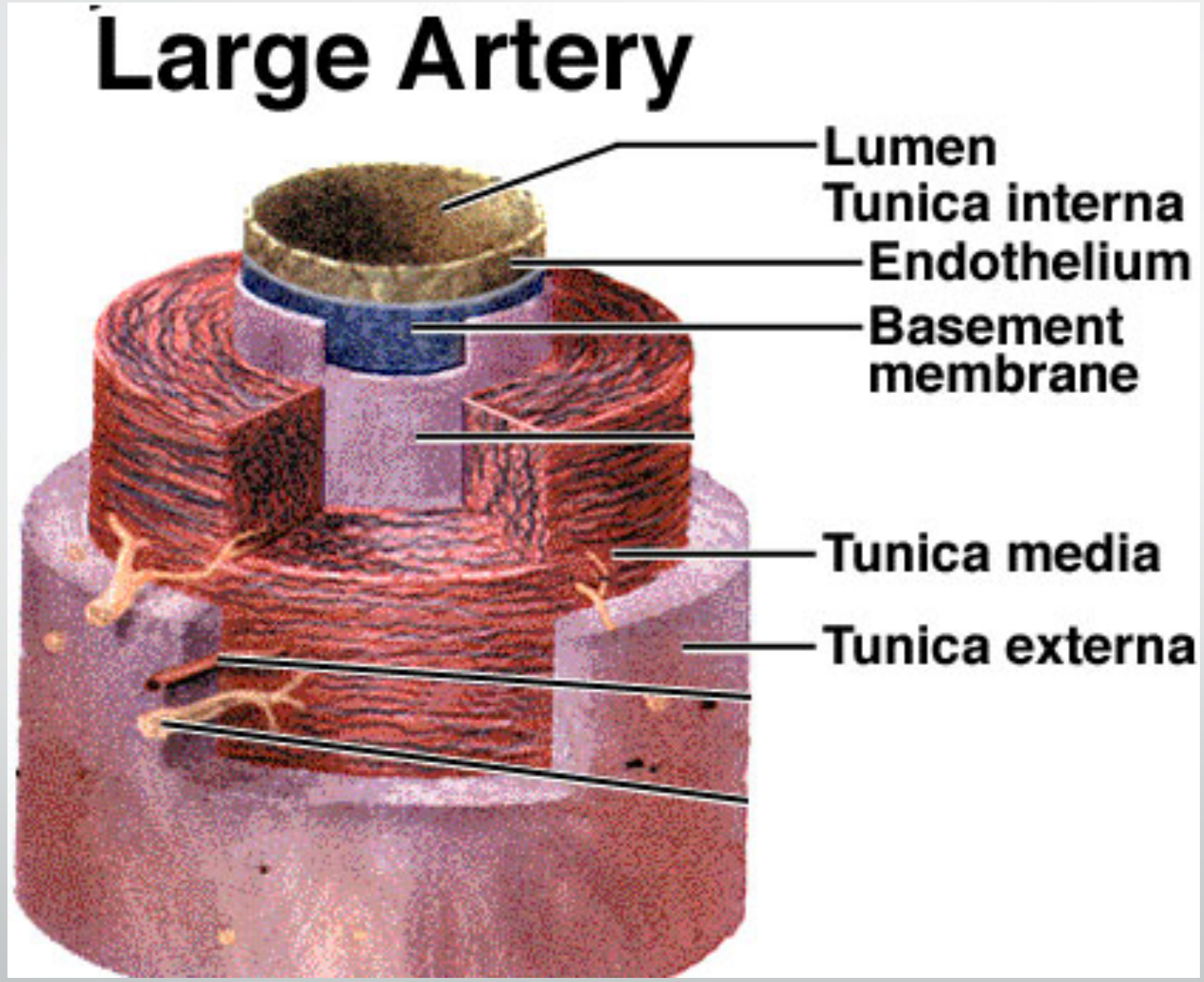
Introduction to Exercise Physiology - Blood Vessels and Lymphatic System

Learning Objectives

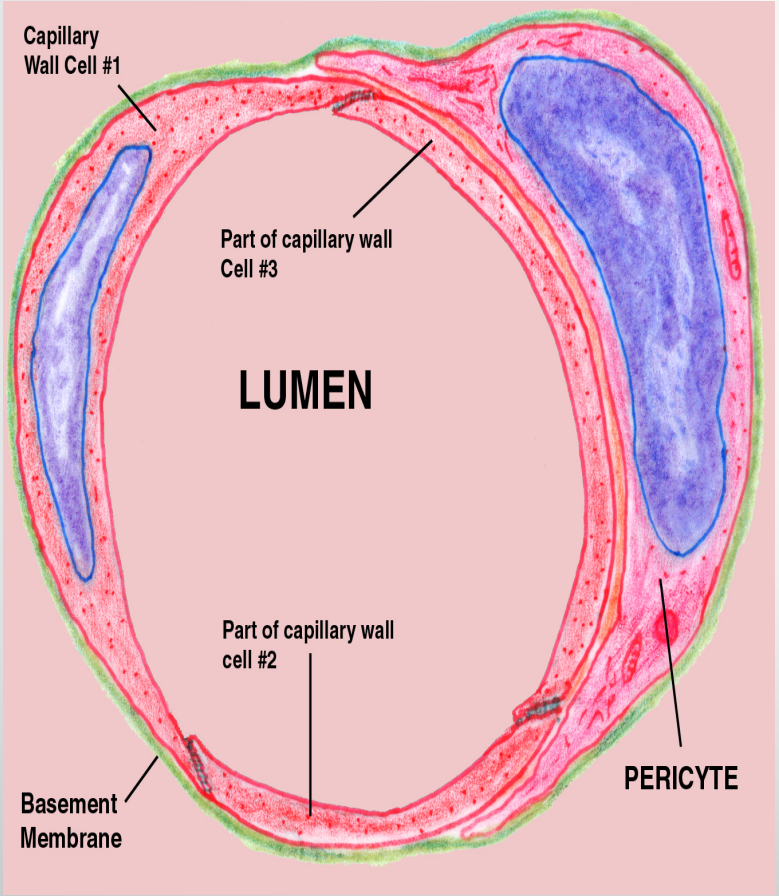
- Describe the structure of the blood vessels and lymphatic system
- Describe the lymphatic organs and tissue
- Understand the pumping mechanism
- Understand the functions of the lymphatic system

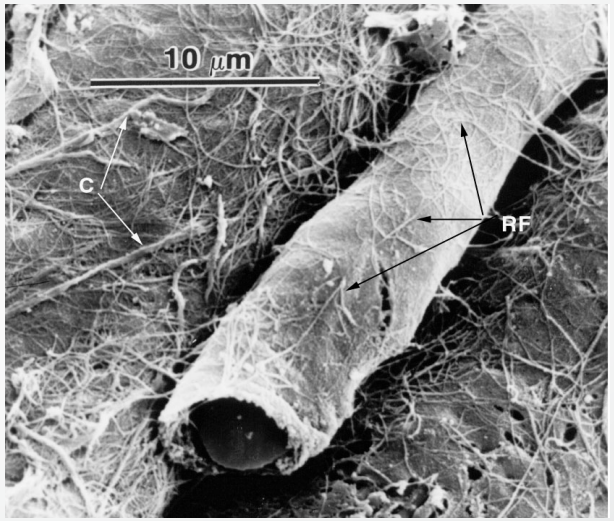

Large Artery
Lumen
Tunica interna
Endothelium
Basement membrane
Tunica media
Tunica externa

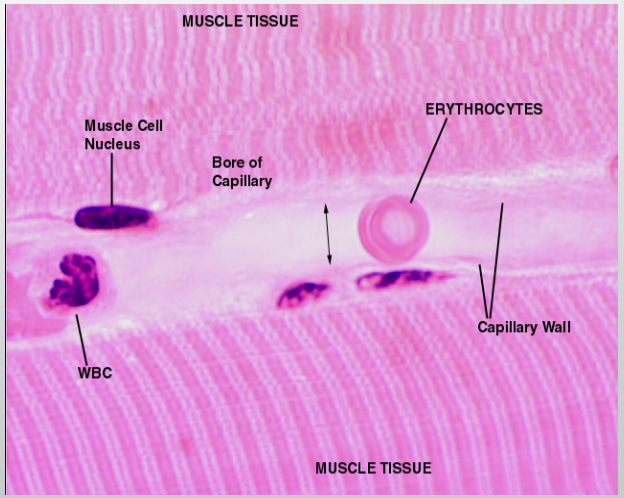
Arteries

- Carry Blood away from the heart
- Blood carried under high pressure
- Carry oxygenated blood (except pulmonary artery)
- Have relatively more muscle and elastic tissue
- Have relatively narrow lumens
- Do not have valves except semi lunar valves of aorta and pulmonary artery

