Point-of-Care Testing:
A Cardiovascular Perfusionist's Perspective

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Objectives / Overview

- ✓ What is a perfusionist?
- ✓ Describe the basics of extracorporeal circulation
- ✓ Concepts that are unique to extracorporeal circulation
- ✓ Discuss standards and guidelines

What is a perfusionist?

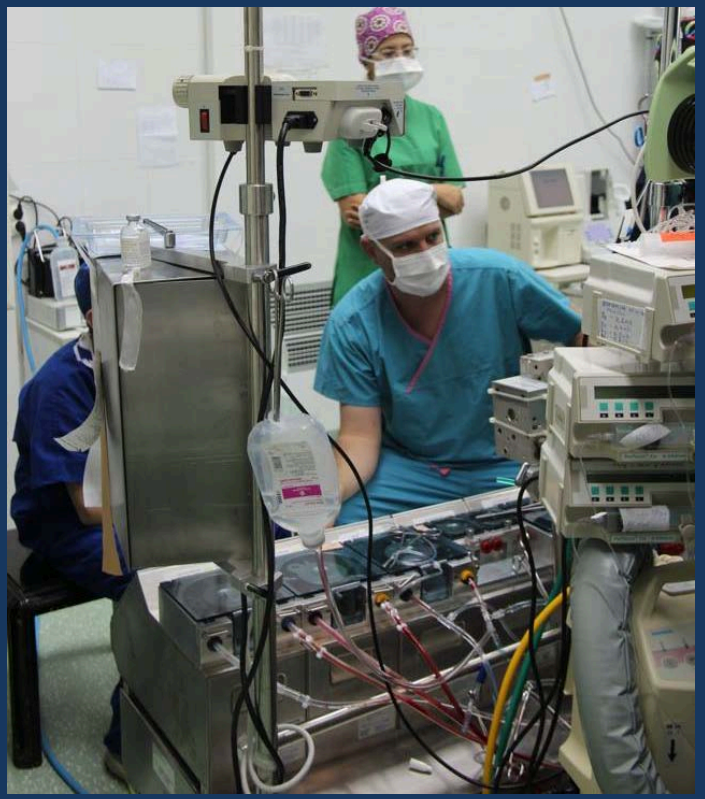
CCP = certified clinical perfusionist

A skilled allied health professional, trained and educated in the following areas:

- Extracorporeal circulation
- Blood management
- Circulatory assist devices

Extracorporeal =
"situated or occurring outside the body"

Cardiopulmonary Bypass!



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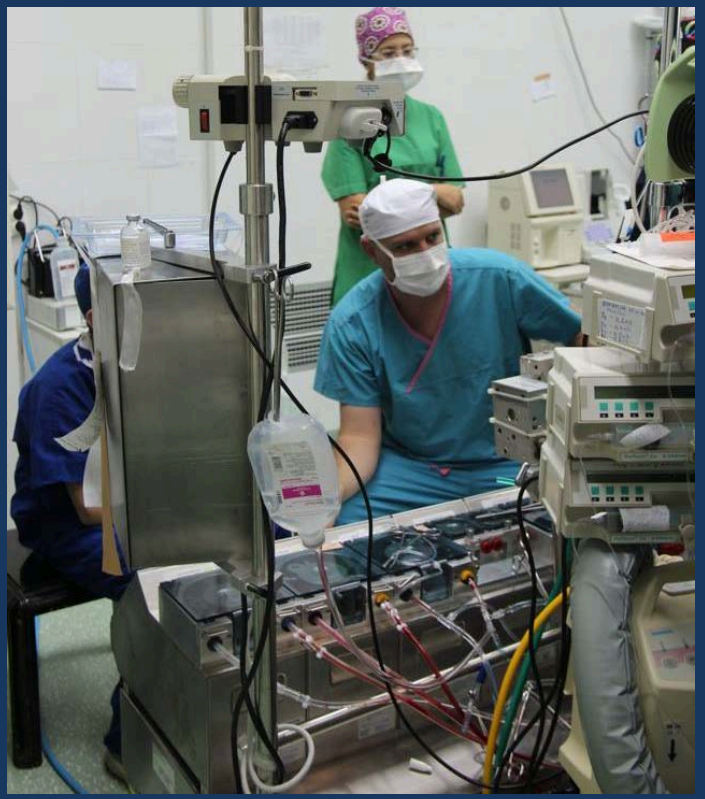
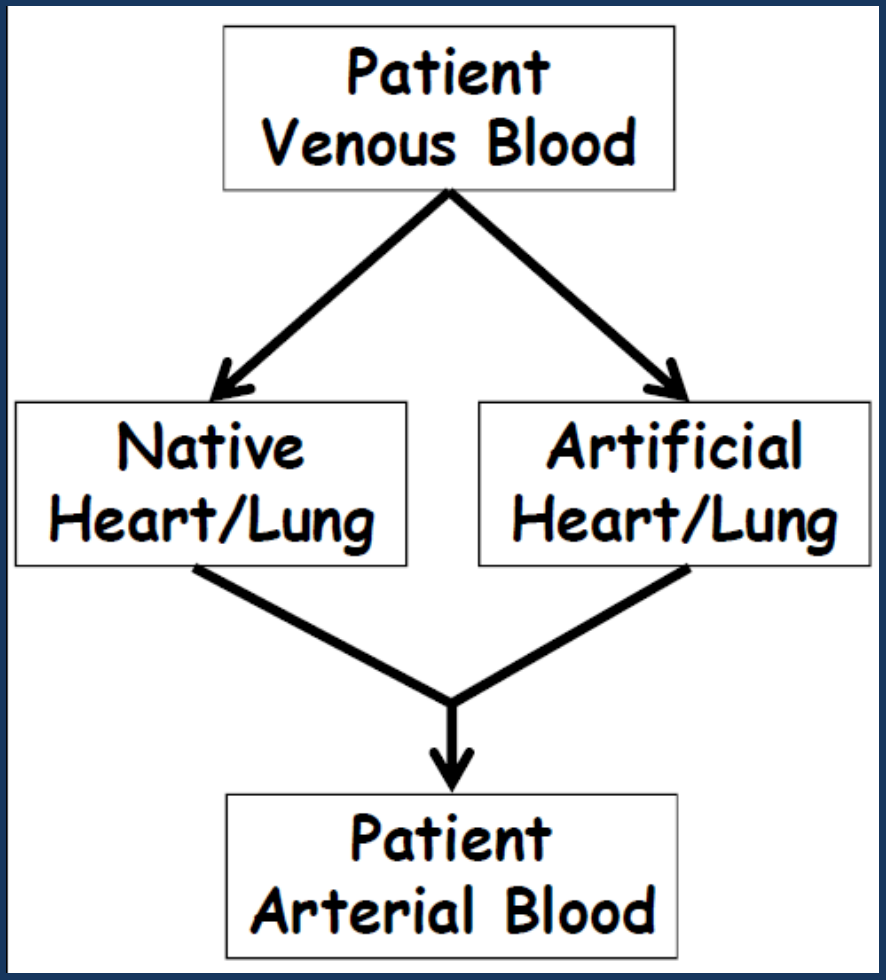
Cardiopulmonary Bypass !

ECMO



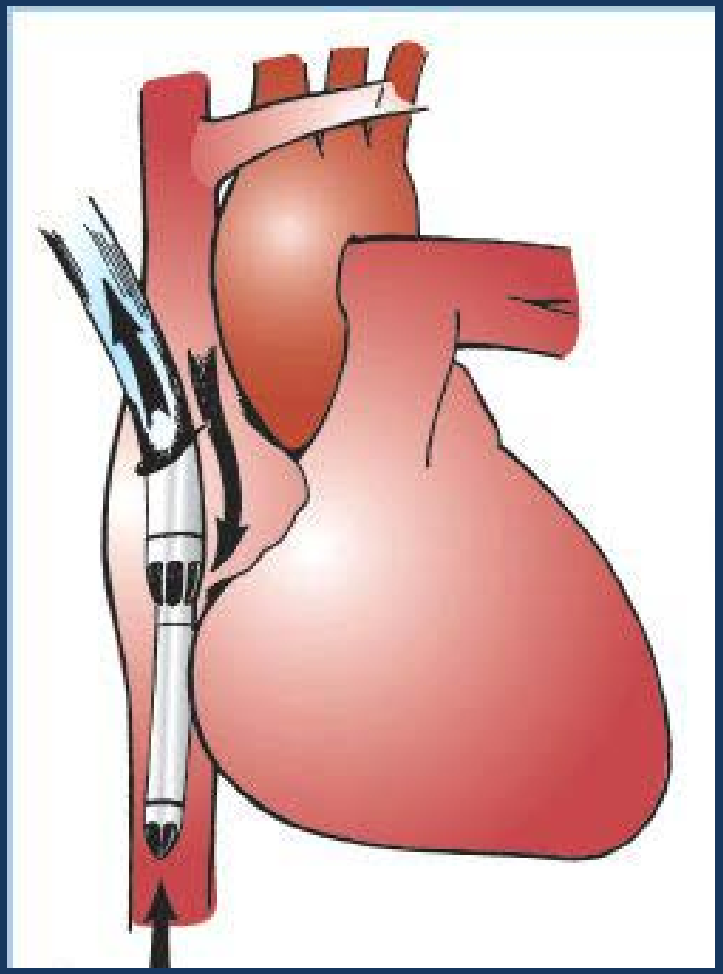
Cardiopulmonary Bypass

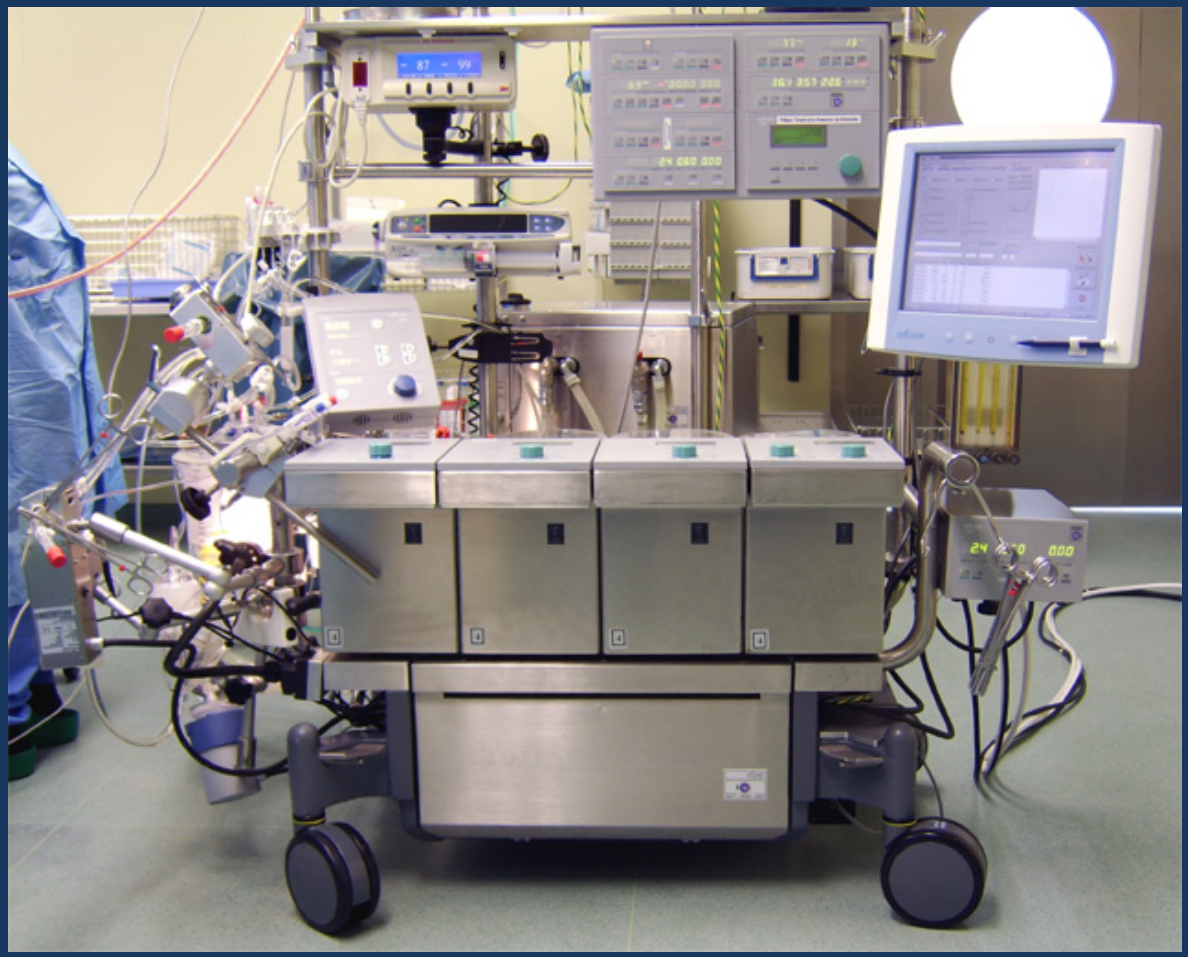
Keeps the heart still or empty (or both) in order to perform surgery.



Cardiopulmonary Bypass

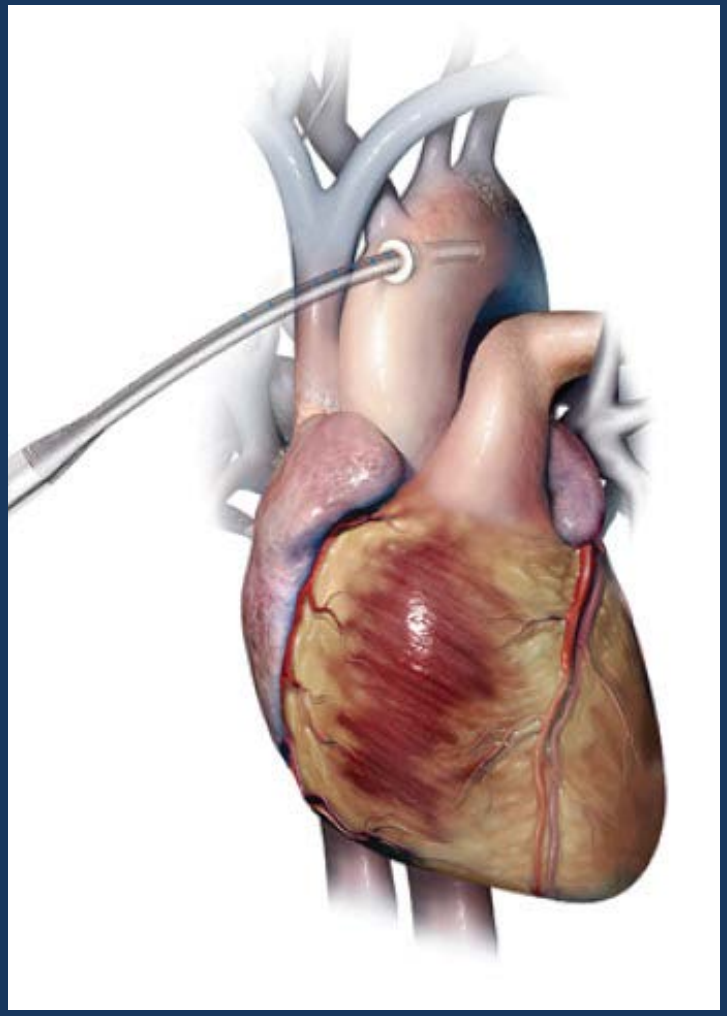
Venous cannula for draining blood from the patient

