CARDIOPULMONARY BYPASS AND THE HEART LUNG MACHINE

Mridula Ajit Kumar

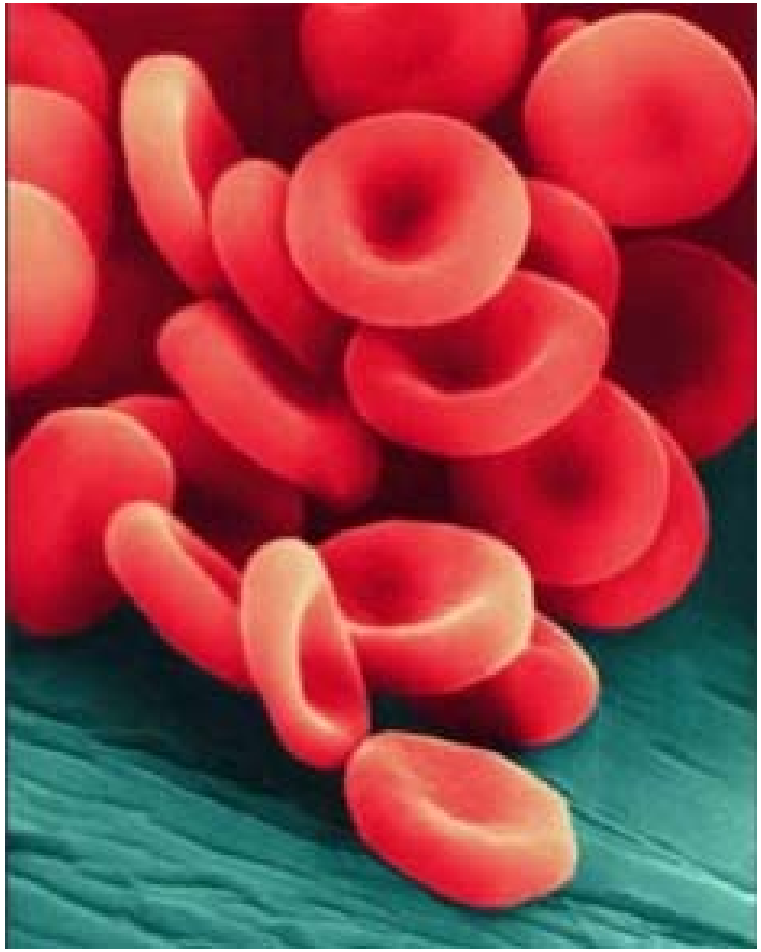
Nilanthy Balendra

STATISTICS

- every 7 minutes in Canada, someone dies from heart disease or stroke
- in 2006 it was 2/3 leading causes of death in Canada
- an estimated 70 000 heart attacks each year
- up to 45 000 cardiac arrests each year
- over 16 000 Canadians die each year due to a heart attack
- 1% of people are born with a congenital heart defect

OVERVIEW

- Introduction
- Circulatory System
- What goes Wrong?
- Blood
- Cardiopulmonary Bypass
- Heart Lung Machine
- Complications
- Future



THE CIRCULATORY SYSTEM

THE CIRCULATORY SYSTEM

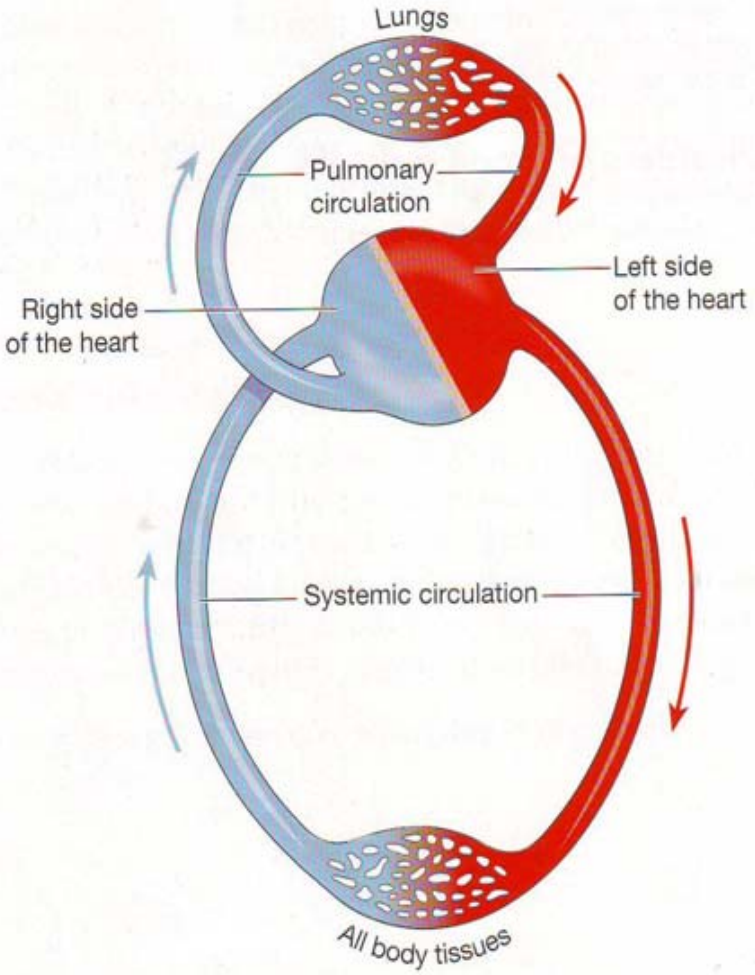
- Used to pass nutrients, gases, hormones, blood cells, etc. to and from cells in the body
- It helps stabilize body temperature and pH to maintain homeostasis
- Move blood to sites where it can be oxygenated
- Oxygenated blood is carried to the tissues of the body

THE CIRCULATORY SYSTEM

- Works on a Closed Circulatory System
- Blood and lymph are the fluids that move through the system
- Human body functions on Cardiovascular System

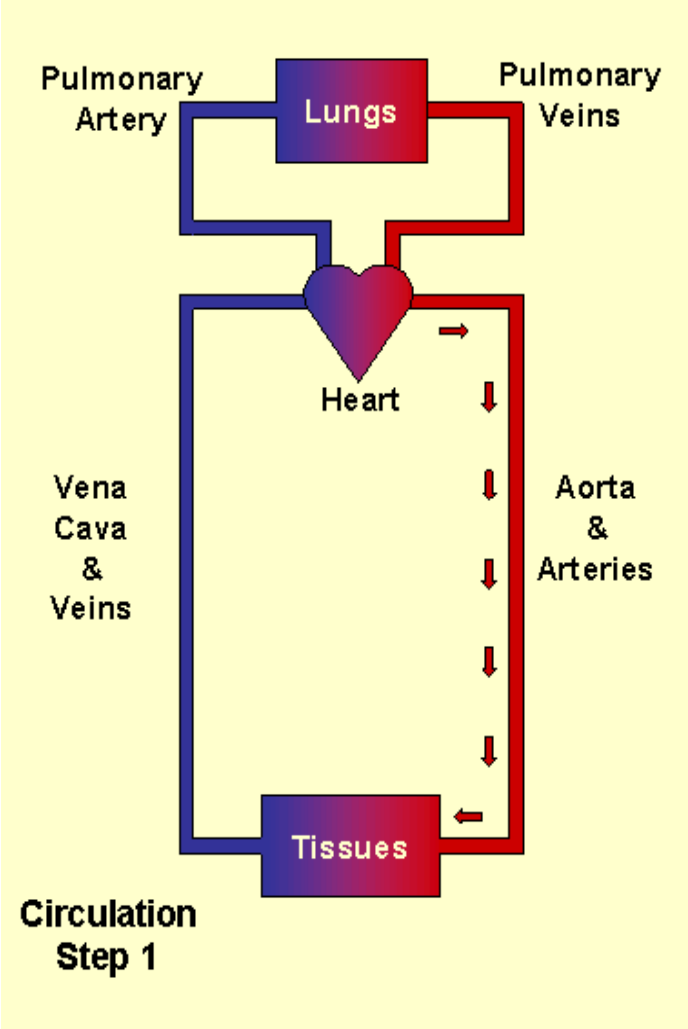
THE CIRCULATORY SYSTEM

- Pulmonary Circulation: oxygen depleted blood taken from the heart to the lungs
- Systemic Circulation: oxygenated blood from heart to rest of the body and depleted blood back to the heart
- Coronary Circulation: blood supply to the heart