Capillaries

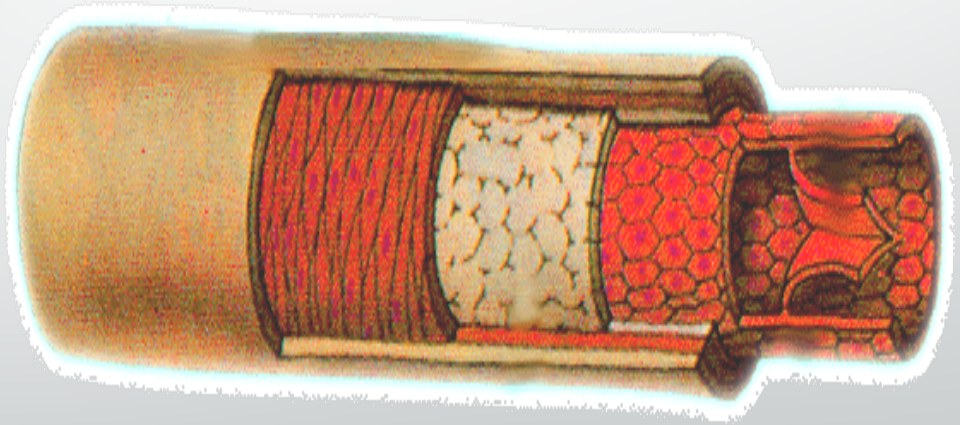


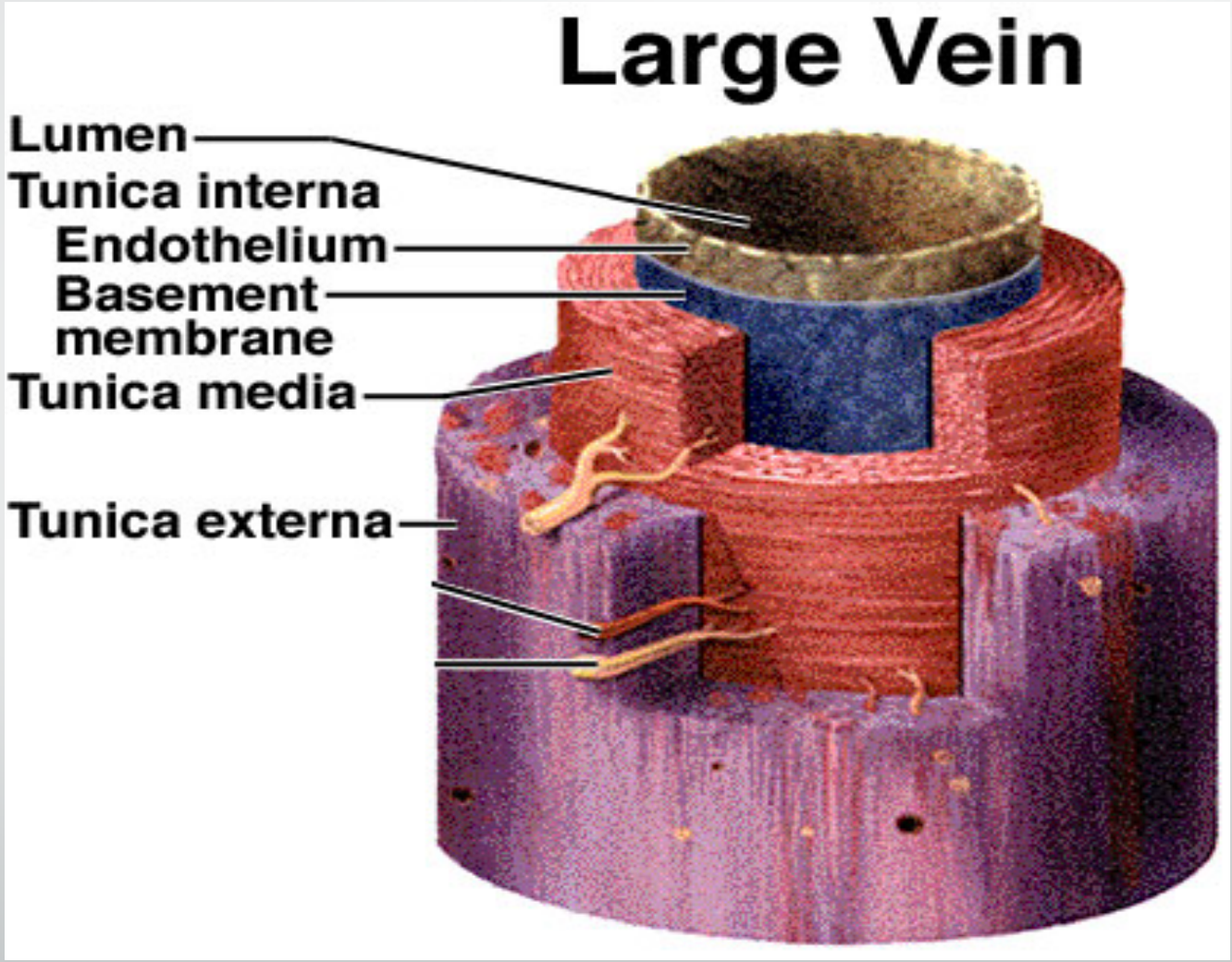




Venule

- Drains blood from capillaries
- Combine to form veins

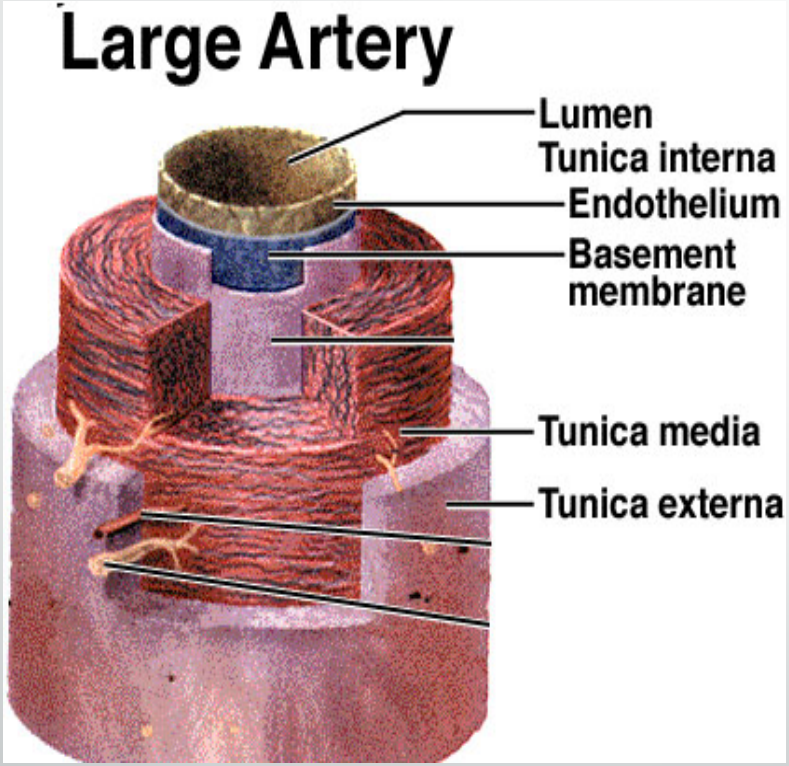


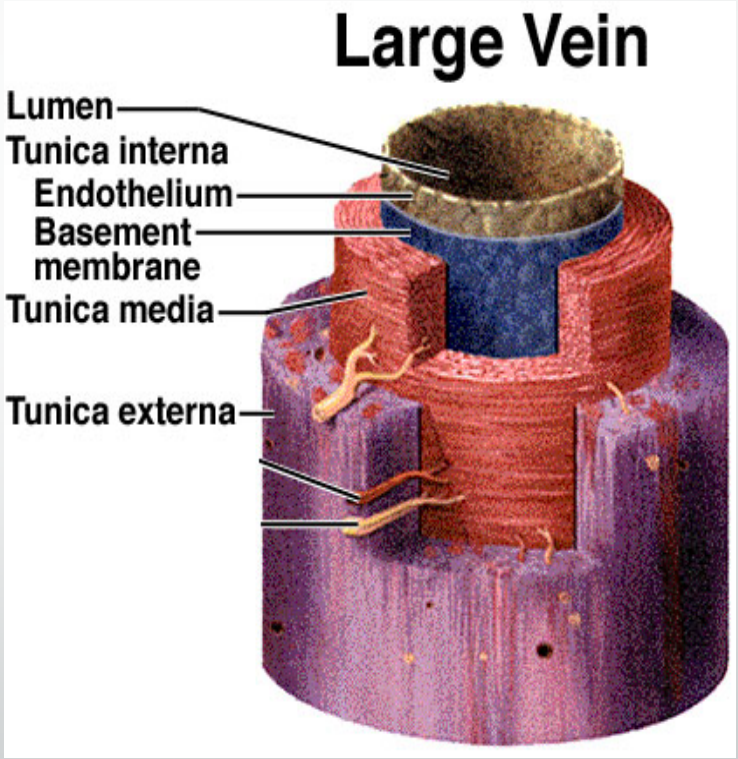

Large Vein
Lumen
Tunica interna
Endothelium
Basement membrane
Tunica media
Tunica externa

