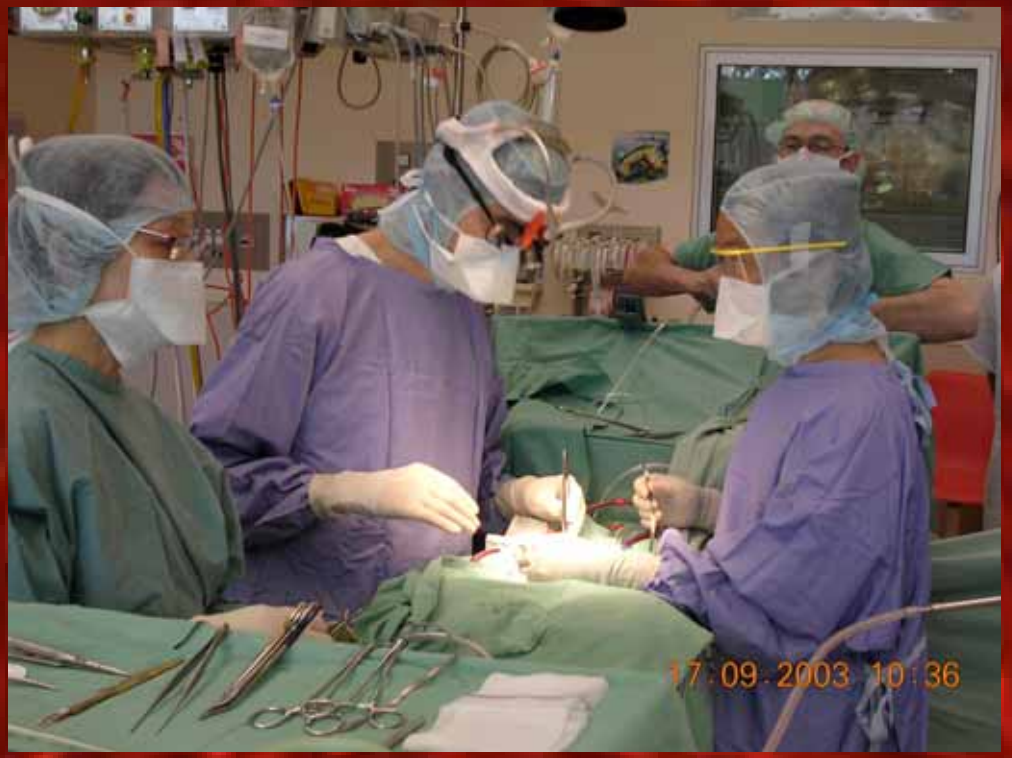
# $O_2$ & $CO_2$, Blood & Bypass.

## Operating theatre aspects.



# $pO_2$ & $pCO_2$, normal values

| | Atmosphere mmHg, % | Alveolar air mmHg, % | Expired air mmHg, % |
|---|---|---|---|
| Oxygen | 159, 21 | 104, 13.6 | 120, 15.7 |
| Carbon Dioxide | 0.3, 0.04 | 40.0, 5.3 | 27.0, 3.6 |

# $pO_2$ & $pCO_2$, abnormal values.

Congenital heart defects.

Emphysema.

Atelectasis.

Pneumonia.

Pulmonary Oedema.

Anaemia.

# Pulse Oximetry

Pulse oximetry is a simple non-invasive method of monitoring the percentage of haemoglobin (Hb) which is saturated with oxygen. The pulse oximeter consists of a probe attached to the patient's finger or ear lobe which is linked to a computerised unit. The unit displays the percentage of Hb saturated with oxygen together with an audible signal for each pulse beat, a calculated heart rate and in some models, a graphical display of the blood flow past the probe. Audible alarms which can be programmed by the user are provided. An oximeter detects hypoxia before the patient becomes clinically cyanosed.

# Pulse Oximetry

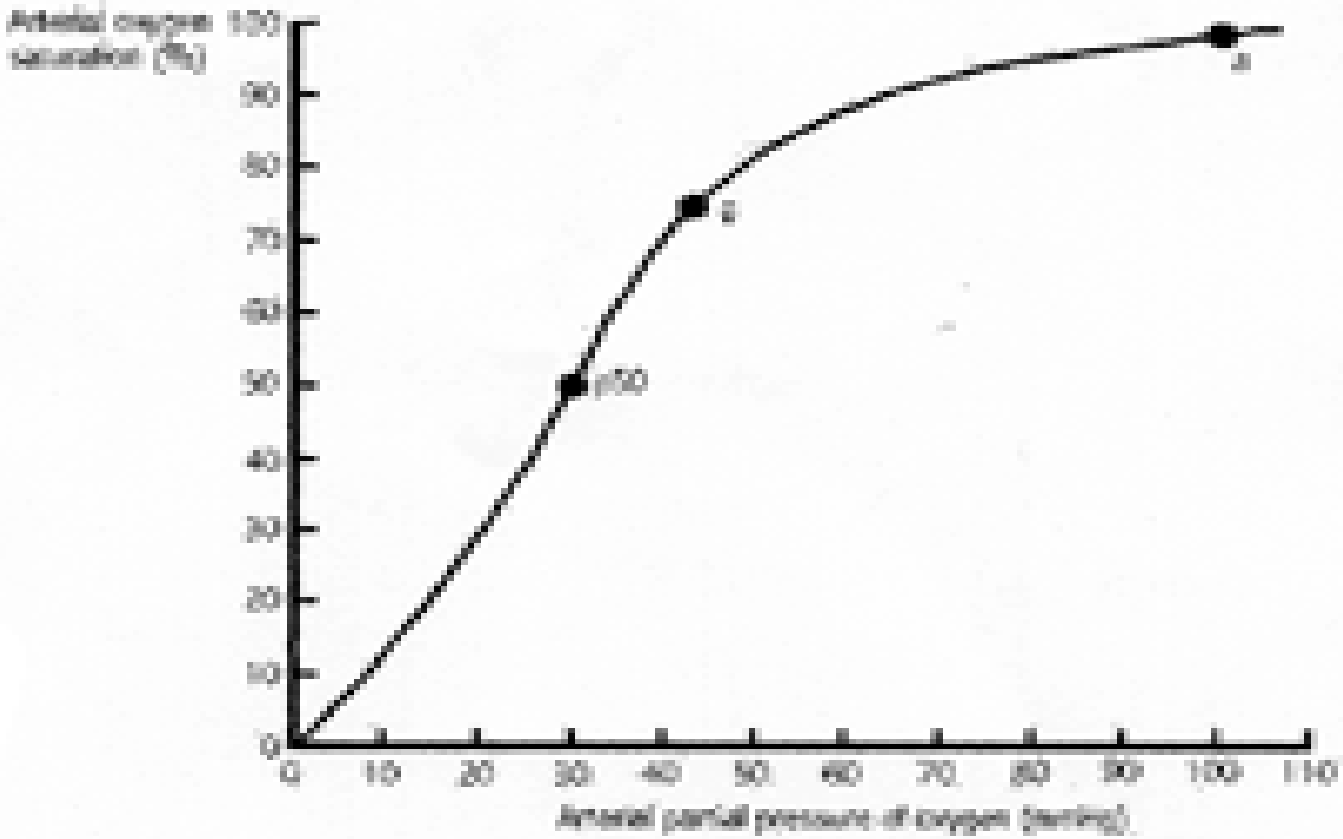
Two wavelengths of light (660 & 940 nm) used.

Intensity of colour reaching the photodetector depends on colour, skin thickness, light brightness, and absorption by arterial and venous blood in tissue.

Pulsation creates change in light path length that modifies the amount of light detected.

# $sO_2$

Oxygen Saturation




| | |
|---|---|
| *a* | *values of arterial blood* |
| $\bar{v}$ | *values of mixed venous blood* |
| *p50* | *Pa02 at which 50% Hb saturated* |

Fig 1

# $sO_2$

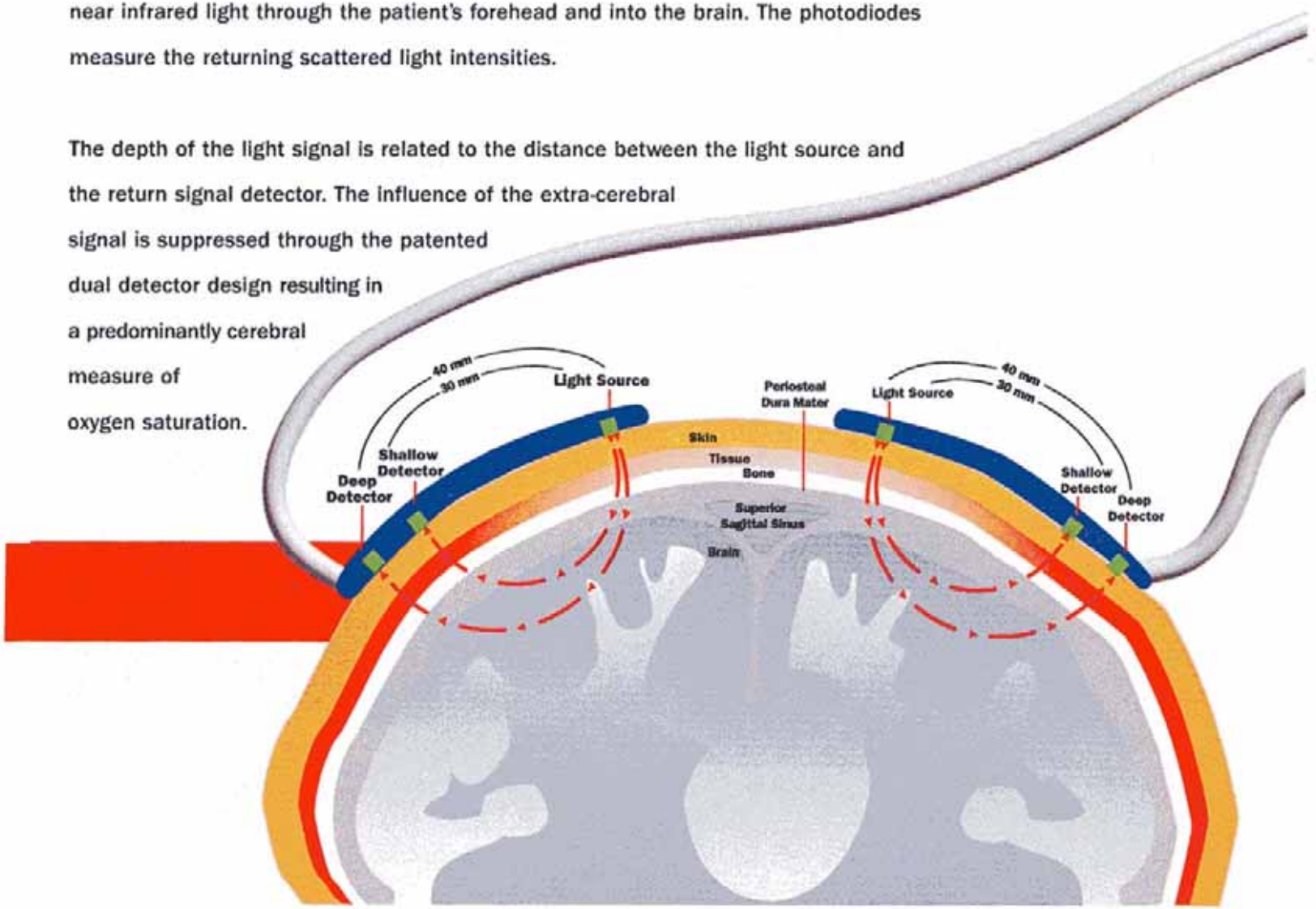
A variety of sensors are available, including:
nose, finger, earlobe, cheek, catheter,
and most recently cerebral.