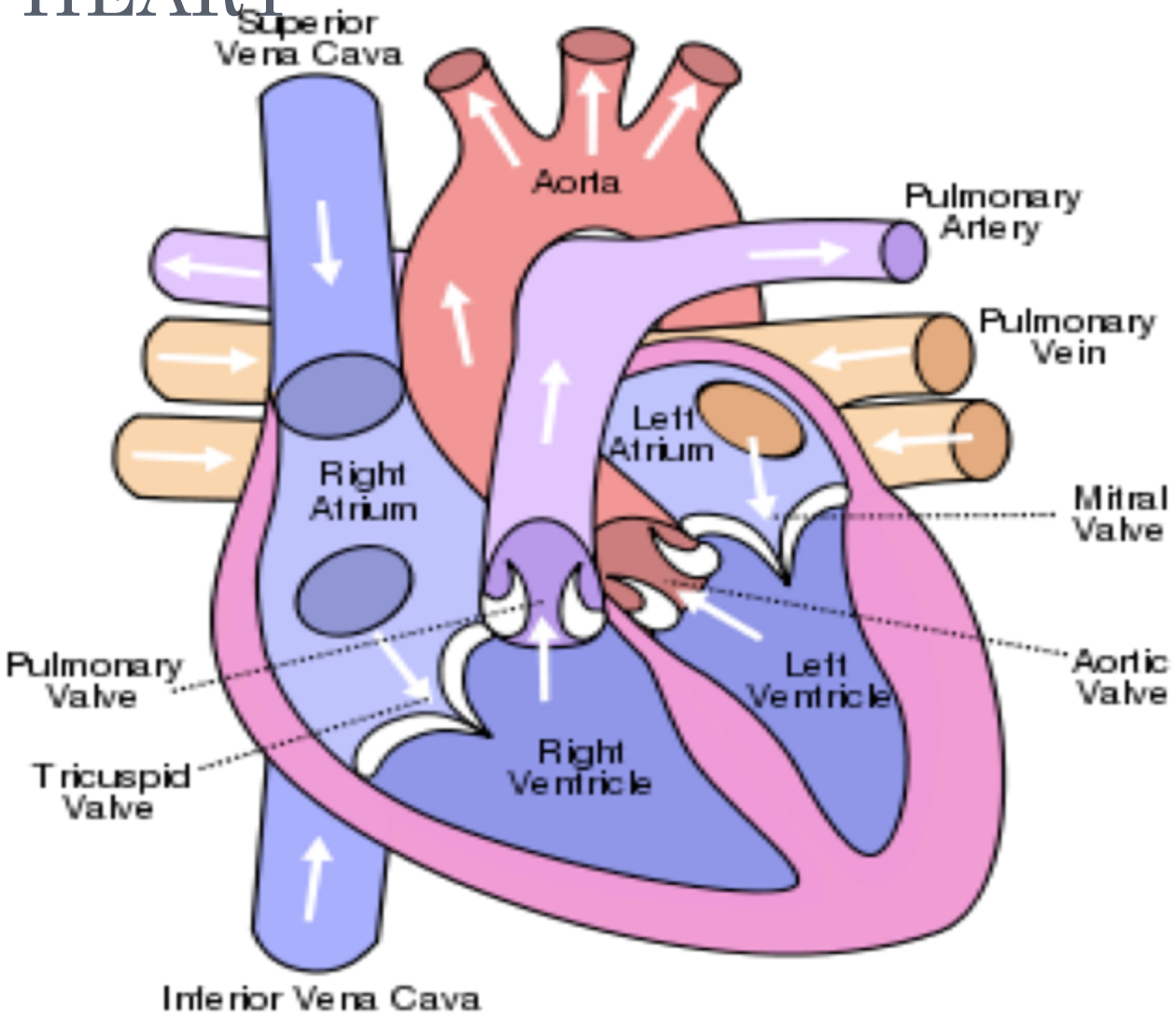


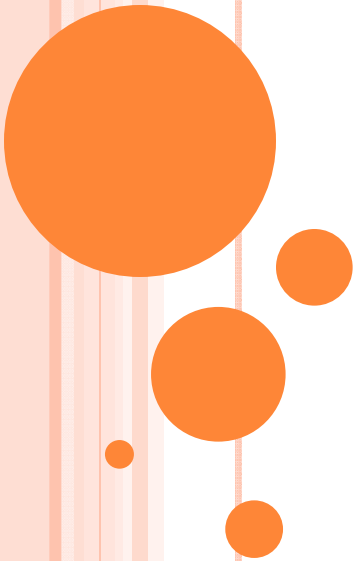
THE HEART

- Heart pumps oxygenated blood to the body and deoxygenated blood to the lungs for purification
- Heart connects the systemic circulation and the pulmonary circulation
- Deoxygenated blood flows through the right part of the heart and oxygenated blood flows through the left



THE HEART


Superior Vena Cava
Aorta
Pulmonary Artery
Pulmonary Vein
Left Atrium
Right Atrium
Mitral Valve
Pulmonary Valve
Aortic Valve
Left Ventricle
Right Ventricle
Tricuspid Valve
Inferior Vena Cava

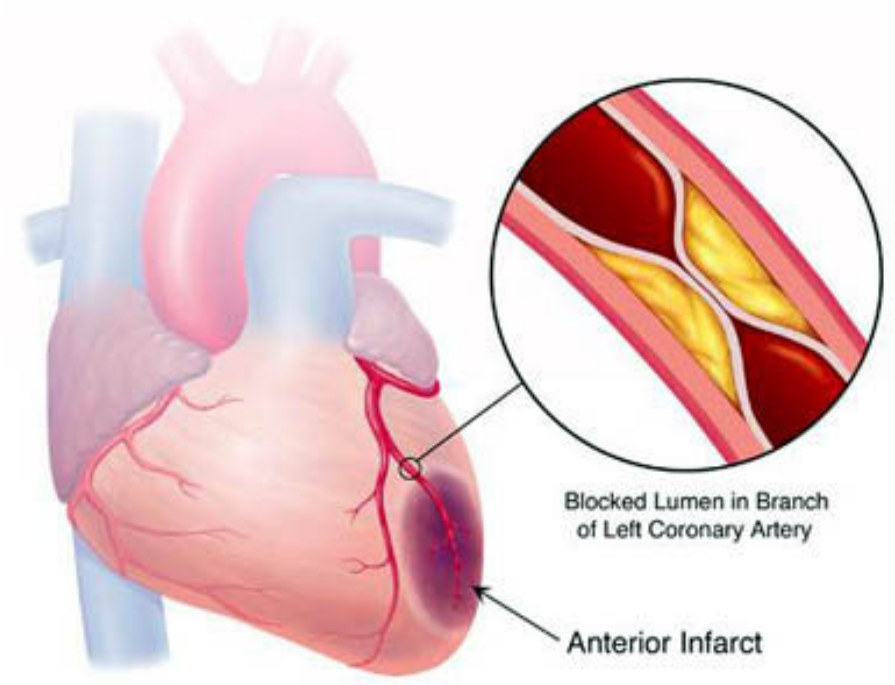


WHAT CAN GO WRONG?