Veins

- Transport Blood towards the heart
- Carry deoxygenated blood (except pulmonary vein)
- Have relatively with lumens
- Relatively less muscle/elastic tissue
- Transport blood under lower pressure
- Have valves to direct blood flow

Comparison Between the Structure Arteries and Veins

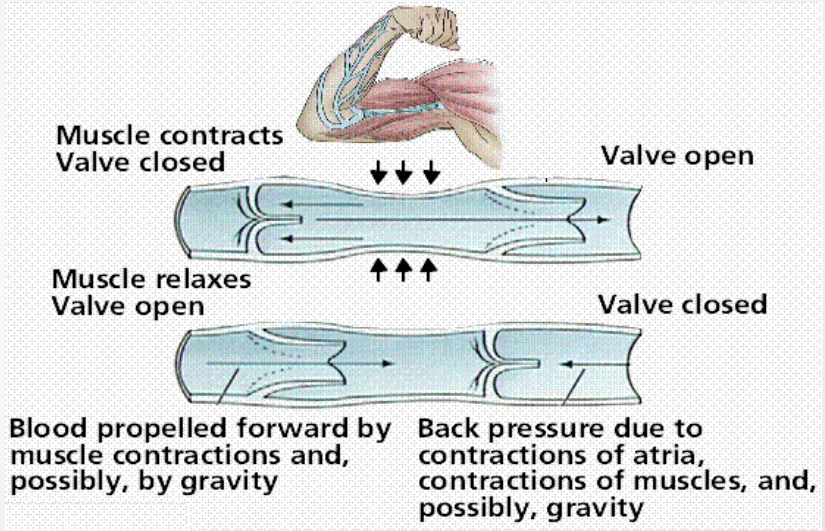


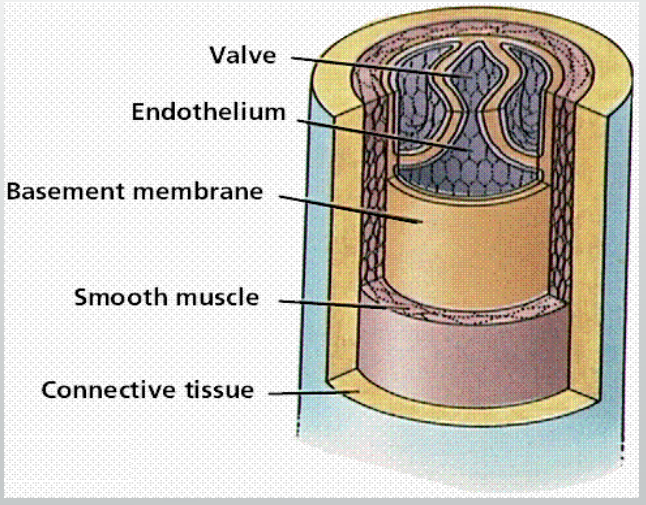


Valves

- To control the direction of blood flow

- To prevent flow back of blood carrying waste materials into tissue





Blood

- Haematopoiesis – formation of the components of the blood.
- Occurs in the liver and spleen of the foetus, but after birth it normally only occurs in the bone marrow.
- All blood cells start as pluripotential stem cells and eventually become red or white depending on requirements.

Blood

- Plasma
- Cells
- Platelets

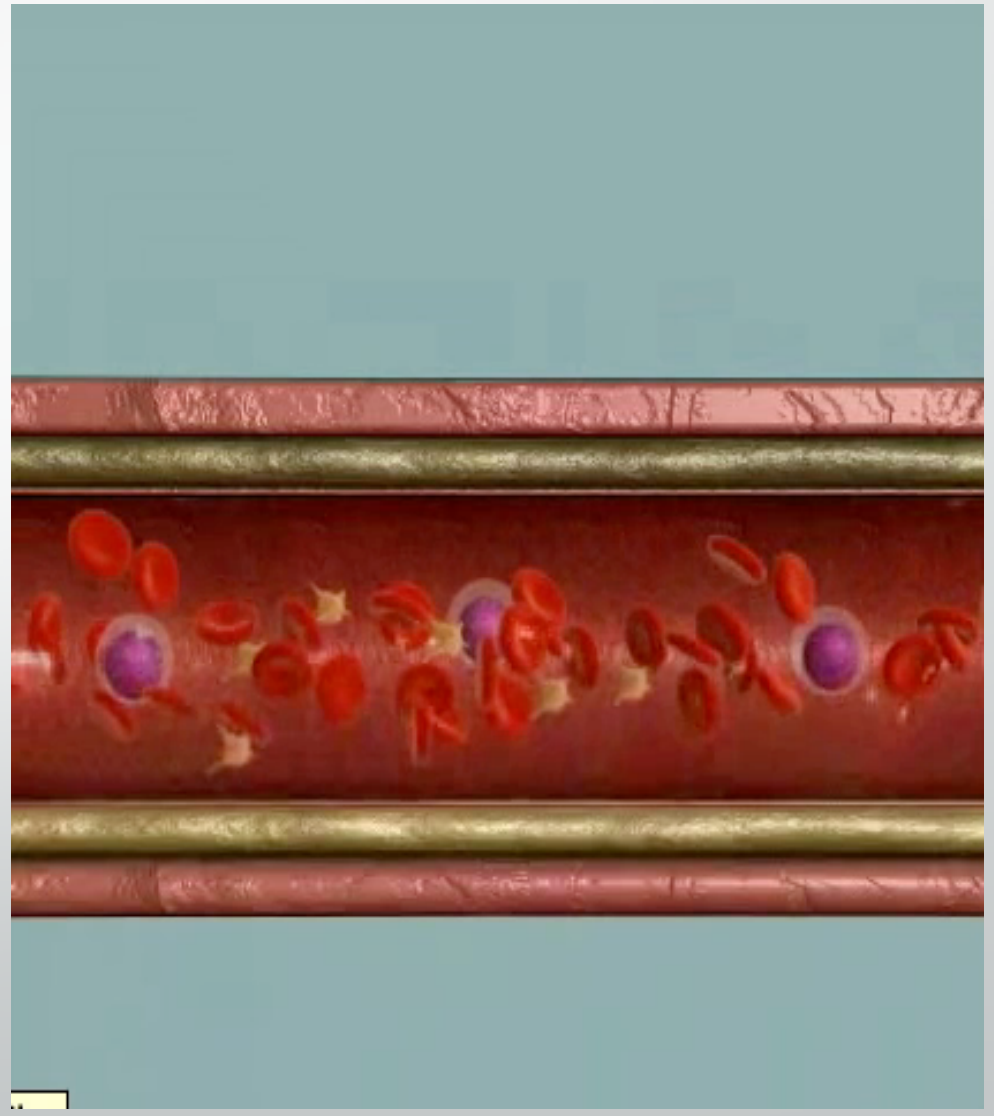
- 4-6lts in adults
- pH 7.35 – 7.45

Components of Blood

Plasma (55%)			Formed Elements (45%)		
Proteins (7%)	Water (91%)	Other Solutes (2%)	Platelets	Leukocytes	Erythrocytes
albumin's (58%)		ions		neutrophils (60-70%)	
globulins (38%)		nutrients		lymphocytes (20-25%)	
fibrinogen (4%)		waste products		monocytes (3-8%)	
		gases		eosinophils (2-4%)	
		regulatory substances		basophils (0.5-1%)	