Reliability will be affected by:
hypotension
hypothermia
vasoconstriction
abnormal haemoglobin
low signal to noise ratio
exposure to room light

# How Does it Measure?

The INVOS Cerebral Oximeter measurement is made by passing harmless, low intensity near infrared light through the patient's forehead and into the brain. The photodiodes measure the returning scattered light intensities.

The depth of the light signal is related to the distance between the light source and the return signal detector. The influence of the extra-cerebral signal is suppressed through the patented dual detector design resulting in a predominantly cerebral measure of oxygen saturation.



# End Tidal $CO_2$ :$ETCO_2$.

Two types of sampling systems.

Mainstream: analyser attached directly to airway.

Sidestream: aspiration of gas sample to analyser.

Three types of analyser systems.

Infrared, Raman scattering & mass spectrometer.

# Infrared $ETCO_2$.

The infrared capnograph passes infrared light through a gas sample where $CO_2$ molecules absorb part of the infrared light. Unabsorbed light passes through the end of the sample chamber and impinges on heat detectors. Differential heating of the sampling and reference detector is transduced to a meter calibrated directly in percent $CO_2$.

These analysers are rapid, avoid blocked tubes, water traps and sampling errors. Size, weight, positioning and cost are disadvantages. They also do not analyse other respiratory gases or anaesthetic agents.

# Raman Scattering $ETCO_2$.

Raman scattering analysers are sidestream devices in which laser light interacts with gas molecules in the sample to produce spectra that identify components of the gas mixture. All molecules, including oxygen, nitrogen, and volatile agents, can be identified.

Subject to sampling error, blocked tubes, water traps etc. Less expensive than other methods. More suitable in the paediatric setting than mainstream devices.

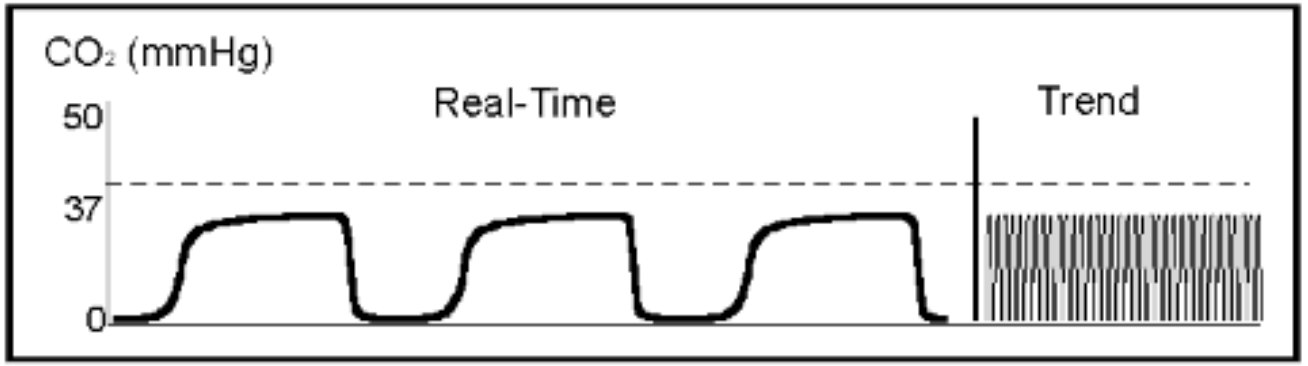
# Mass Spectrometer $ETCO_2$.

Mass spectrometers separate the ions in a gas sample according to their mass/charge ratios using a magnetic field. The separated beams leaving the magnetic field are directed to detectors of the ion currents for oxygen, carbon dioxide, nitrogen, nitrous oxide, enflurane, halothane, isoflurane, and others.

Mass spectrometers are usually shared or multiplexed among many sampling sites.

# Value of the $CO_2$ Waveform

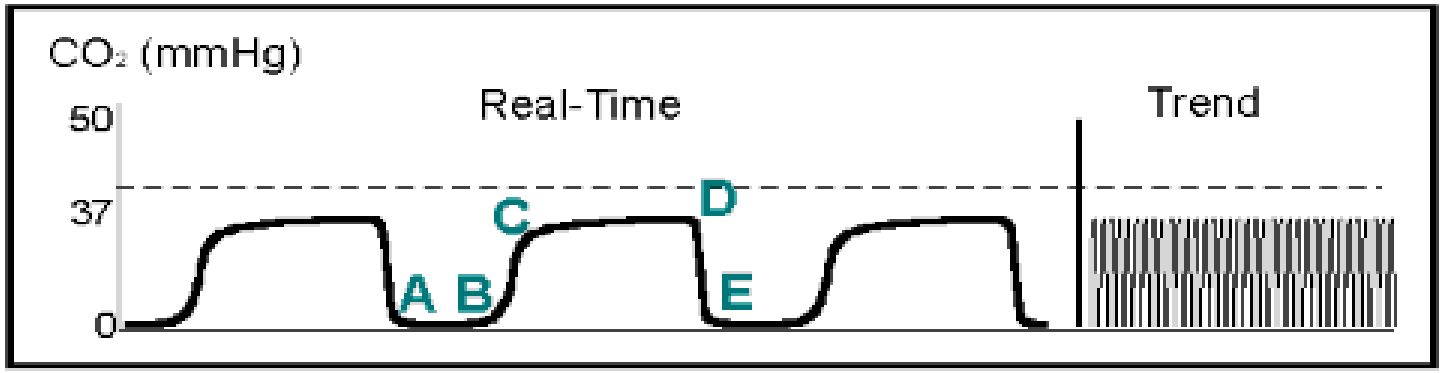
## The Capnogram




- Provides validation of $ETCO_2$ value
- Visual assessment of patient airway integrity
- Verification of proper ET tube placement
- Assessment of ventilator / breathing circuit integrity

# Example Capnogram

## The Normal $CO_2$ Waveform




- A – B Baseline
- B – C Expiratory Upstroke
- C – D Expiratory Plateau
- D $ETCO_2$ value
- D – E Inspiration Begins

# Physiologic Factors Affecting $ETCO_2$ Levels

### Increase in $ETCO_2$

- Increased muscular activity (shivering)
- Malignant hyperthermia

- Increased cardiac output (during resuscitation)
- Bicarbonate infusion
- Tourniquet release

- Effective drug therapy for bronchospasm
- Decreased minute ventilation

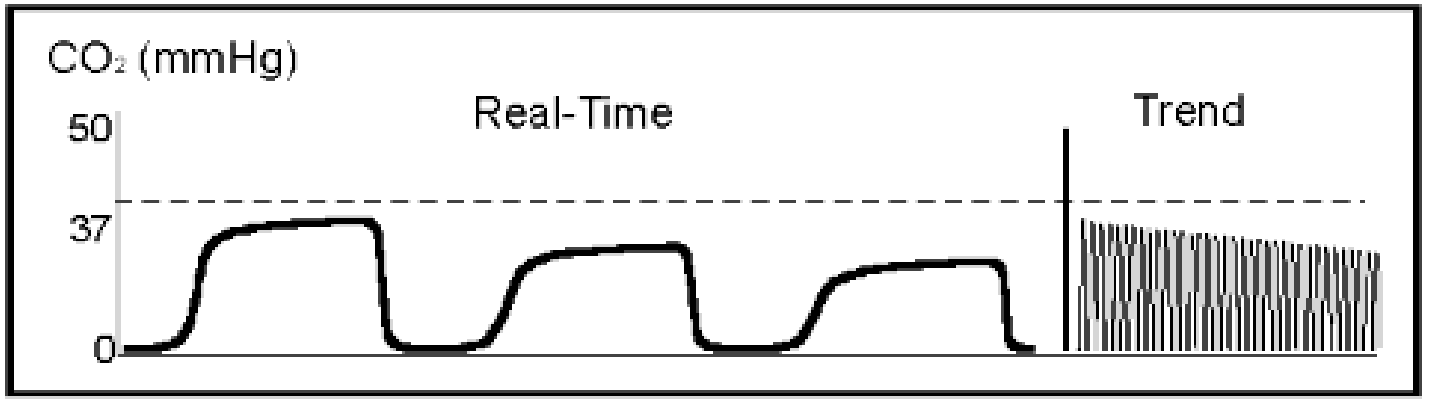
### Decrease in $ETCO_2$

- Decreased muscular activity (muscle relaxants)
- Hypothermia

- Decreased cardiac output (cardiac arrest)
- Pulmonary embolism

- Bronchospasm
- Increased minute ventilation

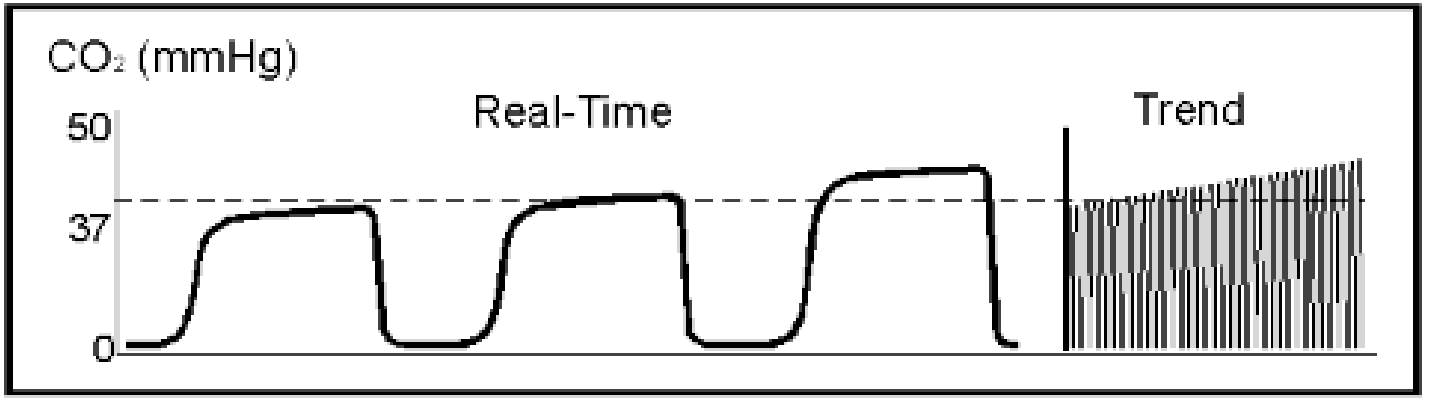
# Hyperventilation (Decrease in $ETCO_2$)




Possible Causes:

- Increase in respiratory rate
- Increase in tidal volume
- Decrease in metabolic rate
- Fall in body temperature