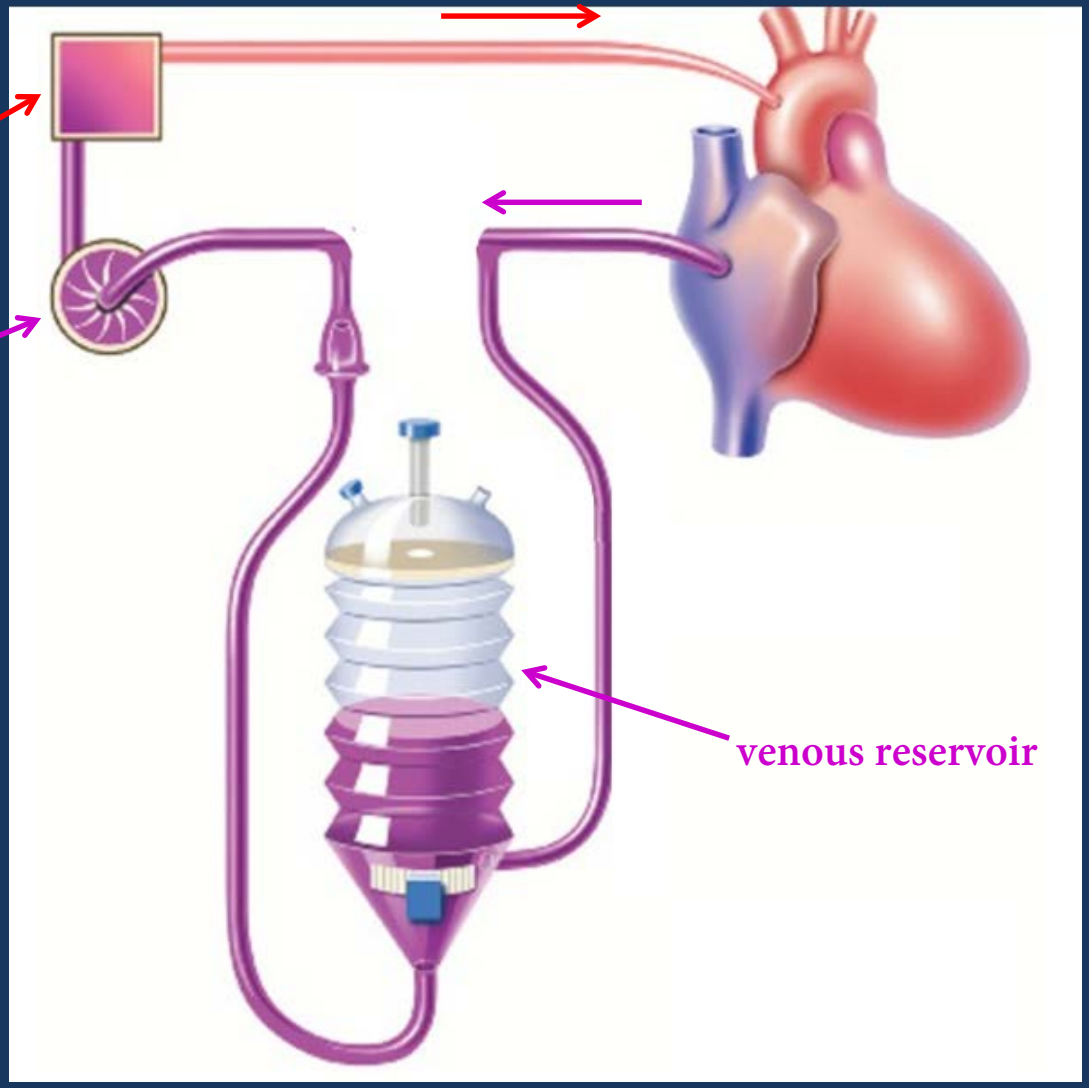




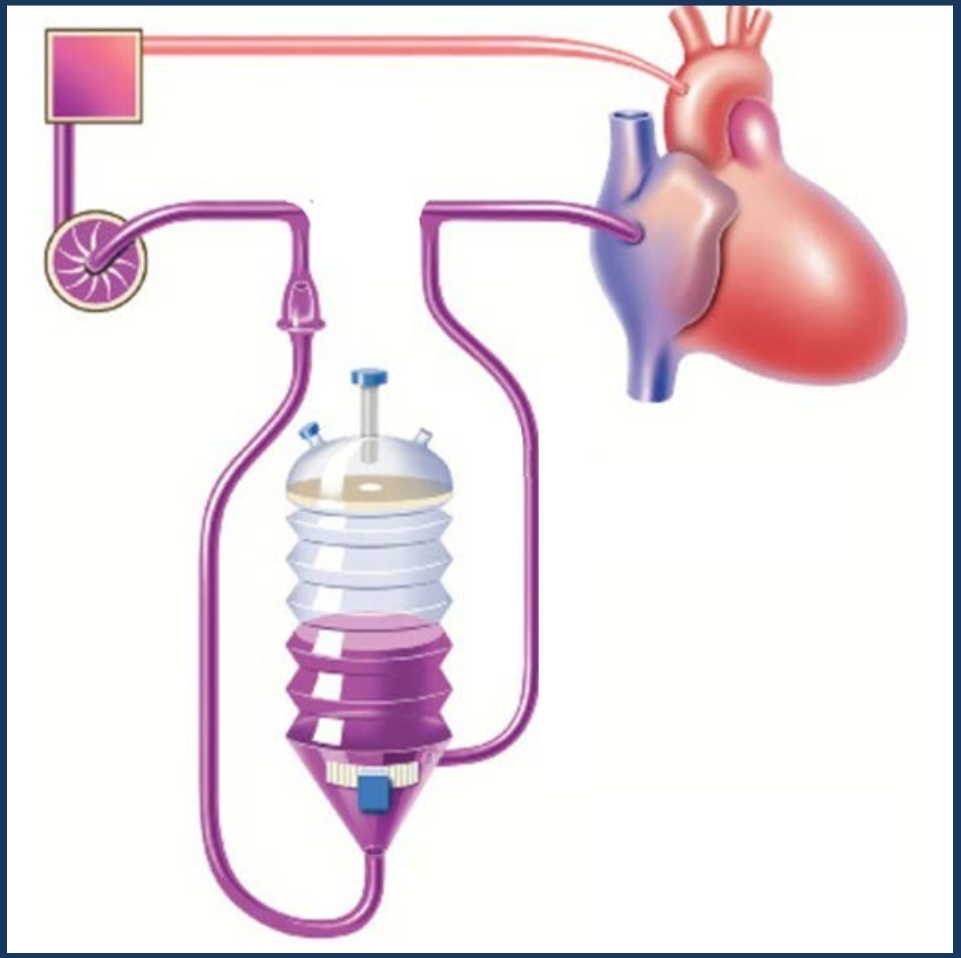
Cardiopulmonary Bypass

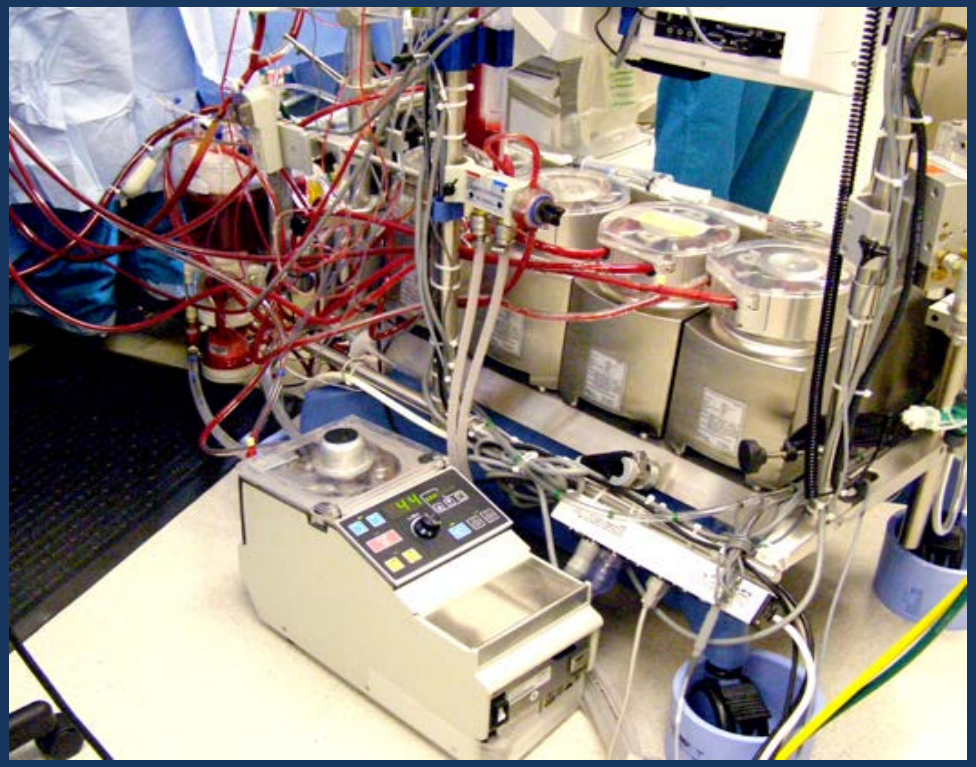
Arterial cannula for returning blood to the patient



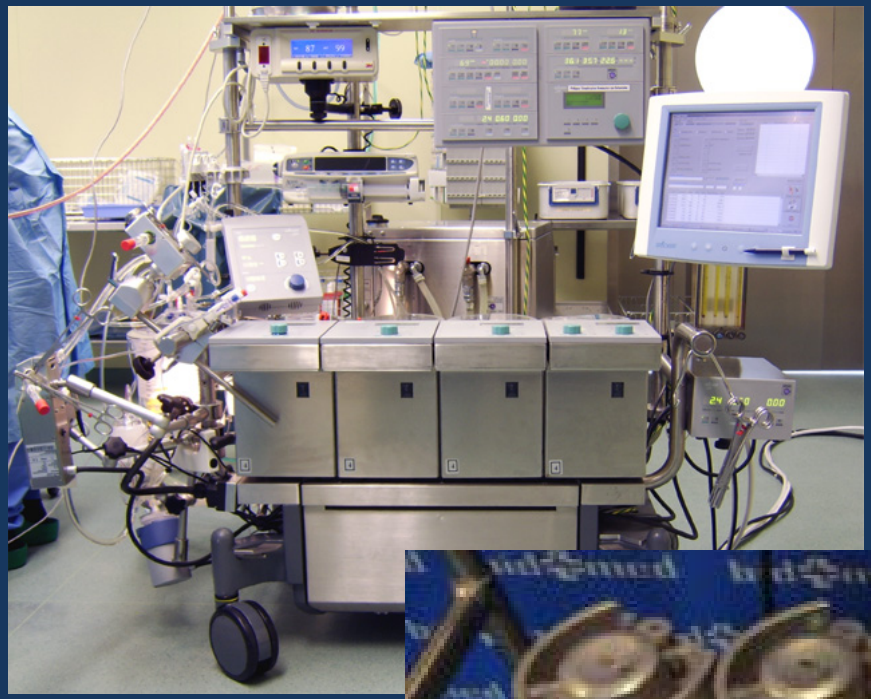

oxygenator
blood pump
venous reservoir

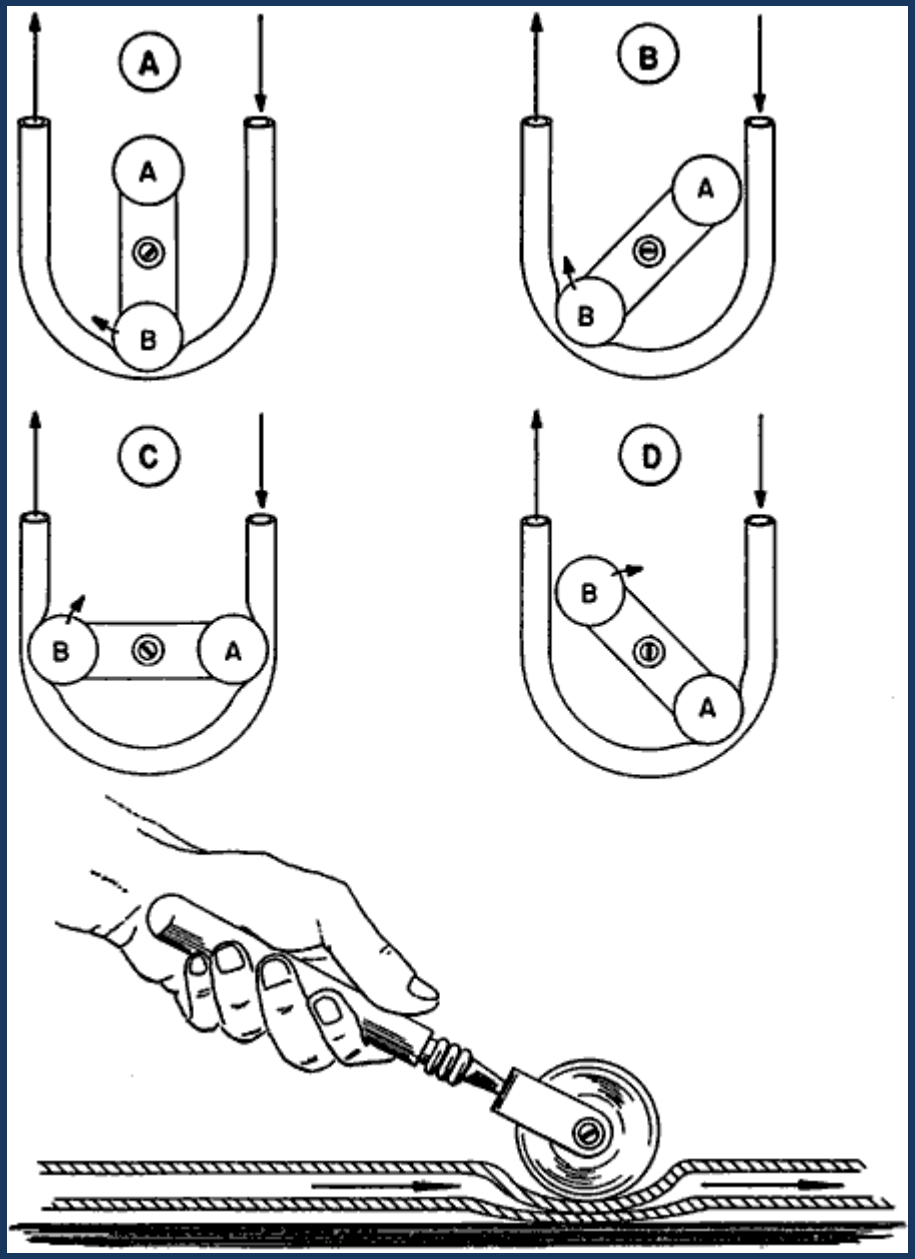
How did we get from this…





…to spaghetti??

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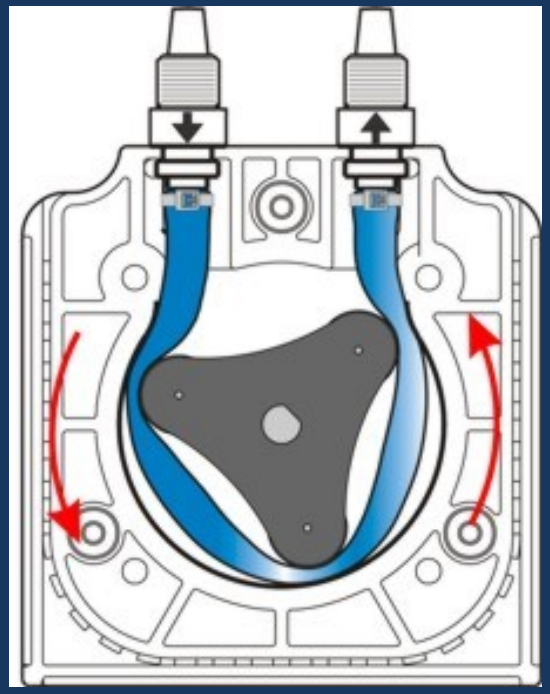

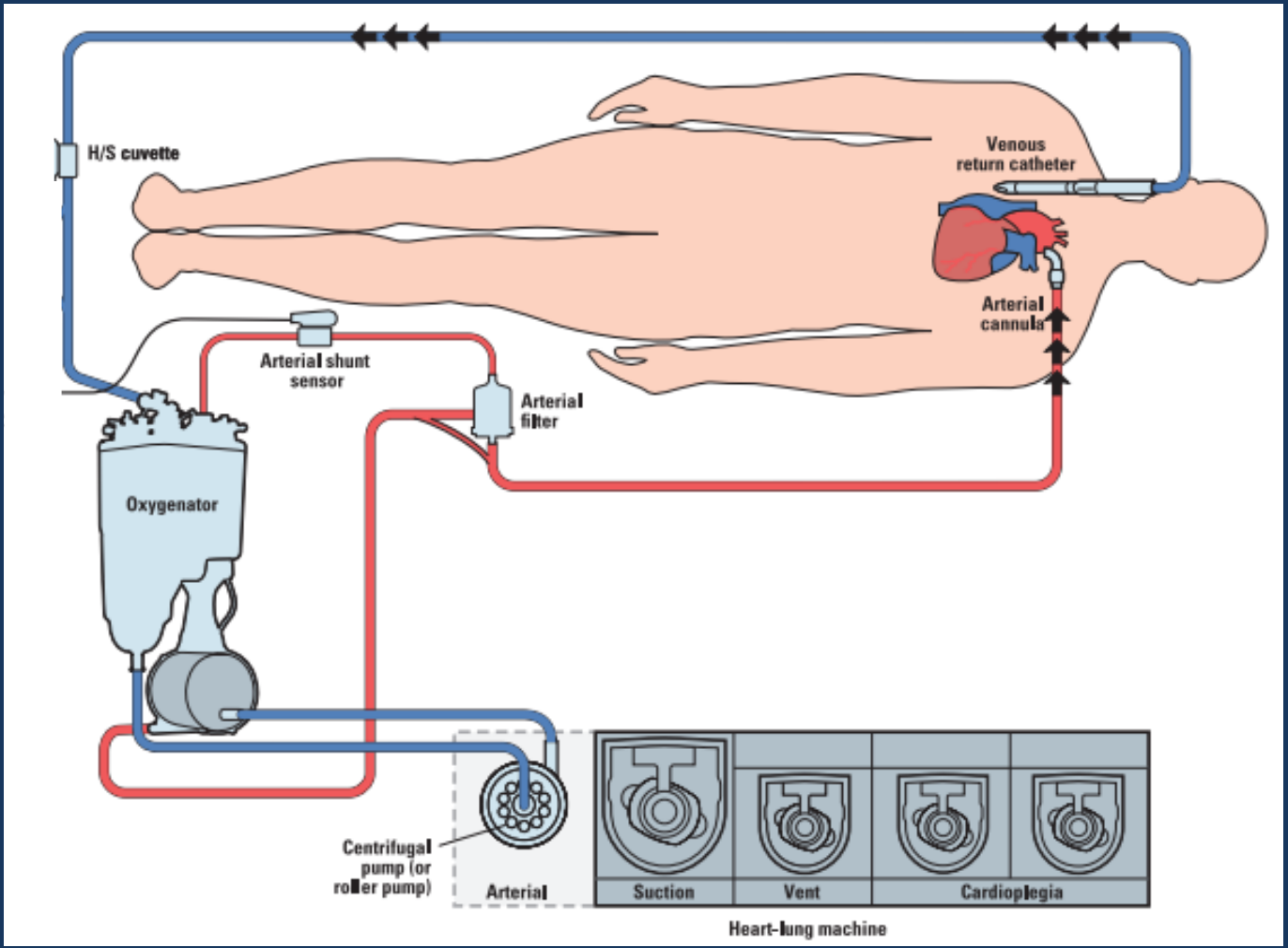

Heart-lung machine

Cardiopulmonary Bypass

Circuit Complexities:

1. Cardioplegia
2. Suction and vents
3. Hemoconcentration
4. Temperature control
5. Circuit monitoring
   - ✓ Circuit pressures
   - ✓ Temperatures
   - ✓ Laboratory values

Cardiopulmonary Bypass

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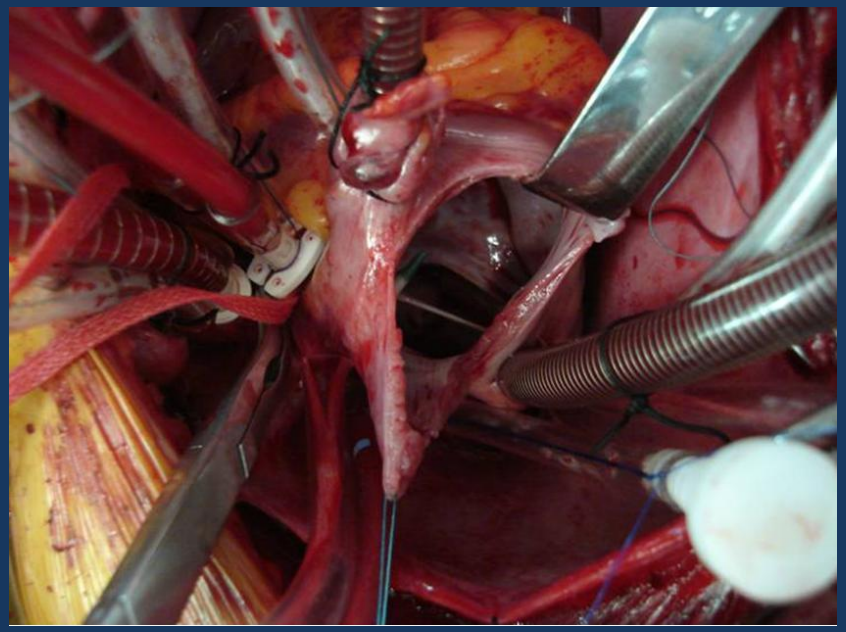
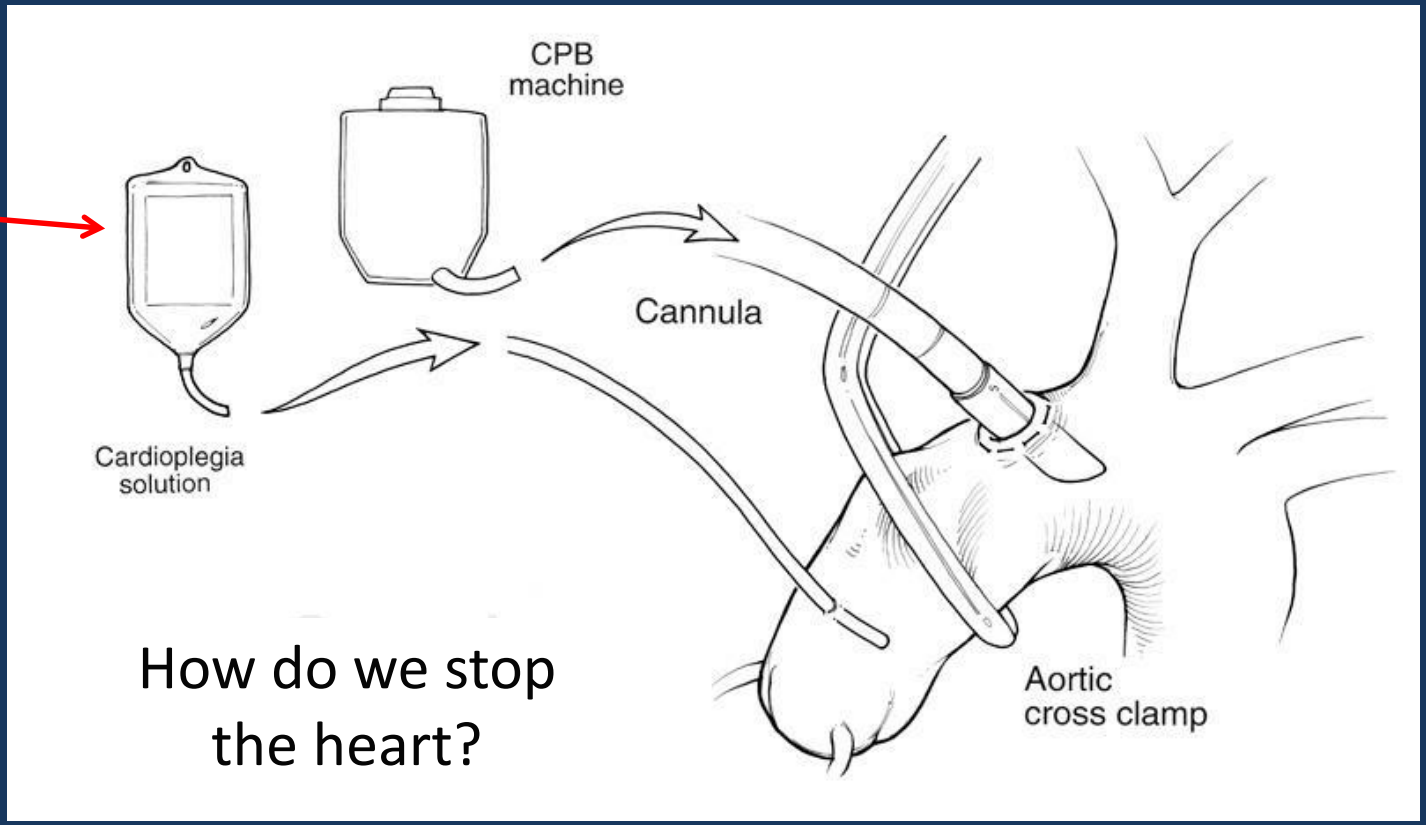
Cardioplegia

1. Stops the heart so that it remains still for surgery
2. Cools the heart to lower it's metabolism
3. Allows opening of the heart



Cardioplegia

Cold,
high potassium



How do we stop
the heart?