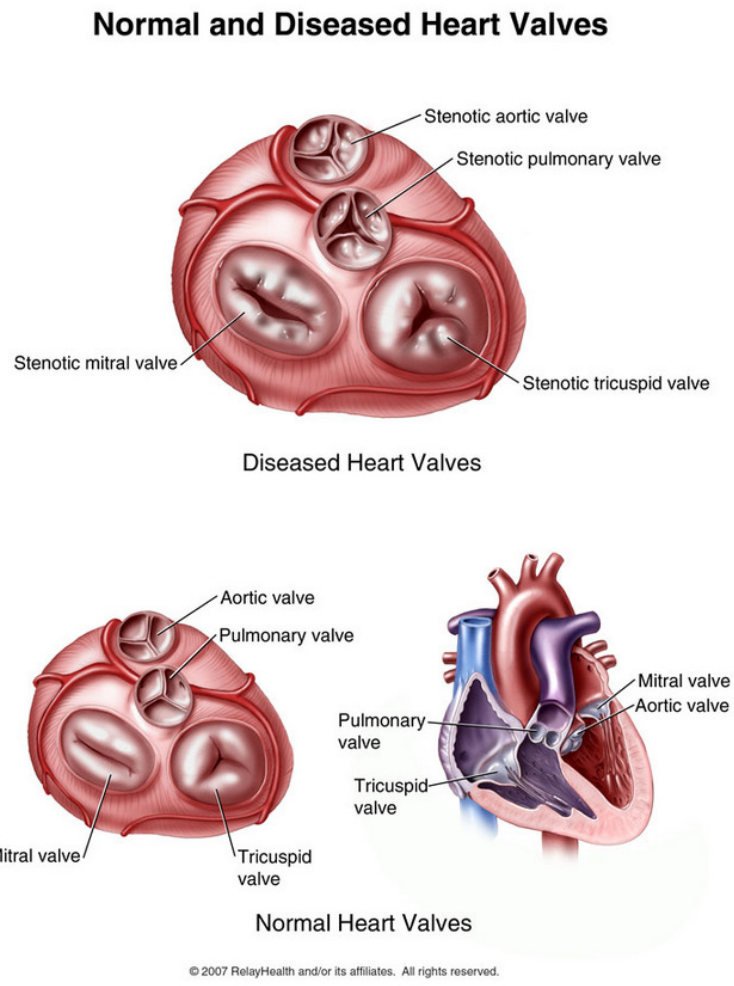
WHAT CAN GO WRONG?

Coronary Artery Disease

- failure of coronary circulation to supply adequate circulation to the heart
- most common form of heart disease
- many causes, including smoking, diabetes, hypertension etc.
- a myocardial infarction is a complication of coronary disease



WHAT CAN GO WRONG?



Stenosis or Leakage of Valves

- four valves: tricuspid, pulmonary, mitral and aortic
- narrowing due to valve flaps thickening, stiffening or fusing together (stenosis)
- backflow due to valve not closing properly
- can cause heart failure, stroke, clots or sudden cardiac arrest

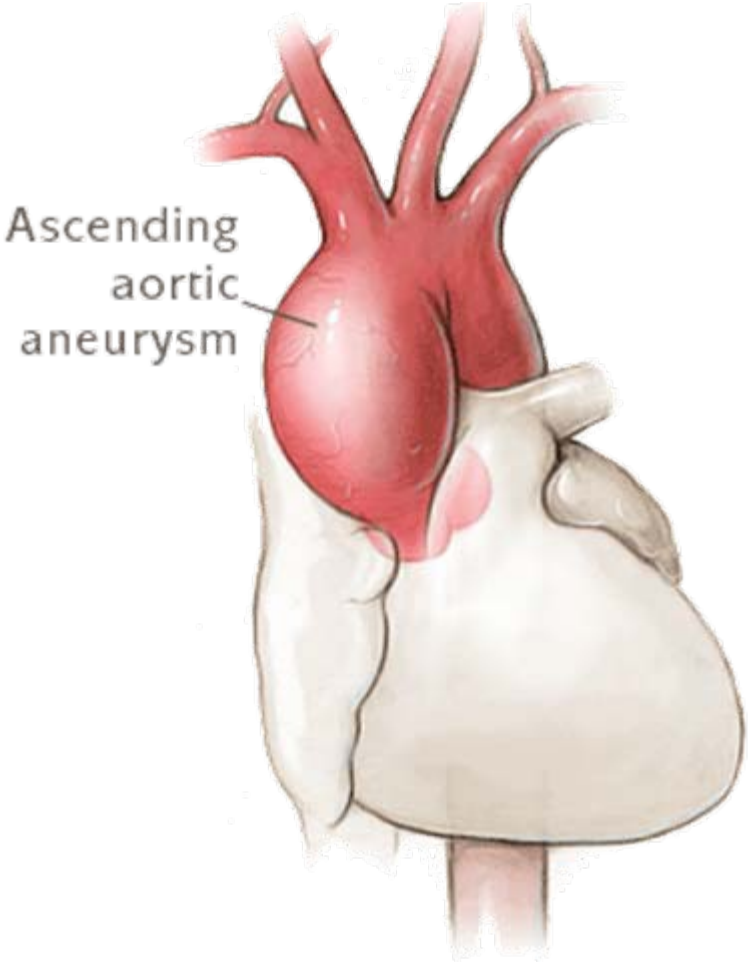
WHAT CAN GO WRONG?

Aortic Aneurysm

- weakening and dilation of the wall of the aorta
- can be a birth defect or can be due to a disease of injury

Thrombus (Blood Clots)

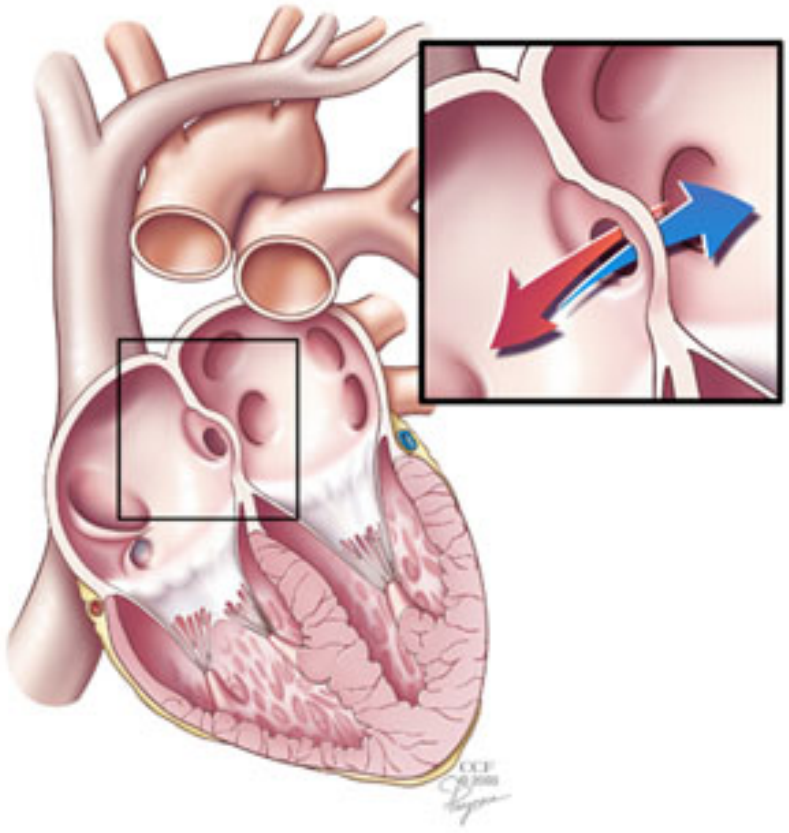
- the final step of blood coagulation
- in a blood vessel it can decrease or fully stop blood flow
- can happen anywhere in the body (coronary vessels, pulmonary vessels etc)



WHAT CAN GO WRONG?