Plasma

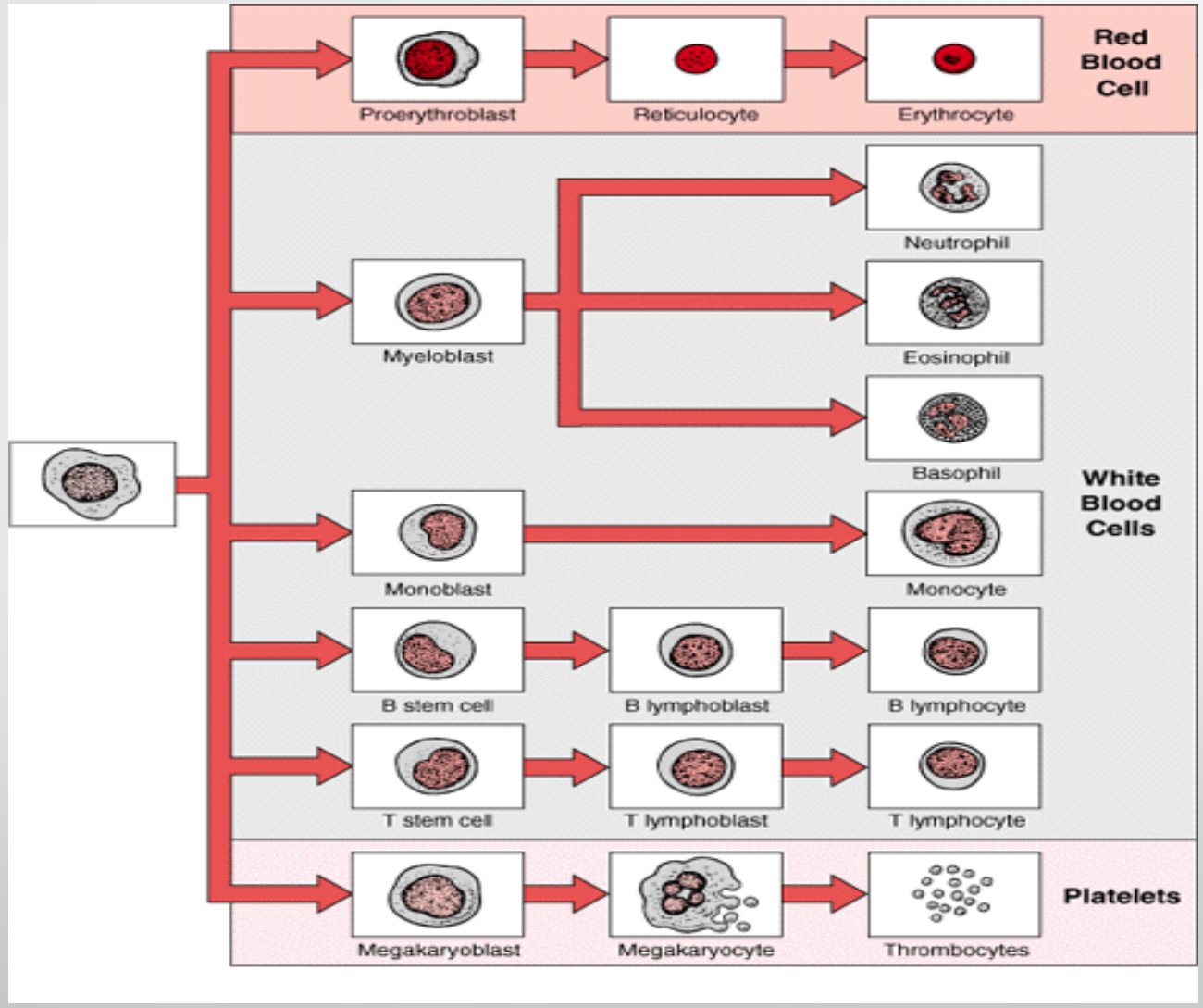
- Fluid part of the blood
  - albumin (helps to thicken the blood)
  - globulins (include the antibodies that help protect from infections)
  - fibrinogen (necessary for blood clotting)
- Delivery of necessary substances for cellular metabolism in tissues
- Defending against micro-organisms and injury
- Acid - base balance



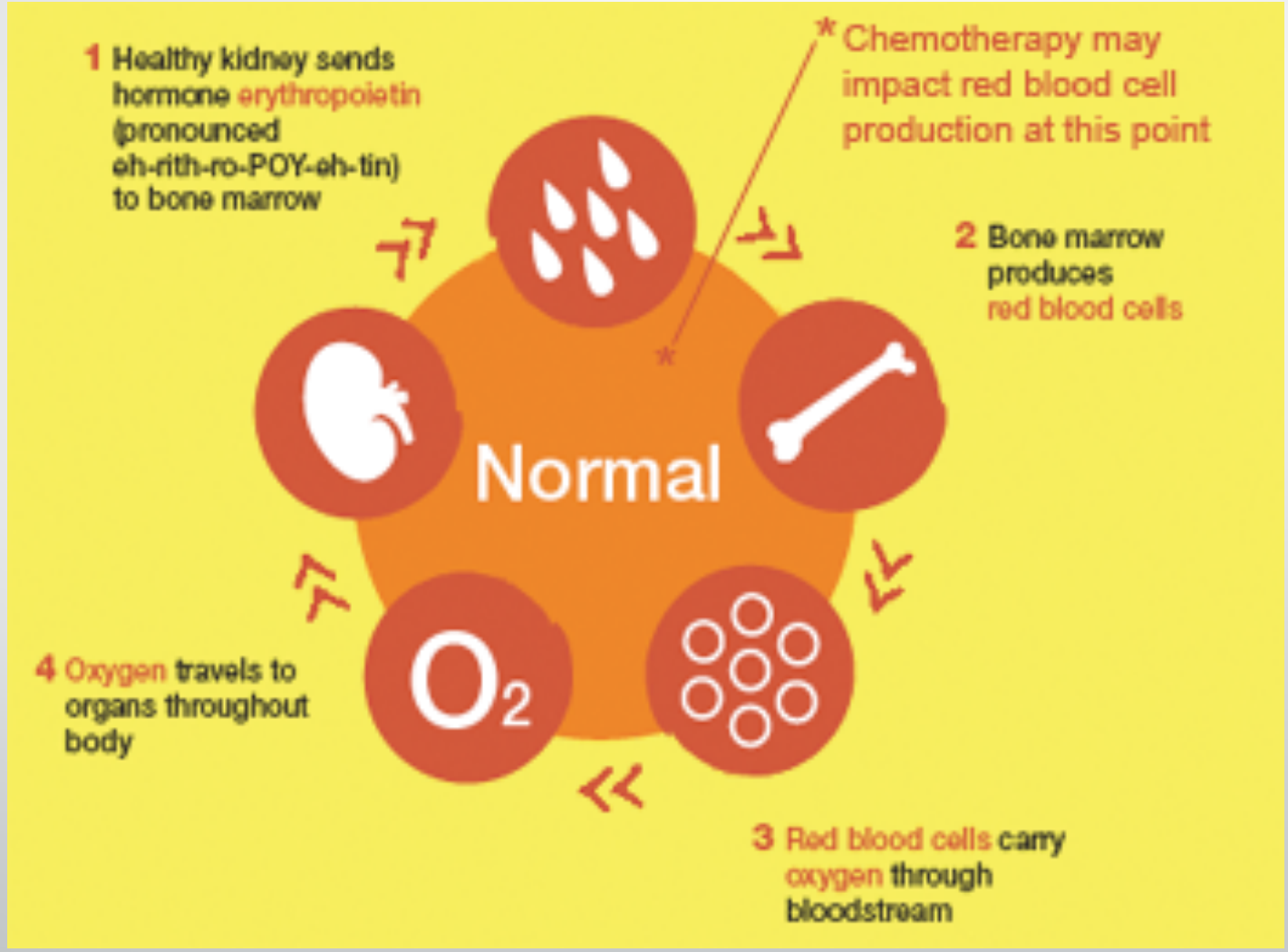
Solid Elements in the Blood

- Erythrocyte (RBC) - Oxygen and carbon dioxide transport
- Neutrophil - Immune defence (phagocytosis)
- Eosinophil - Defence against parasites
- Basophil - Inflammatory response
- B-lymphocyte - Antibody production (precursor of plasma cells)
- T-lymphocyte Cellular - immune response
- Monocyte - Immune defence (phagocytosis)
- Platelet - Blood clotting