Cardioplegia

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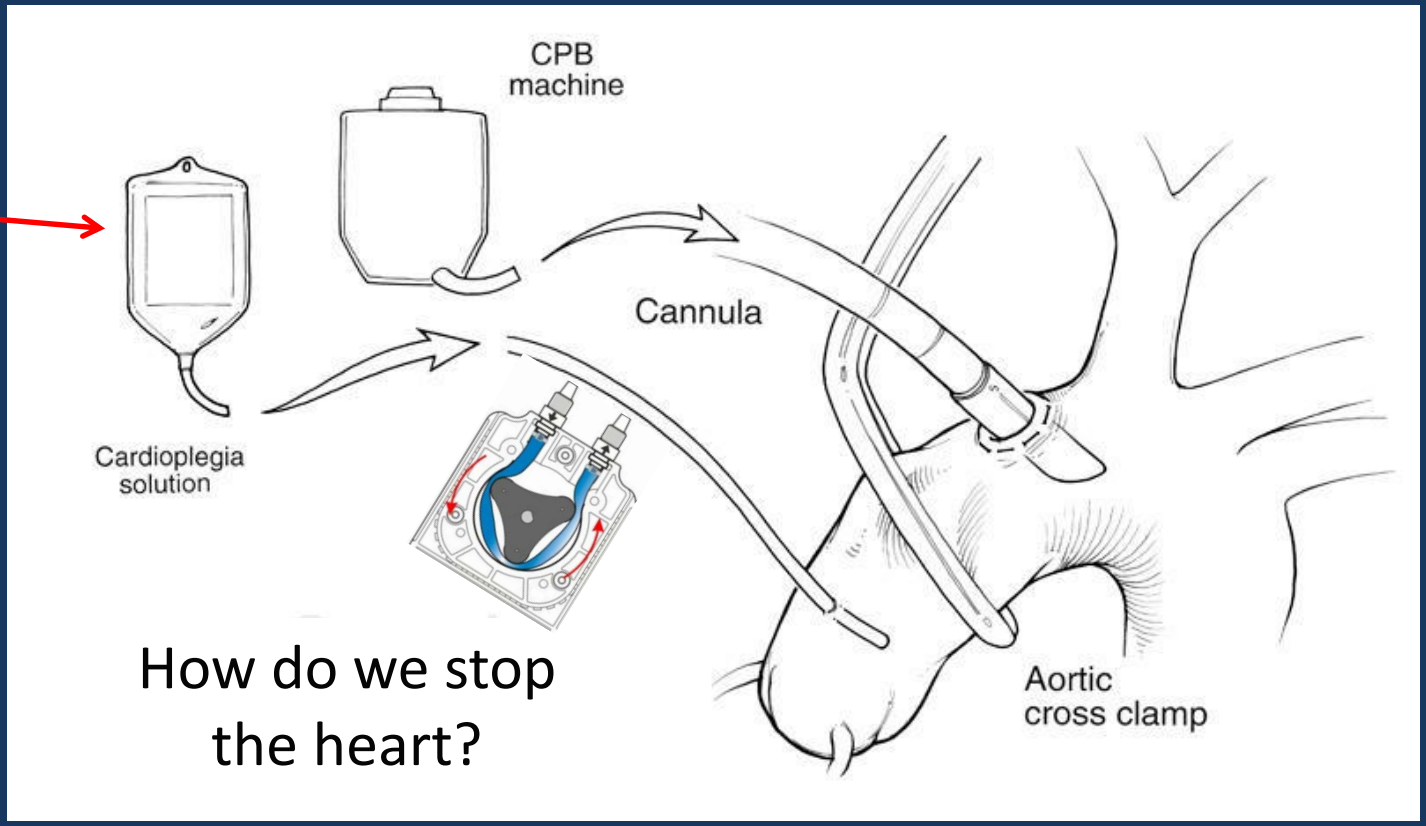

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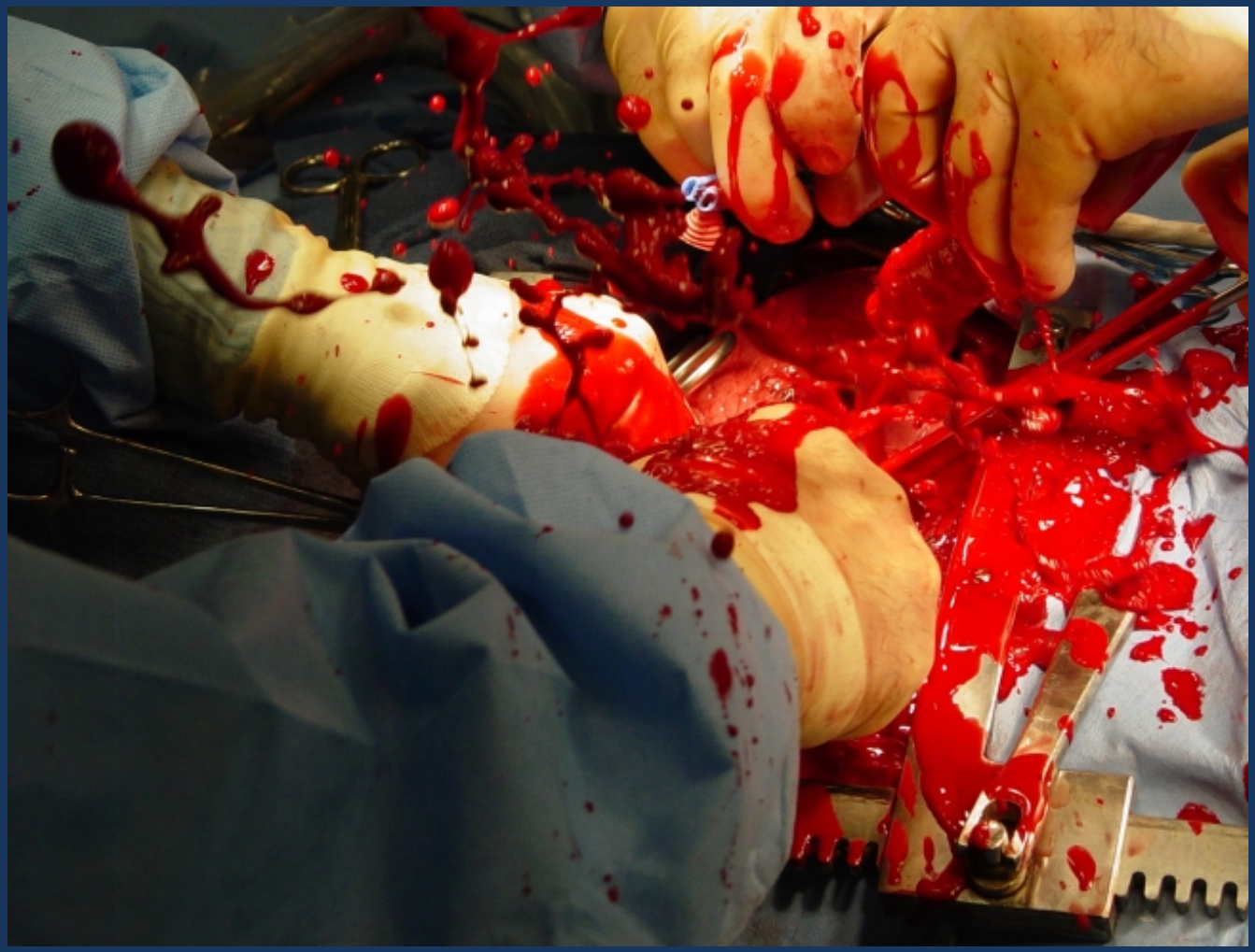

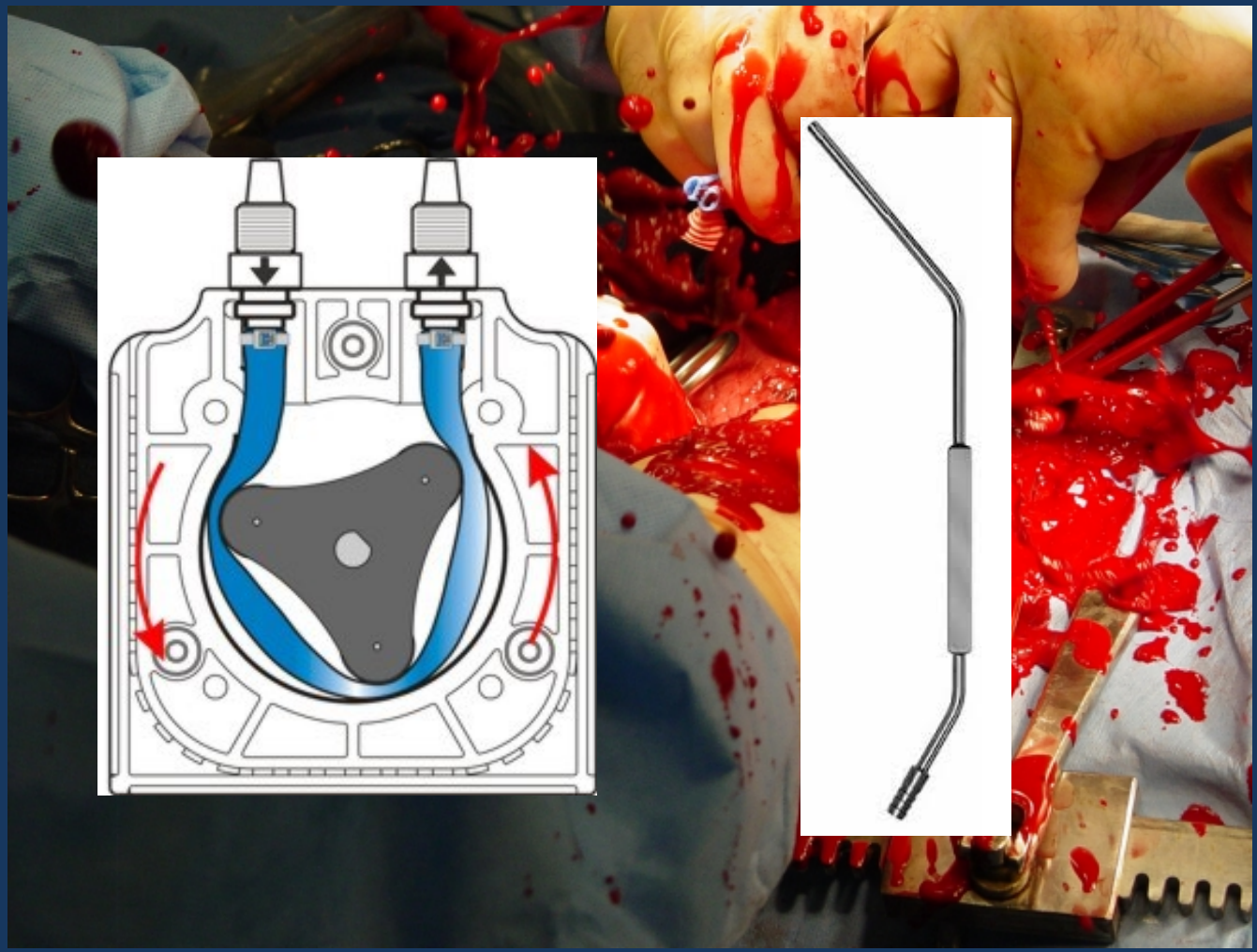

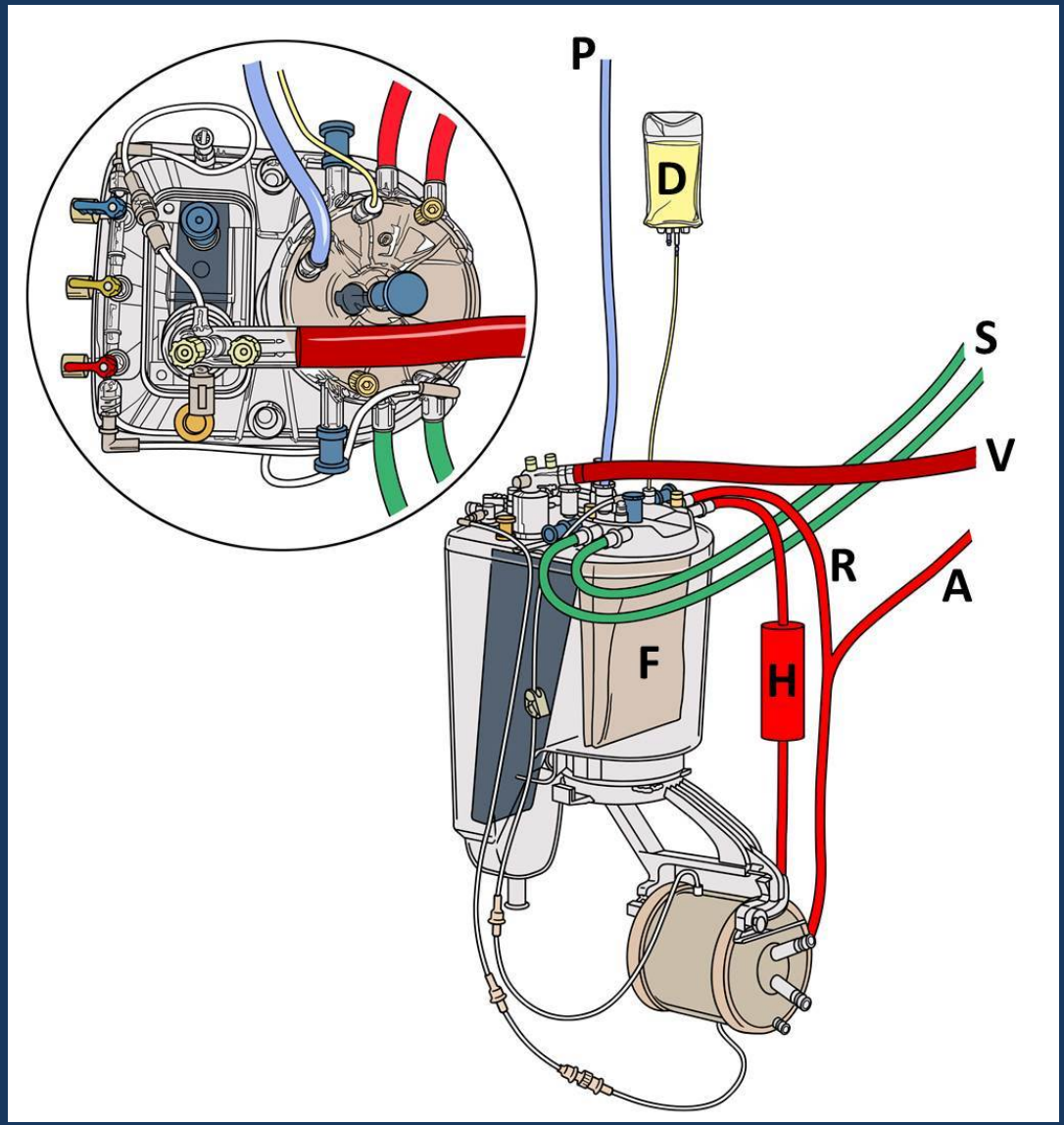
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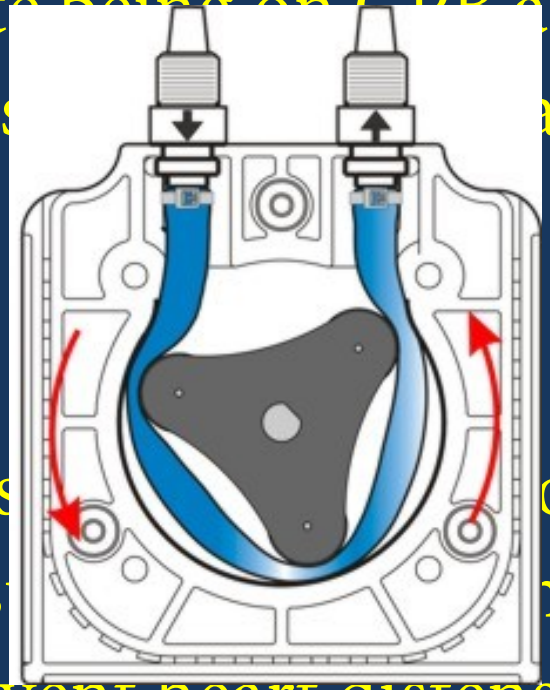
Despite being on CPB and the heart stopped, blood can still enter the heart.