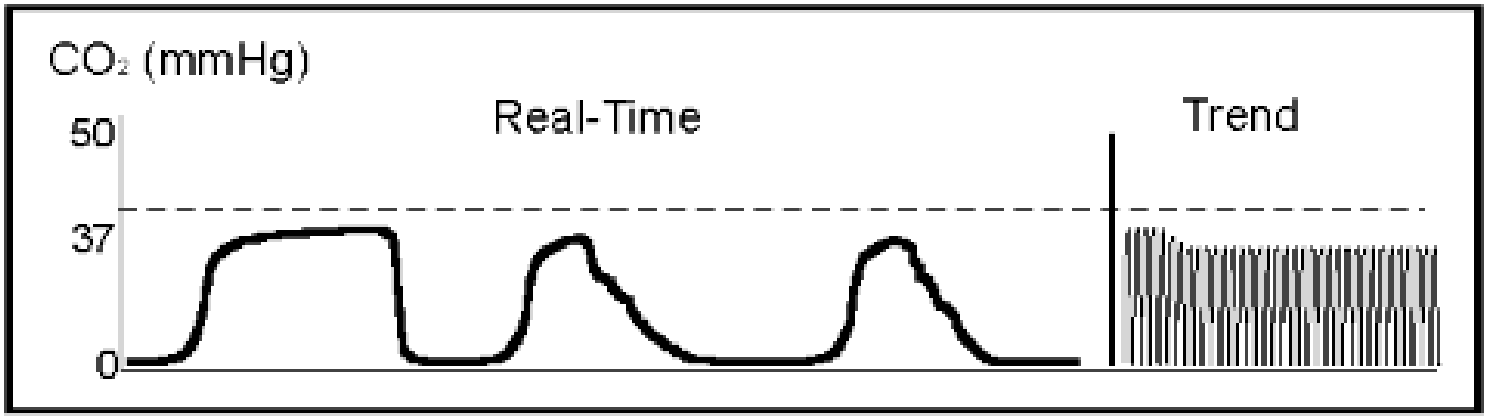
# Hypoventilation (Increase in $ETCO_2$)




Possible Causes:

- Decrease in respiratory rate
- Decrease in tidal volume
- Increase in metabolic rate
- Rapid rise in body temperature (hyperthermia)

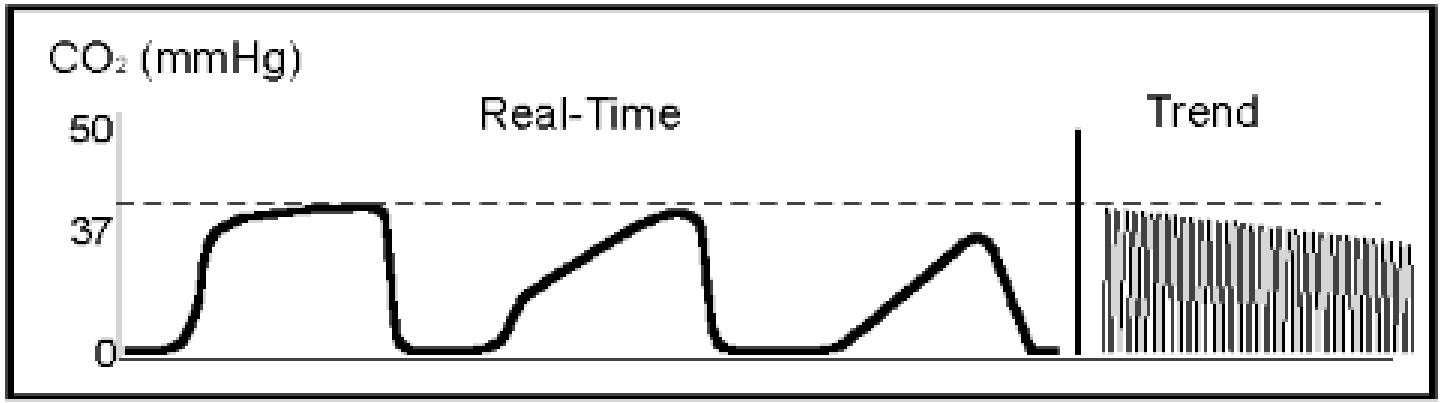
# Inadequate Seal Around ET Tube




Possible Causes:

- Leaky or deflated endotracheal or tracheostomy cuff
- Artificial airway is too small for the patient

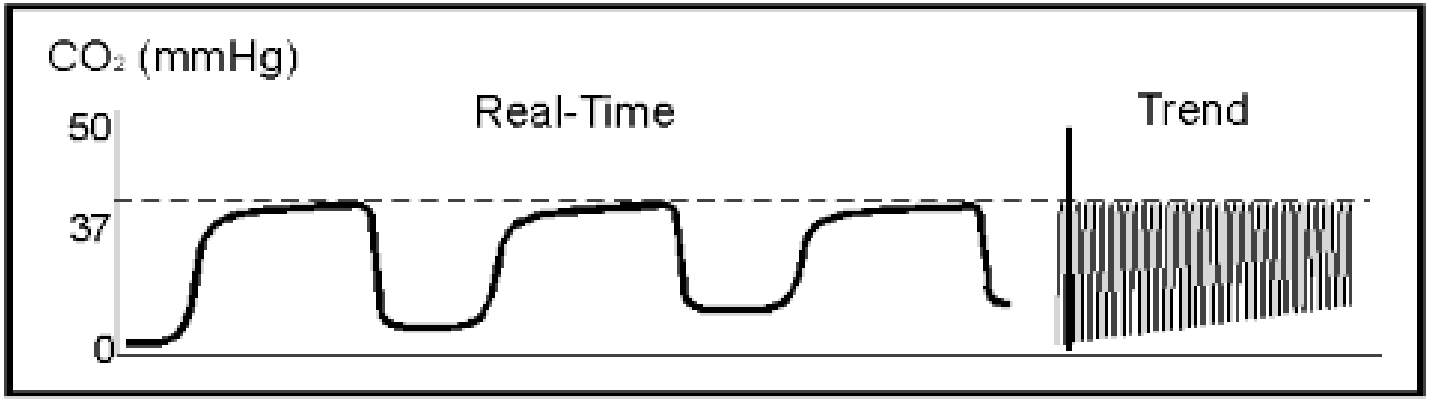
# Obstruction in Airway or Breathing Circuit




Possible Causes:

- Partially kinked or occluded artificial airway
- Presence of foreign body in the airway
- Obstruction in expiratory limb of breathing circuit
- Bronchospasm

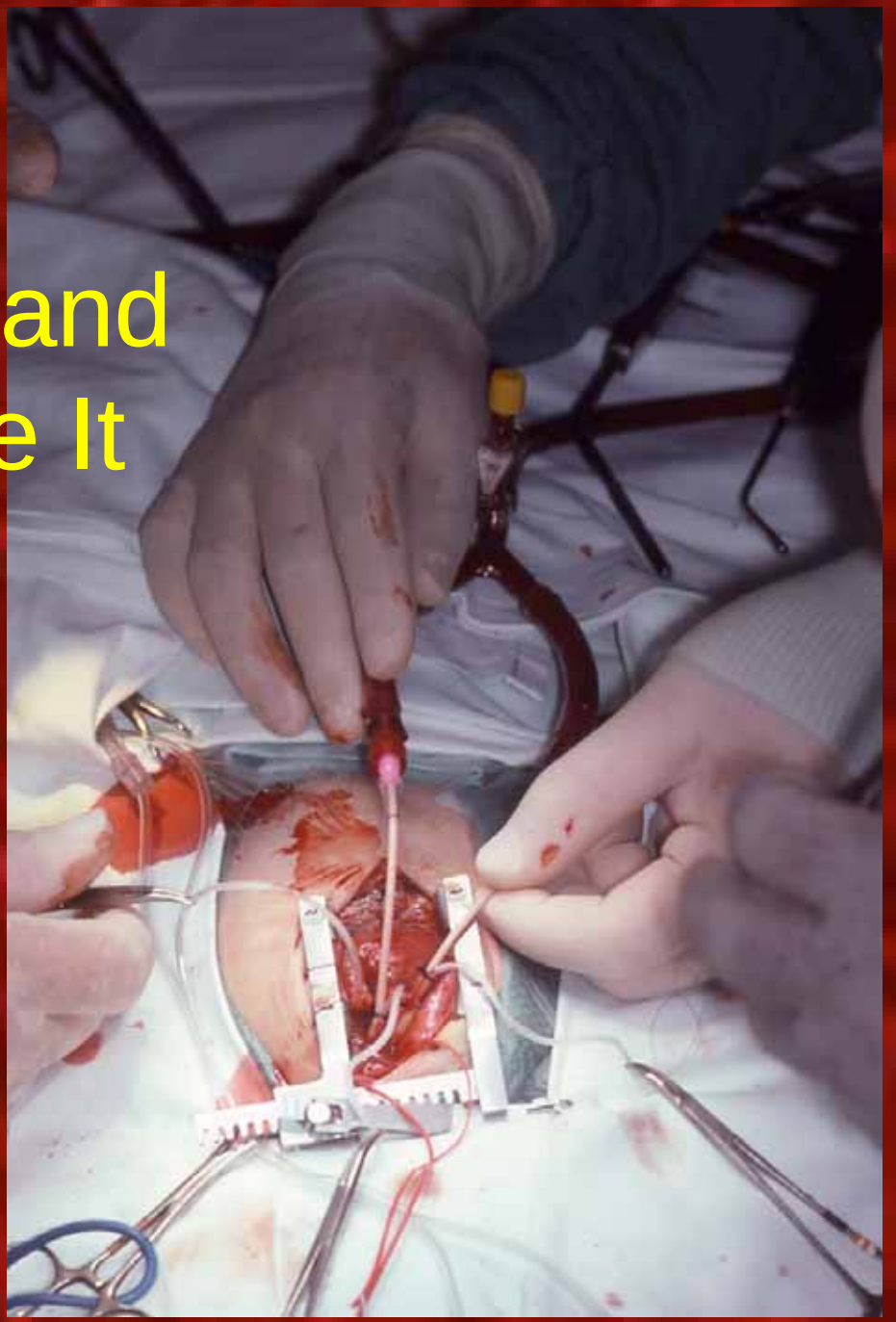
# Rebreathing




Possible Causes:

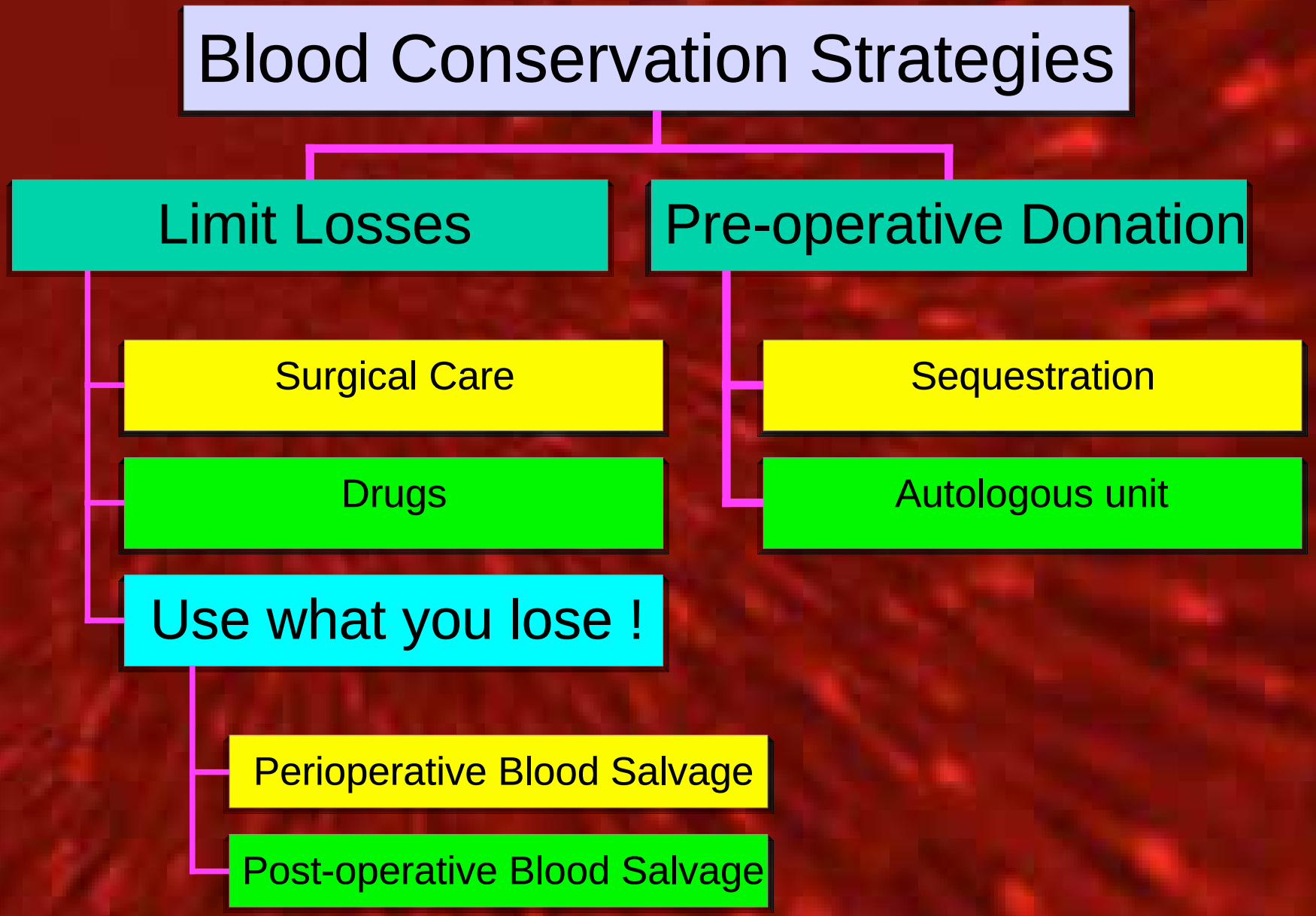
- Faulty expiratory valve
- Inadequate inspiratory flow
- Insufficient expiratory time
- Malfunction of $CO_2$ absorber system

# Blood, Bleeding and How We Manage It In Theatre.



# Blood: management strategies.

1. Use strategies that limit blood loss.
2. If possible avoid allogenic transfusion.
3. If large losses are expected use a cell saver peri-operatively.
4. Autologous or directed donation.


Blood Conservation Strategies
Limit Losses
Pre-operative Donation
Surgical Care
Drugs
Use what you lose !
Sequestration
Autologous unit
Perioperative Blood Salvage
Post-operative Blood Salvage

# Peri-operative Blood Salvage

Peri-operative blood salvage and reinfusion is used in an effort to reduce allogeneic blood transfusion. It is indicated in a variety of surgical procedures whenever major blood loss is anticipated. Intraoperative blood salvage usually becomes cost-effective when 1,500 mL or more of blood is collected; however, it does eliminate the risk of transmission of infectious diseases, even when smaller volumes are salvaged and allogeneic blood can be avoided. It is also indicated if the patient has a rare blood type and adequate amounts of allogeneic blood cannot be found. Peri-operative blood salvage is often acceptable to Jehovah's Witnesses, provided the salvaged blood remains in continuity with the circuit. When peri-operative blood salvage is utilized, the patient should be free from bacterial infection and the operative field from contamination. The reinfusion of blood collected during cancer operations such as radical prostatectomy remains controversial.

# Peri-operative Blood Salvage.

## Indications:

Anticipated loss > 20% of blood volume.

Loss from a clean wound.

Blood can be retrieved without undue haemolysis.

Transfusion rate for procedure usually > 1 unit.

No alternative source of blood e.g. JW.

# Peri-operative Blood Salvage.

## Contra-indications.

Salvage and re-infusion of blood containing malignant cells.

Salvage and re-infusion of blood with bowel content or infection at the site of salvage.

Aspiration of haemostatic agents.

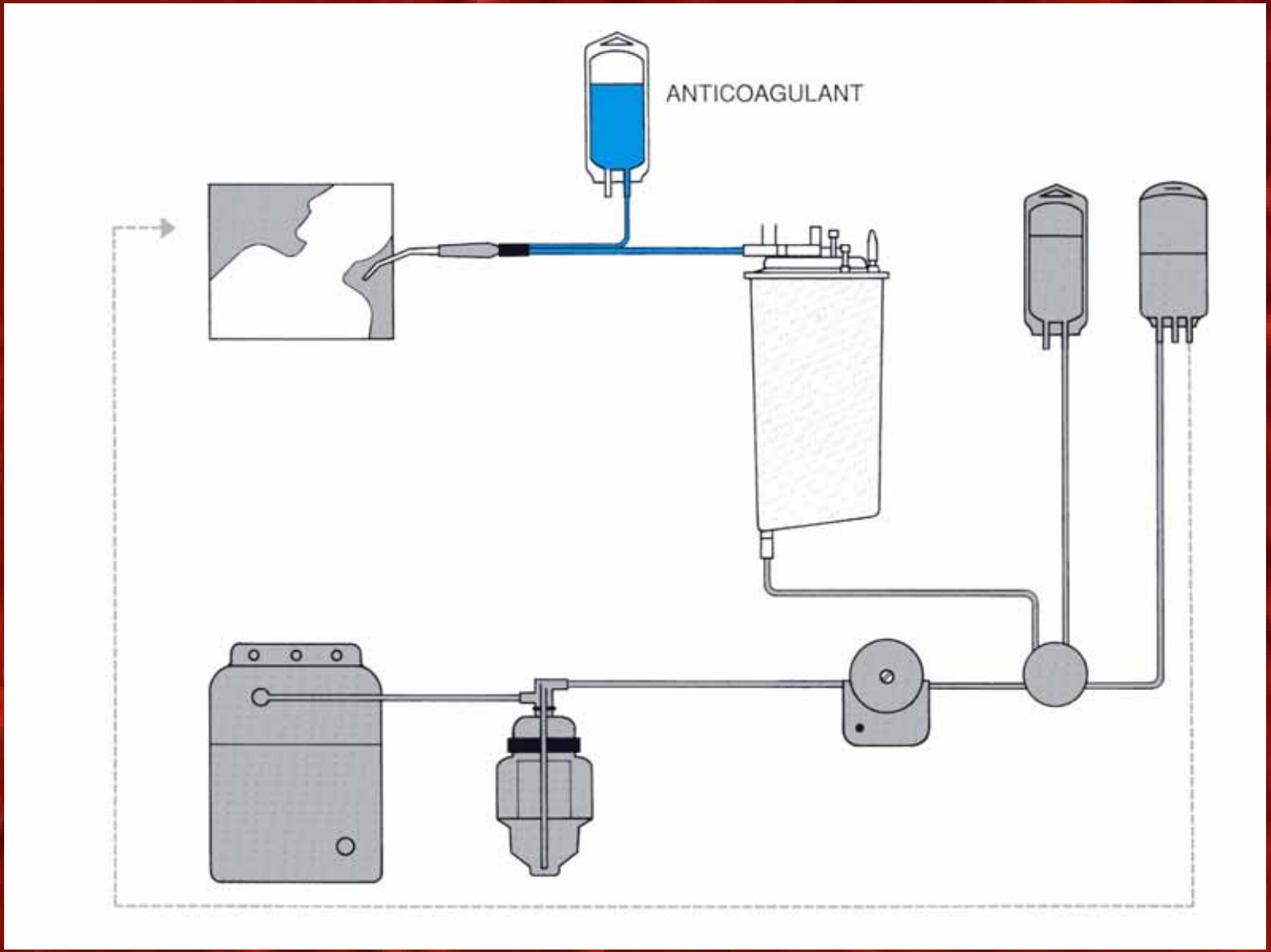
Blood containing Betadine & similar irrigants, drugs and agents not approved for parenteral use.

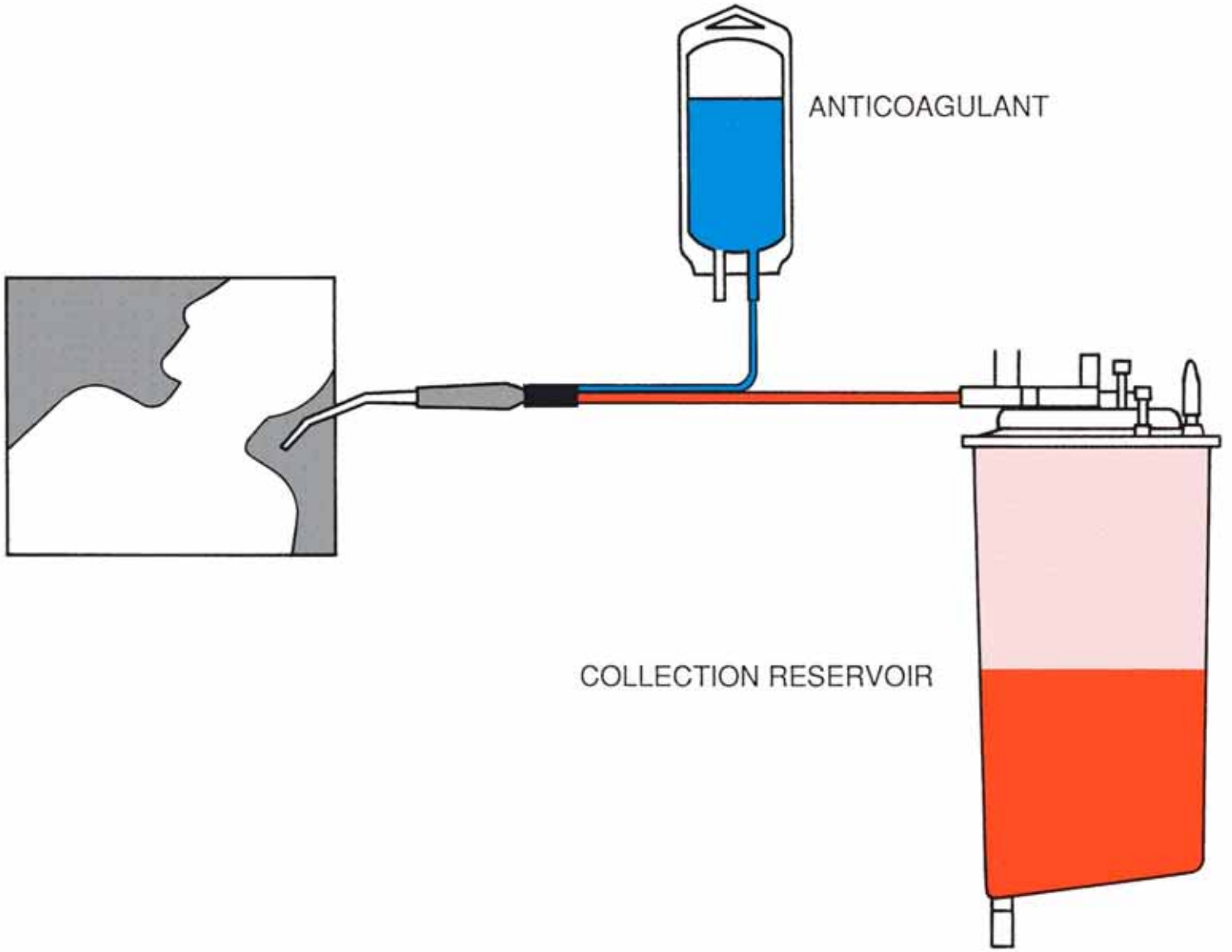
In obstetrics, blood containing a significant amount of amniotic fluid.