pluripotential stem cells



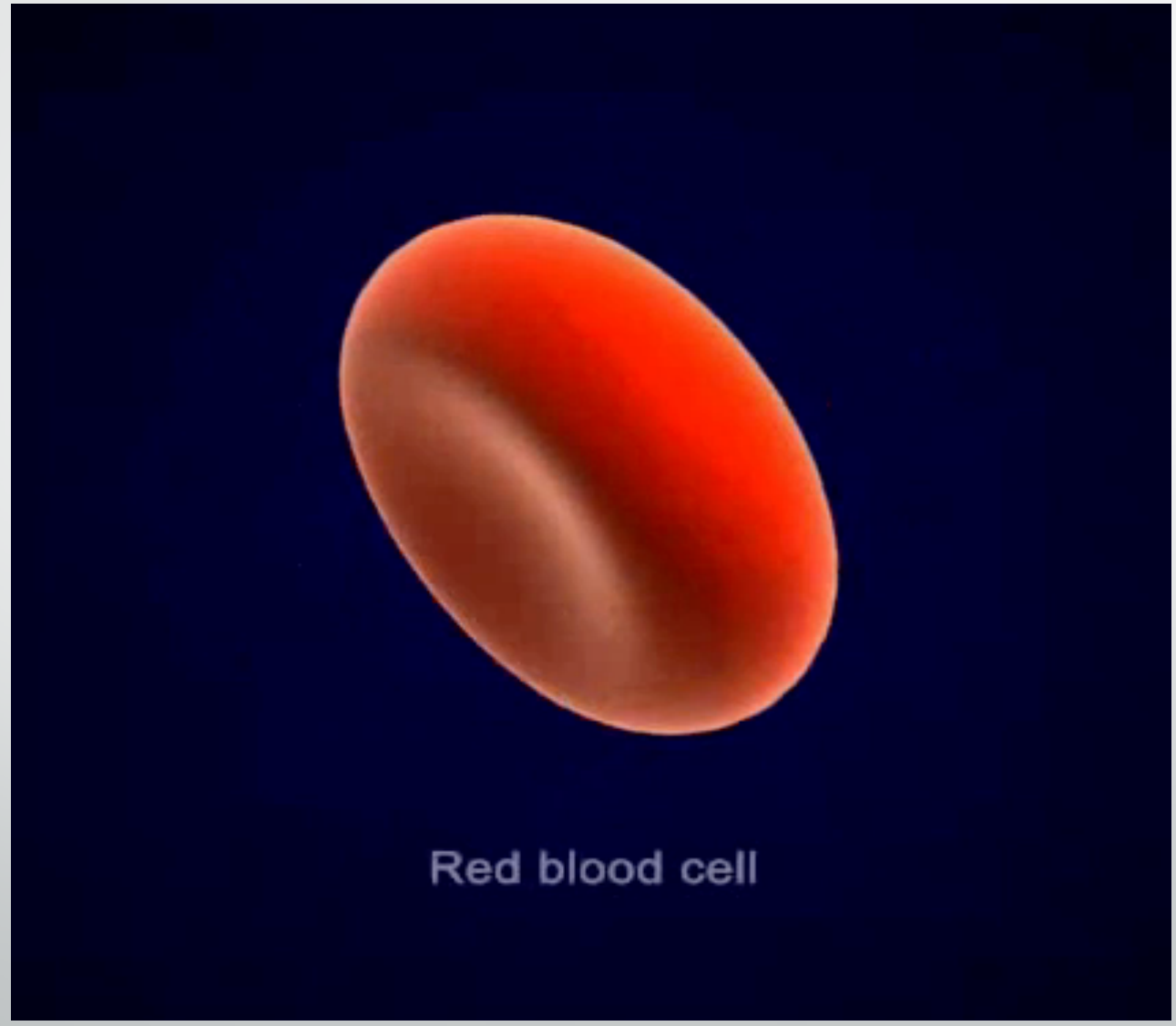
Red Blood Cells



Red Blood Cells (Erythrocytes)

- Consist mainly of haemoglobin, a complex molecule containing haeme groups (4) whose iron molecules temporarily link to oxygen molecules in the lungs.
- Diameter of a typical human erythrocyte disk is 6–8 μm
- For by the process of erythropoiesis in 7 days and live a total of about 120 days.

Red Blood Cells (Erythrocytes)

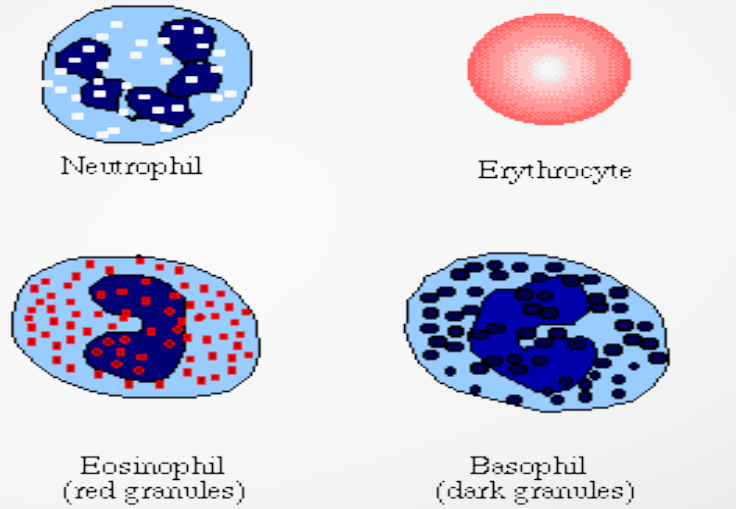


White Blood Cells (Leukocytes)

- Largest Blood Cells
- Protection from infection
- Removal of dead damaged cells / tissues
- Autoimmune response

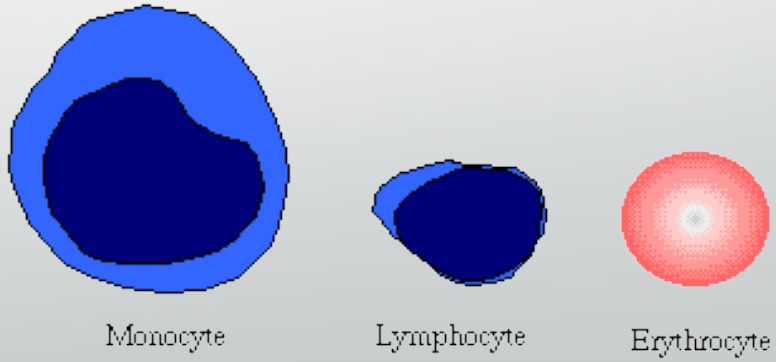
Types of Leukocytes

- Granulocytes
  - neutrophils
  - eosinophils
  - basophils



Typical granulocytes (with erythrocyte for size comparison)

- Agranulocytes
  - Monocytes
  - Lymphocytes



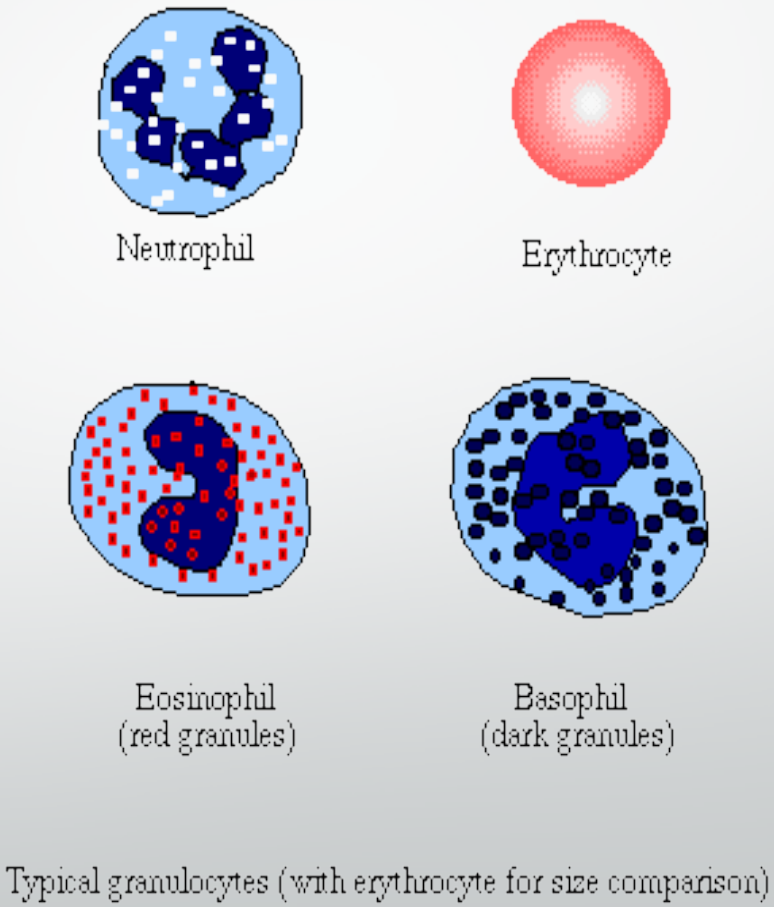
Typical agranulocytes (with erythrocyte for size comparison)