It must be vented out to keep the surgical field clean and prevent heart distension

Despite being on CPR and the heart s an still



It mus o keep the s n and prevent heart distension

Cardiopulmonary Bypass

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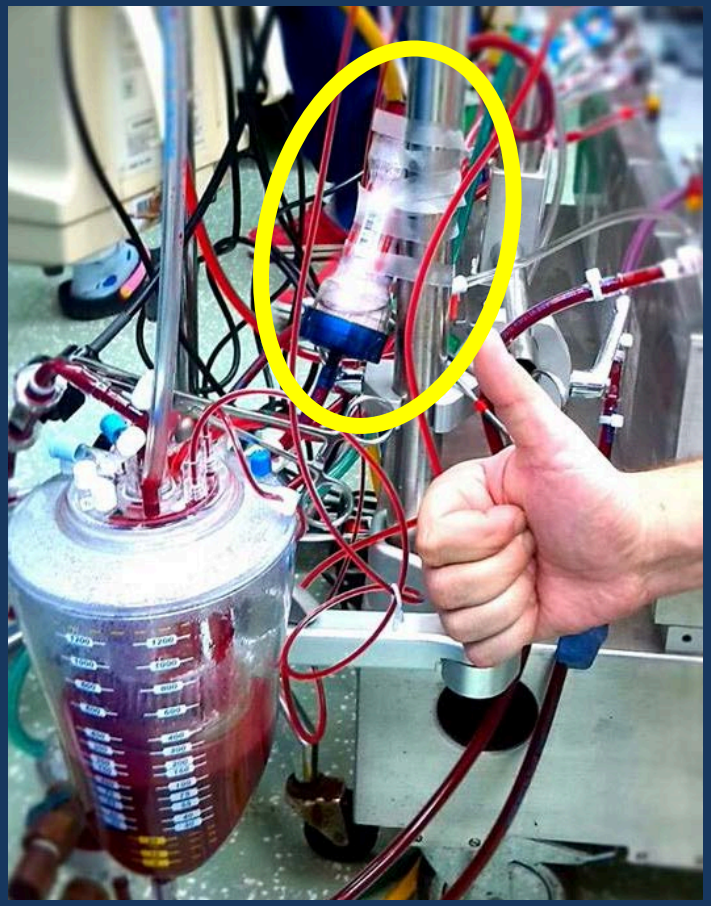
HEMOCORH·K
HPH 700



Cardiopulmonary Bypass

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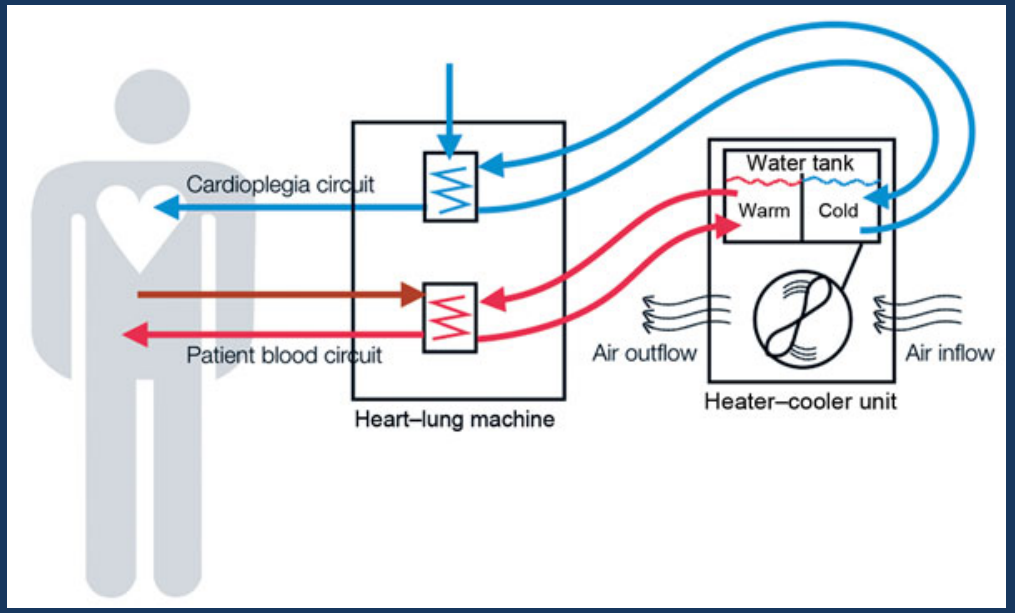
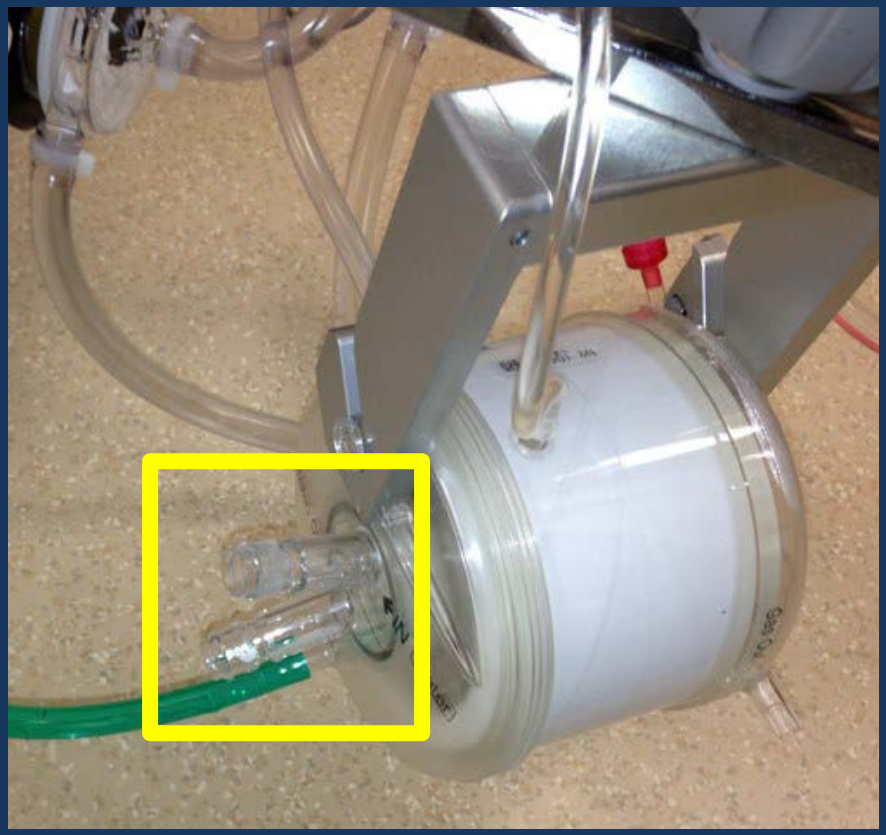

Cardioplegia circuit
Patient blood circuit
Heart–lung machine
Water tank
Warm
Cold
Air outflow
Air inflow
Heater–cooler unit




Water

Cardiopulmonary Bypass

- Circuit Complexities:
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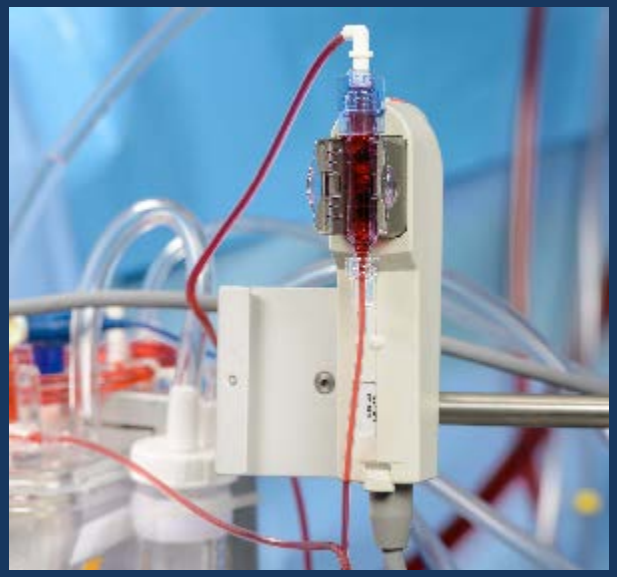
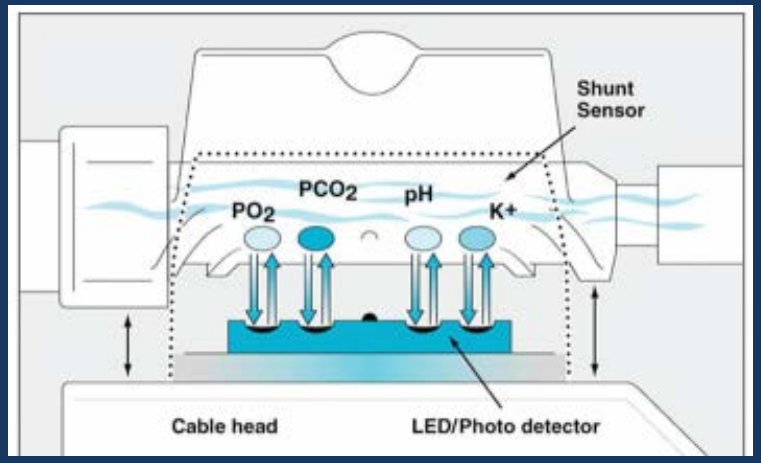
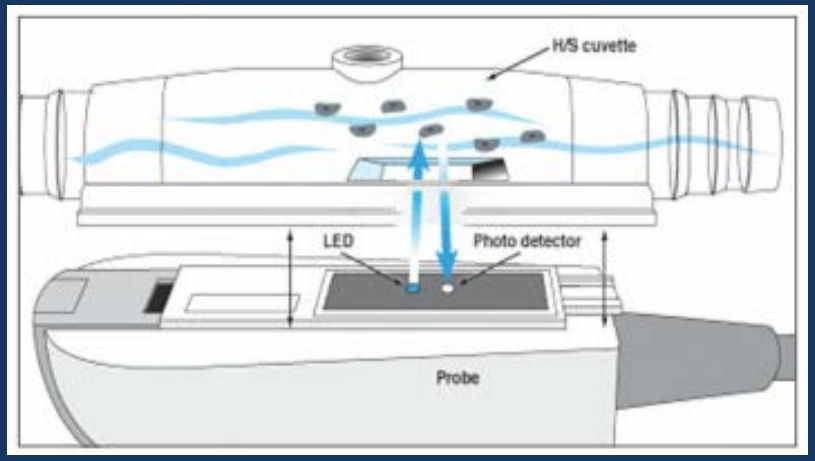
Terumo CDI-500
In-Line Blood
Monitoring System

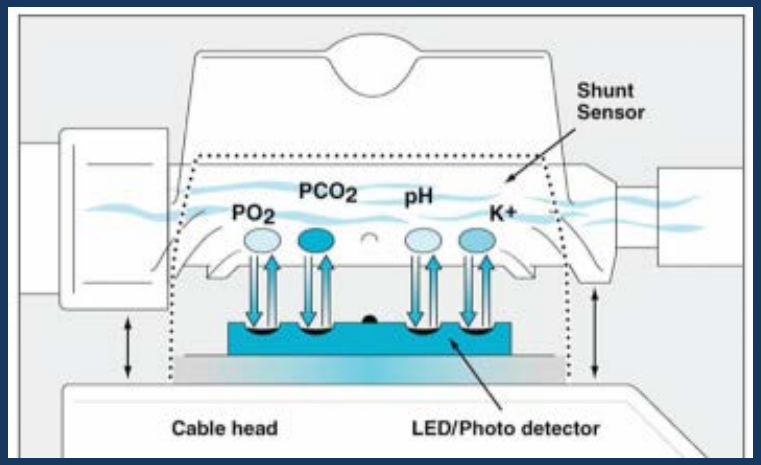




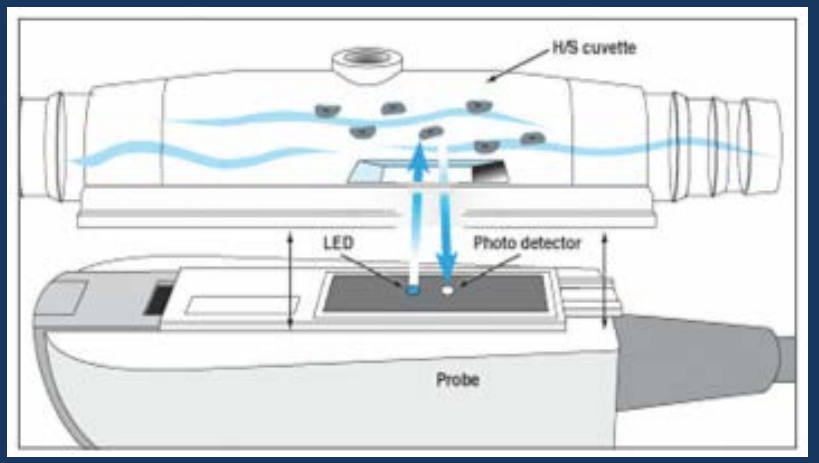
optical fluorescence



optical reflectance



optical fluorescence

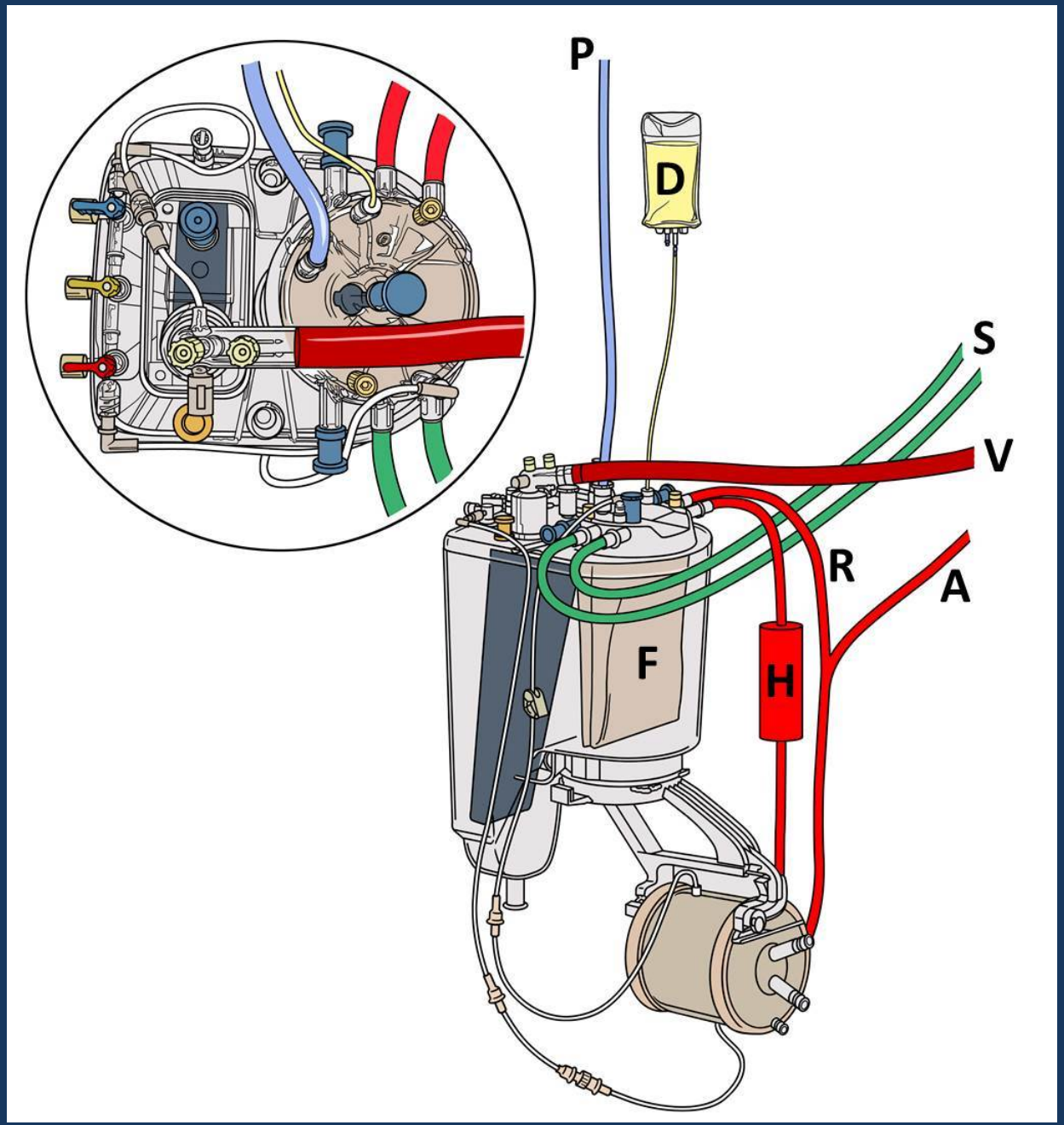


optical reflectance

recalibration 10:28

Enter new values and press the OK (√) key ...

	pH	PCO_2	PO_2	SO_2	K^+	pH	PCO_2	PO_2	SO_2	HCT	Hgb
Stored Values	7.36	38	145	97	4.3	-.--	---	---	86	37	12.5
Adjusted Values	7.36	38	145	97	4.3	-.--	---	---	86	37	12.5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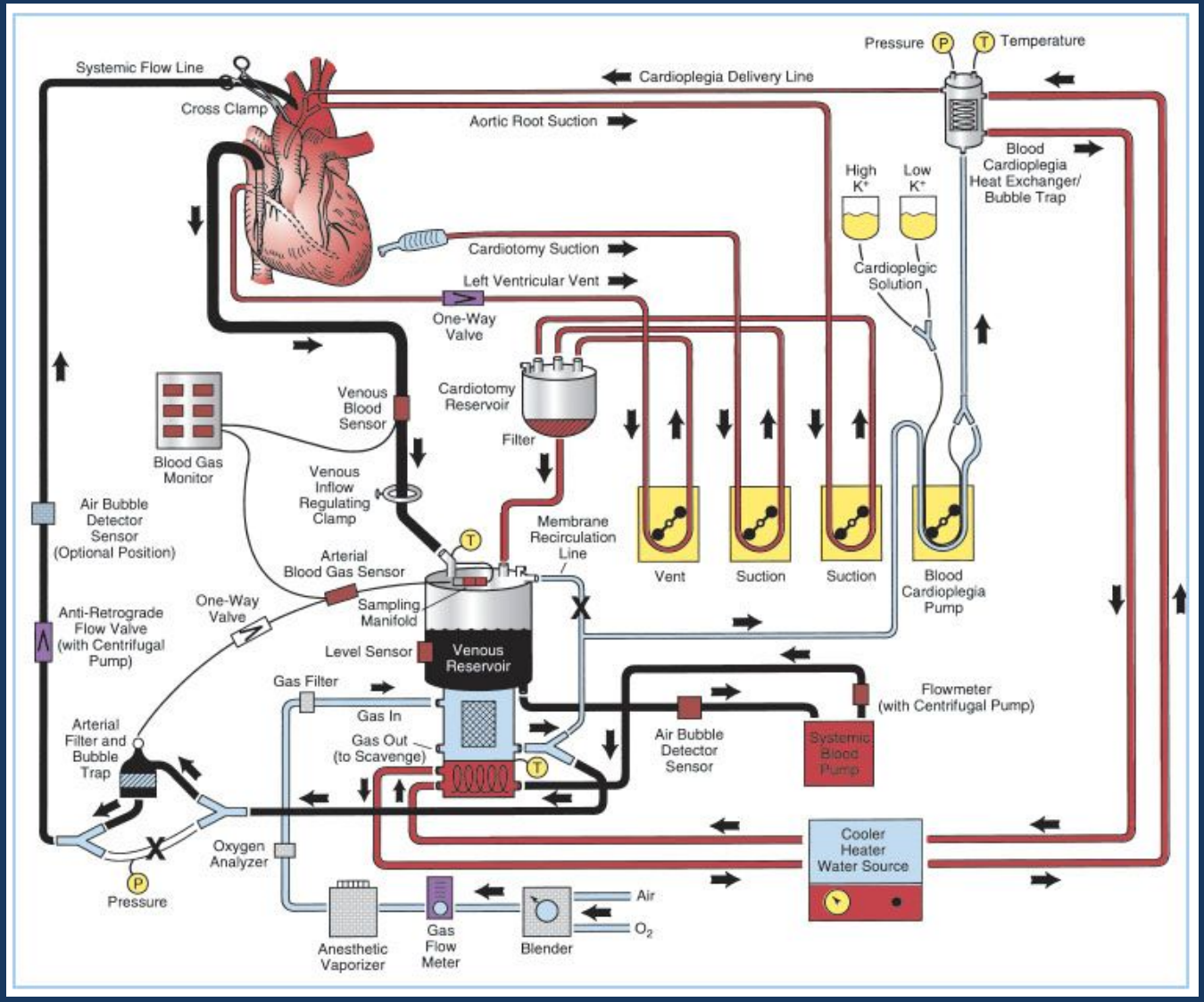

Pressure
Temperature
Systemic Flow Line
Cardioplegia Delivery Line
Cross Clamp
Aortic Root Suction
Blood Cardioplegia Heat Exchanger/ Bubble Trap
High K+
Low K+
Cardiotomy Suction
Cardioplegic Solution
Left Ventricular Vent
One-Way Valve
Cardiotomy Reservoir
Venous Blood Sensor
Filter
Blood Gas Monitor
Venous Inflow Regulating Clamp
Air Bubble Detector Sensor (Optional Position)
Membrane Recirculation Line
Vent
Suction
Suction
Blood Cardioplegia Pump
Arterial Blood Gas Sensor
One-Way Valve
Sampling Manifold
Anti-Retrograde Flow Valve (with Centrifugal Pump)
Level Sensor
Venous Reservoir
Gas Filter
Flowmeter (with Centrifugal Pump)
Gas In
Arterial Filter and Bubble Trap
Gas Out (to Scavenge)
Air Bubble Detector Sensor
Systemic Blood Pump
Cooler Heater Water Source
Oxygen Analyzer
Pressure
Air
O_2
Anesthetic Vaporizer
Gas Flow Meter
Blender

Concepts unique to Extracorporeal Circulation

Unique Concepts

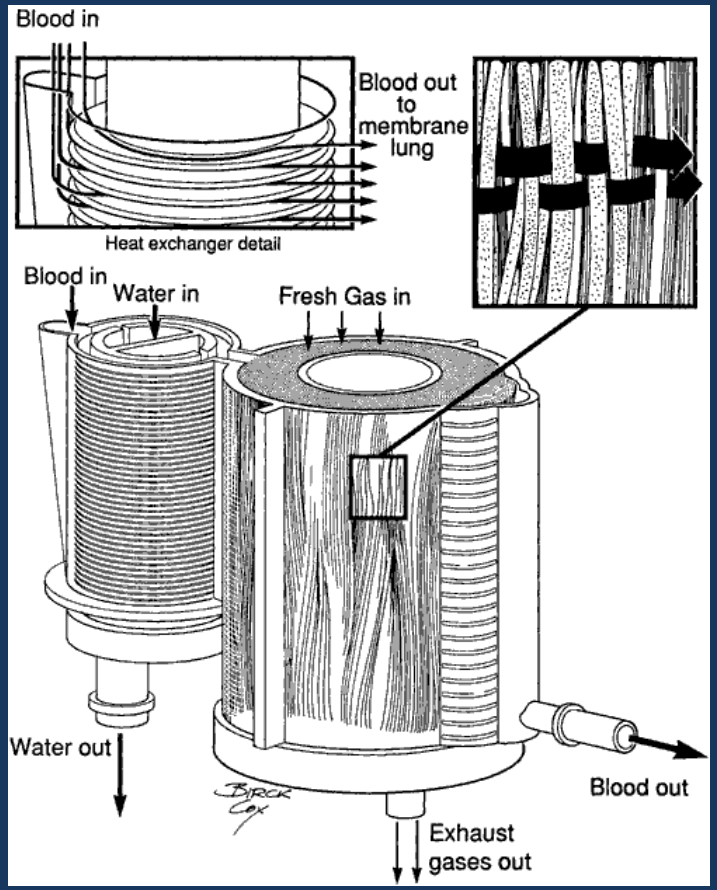
1. Rapid, dramatic changes in laboratory values
   - ✓ Blood gases
   - ✓ Electrolytes and pH
   - ✓ Anticoagulation
2. Hypothermia and blood gas management
3. Blood mixing and regional perfusion (ECMO)

Rapid Changes in Blood Gases

- We can quickly and easily manipulate pO2 and pCO2 of the blood using the rate of gas flow across the oxygenator, and the FiO2
- pO2 and pCO2 are not completely predictable due to the artificial nature of oxygenators. No two are the same.
- Efficiency changes with time, temperature, anticoagulation, viscosity, etc

Rapid Changes in Blood Gases

- We can quickly and easily manipulate pO_2 and pCO_2 of the blood using the rate of gas flow across the oxygenator, and the FiO_2
- pO_2 and pCO_2 are not completely predictable due to the artificial nature of oxygenators. No two are the same.
- Efficiency changes with time, temperature, anticoagulation, viscosity, etc



Rapid Changes in Blood Gases

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Rapid Changes in pH

Why does pH change rapidly?

