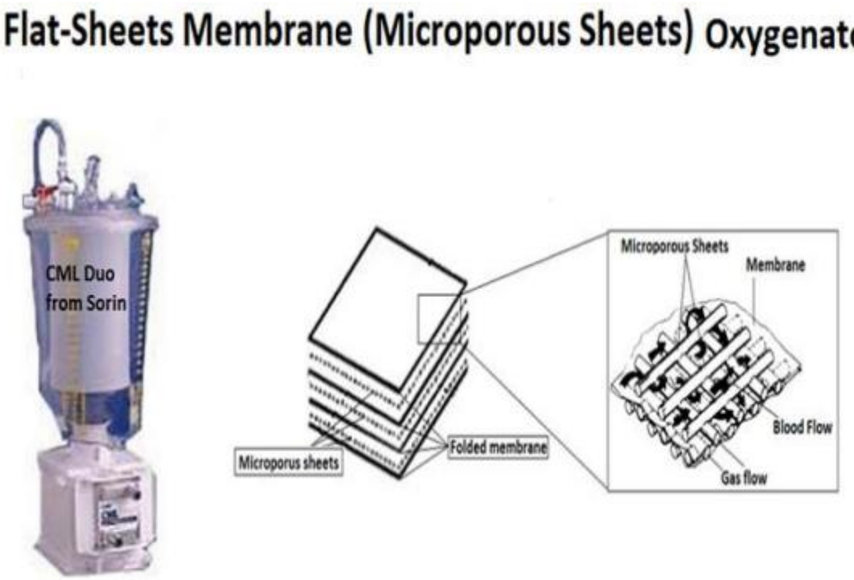


❖ The pressure in blood side must always exceed the pressure in the gas side to prevent the possible of entering any gas emboli from gas side to blood side via the micro channels.

Type of Membrane Oxygenator (cont)

(B) **Flat-Sheets Membrane (Microporous Sheets) "Folded-Envelope Design".**

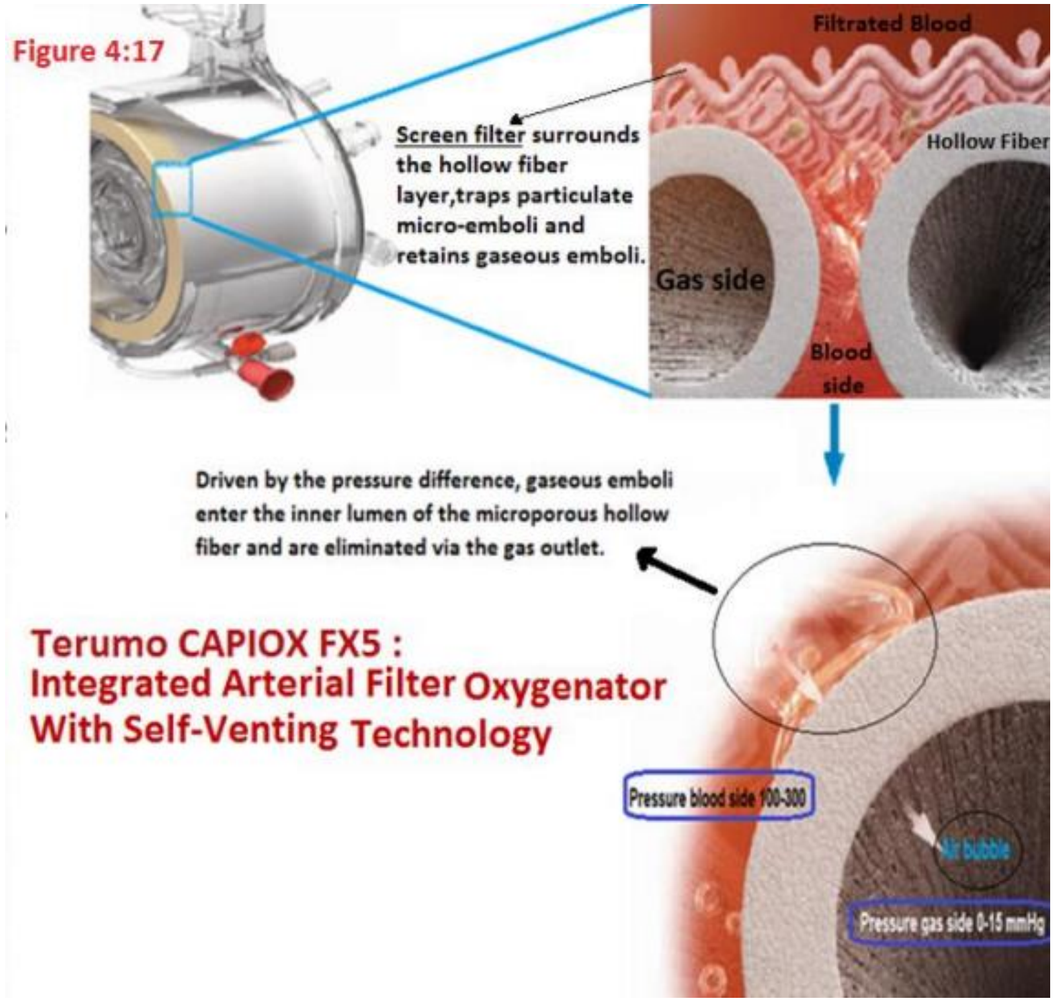
- Membrane is a flat sheet which is folded to create plates that separate a blood compartment from the gas compartment
- More effective in trapping and expelling air bubble
- But they have a larger surface area than hollow-fiber oxygenators
- Demand larger priming volumes.