# Peri-operative Blood Salvage.

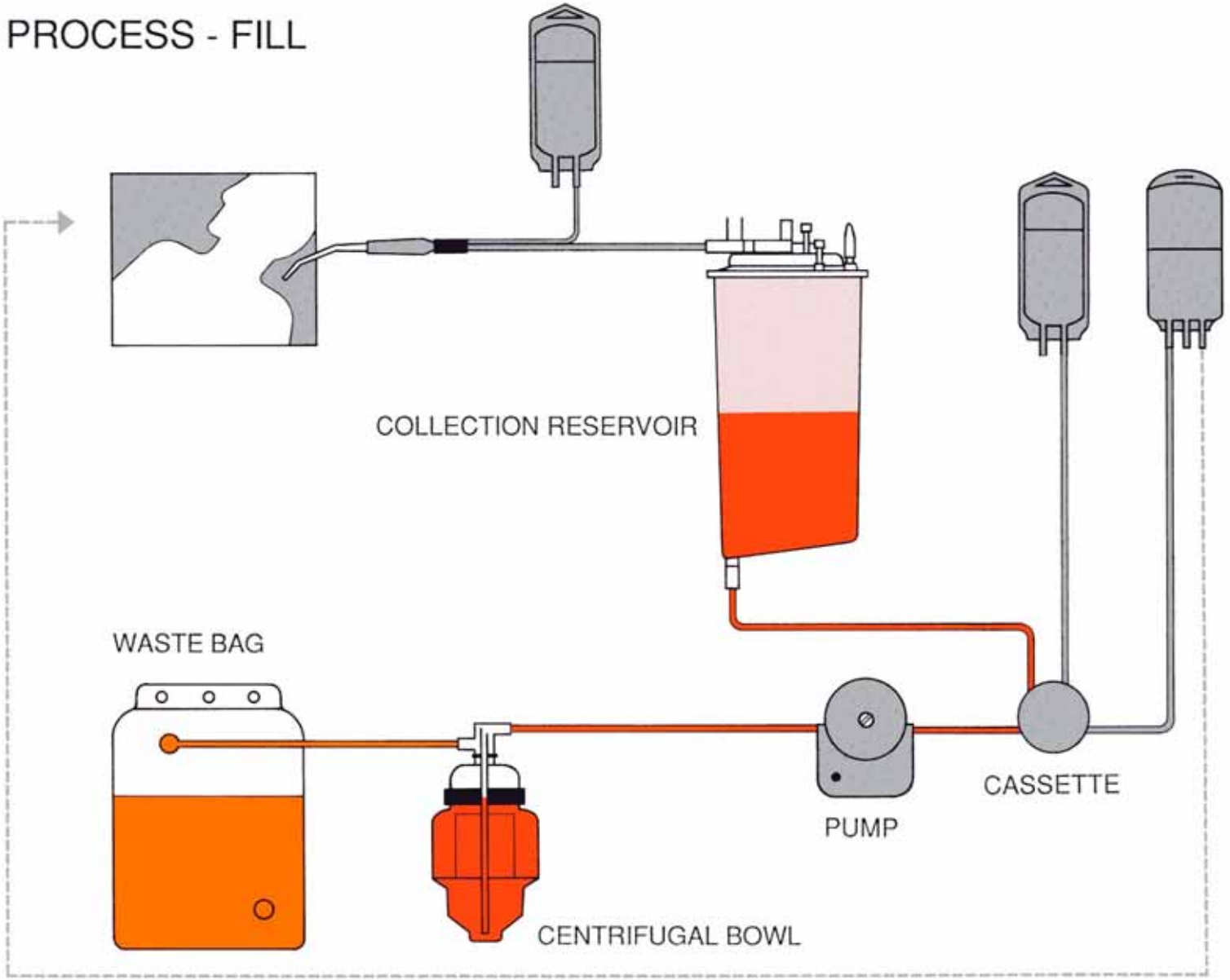
Peri-operative blood salvage is typically accomplished with a semicontinuous flow device that utilizes special suction tubing that allows mixing of recovered blood with an anticoagulant solution. Blood is collected in a reservoir and then centrifuged to separate the blood components, and the red blood cells are washed and then directed to a collection bag for transfusion. Blood can also be collected with canister systems and reinfused following washing or only filtration.