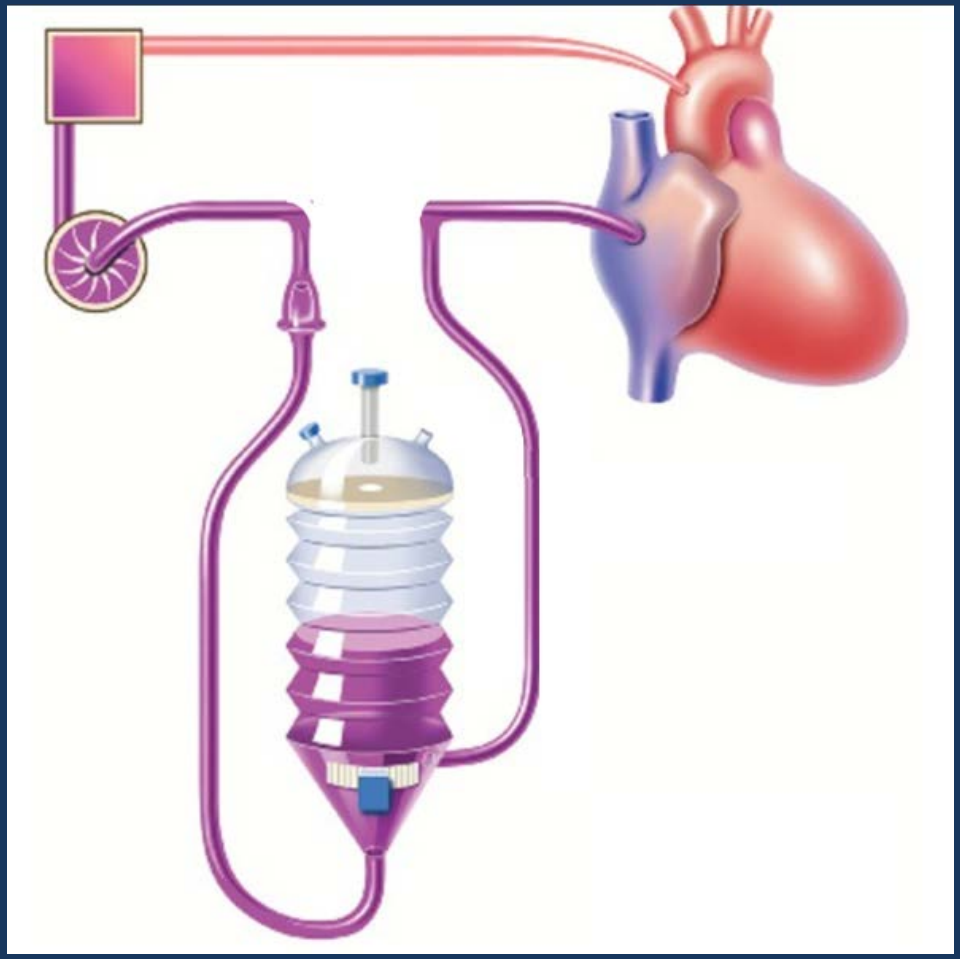
- Changes in pCO_2
- Changes in temperature
- Drugs such as sodium bicarbonate, THAM, etc
  - Sometimes boluses, sometimes drips
- Solutions such as NaCl

Rapid Changes in Electrolytes

What other values do we monitor closely?

- Potassium!
  - Delivery of cardioplegia can result in the patient getting as much as 30 mEq of potassium in only a few minutes
- Sodium and chloride (Saline)
- Calcium
  - We want this low during bypass, correcting it prior to weaning from bypass
  - Can cause ischemic damage due to contracture
- Bicarbonate (drugs such as sodium bicarbonate)
  - Lactic acidosis can occur during CPB

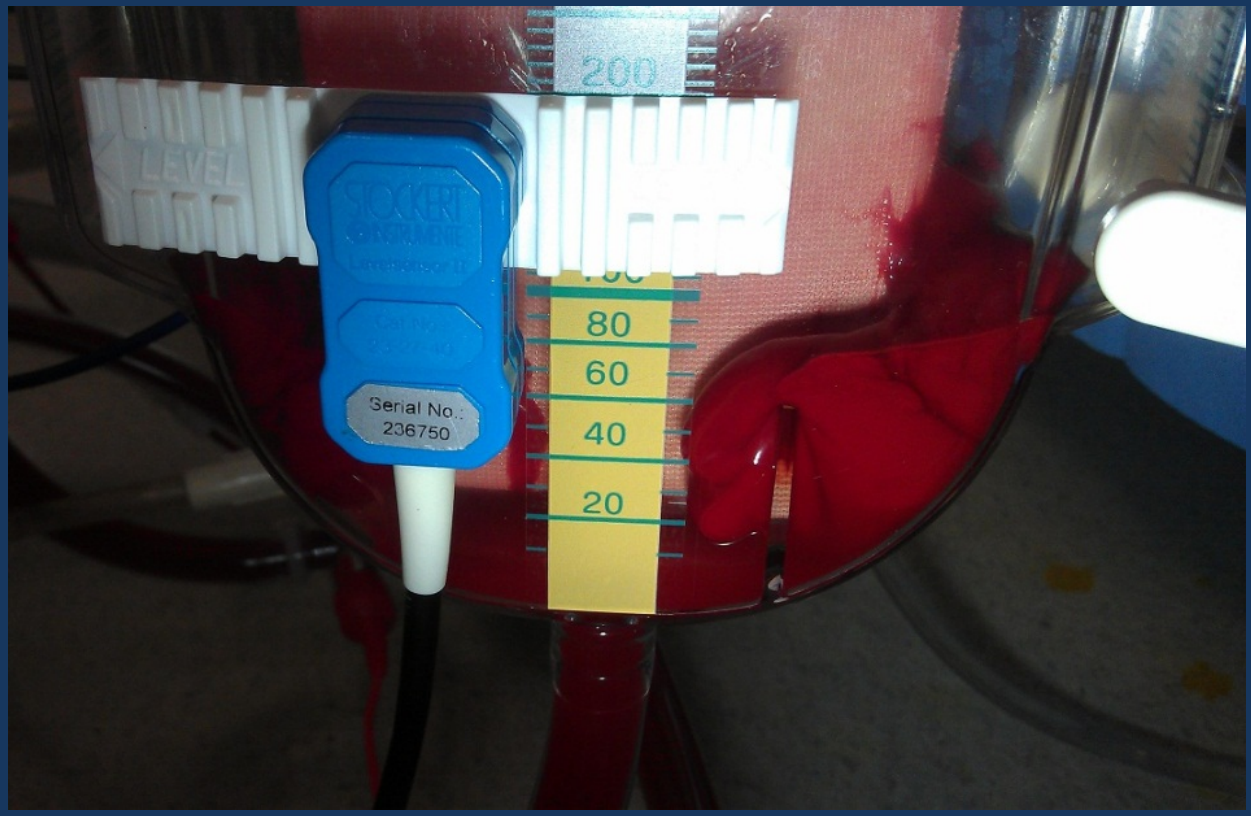
Rapid Changes in Anticoagulation



Rapid Changes in Anticoagulation

Activated clotting time (ACT)

- Target ACT during bypass = >480 seconds
  - Normal = ~120 seconds
- Without large doses of anticoagulant such as heparin, the bypass circuit would clot off within seconds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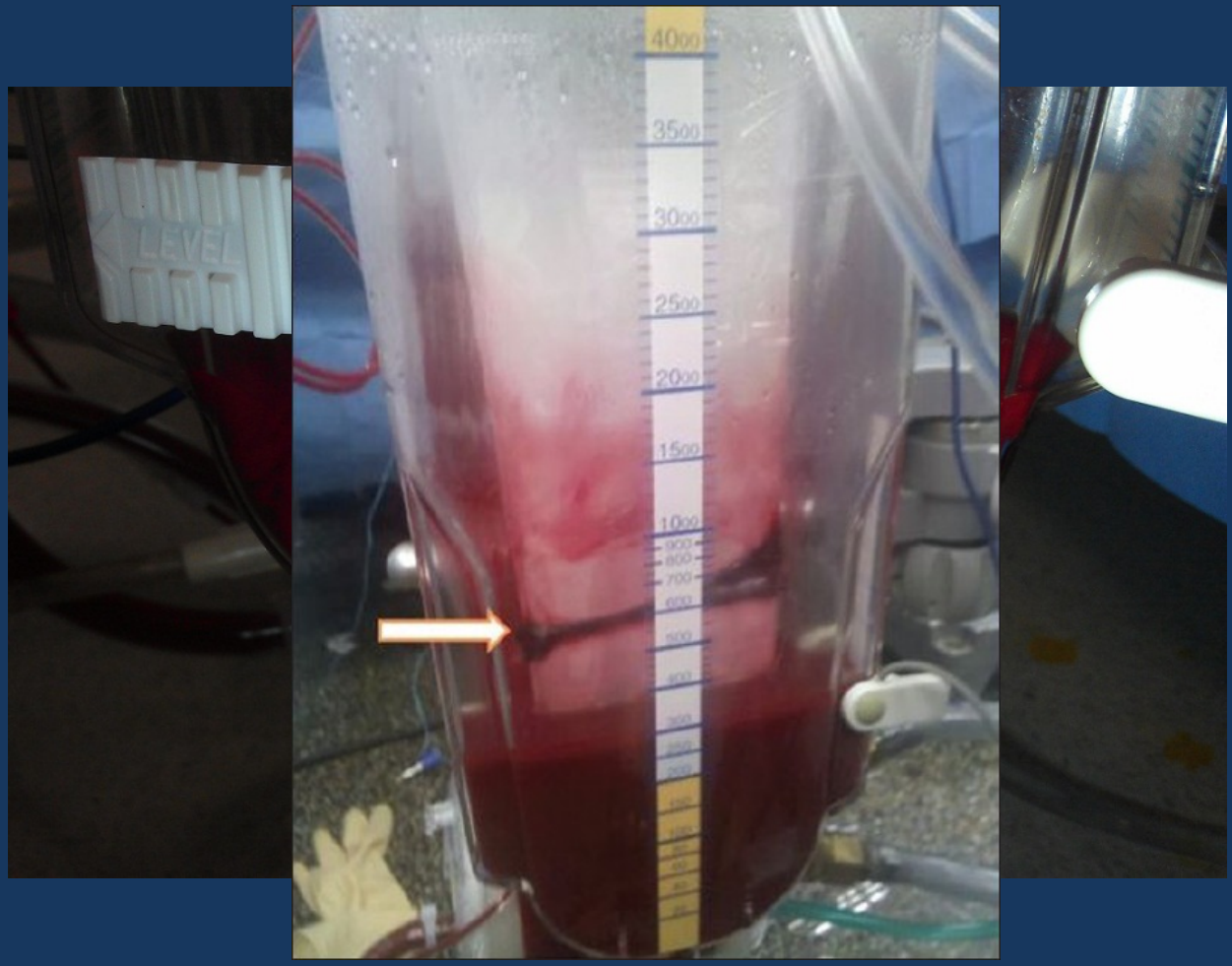
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HEPCON®
HMS PLUS
Medtronic


i-STAT
BLOOD GASES
ELECTROLYTES
CHEMISTRIES
Hgb & Hct
ACT
GLUCOSE STRIPS
CARDIAC Troponin I
Scan


HEMOCHRON® Response


HEMOCHRON® Jr.
Signature+
START
NOTE
ID
QC
DATA BASE
PRINT
CANCEL
ENTER

Unique Concepts

1. Rapid, dramatic changes in laboratory values
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Unique Concepts: Hypothermia

- ✓ Heart and brain are most vital organs to protect
- ✓ Heart gets cooled to below 10°C when arrested to protect against ischemic injury
- ✓ We sometimes cool the brain to as low as 16°C during circulatory arrest
- ✓ These changes in temperature can have a dramatic affect on blood gases

Unique Concepts: Hypothermia

Hypothermia is cytoprotective and
organ protective

7 C temperature decrease = 50% decreased metabolism

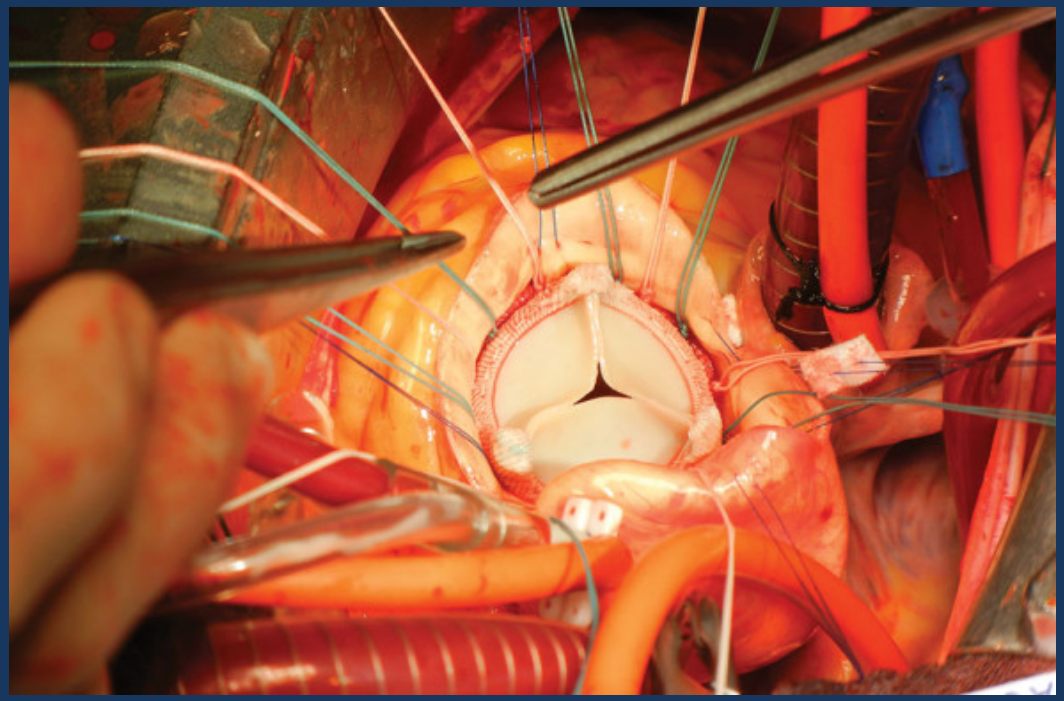
30°C = 50%

23°C = 25%

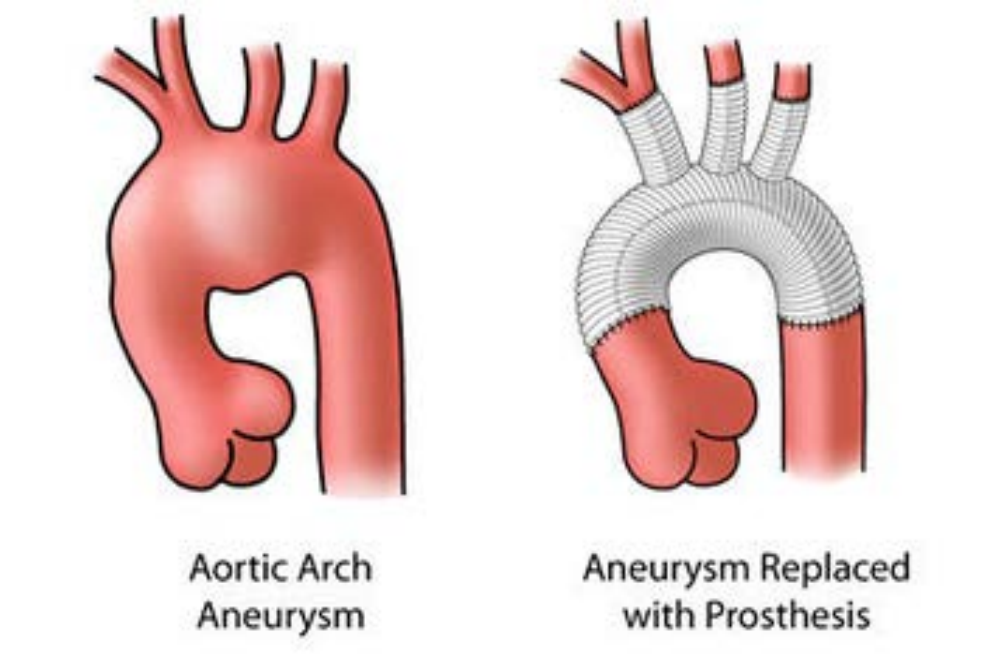
16°C = 12.5%

9°C = 6.25%

Why cool the heart?

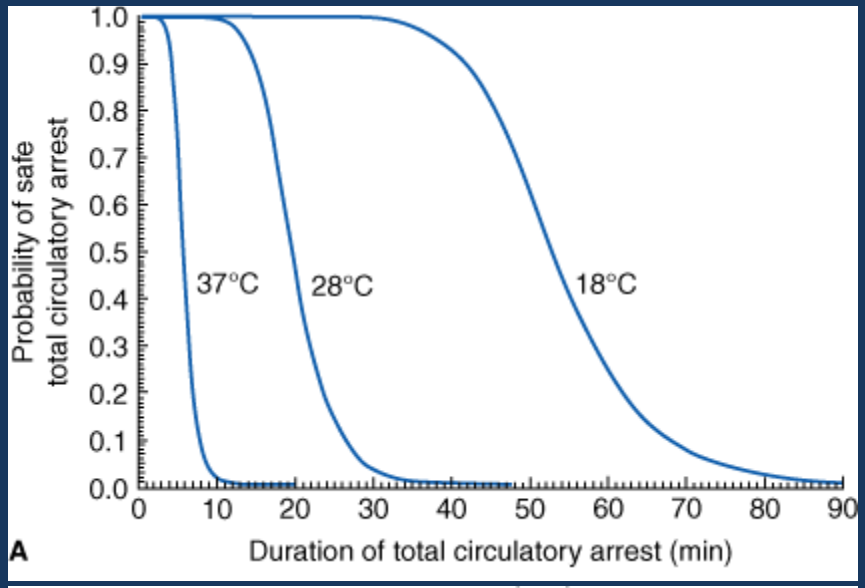


Why cool the brain?