Congenital Heart Defects

- a defect of heart and its vessels present at birth
- most common type of congenital defect
- four classes: hypoplasia, obstruction defects, septal defects, cyanotic defects



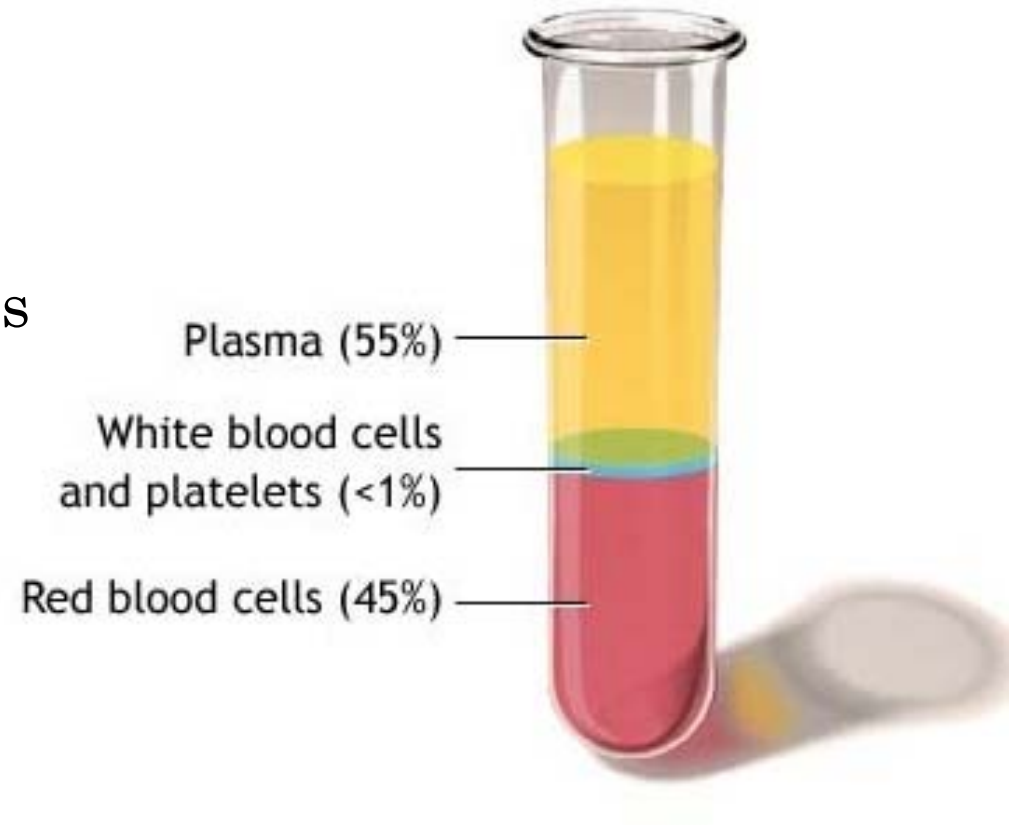
BLOOD

BLOOD FUNCTIONS

- Supply oxygen and nutrients to tissues
- Removal of waste
- Immune System: circulates white blood cells and detects foreign bodies
- Coagulation
- Messenger: transport hormones
- Regulate pH and body temperature

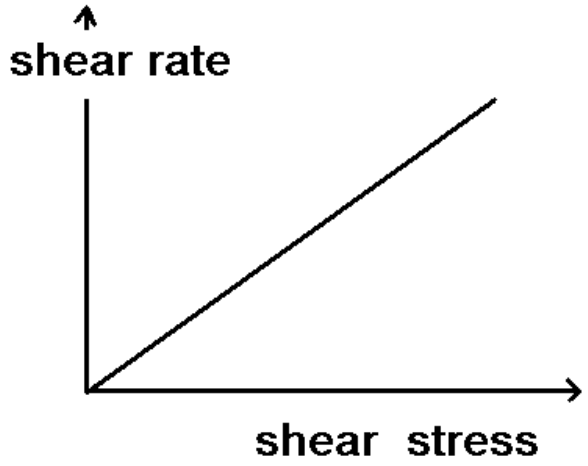
BLOOD COMPONENTS

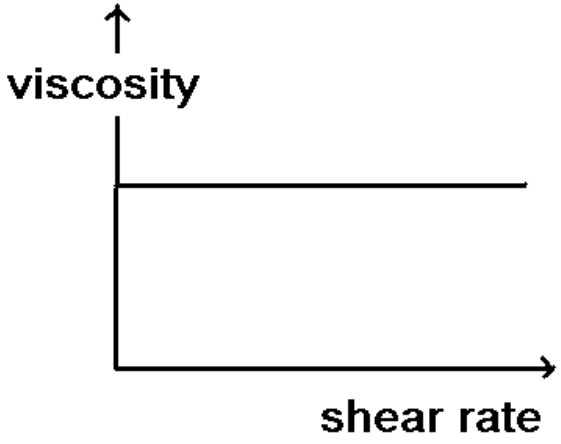
- 54.3% Plasma
- 45% Red blood cells (erythrocytes)
- 0.7% White blood cells (leukocytes) and platelets (thrombocytes)



NEWTONIAN OR NOT?

- Newtonian Fluid: stress-strain curve is linear and passes through origin
- Viscosity is independent of shear rate
- Blood Density = 1060 kg/m3
- Water = 1000 kg/m3



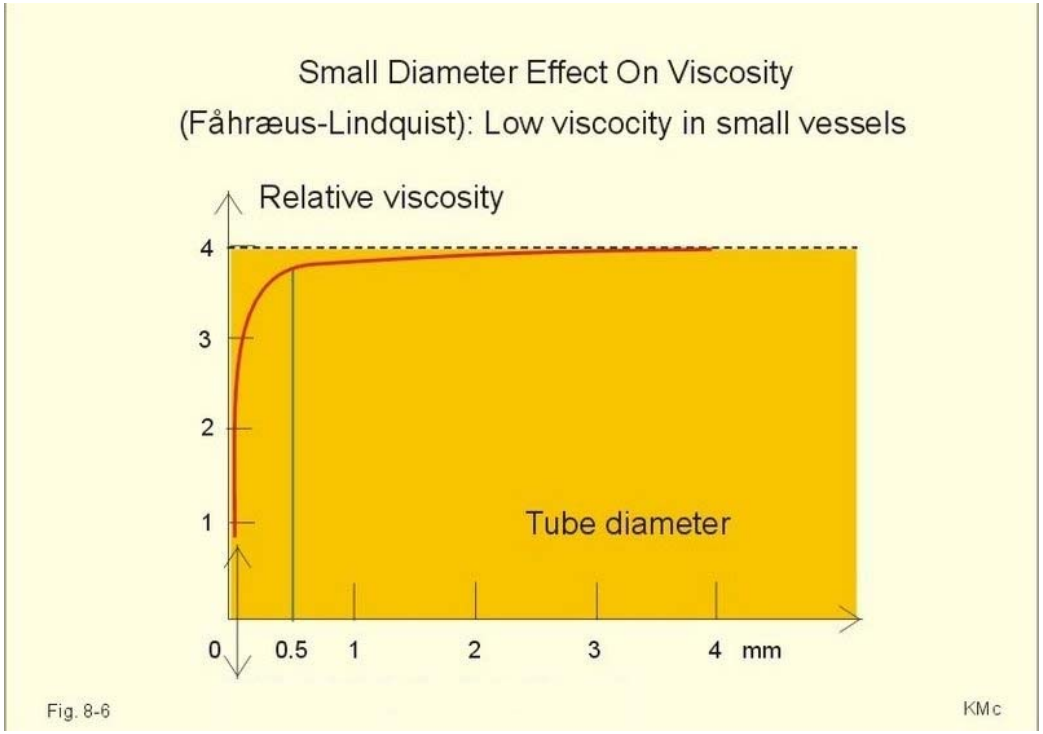


NEWTONIAN OR NOT?