# Blood Salvage Circuit

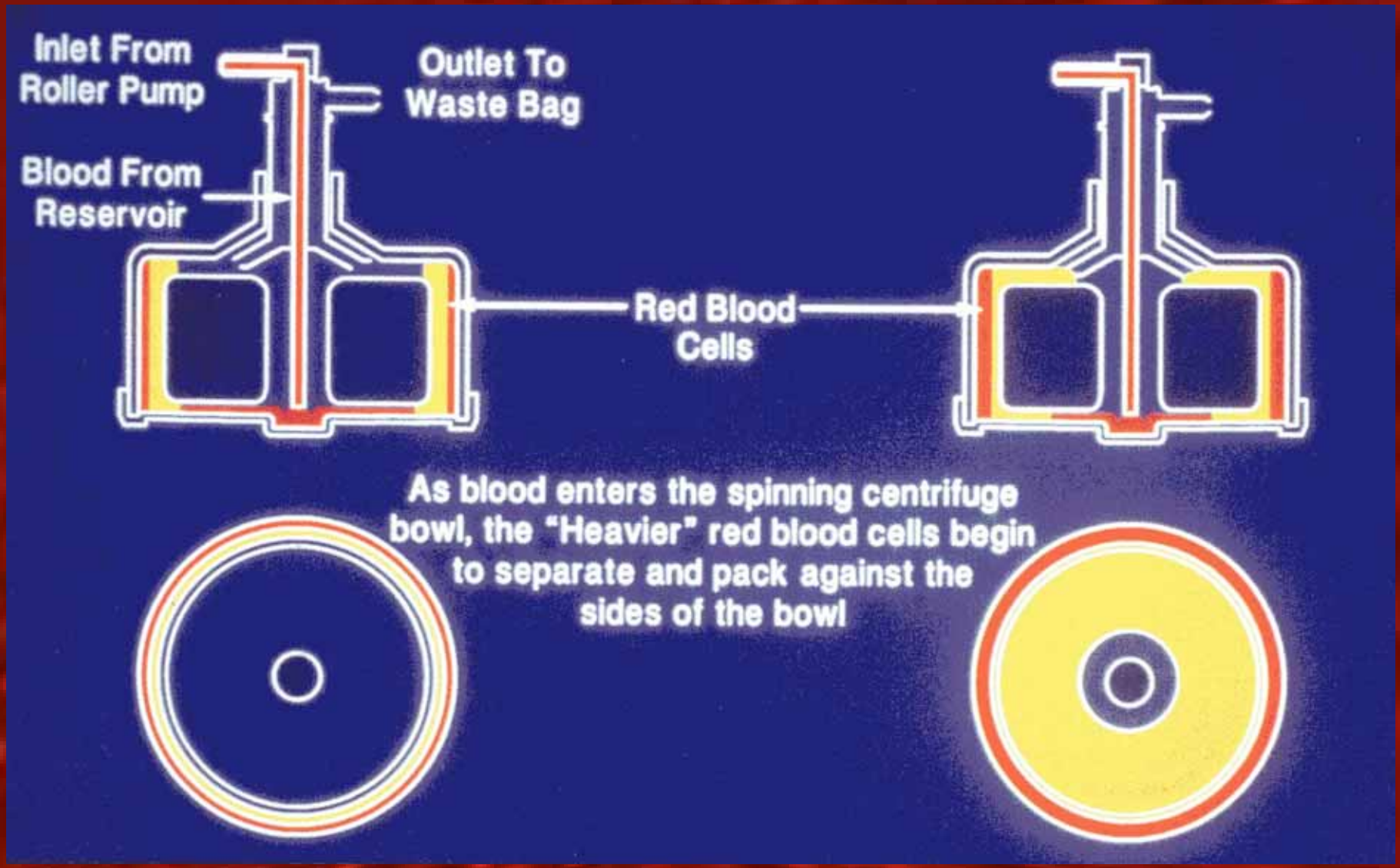



ANTICOAGULANT
COLLECTION RESERVOIR

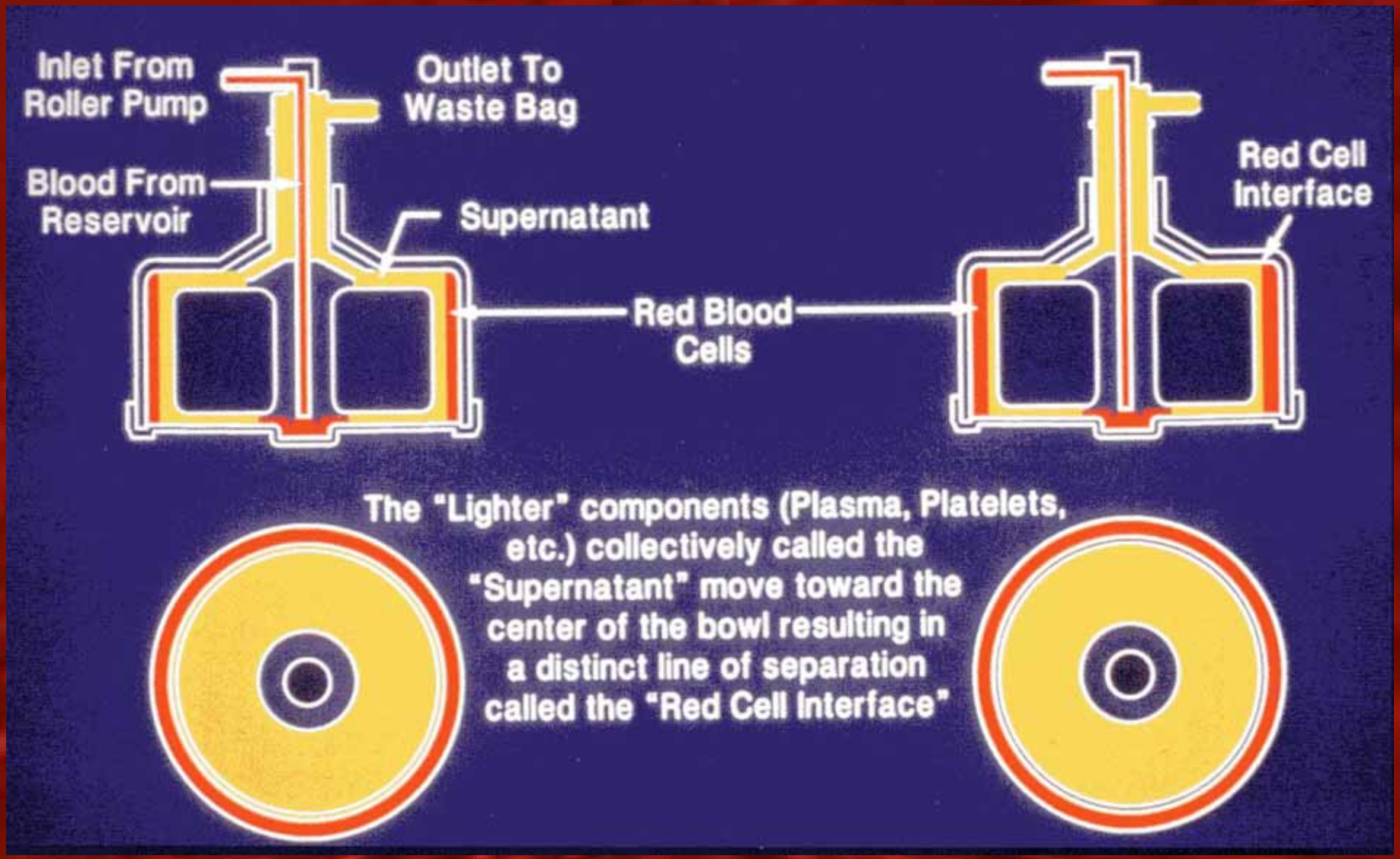
# PROCESS - FILL



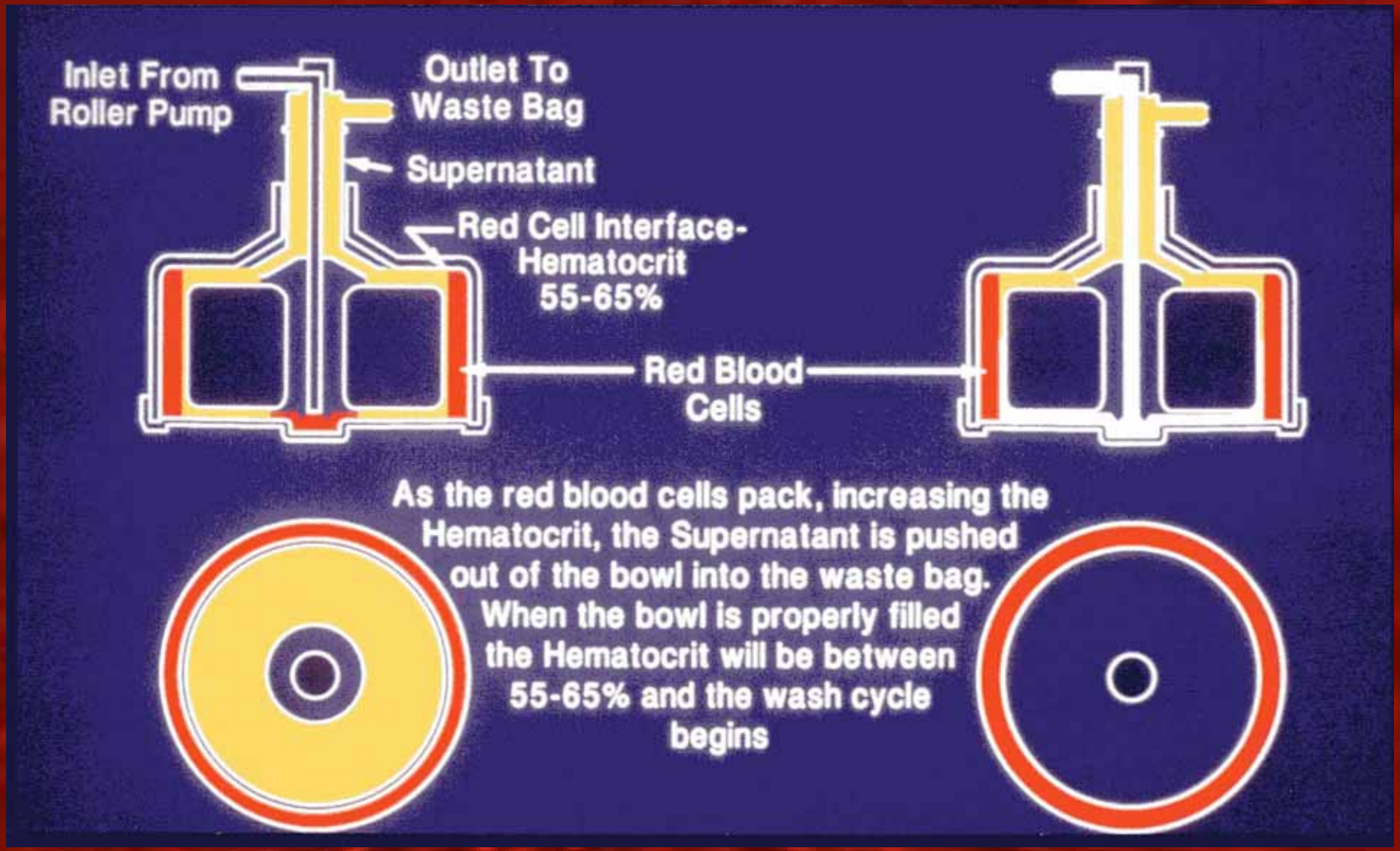
# Fill Cycle Begins:



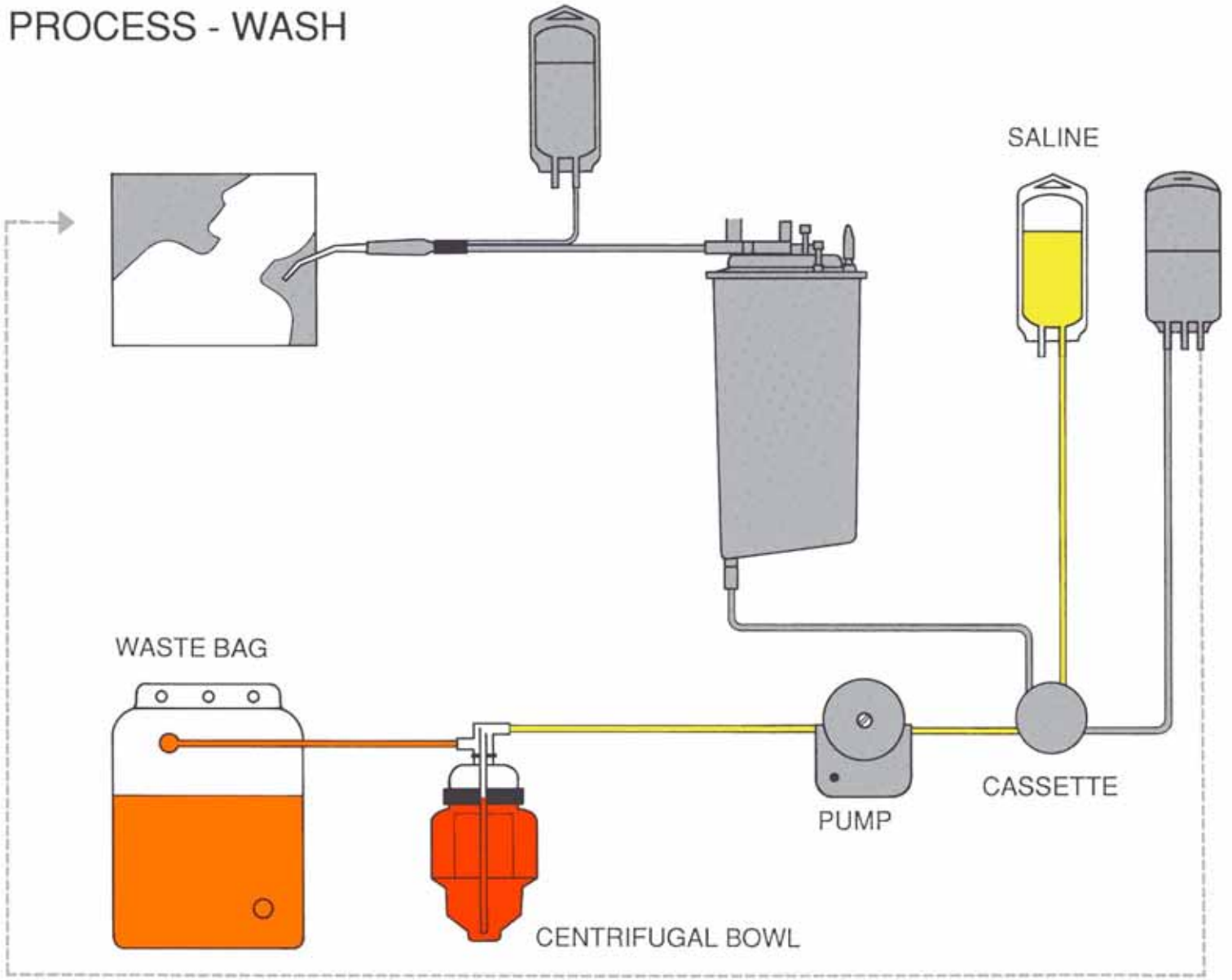
# Red Cell Interface Forms:



# Fill Cycle Complete:

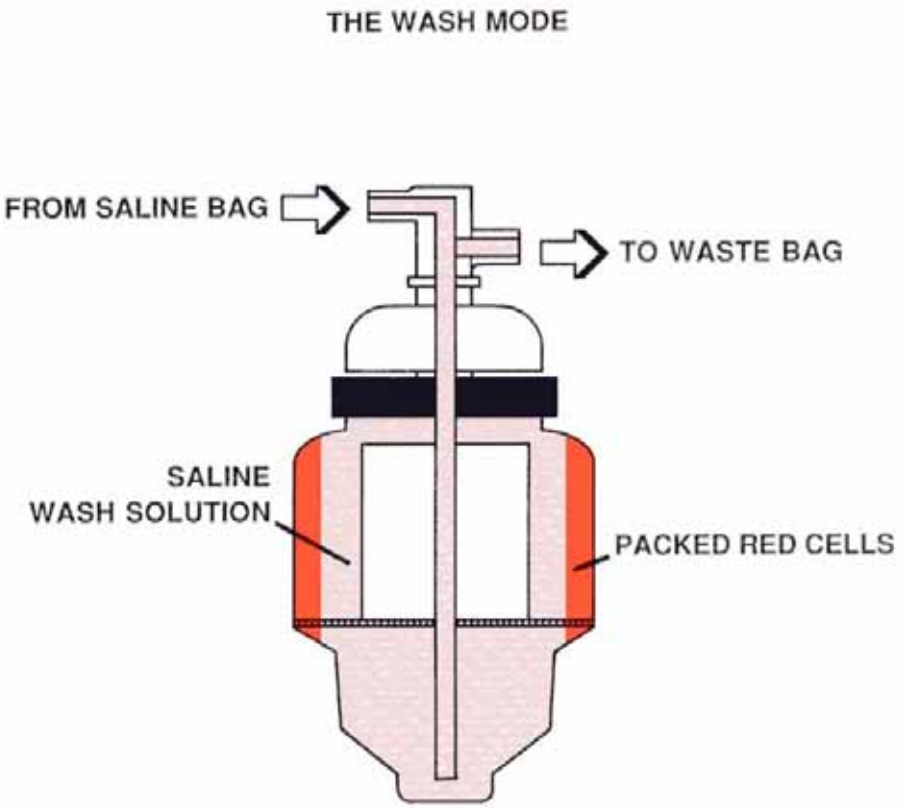


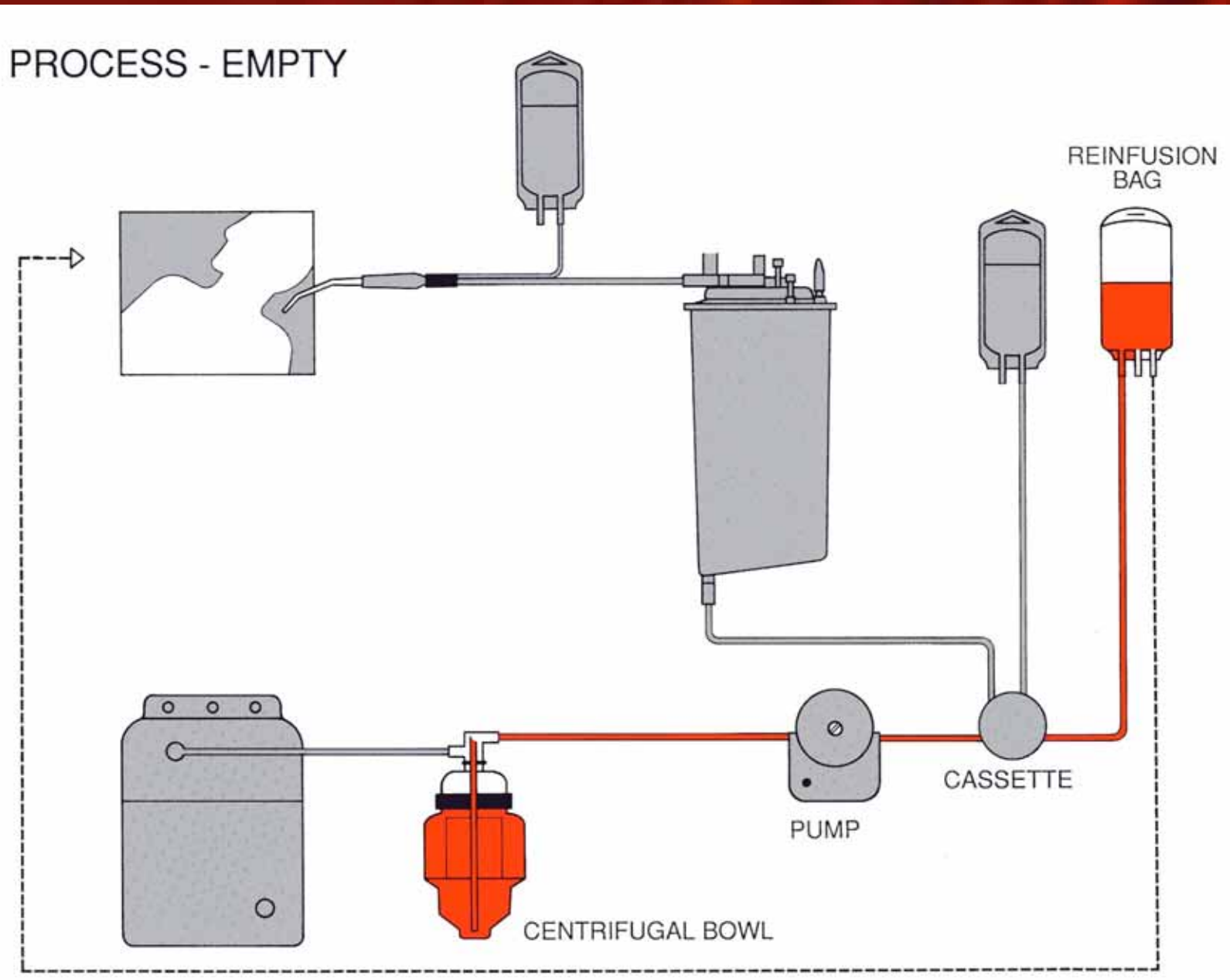
# PROCESS - WASH



# THE WASH MODE

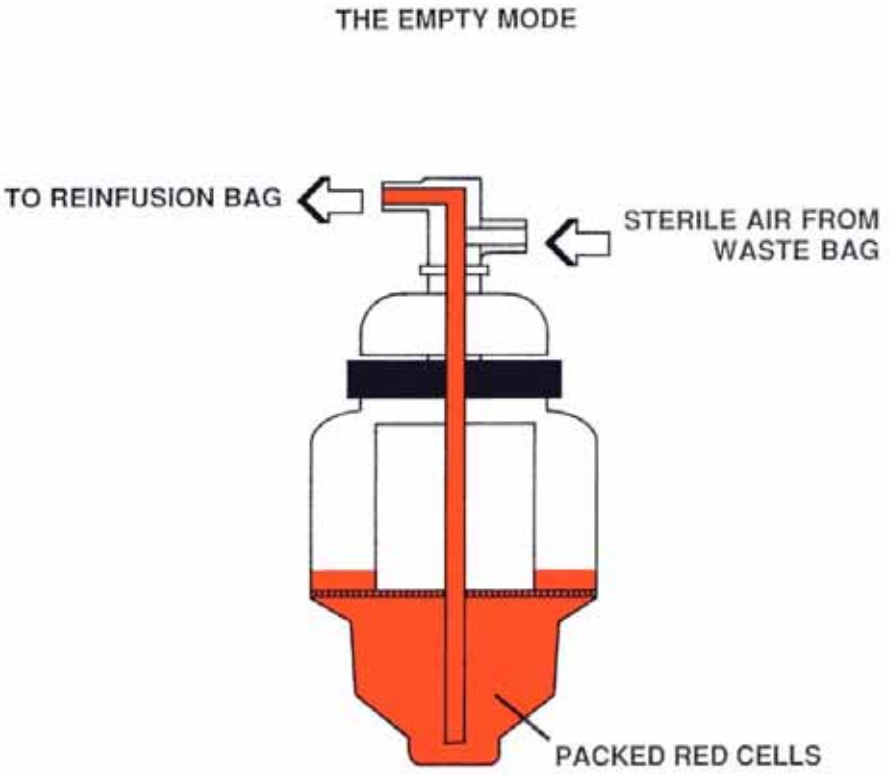
IN THE WASH MODE, SALINE IS INTRO-DUCED, DISPLACING THE LIGTHER LAYER CONTAINING PLASMA AND DEBRIS.