Deep Hypothermic
Circulatory Arrest

Why cool the brain ?



Source: Cohn LH: *Cardiac Surgery in The Adult, 4th Edition*: www.accesssurgery.com

Deep Hypothermic Circulatory Arrest

Blood Temperature

"Normal" values for pH and pCO_2 are usually thought of as 7.40 and 40 mmHg. However, these values are only appropriate at 37°C.

Blood Temperature

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Why is this, and how is this important during extracorporeal circulation?

Blood Temperature

Henry's Law – the concentration of a gas is determined by the product of partial pressure and solubility

Gas content = Partial pressure x solubility

Blood Temperature

Gases are more soluble at decreased temperature, but *gas content does not change.*

Blood Temperature

What MUST happen to partial pressure if temperature decreases?

Heart is 37°C

pCO_2 = 40 mmHg

Perfusionists are totally HOT

Skin is 25°C

pCO_2 = 25 mmHg

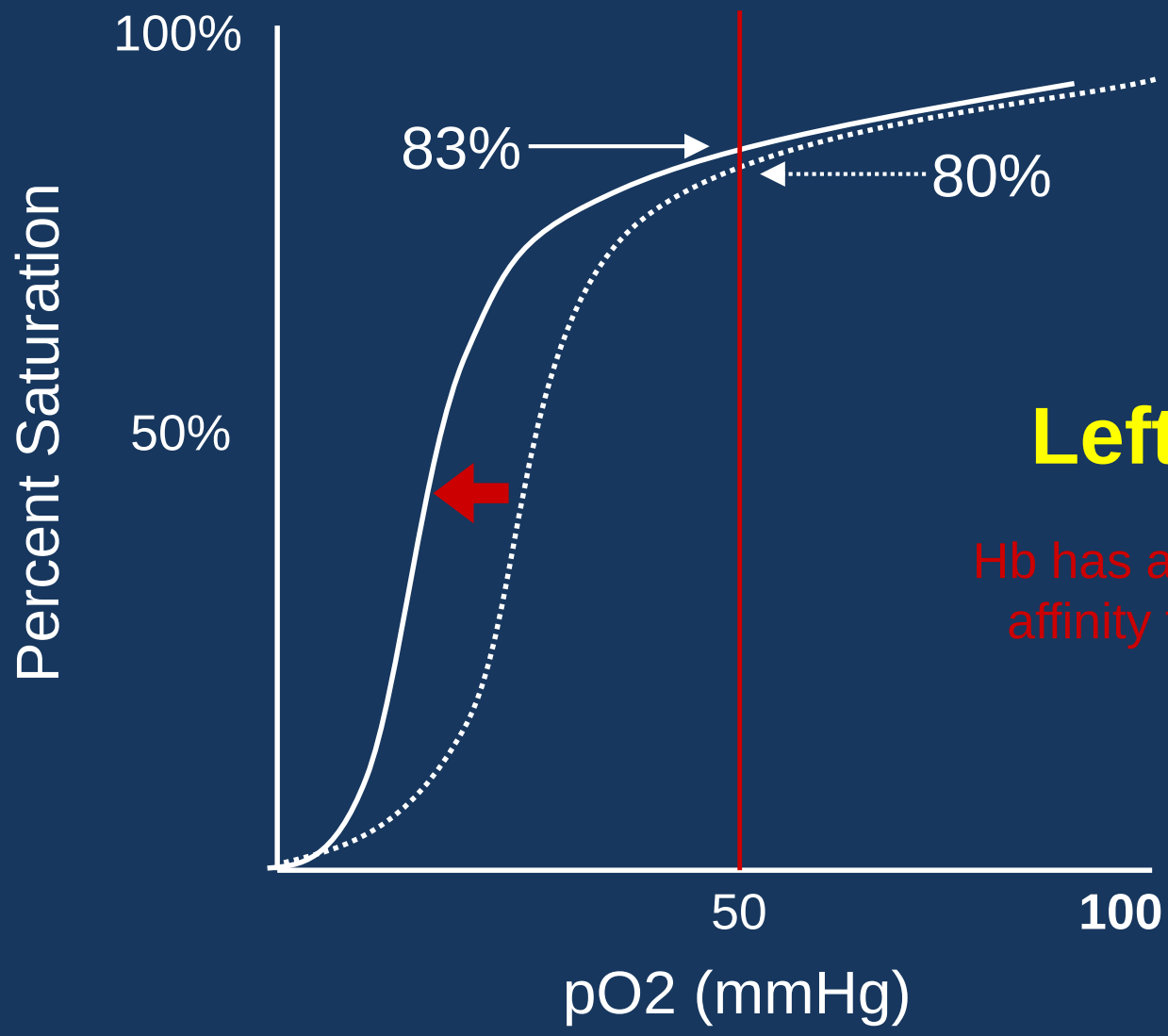
Blood Temperature

Decreased temperature = Decreased pCO_2

The problem with decreased pCO_2 ?

Cerebral vasoconstriction

Poor unloading of oxygen



Left Shift

Hb has an increased affinity for oxygen

What should we do?

Blood Temperature

pH versus alpha stat

Both are methods of pCO2 management.

Goal of BOTH techniques is to keep the pH at 7.4 and the pCO_2 near 40 mmHg.

Main difference = temperature correction

Blood is drawn from 28°C patient

Blood is placed in analyzer and warmed to 37°C

Analyzer reports as if 37°C

pH = 7.40

pCO_2 = 40 mmHg

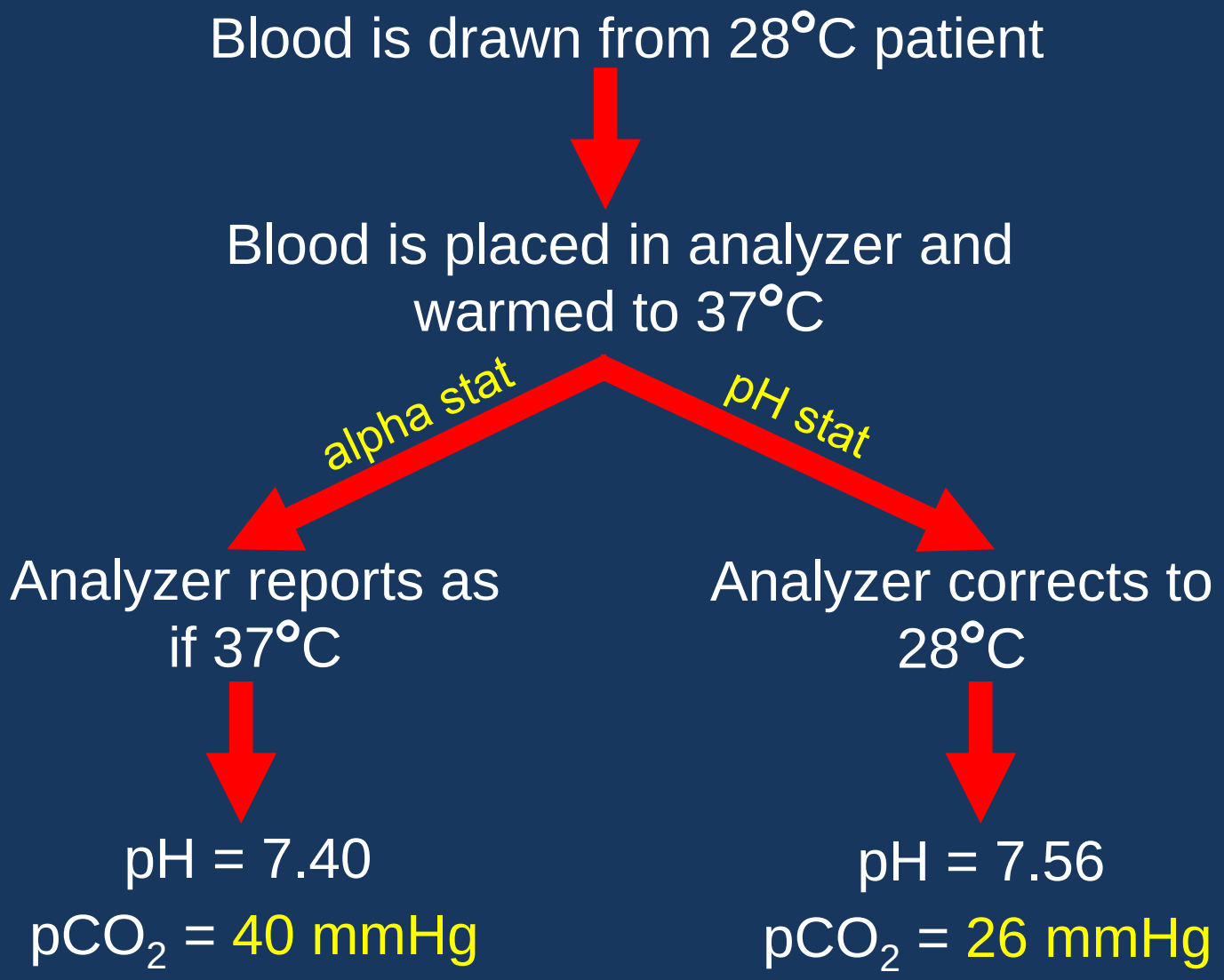
Blood is drawn from 28°C patient

Blood is placed in analyzer and warmed to 37°C

Analyzer reports as if 37°C

pH = 7.40

pCO_2 = 40 mmHg


Blood is drawn from 28°C patient
Blood is placed in analyzer and warmed to 37°C
alpha stat
pH stat
Analyzer reports as if 37°C
Analyzer corrects to 28°C
pH = 7.40
pCO2 = 40 mmHg
pH = 7.56
pCO2 = 26 mmHg

Arguments for pH stat

- ✓ High pCO_2 dilates cerebral vessels
- ✓ Good for cerebral blood flow
- ✓ Better homogenous cooling
- ✓ Counteracts the left-shift in the dissociation curve
- ✓ Better unloading of oxygen

Arguments for Alpha stat

- ✓ Preserved cellular transmembrane pH gradients
- ✓ Preserved enzyme activity
- ✓ Avoids intracranial hypertension and microembolism

Which is better?

We aren't totally sure!

Gas	Actual Solubility*	Relative Solubility
Oxygen	.024	1
Carbon Dioxide	.57	24

*Units = mL of gas / mL of solution / atmospheric pressure

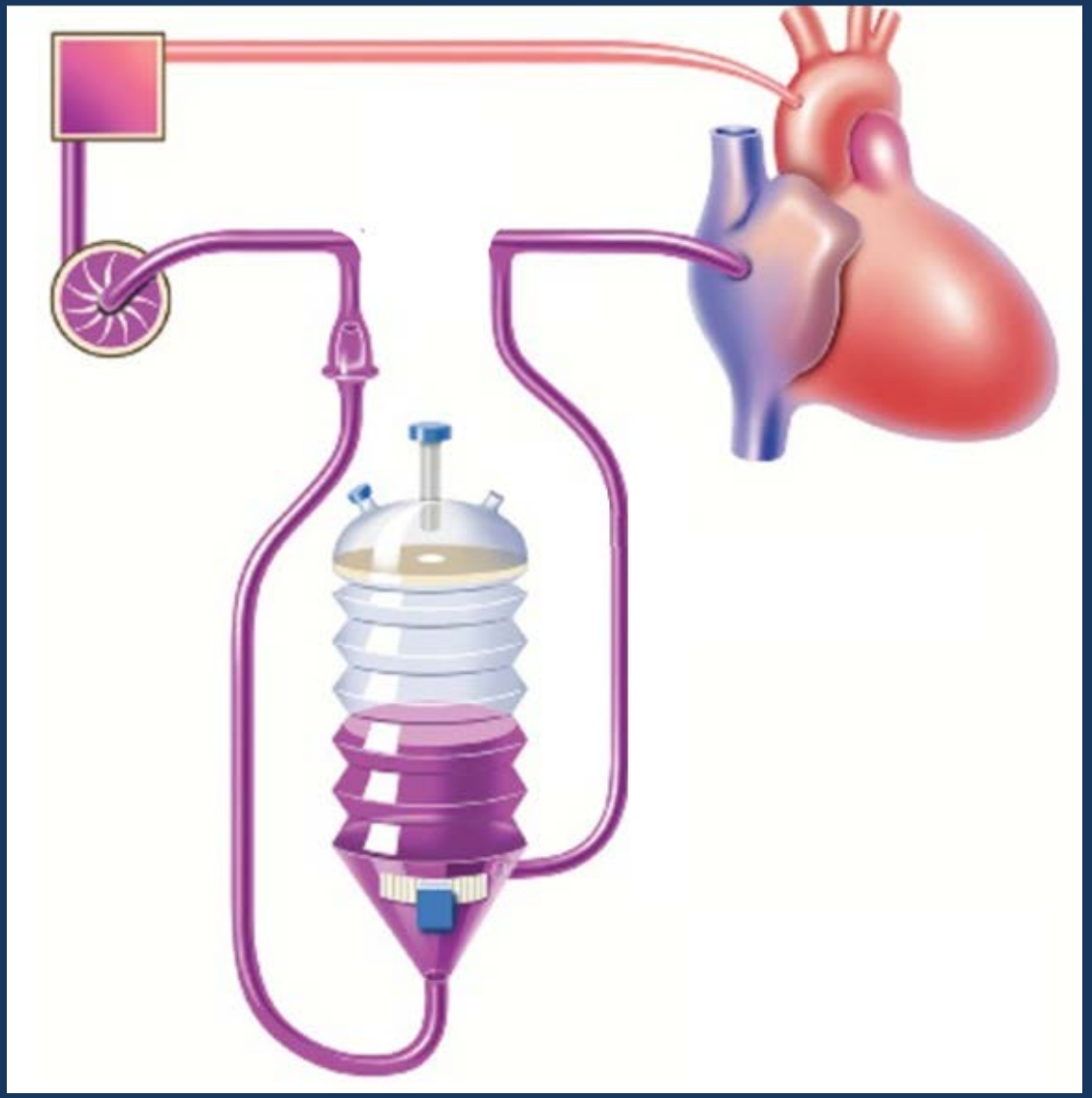
Unique Concepts

1. Rapid, dramatic changes in laboratory values
   - ✓ Blood gases
   - ✓ Electrolytes and pH
   - ✓ Anticoagulation
2. Hypothermia and blood gas management
3. Blood mixing and regional perfusion (ECMO)

What is ECMO?

ExtraCorporeal Membrane Oxygenation

CPB



ECMO

no venous reservoir ! !

ECMO

no venous reservoir ! !

What is ECMO?

Similar to CPB, but:

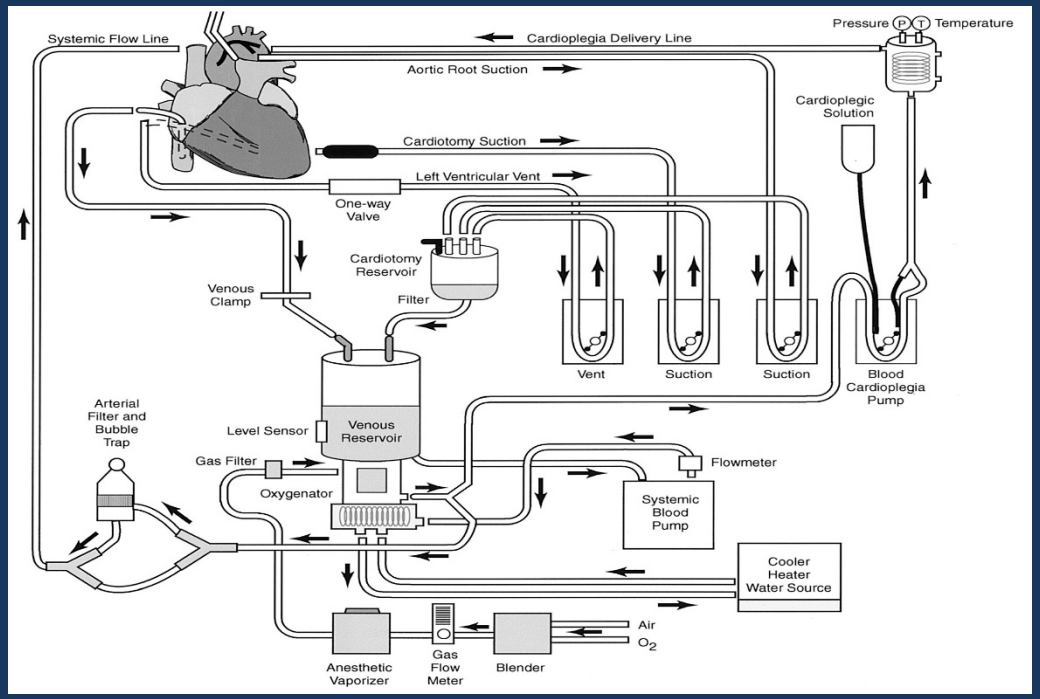
- ✓ No venous reservoir
- ✓ Less capabilities (no cardioplegia, suction, etc)
- ✓ Designed for longer-term use
- ✓ No deep hypothermia

Circuit monitoring is still important:

- ✓ Temperatures
- ✓ Pressures
- ✓ Laboratory values

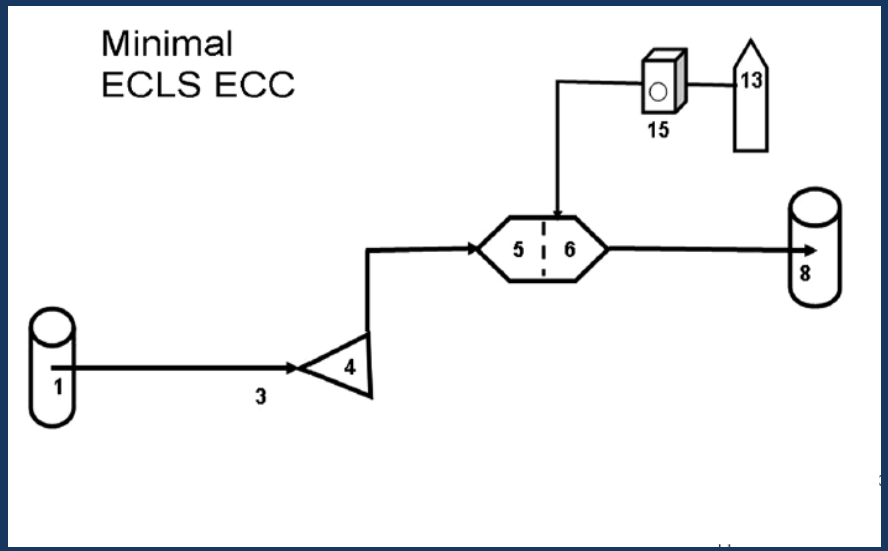
What is ECMO?