- Blood acts Newtonian in regions of high shear rate
  - Large Arteries
    - Shear Rate > 100s-1
- Blood acts non-Newtonian in regions of low shear rate
  - Smaller Arteries and Capillaries
  - Due to red blood cells (hematocrit level)

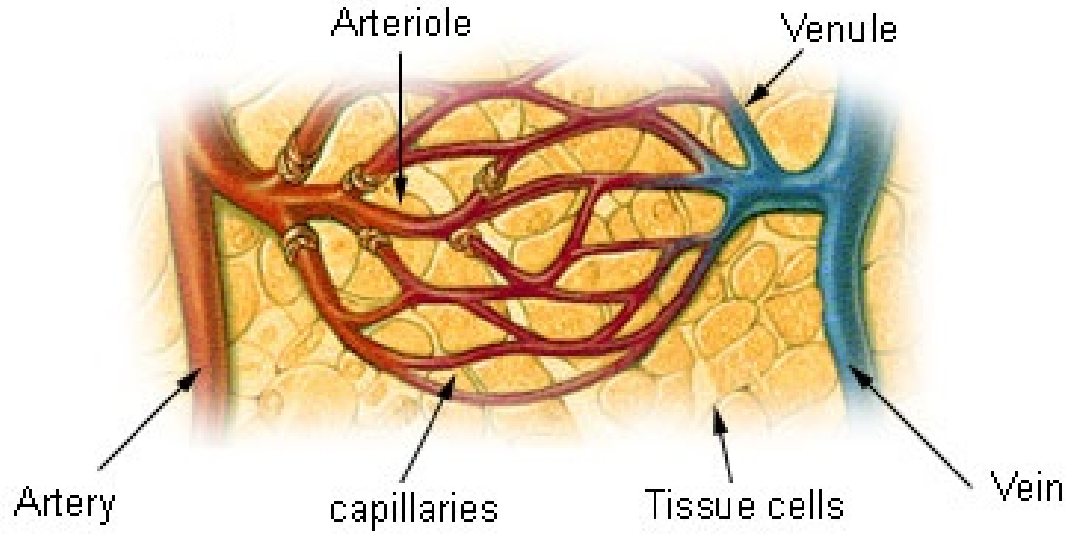
FAHRAEUS-LINDQVIST EFFECT

- Below a critical blood vessel radius, blood viscosity becomes dependent on vessel radius
  - Critical radius = 1 mm

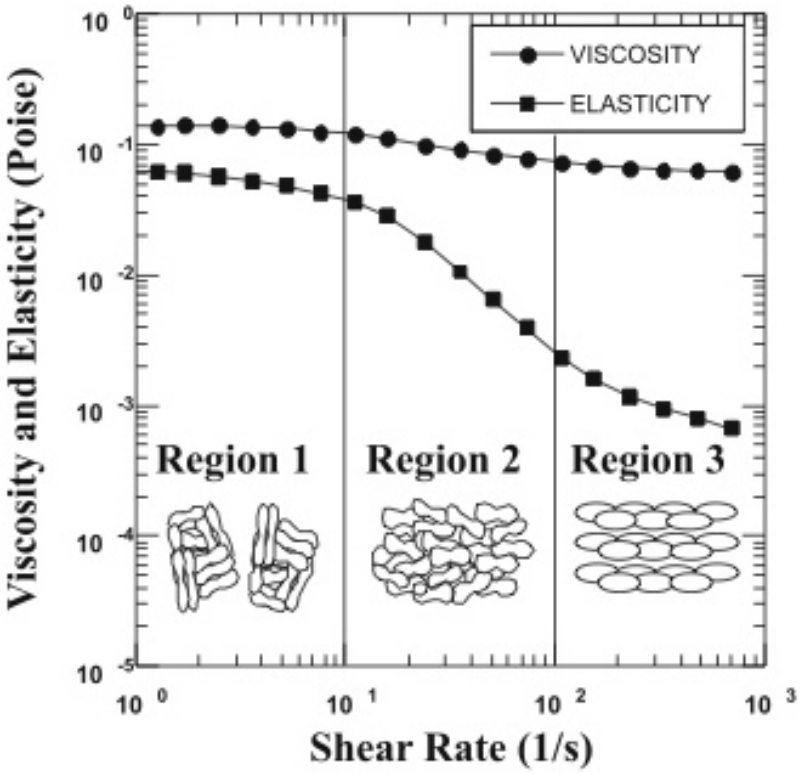


FAHRAEUS-LINDQVIST EFFECT

- Beneficial : less resistance, especially in regions with highest flow resistance (arterioles)
  - Lower perfusion pressure
  - Lower blood pressure
  - Smaller pump (heart!)



BLOOD: A VISCOELASTIC FLUID



- Region 1: red blood cells at rest stack together
- Region 2: force that splits them causes elastic deformation and adds elastic E to cell
- Region 3: sliding of internal cell needs energy input, released via viscous friction

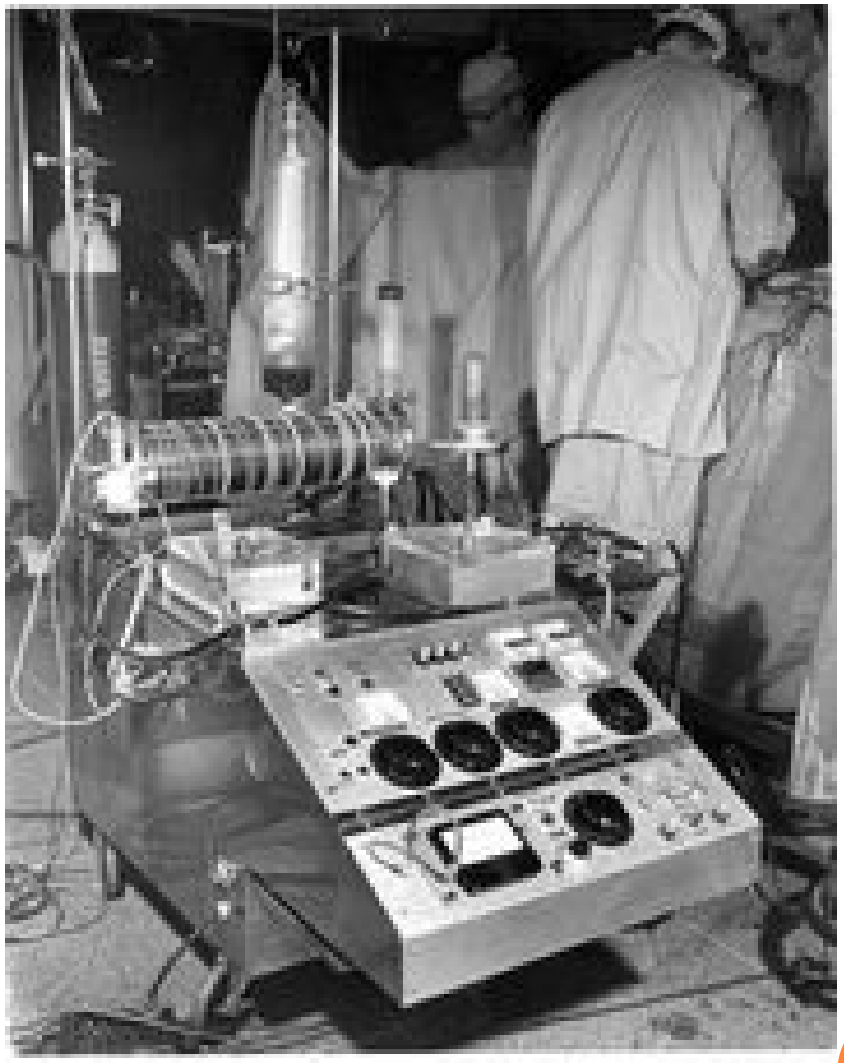
CARDIOPULMONARY BYPASS
A HISTORY

HISTORY

- Concept of using the oxygenator has been around since the 17th Century by Robert Hooke
- First mechanical takeover of both heart and lung functions was on April 5th, 1951
- First successful open heart surgery was carried out on May 6th, 1953