Numbers of different Leukocytes

Type	Number (billions per litre)	Percentage %
Neutrophils	2.5 - 7.5	40 - 75
Eosinophils	0.04 - 0.44	1 - 6
Basophils	0.015 - 0.15	0.1-1.0
Monocytes	0.2 - 0.8	2-10
Lymphocytes	1.5 - 3.5	20 - 50

Granulocytes (Polymorphonuclear Leukocytes)

- Originate from Haemocytoblast (stem Cells) in red bone marrow.
- Contain lobes or granules in the cytoplasm
  - Neutrophil
  - Basophil
  - Eosinophil



Typical granulocytes (with erythrocyte for size comparison)

Neutrophils

- Protect against microbes
- Remove waste materials - cell debris
- Attracted to site of infection by chemo toxins secreted by damages cells
- Pass through capillary walls to infected area by amoeboid movement
- Ingest and kill microbes by phagocytosis
- In viral infection neutrophils secrete interferons which inhibit viral replication inside cells
- Increase in number after infection; severe exercise, later stages of pregnancy, microbe infection, tissue damage, metabolic disorders, leukaemia, heavy smoking, use of oral contraceptives

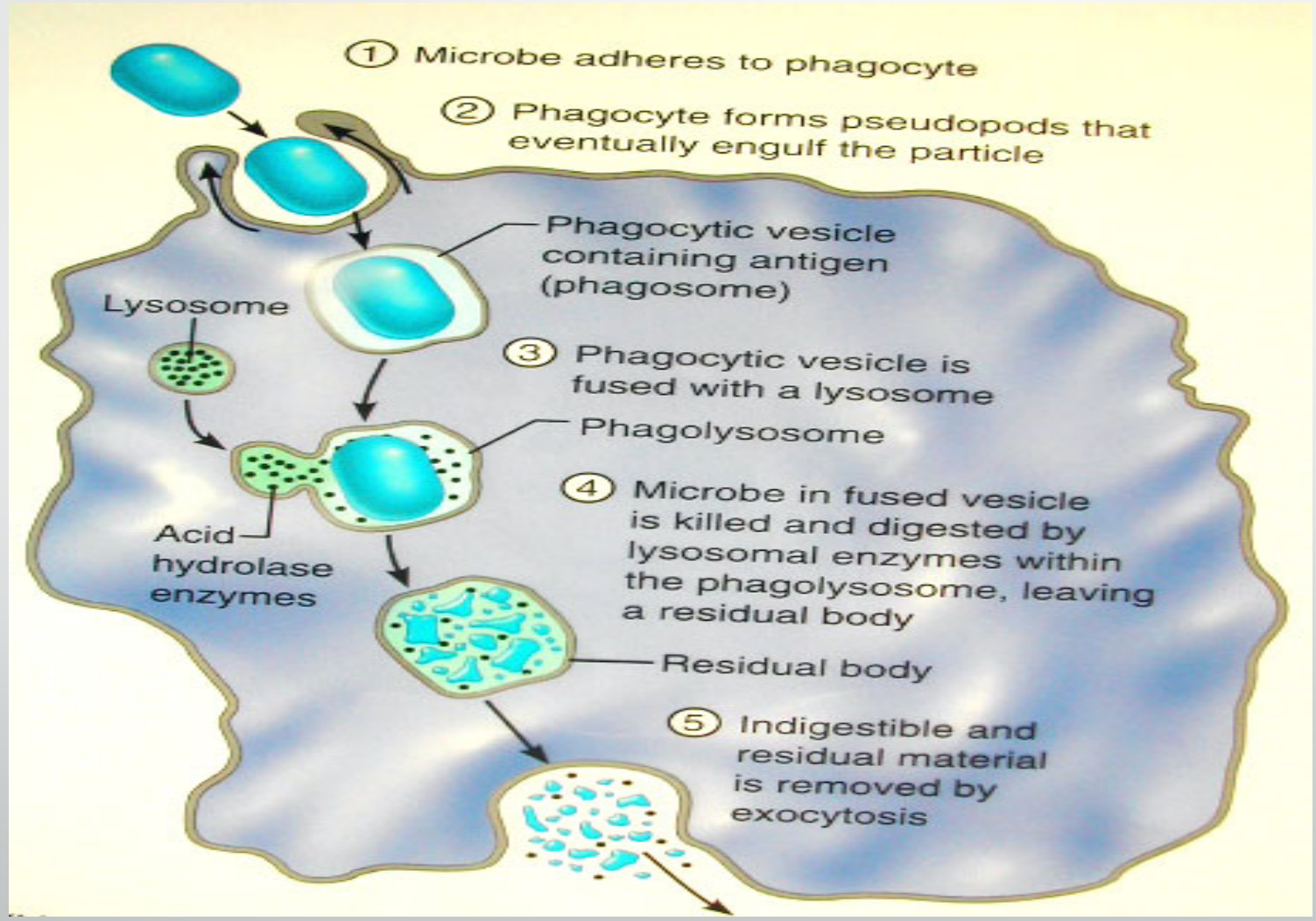
Eosinophils

- Migrate to areas exposed to external environment i.e. connective tissue under the skin, mucal membranes of respiratory and digestive tracts.
- Protect from foreign materials such as parasites.
- Neutralise histamine and help remove fibrin (blood clotting)
- Increase numbers in response to allergic reactions

Basophils

- Secrete histamine causing vasodilation and increased permeability of capillary cell walls.
- This assists in the phagocytic movement of other white cells as well as antibodies
- Accumulate in areas of inflammation during healing

Phagocytosis

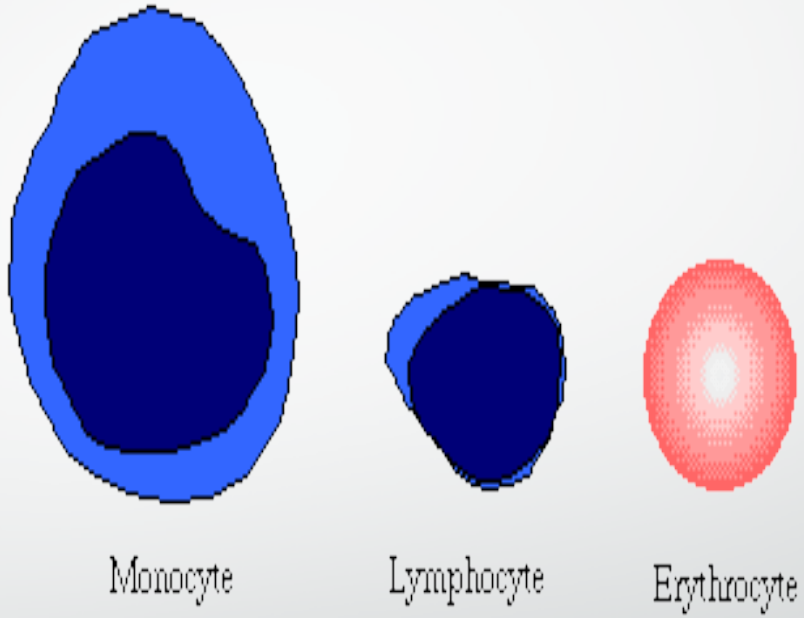


Agranulocytes

- No lobes in the cytoplasm

Examples:

- Monocytes
- Lymphocytes



Typical agranulocytes (with erythrocyte for size comparison)