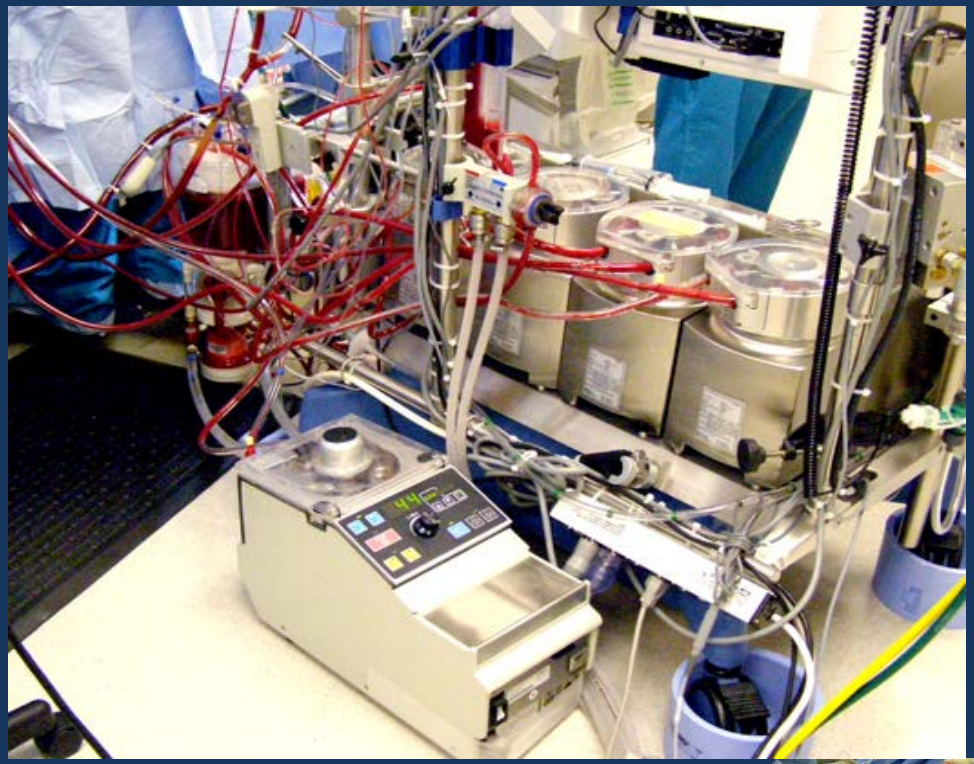
- ✓ ECMO is a temporary form of support for any recoverable cardiac and/or respiratory failure
- ✓ Support can last from a few hours to a few months
- ✓ Not a therapeutic intervention – only buys time


Systemic Flow Line
Cardioplegia Delivery Line
Pressure
Temperature
Aortic Root Suction
Cardioplegic Solution
Cardiotomy Suction
Left Ventricular Vent
One-way Valve
Cardiotomy Reservoir
Venous Clamp
Filter
Vent
Suction
Suction
Blood Cardioplegia Pump
Arterial Filter and Bubble Trap
Level Sensor
Venous Reservoir
Gas Filter
Flowmeter
Oxygenator
Systemic Blood Pump
Cooler Heater Water Source
Air
O_2
Anesthetic Vaporizer
Gas Flow Meter
Blender

CPB

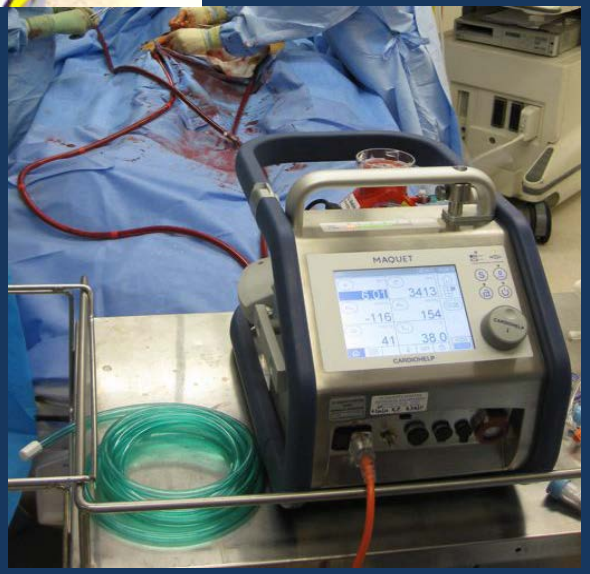
ECMO


Minimal
ECLS ECC
15
13
5
6
8
4
1
3



CPB

ECMO



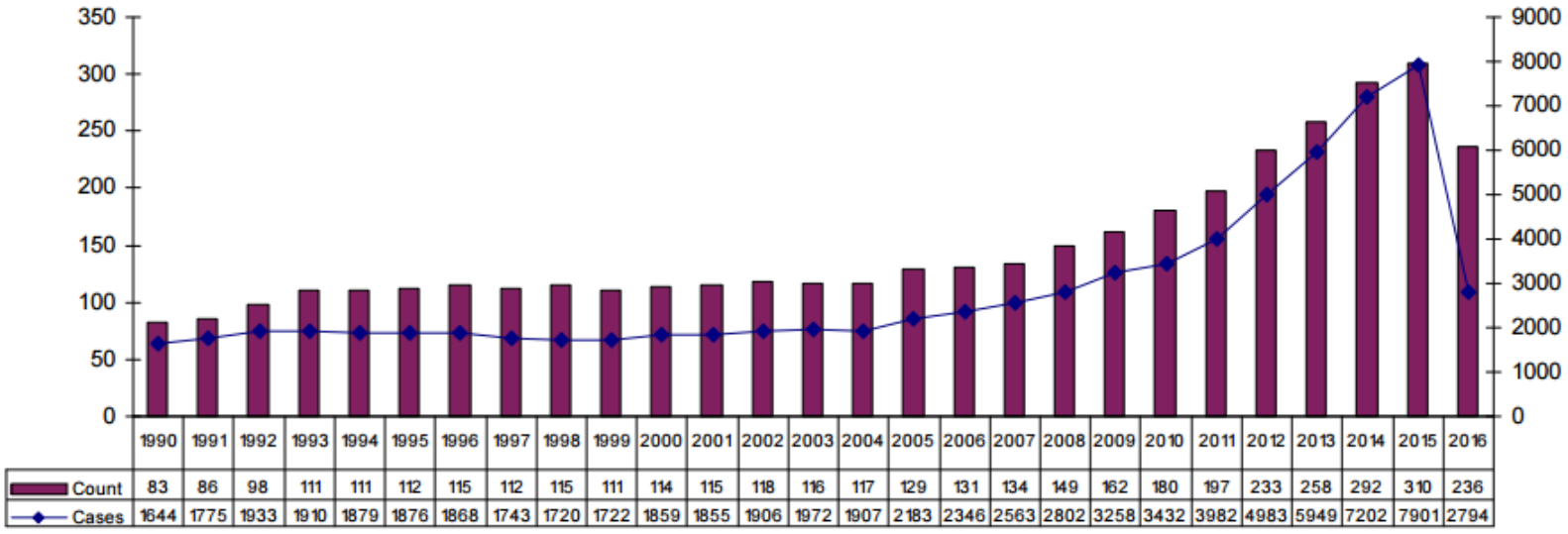
ECLS Registry Report

International Summary

July, 2016

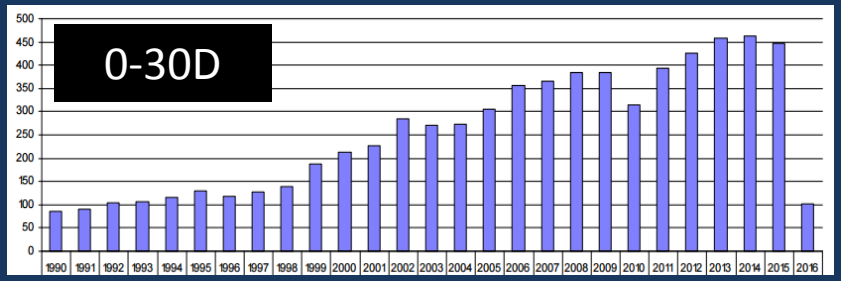
Extracorporeal Life Support Organization
2800 Plymouth Road
Building 300, Room 303
Ann Arbor, MI 48109

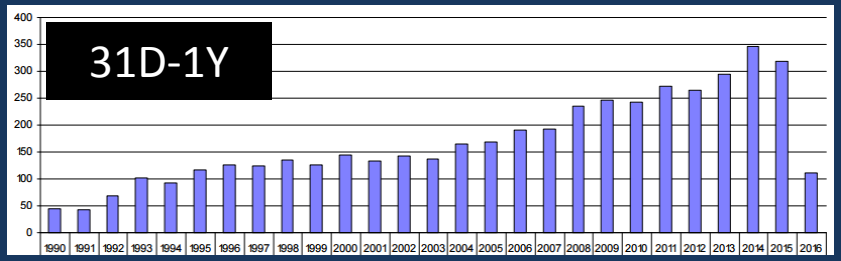
Centers by Year

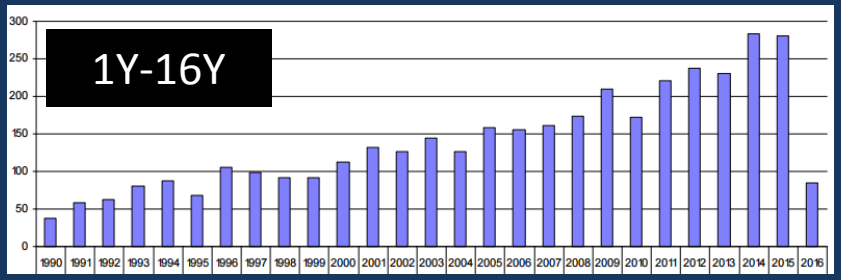


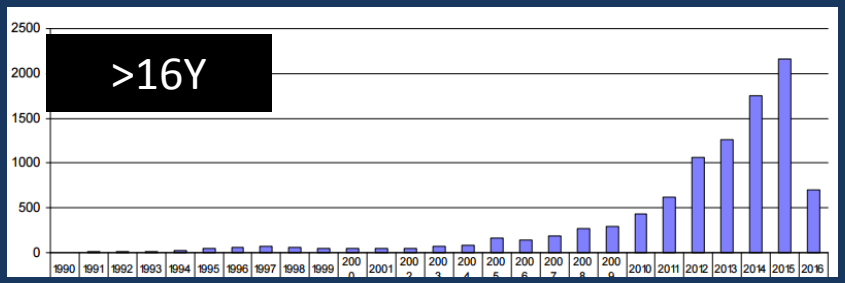
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Count	83	86	98	111	111	112	115	112	115	111	114	115	118	116	117	129	131	134	149	162	180	197	233	258	292	310	236
Cases	1644	1775	1933	1910	1879	1876	1868	1743	1720	1722	1859	1855	1906	1972	1907	2183	2346	2563	2802	3258	3432	3982	4983	5949	7202	7901	2794

Respiratory ECMO 1990 - 2016

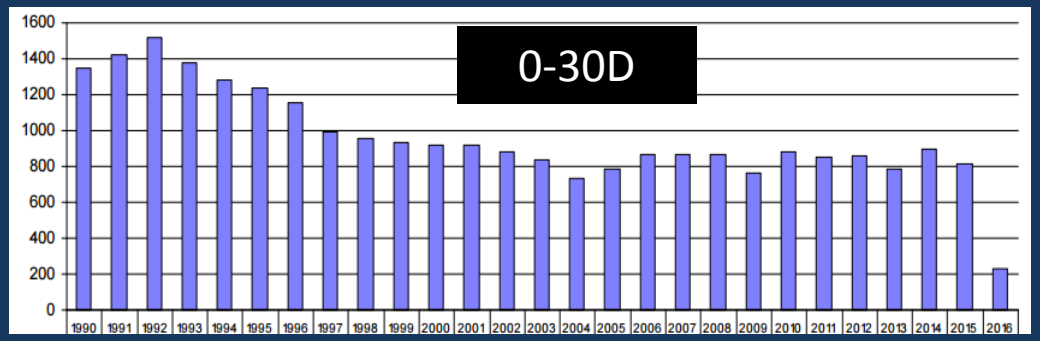


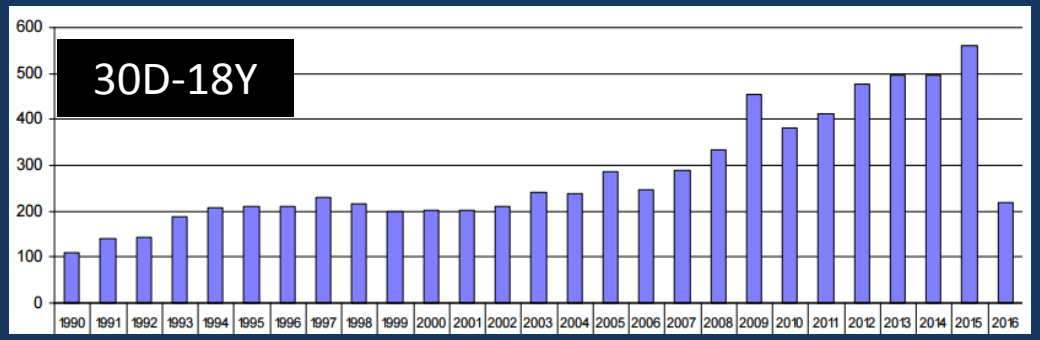


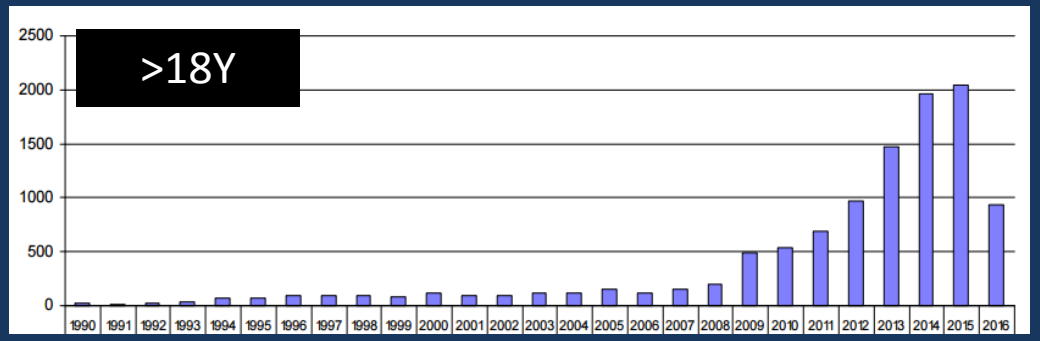




Cardiac ECMO 1990 - 2016





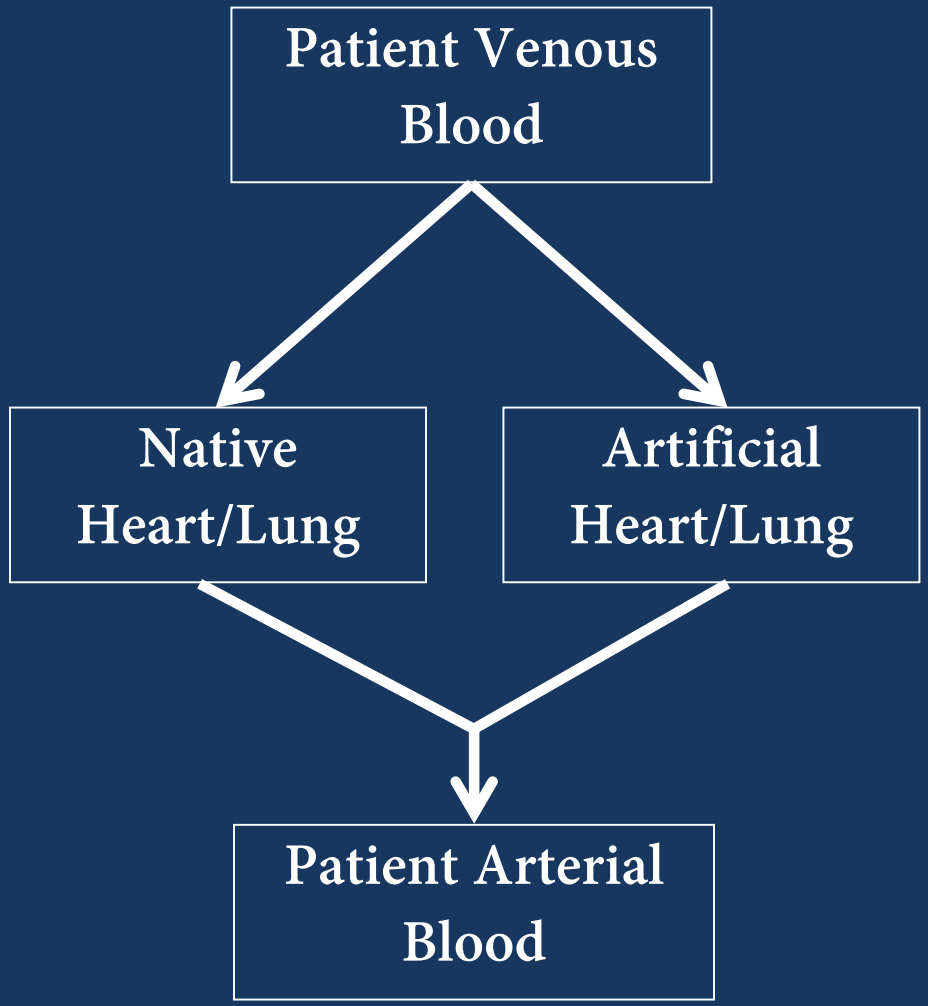


Two types of ECMO:

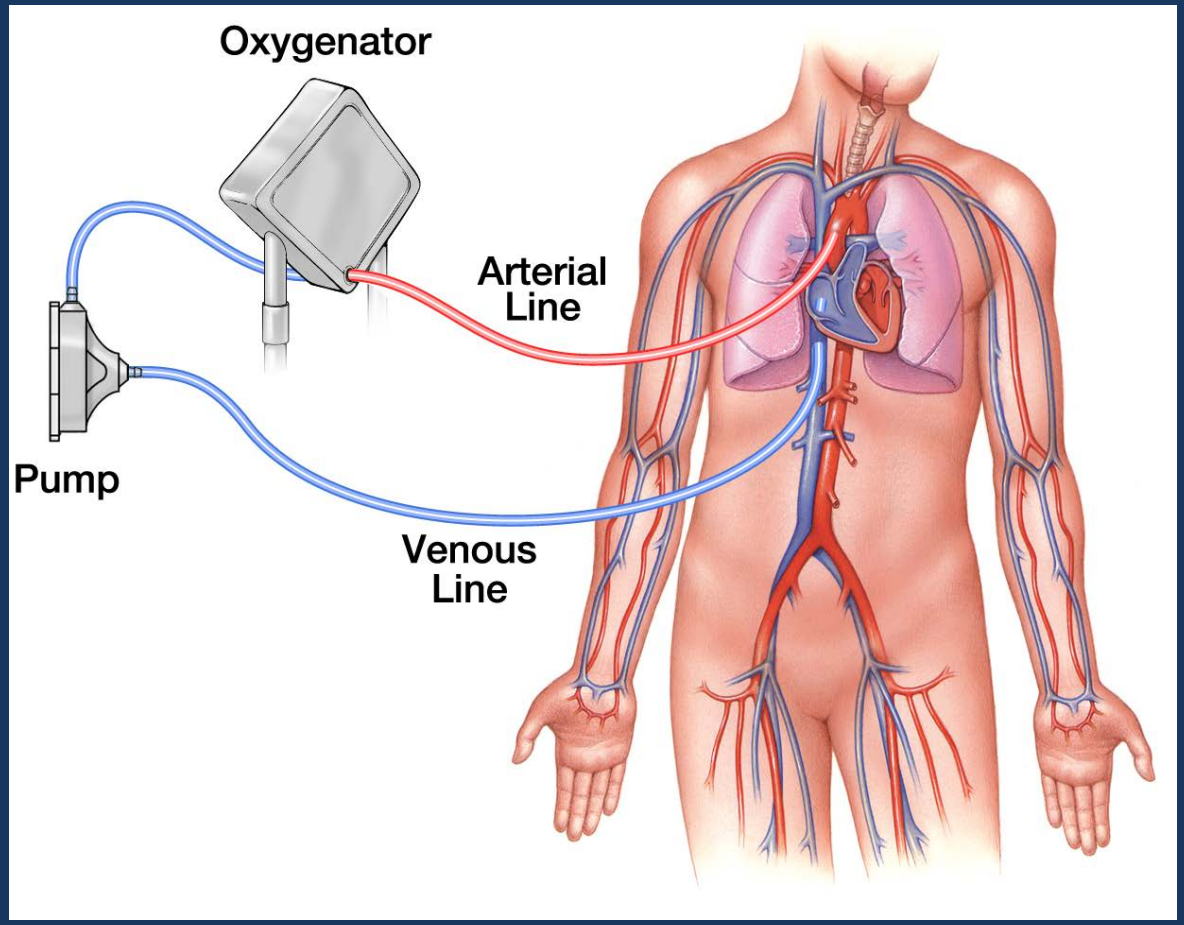
1. Veno-arterial (VA) ECMO
   - ✓ Provides cardiac and respiratory support
   - ✓ Similar to cardiopulmonary bypass