HISTORY

- Before 1950's → Conceptual and development Period
  - John Heysham Gibbon made the first heart lung machine in 1937
- 1950-1970 → Applied Technological Period
- 1970-Present → Refinement Period



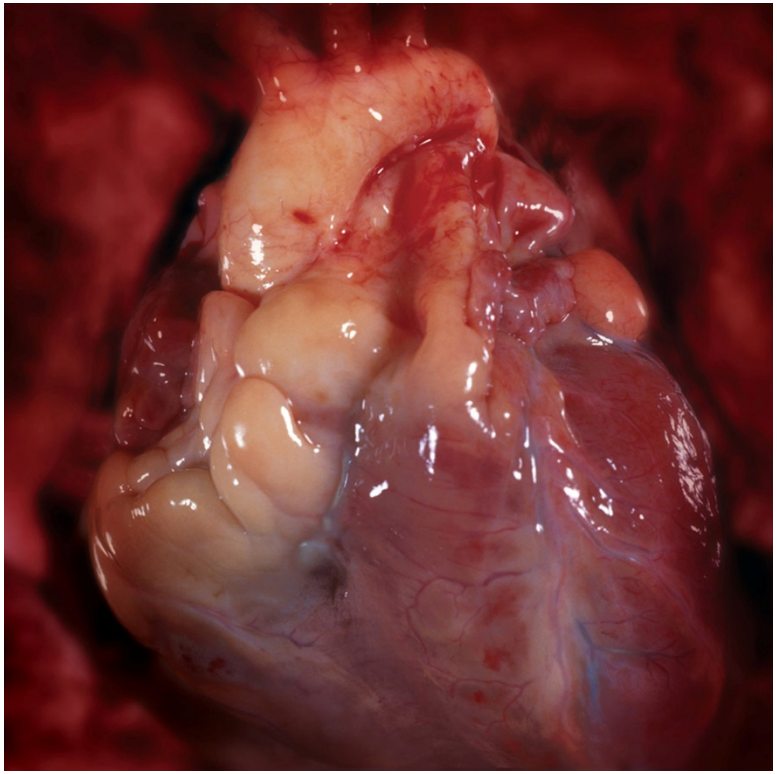
CARDIOPULMONARY BYPASS USES

USES

- Cardiopulmonary Bypass Process is carried out using the Cardiopulmonary Bypass Machine (CBM)
- Biomedical Device that is used to carry out open-heart bypass surgeries on patients
- Hundreds of thousands of patients lives are saved every year due to this procedure

USES

- The machine is used for two reasons:
  - Heart can be stopped for surgery
  - Help a person with heart failure



USES

- Coronary artery bypass surgery
- Cardiac valve repair or replacement
- Repair large septal defects
- Repair of congenital heart defects
- Transplantation
- Repair of large aneurysmns
- Pulmonary thromboendarterectomy (PTE)
- Pulmonary thrombectomy