Type of Membrane Oxygenator (cont)

(C) Integrated Arterial Filter Oxygenator

- Hollow fiber oxygenator with integrated arterial filters
- It has a screen filter surrounds the hollow fiber layer of the oxygenator to trap and/or remove particulate and air emboli from the blood before return to the arterial line.
- Gaseous emboli that may be present in the blood are trapped in the screen filter mesh
- Gaseous emboli enter the inner lumen of the microporous hollow fiber and are eliminated via the gas outlet



2. True Membrane (Diffusion membrane)

- True membrane oxygenators are manufactured by coiling silicone rubber sheets in a cylindrical fashion

- Blood is kept on one side of the membrane and gas on the other side.

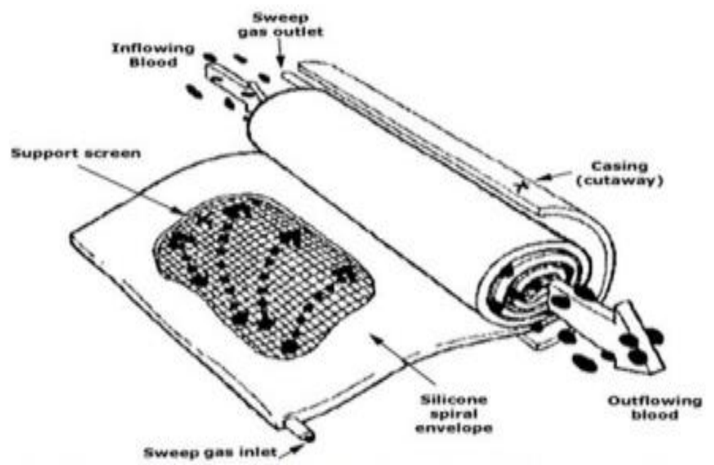
- The membrane provide a complete barrier between the blood and gas so that gas transfer depends totally on diffusion of gases through the membrane material.

- Gas transfer dependent on
  - the permeability of the membrane
  - the driving pressure of gas on either side of the membrane
  - the diffusion distance of the gas in blood .

- It is costly and have large priming volume

Figure 4:18

True Membrane (Diffusion membrane)