2. Veno-venous (VV) ECMO
   - ✓ Provides NO cardiac support, only respiratory
   - ✓ Analogous to an artificial lung in the right atrium

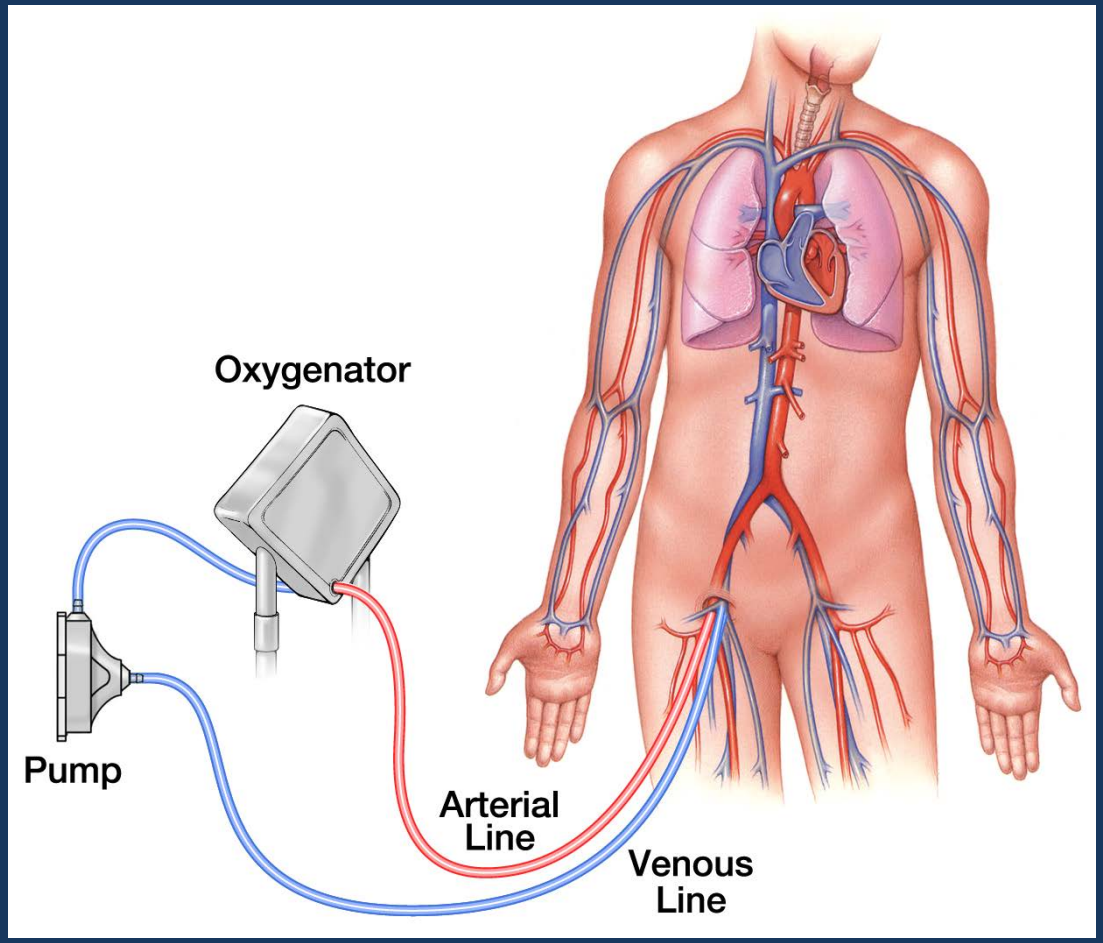
Venoarterial (VA) ECMO



VA ECMO: Central



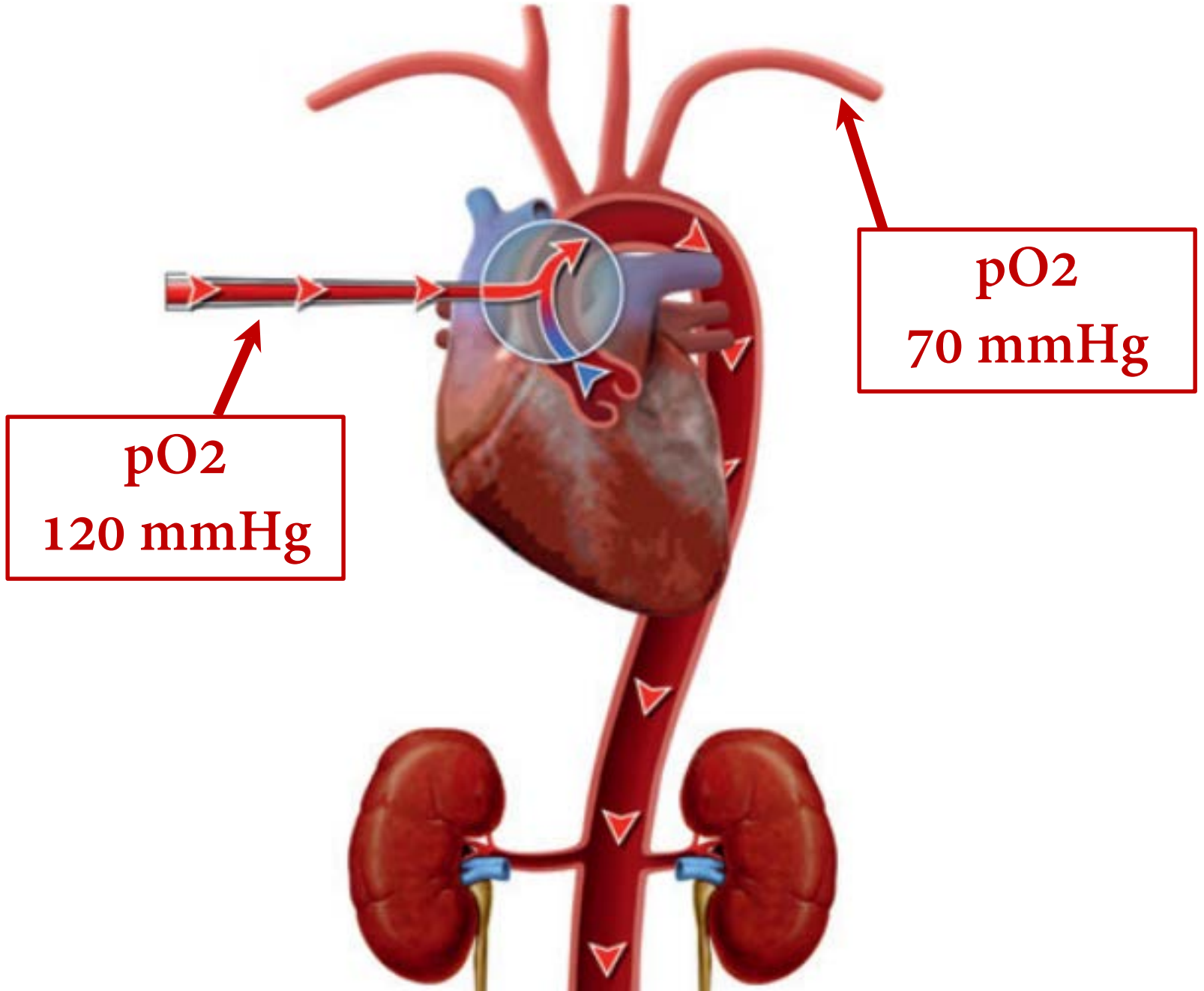
VA ECMO: Peripheral

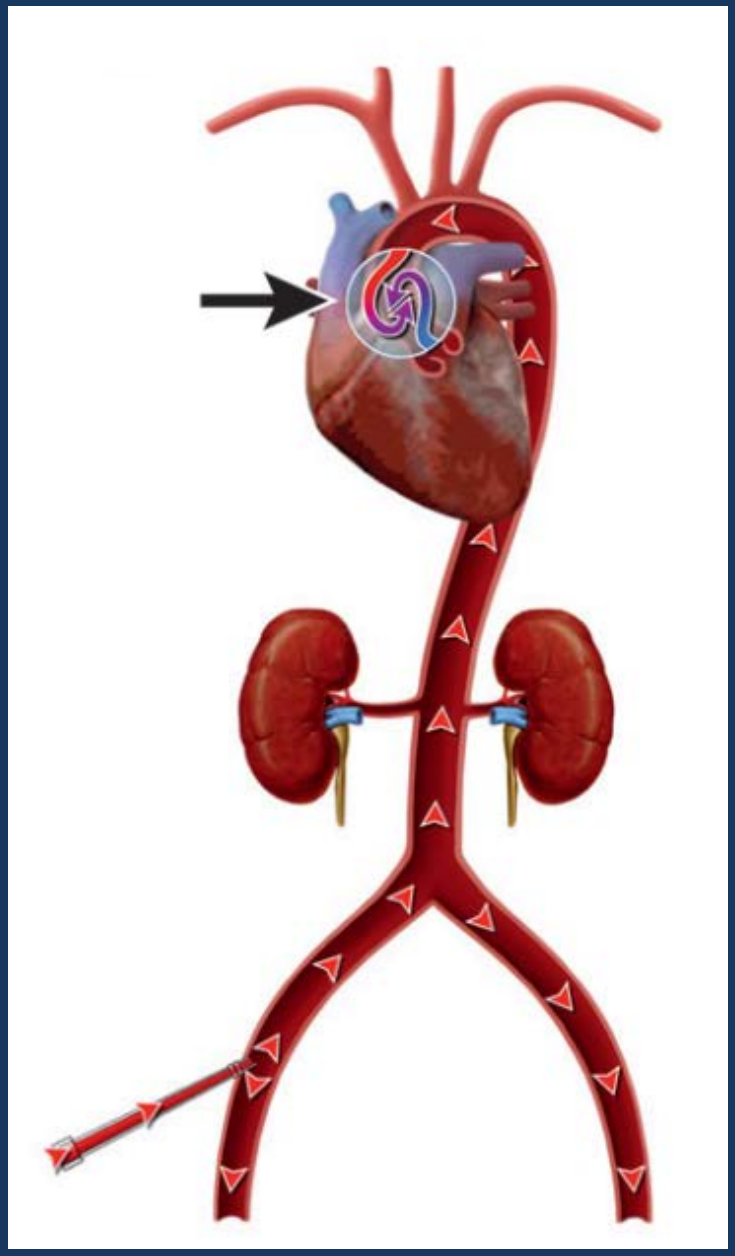


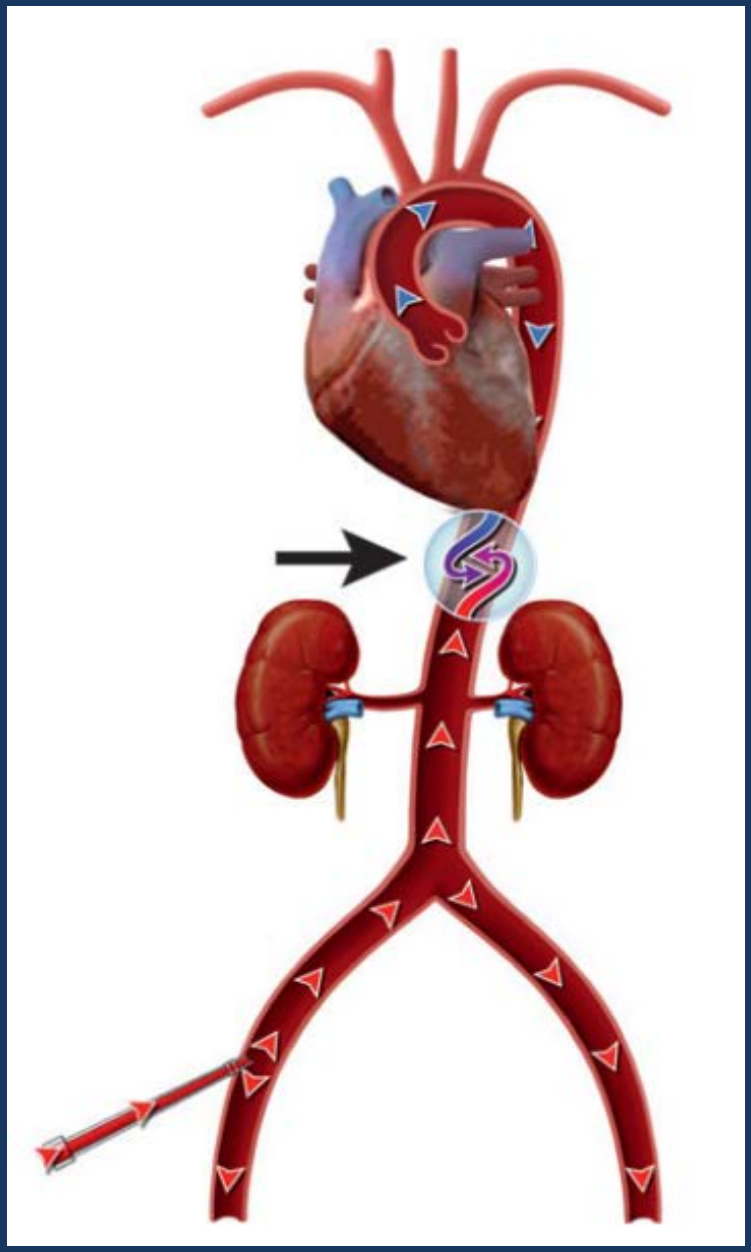
Blood Mixing During ECMO:

We often draw blood samples from multiple sites during VA ECMO.

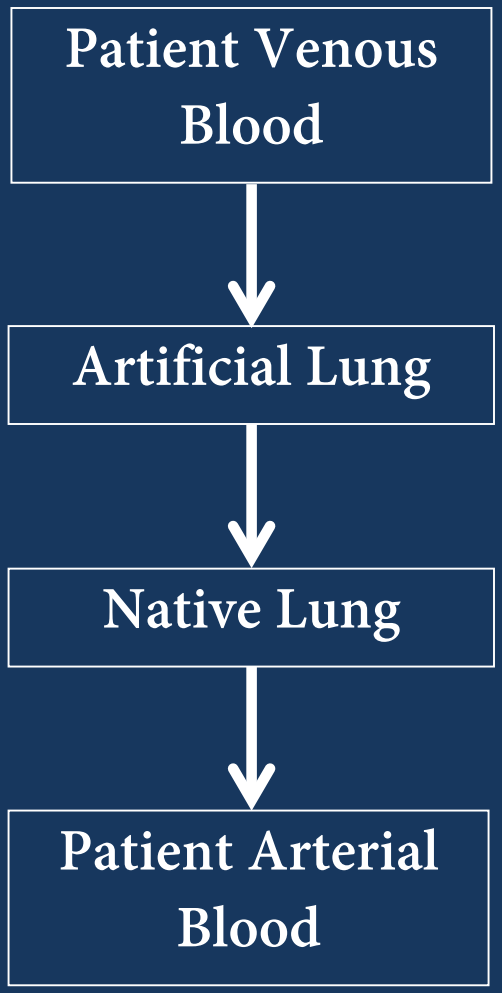
Why?

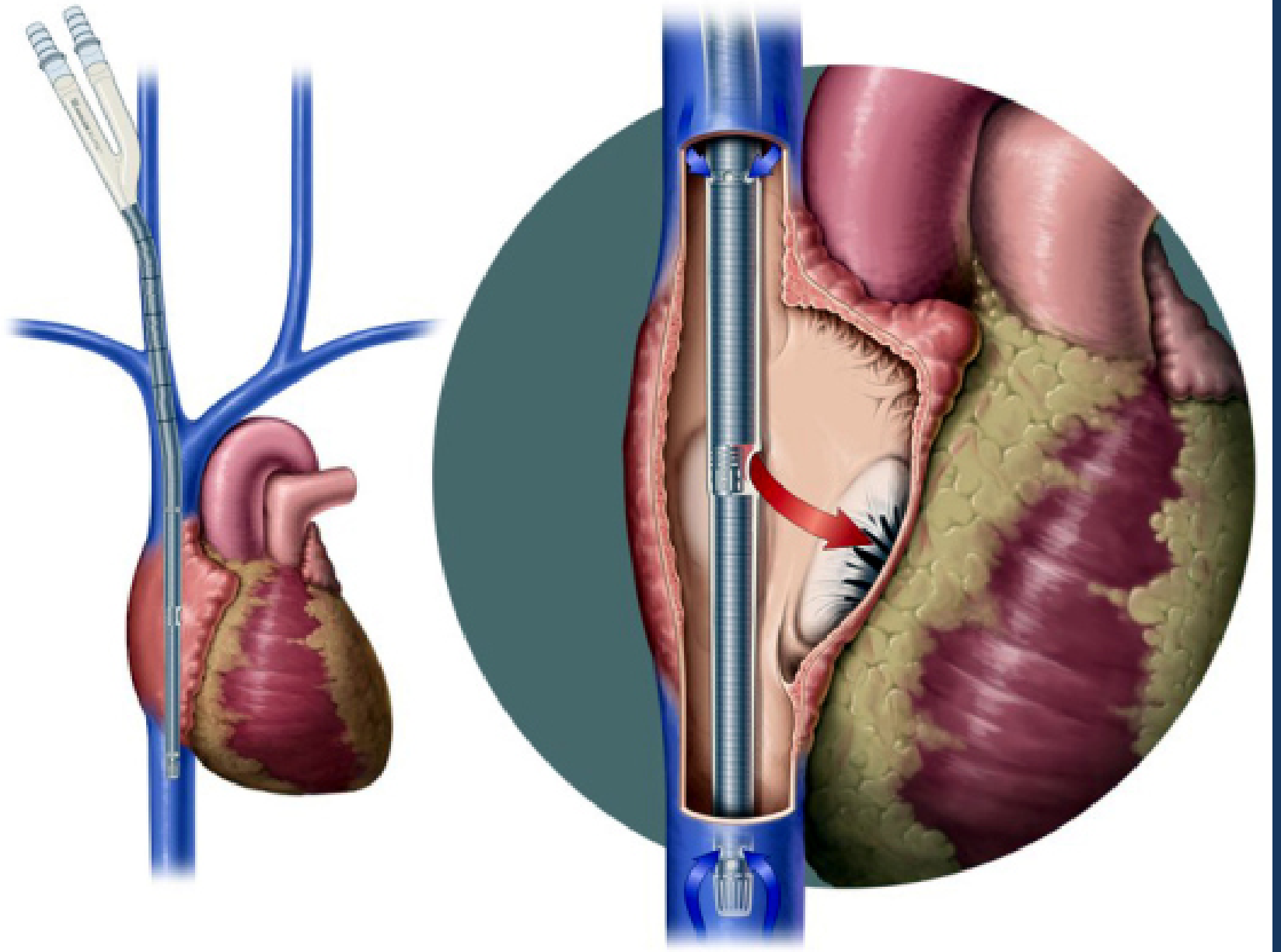

pO2
120 mmHg
pO2
70 mmHg





Venovenous (VV) ECMO





Venovenous (VV) ECMO

Blood from the ECMO circuit may not look at all like blood drawn from the actual patient

Standards and Guidelines

Standards and Guidelines – Cardiopulmonary Bypass

Guideline 9.2:

Point-of-care hemostasis monitoring should be utilized to minimize blood loss

Guideline 10.1:

Point-of-care testing should be considered to provide accurate and timely information for blood gas analysis

Standards and Guidelines – ECMO (General Guidelines)

Guideline 4a1:

ACT is measured at the bedside (not sent to the laboratory) because heparin dosing decisions are often required immediately

Standards and Guidelines – ECMO (Transport)

Guidelines for transport equipment:

A mobile ECMO system shall consist of...

- ✓ Point-of-Care anticoagulation monitoring equipment
- ✓ Point-of-care device for monitoring blood gases, electrolytes, glucose, and hemoglobin

The End