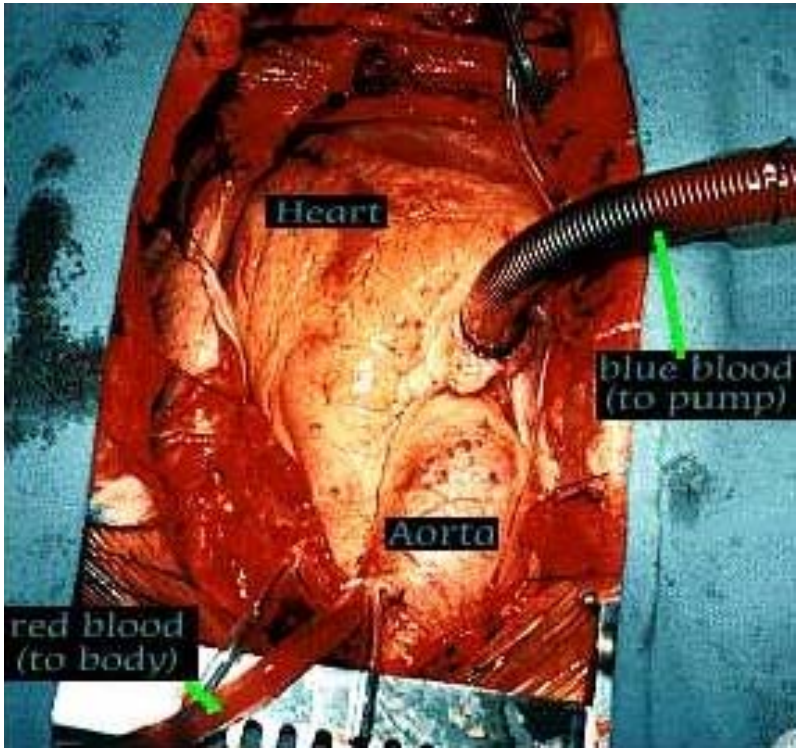
THE PROCEDURE

PROCEDURE

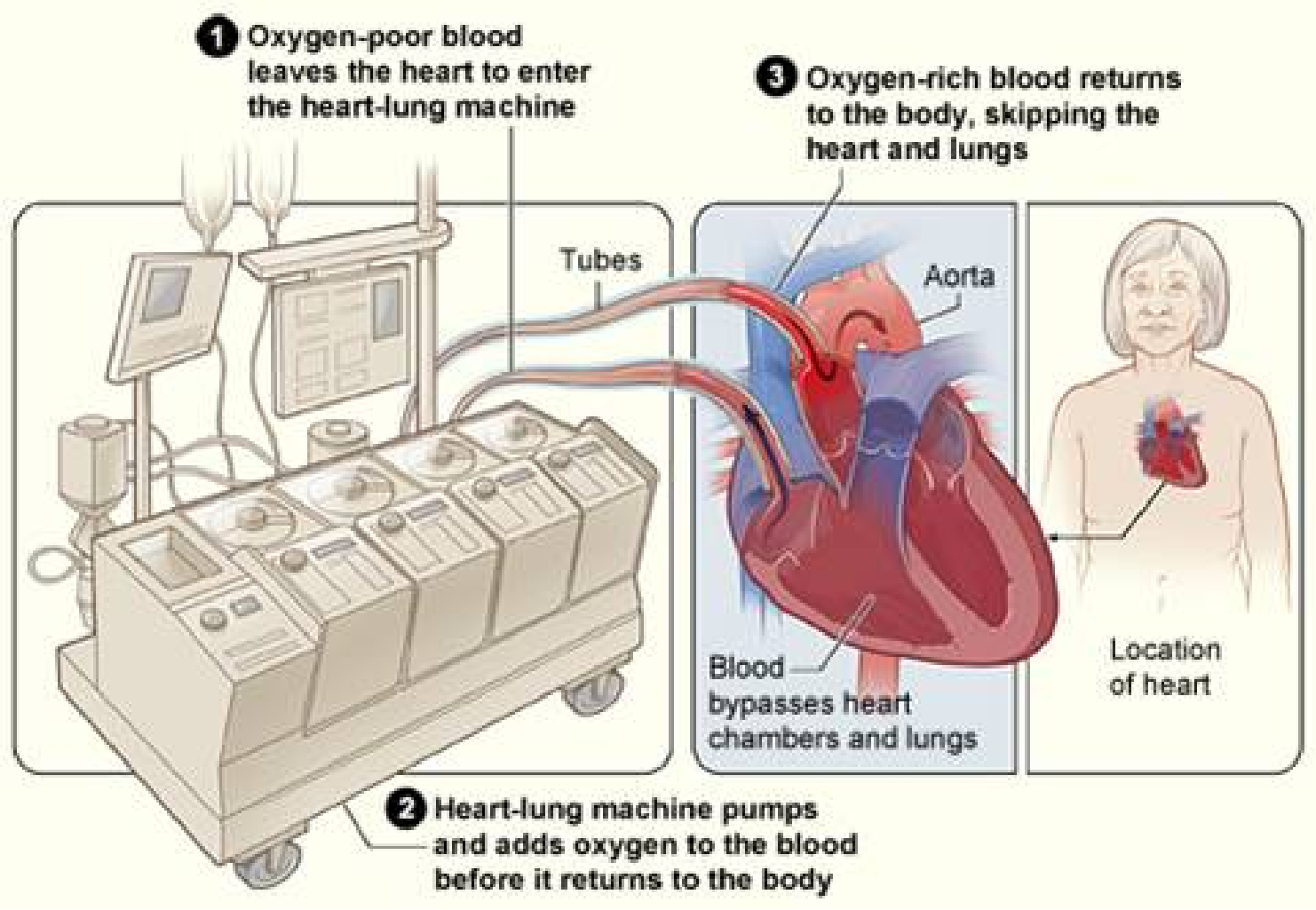
- A cannula (tube) is placed in the right atrium, vena cava or femoral vein to withdraw blood from body
- The blood is sent to cardiopulmonary bypass machine (CBM)
- Cardiovascular perfusionist assembles the circuit as per the patients requirements and makes sure that the heart lung machine runs specific to a given patient

PROCEDURE

- Oxygenator performs the same function as the lungs
- It is filtered, cooled, oxygenated and pumped back via a second cannula in the aorta or femoral artery
- A third tube near or in the heart flushes it with potassium solution to stop the heart
  - cardioplegia



CARDIOPULMONARY BYPASS



THE HEART-LUNG MACHINE

THE HEART LUNG MACHINE

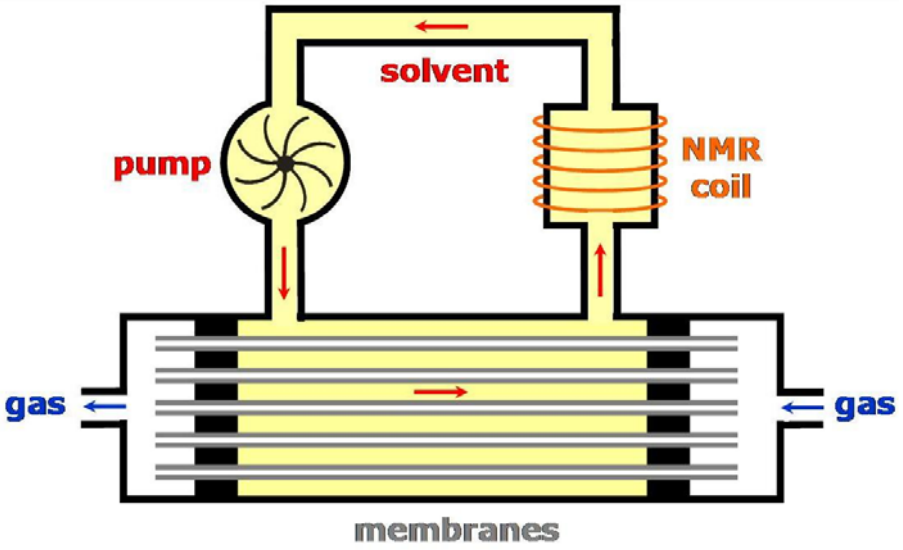
- CBM, “The Pump”
- Six main parts
  - Cannulae
  - Reservoir
  - Oxygenator
  - Temperature Control
  - Filter
  - Roller/Centripetal Pump
- Connected by a series of silicone or PVC tubes

OXYGENATOR

- Takes place of the lungs
- Exchanges O_2 for CO_2 in the blood pumped from the reservoir
- Three types:
  - Bubble
  - Membrane
  - Heparin-coated

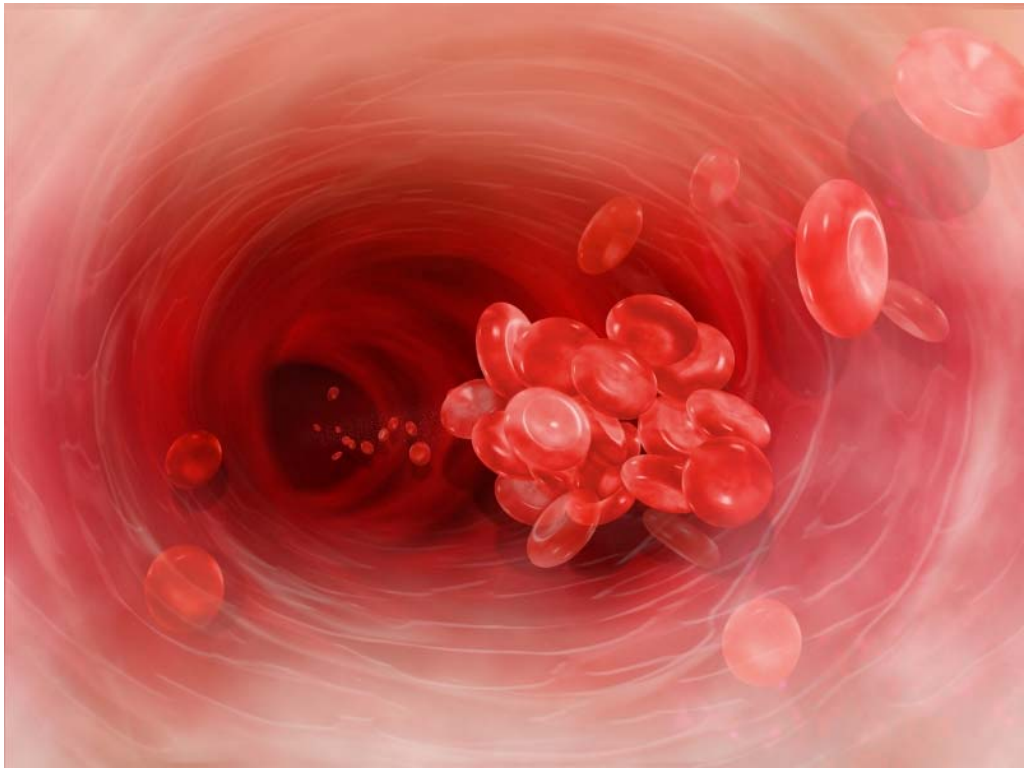
MEMBRANE OXYGENATORS

- Thin gas permeable membrane separates blood and gas flow
- Blood flow = 3-5 L/min
- Gas flow is 60% of blood flow
- Blood contacts membrane → direct oxygenation