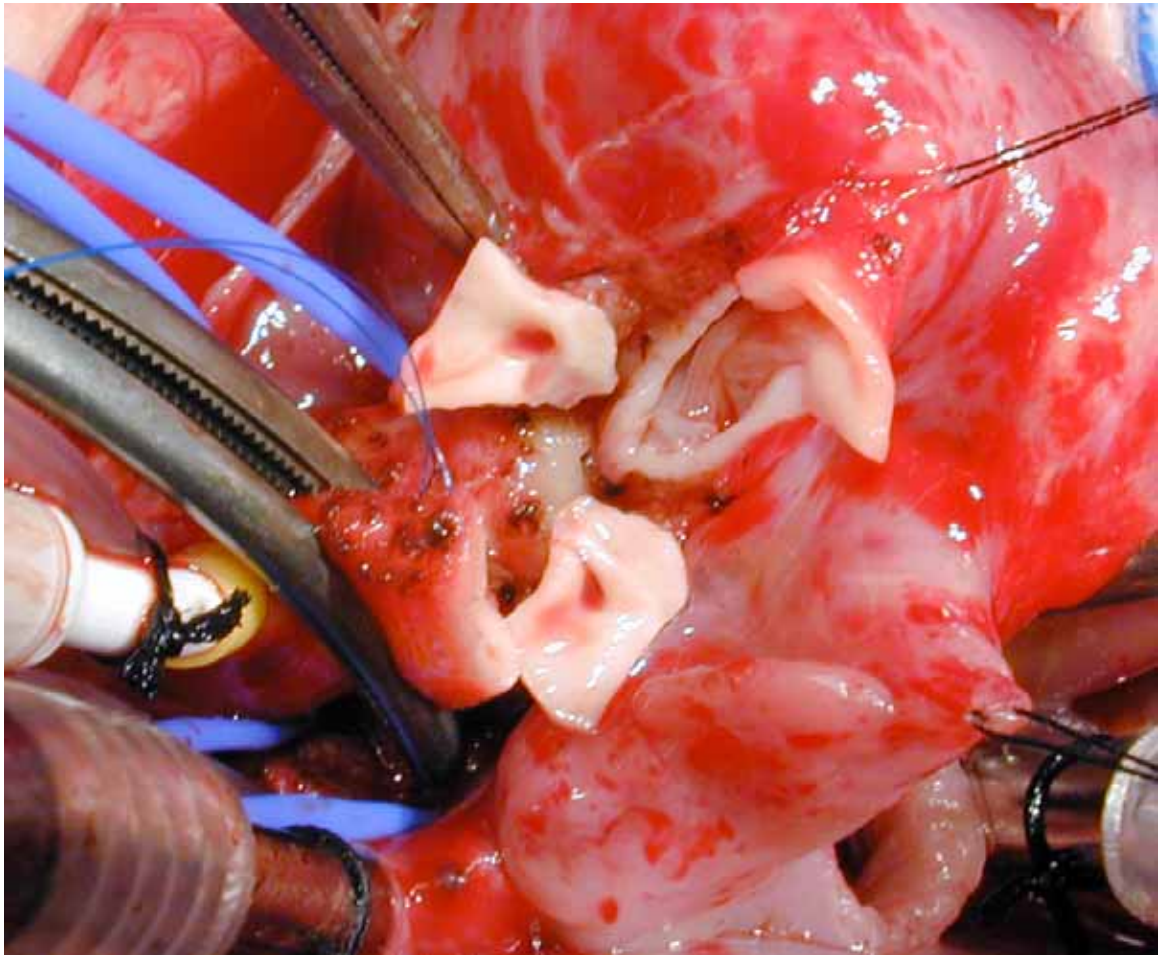

PROCESS - EMPTY
REINFUSION BAG
CASSETTE
PUMP
CENTRIFUGAL BOWL

# THE EMPTY MODE

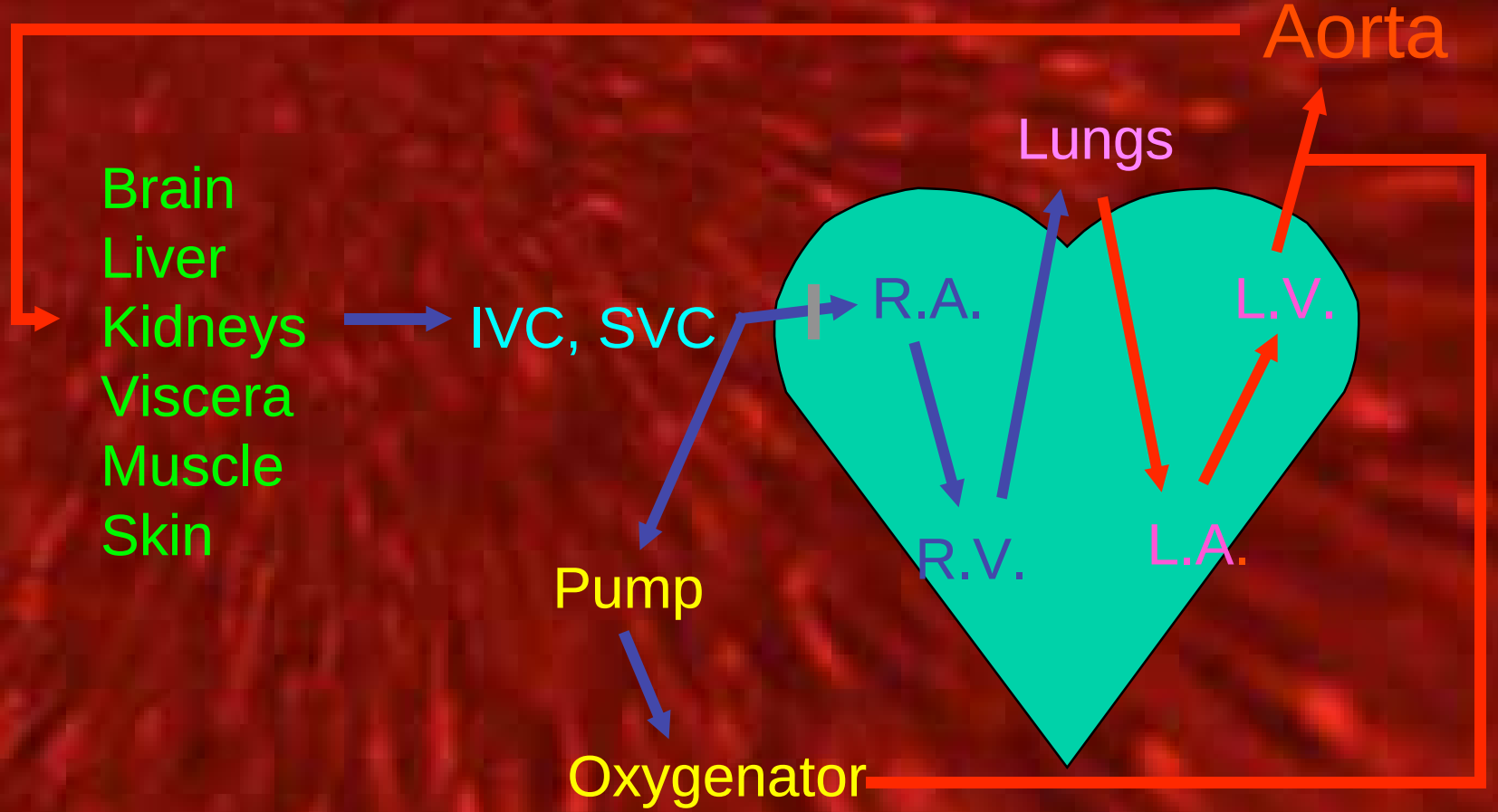
IN THE EMPTY MODE, PACKED RED BLOOD CELLS, SUSPENDED IN SALINE, ARE PUMPED TO THE REINFUSION BAG.

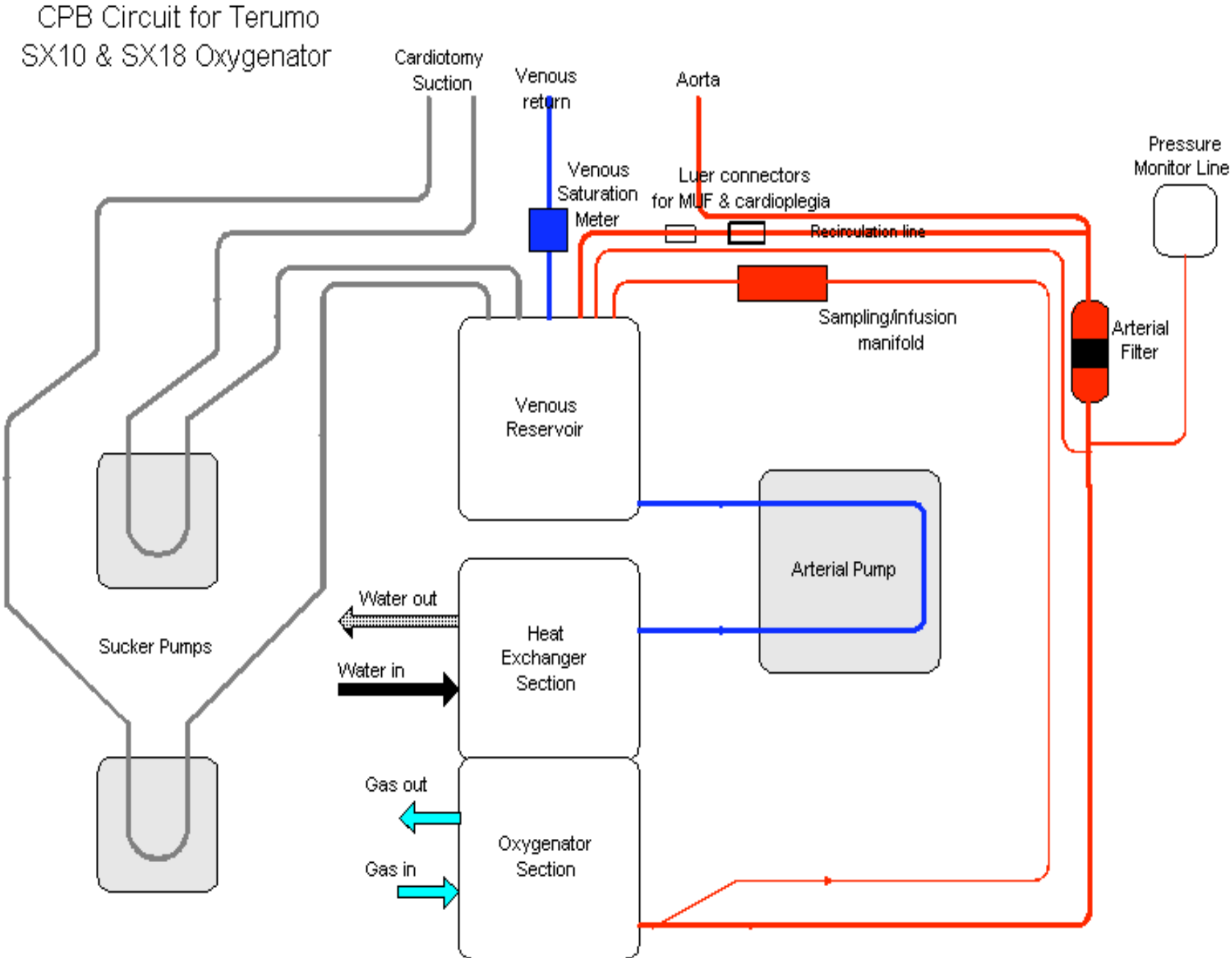


# Cardiopulmonary Bypass (CPB)



# Bypass: what happens?




CPB Circuit for Terumo
SX10 & SX18 Oxygenator
Cardiotomy Suction
Venous return
Aorta
Pressure Monitor Line
Venous Saturation Meter
Luer connectors for MUF & cardioplegia
Recirculation line
Sampling/infusion manifold
Arterial Filter
Venous Reservoir
Arterial Pump
Water out
Water in
Heat Exchanger Section
Sucker Pumps
Gas out
Gas in
Oxygenator Section

# Cardio-pulmonary Bypass Prime

Aim: to have enough fluid volume to prime the circuit, whilst not overdiluting the total haemoglobin pool.

In paediatric CPB size is important!

| Weight(kg) | Blood Volume (ml) | Prime Volume (ml) | Ratio |
|---|---|---|---|
| 2 | 200 | 400-650 | >2 : 1 |
| 4 | 400 | 650 | 1.5 : 1 |
| 6 | 600 | 650 | 1 : 1 |
| 16 | 1300 | 1100 | .85 : 1 |
| 70 | 4900 | 1600 | .32 : 1 |

# Cardio-pulmonary Bypass Prime

At RCH:
* Tailored individually.
* Aim for a final, combined Hb (ie Patient + pump) of 8-9 gm/dL.
* Computer generated.

3 Basic Types of Prime:

1. Using fresh heparinised blood.
2. Using fresh citrated blood or packed cells.
3. Using no blood.

# At Initiation of Bypass……

- Abrupt reduction in haematocrit & protein leads to:

↓ Viscosity

↓ Systemic Venous Resistance (SVR)

∴ ↓ Blood pressure

Reflex ↑ in catecholamine release (adrenalin reaction)

# At Initiation of Bypass……

Right and Left atrial pressures → 0 mmHg
which leads to:

↑ADH and aldosterone (↑ renal vascular resistance)

→ ↓ Urine output

And → ? Inadequate blood volume

Reflex ↑ in catecholamine release

# At Initiation of Bypass……

Flow < previously which leads to:

↓ Haematocrit

↓ Pulsatility

↓ Blood Pressure

∴ ↓ Systemic oxygen delivery

Reflex ↑ in catecholamine release

# Adequate/Optimal Perfusion

Dilated, well perfused, not shut down, warm, not acidotic, not water loaded, urine producing, non bleeding patients.

# Weaning from Bypass

While on full bypass via venous occlusion start volume loading.

Ventilating

Appropriate ECG

Ra > 5 mmHg

LA > 4 mmHg

PA < 1/2 systemic pressure

# Volume Requirements after CPB

Maintain adequate pressures.

Maintain or improve haematocrit.

Control bleeding using appropriate fluids/drug combinations.

# “Undesirable” Features of CPB

- Haematology / Haemostasis
- Use of suction
- Blood contact with CPB circuit
- Perfusion imbalances
- Haemodilution
- Prolonged cross-clamp times
- Use of relatively large amounts of donor blood and blood products
- Emboli

# Conclusion

- Physiological systems interact with each other.
- Oxygen & carbon dioxide transport are related.

- Peri-operative blood salvage can be an effective means of limiting blood loss in all patients.

- Bypass causes disruption to physiological systems.  We minimise the effects of bypass as best we can.