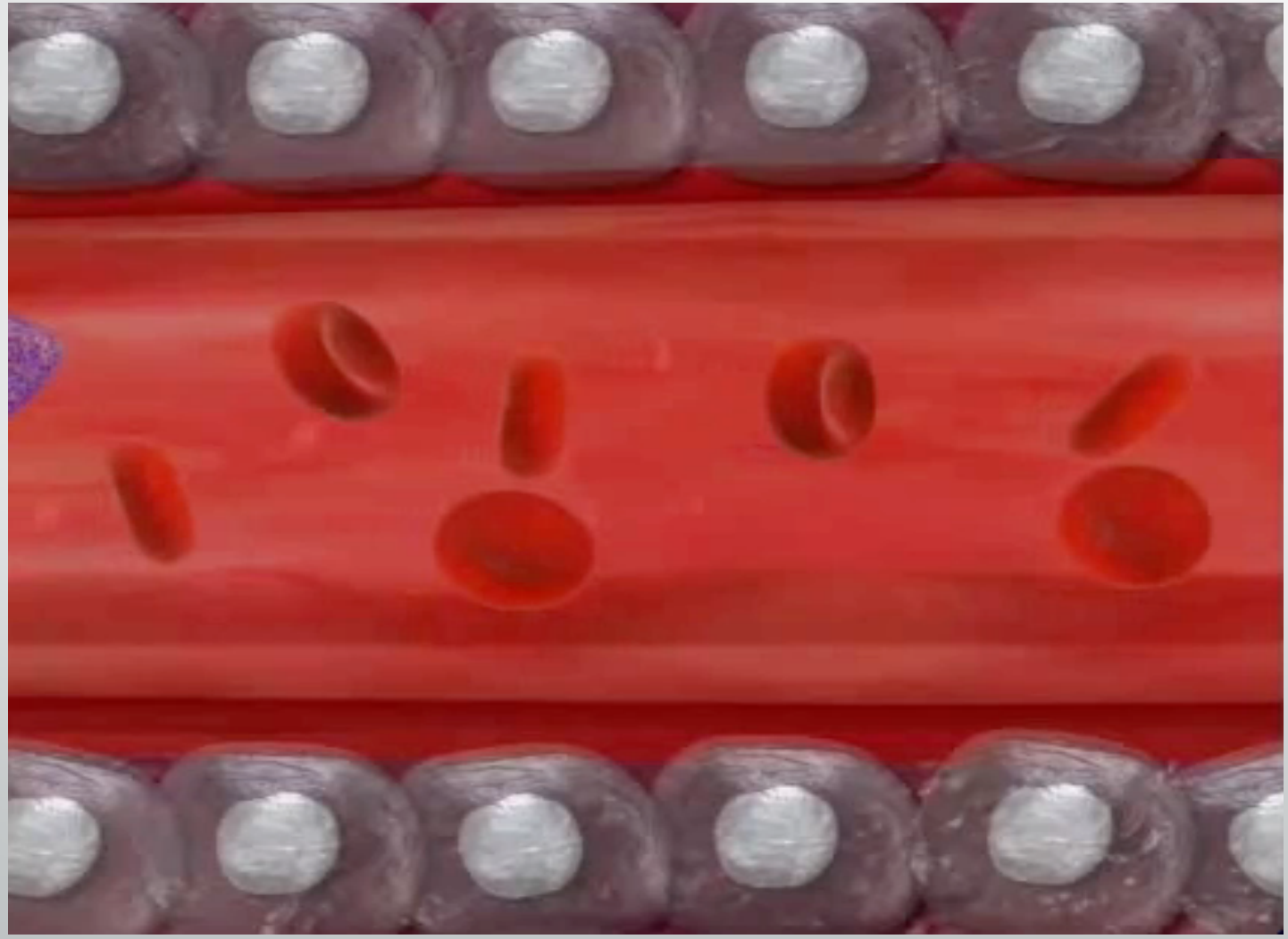
Monocytes

- Large mononuclear cells originating in bone marrow further developing into two forms.
- Monocytes - Circulate in blood, are mobile and phagocytic.
- If they migrate into the tissue monocytes develop into macrophages.
- Both types produce interleukin 1 which acts on the hypothalamus causing a rise in body temp, increases production of some globulins by the liver and increases production of activated T-lymphocytes.

Macrophages

- Lymph system
- Fixed phagocytic cells which multiply in situ.
  - Histocytes - connective tissue
  - Kupffer cells - liver
  - Alveolar macrophages - lungs
  - Ostoclasts - bone
  - others

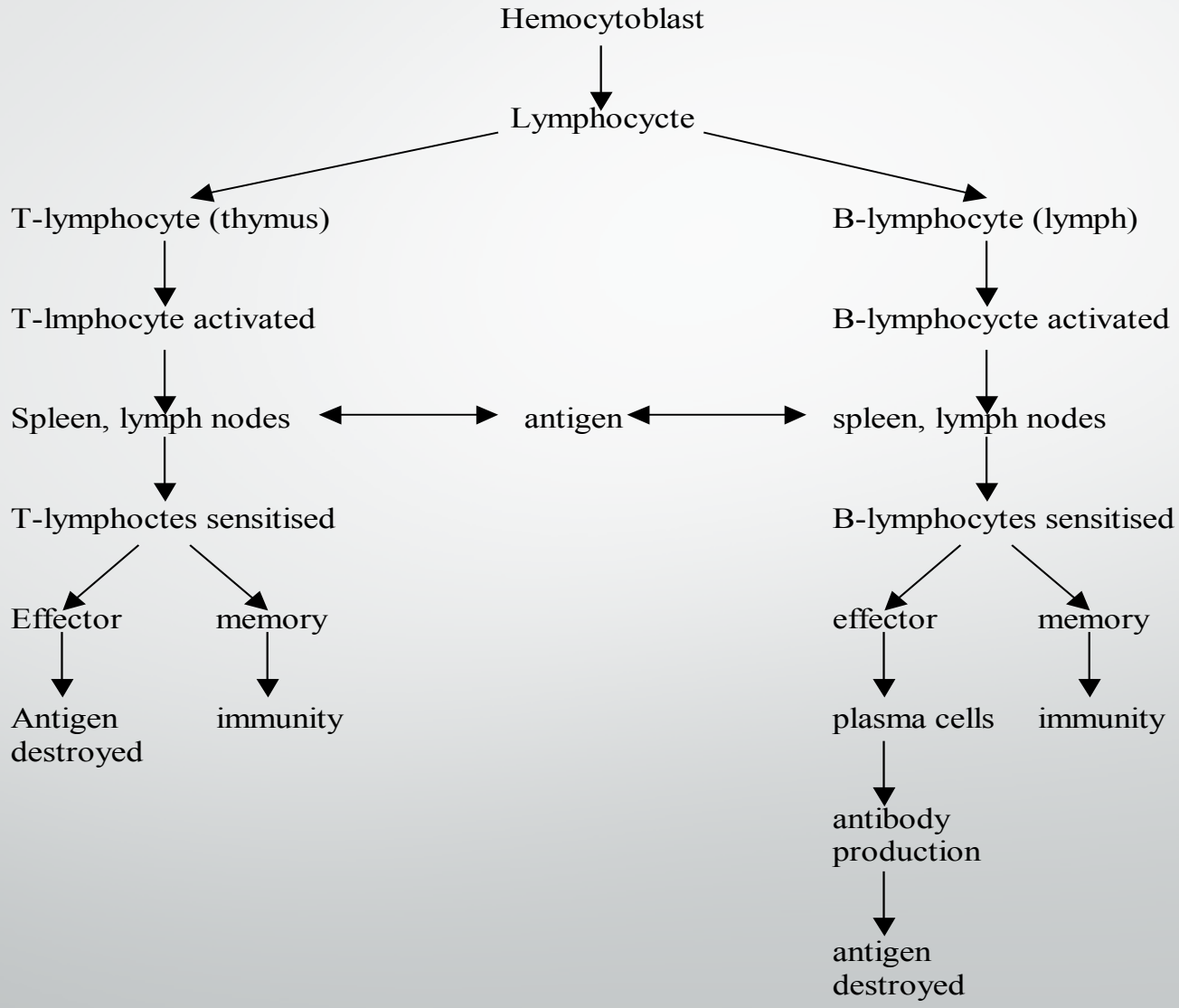
White Blood Cells



Lymphocyctes

- Protect against foreign materials
- Develop from stem cells in red bone marrow and become activate when they enter lymph tissue and or thymus gland.
- Hence two forms
  - T-lymphocytes
  - B-lymphocytes
- When activated and encountering an antigen they divide into two groups - effector cells and memory cells