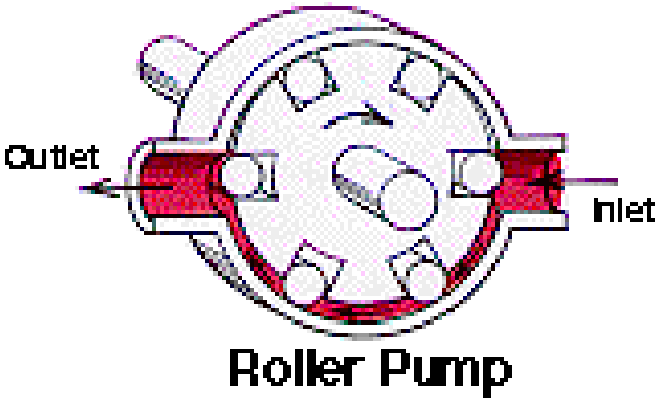
HEPARIN-COATED OXYGENATOR

- Herparin is an anticoagulant
- Added to oxygenator polymer
- Avoid complications resulting from abnormal pressure gradient across oxygenator
- Reduces need for systemic herparinization

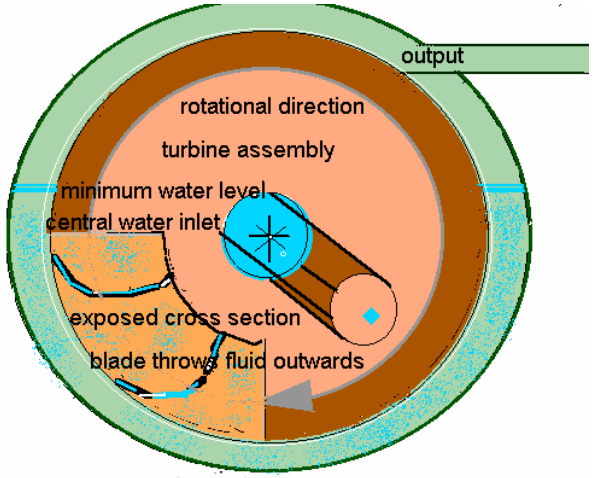


PUMP

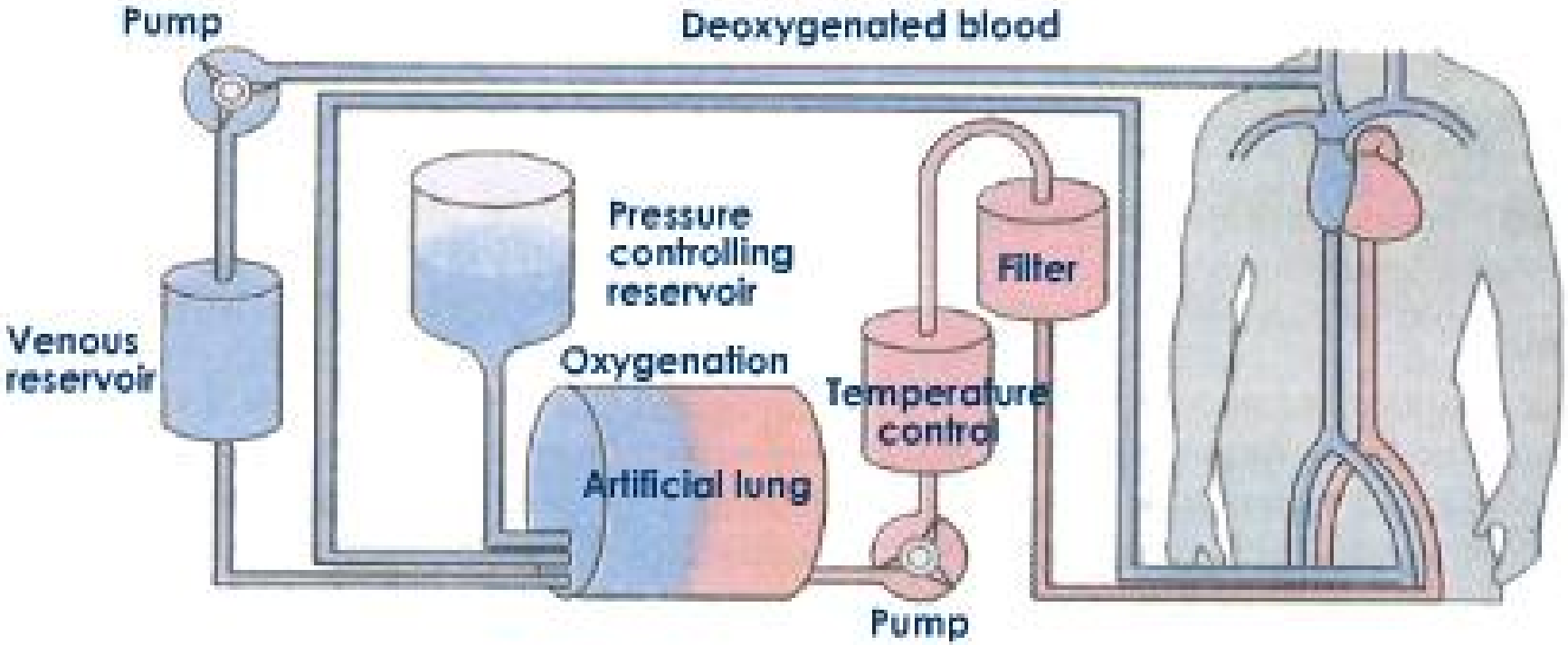
- Takes place of the heart
- Roller Pump
  - Made up of several motor-driven pumps
  - Peristaitically massage the tubing, propels the blood through
- Centripetal
  - RPM of the pump head is altered to cause blood flow due to centripetal force
  - Thought to be superior to roller pump as it produces less blood damage



Roller Pump



THE HEART-LUNG MACHINE



Heart-lung machine

VIDEO

COMPLICATIONS

COMPLICATIONS

- Postperfusion/Pump-head syndrome
- Hemolysis
- Capillary leak syndrome
- Clotting of blood in the circuit
- Air embolism
- Inflammation

THE FUTURE

IMPROVEMENTS FOR THE FUTURE

Lifebridge B2T

- First portable heart-lung machine
- Been around since 2007
- Weighs 17.5 kilograms
- Can be used by emergency room physicians and paramedics on the site, for critical patients

IMPROVEMENTS FOR THE FUTURE

MiniHLM

- Miniaturized heart-lung machine for infants
- Functions of the machine are integrated, to make the machine small and compact

THANK YOU

QUESTIONS?

REFERENCES

- Wikipedia. “Cardiopulmonary Bypass." Accessed November, 2010. URL: <http://en.wikipedia.org/wiki/Cardiopulmonary_bypass>
- By Cincinnati Children’s – change the outcome. " Procedure and Risk of Cardiopulmonary Bypass." Accessed November, 2010. URL: <hhttp://www.cincinnatichildrens.org/health/heart-encyclopedia/treat/surg/bypass.htm>
- By About.com Inventors. "John Heysham Gibbon - Heart Lung Machine - Pump Oxygenator." Accessed November, 2010. URL: <http://inventors.about.com/library/inventors/blheartlungmachine.htm >
- Julie Woodburn by Illumin – A review of Engineering in Everyday Life. " Engineering the Heart Lung Machine." Accessed November, 2010. URL: < http://illumin.usc.edu/article.php?articleID=199&page=4>
- " The Heart and the Circulation." Accessed November, 2010. URL: < http://www.nsbri.org/HumanPhysSpace/focus2/heart-circulation.html>
- <http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.3483991/k.34A8/Statistics.htm >
- < http://www.linux-host.org/energy/spump.htm >
- < http://en.wikipedia.org/wiki/Fåhræus–Lindqvist_effect >
- Madihally. (2010) “Principles of Biomedical Engineering.” Artech House
- < http://en.wikipedia.org/wiki/Newtonian_fluid >