SOME TYPES OF OXYGENATORS

Dideco Lilliput 2

Oxygenator with a separate reservoir

Medtronic Affinity Fusion

Integrated Arterial Filter Oxygenator

Terumo CAPIOX

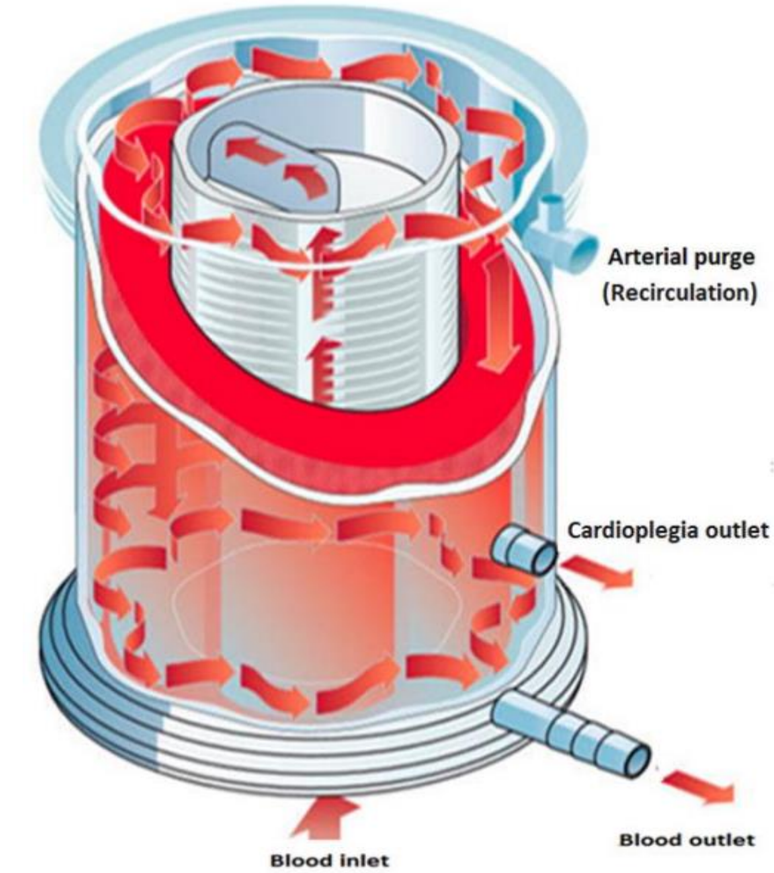
EUROSETS ALONE

Oxygenator with Soft shell reservoir

Blood Flow Path through Oxygenators

- Blood flow through the oxygenators are passes in radial or axial paths

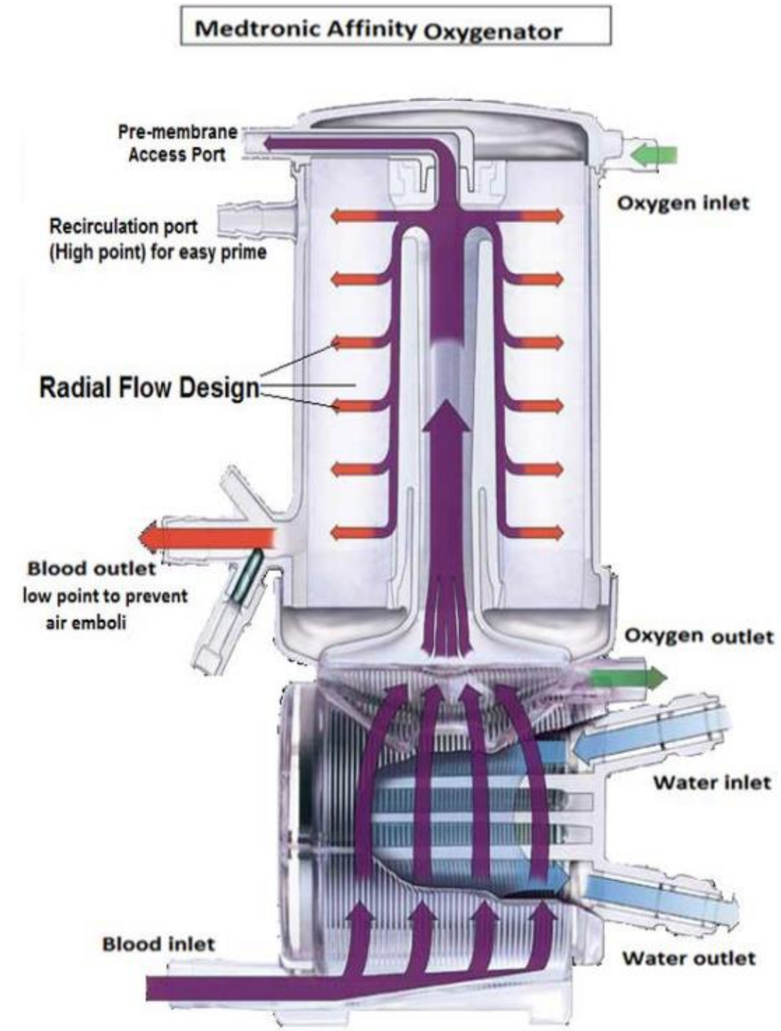
- The path of blood flow is affect in
  - oxygenating efficiency
  - air emboli removal
  - pressure drop
  - heat exchanger performance



Dideco EVO Oxygenator

Blood Flow Path through Oxygenators

- The blood enters the oxygenator from blood inlet and passes through the heat exchanger first, and then through oxygenator bundle before exiting from blood outlet



Principles of Membrane Oxygenator

- Gas transfer occurs in membrane oxygenator by diffusion
- Diffusion: is a random movement of molecules or atoms from higher concentration area to lower concentration area.
- Diffusion of gases in membrane oxygenator depend upon
  1. Partial pressure gradient of particular gas in blood and gas phase.
  2. Diffusive characteristics of a gas.
  3. Concentration of particular gas.
  4. Physical characteristics of membrane (surface area, flow path, type of).

Definitions Useful in the Comparing Between Oxygenators:

- Initial Priming Volume: It is a volume(ml) to fill up the oxygenator(Membranes), heat exchanger, and recommended minimum venous reservoir.

- Static Priming Volume: This is volume to prime oxygenator(Membrane) without any flow.

- Minimum Operating volume: Minimum volume in the reservoir which is recommended by manufacturer to prevent release air emboli through blood at reference maximum blood flow.

- Maximum Operating Volume (Reservoir capacity): Maximum volume in the reservoir which is recommended by manufacturer

- Max Blood Flow: It is a flow range which is recommended by manufacturer by considering better gas exchange, heat exchange and pressure drop

ASSESSMENT - 2

- What are the parts of membrane oxygenators?
- Types of cardiotomy reservoirs
- Types of membranes
- Principle of gas exchange

THANK YOU