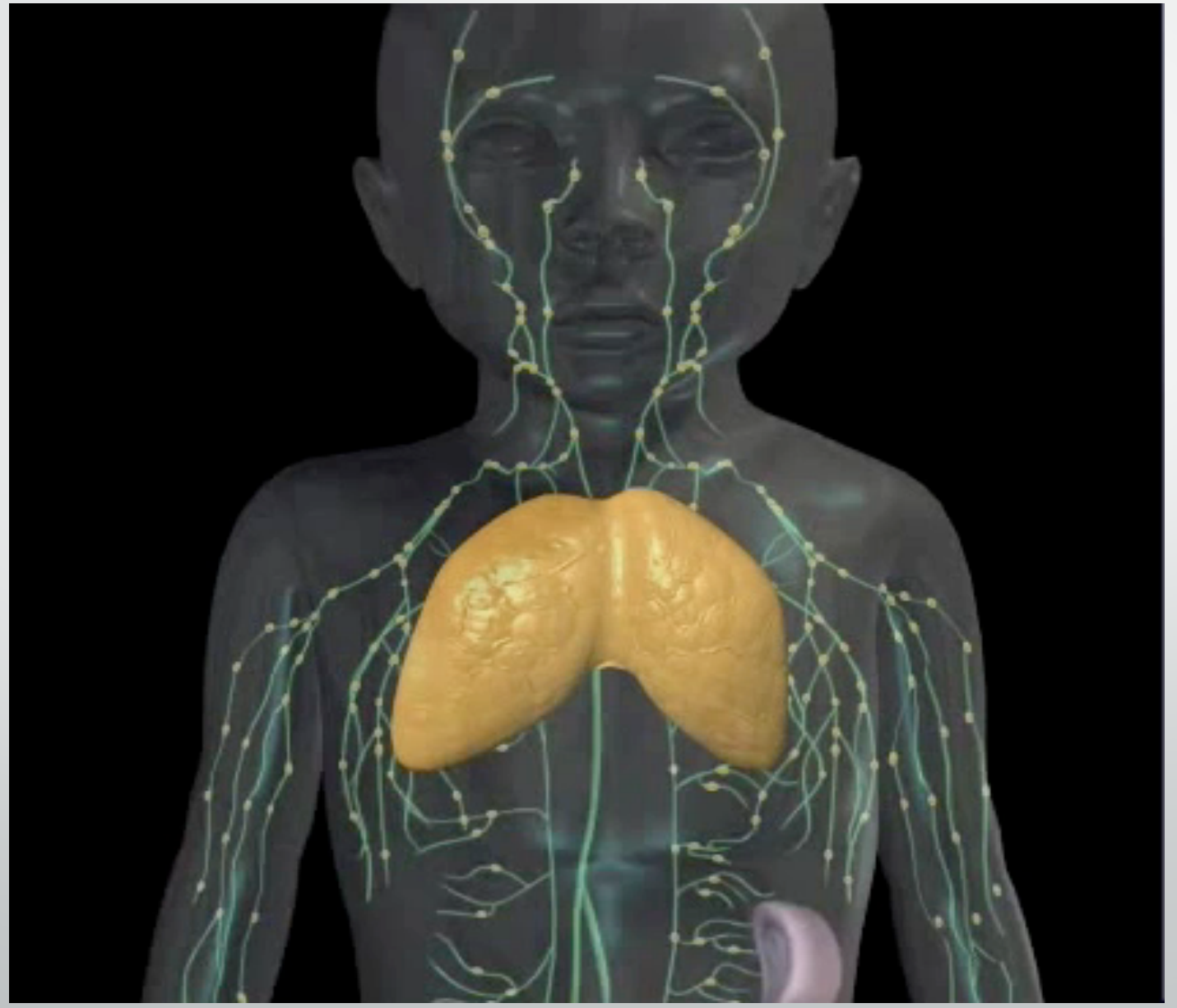
Formation of Lymphocyctes



T-Lymphocytes

- Sensitised when encountering antigen for first time
- Effectors act directly against antigens with phagocytes
- Memory cells confer cell-mediated immunity i.e. rapid production of sensitised cells on subsequent encounters
    - virus
    - cancers
    - pollen
    - fungi
    - bacteria
- Produce lymphokines which attract macrophages
- Lymphotoxins which kill foreign cells
- Interferons preventing viral reproduction

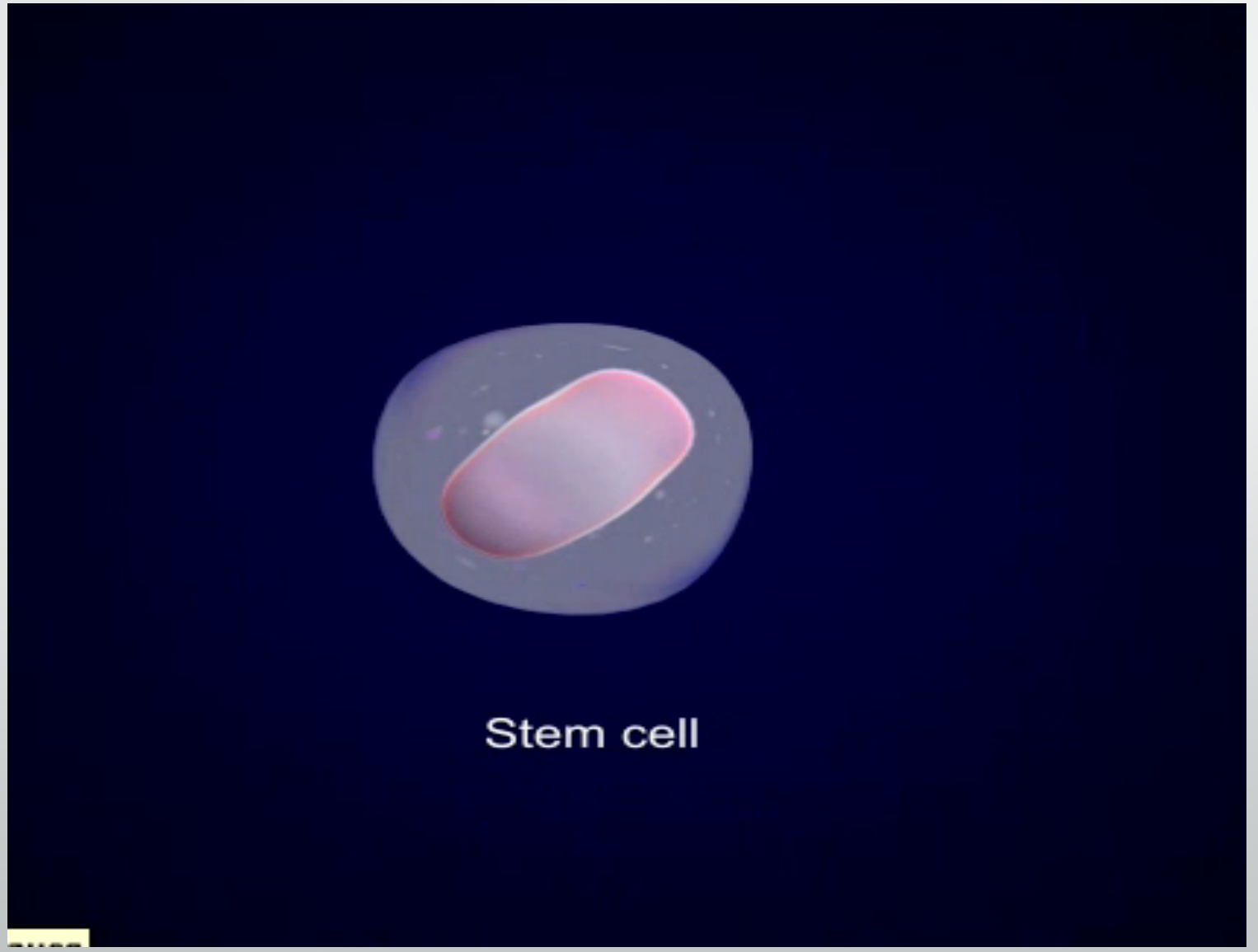
T-Lymphocytes



B-Lymphocytes

- Activated by microbes and their toxins
- Grow into plasma cells which produce antibodies (immunoglobulins).
- Antibodies promote phagocytosis and neutalise toxins
- Memory cells confer humoral immunity.
- React rapidly to subsequent encounters of antigen by stimulating production of effector cells and antibodies

B-Lymphocytes



Lymphatic System

- The Lymphatic System is part of the circulatory system and a vital part of the immune system
- The human circulatory system processes an average of 20 litres of blood per day through capillary filtration
- Roughly 17 litres is reabsorbed directly into the blood vessels while the remaining 3 litres remains as interstitial fluid
- After interstitial fluid passes into lymphatic vessels it is called LUMPH

Functions

- Fluid balance
  - 3L escapes from blood per day
  - Maintains Blood Volume
  - Formation of oedema
- Immunology
  - Defend the body from abnormal cells
  - Assist with Immune defence
  - Keeps bloodstream foreign body free
- Lipid transport
  - Intestine → Lymph → Blood

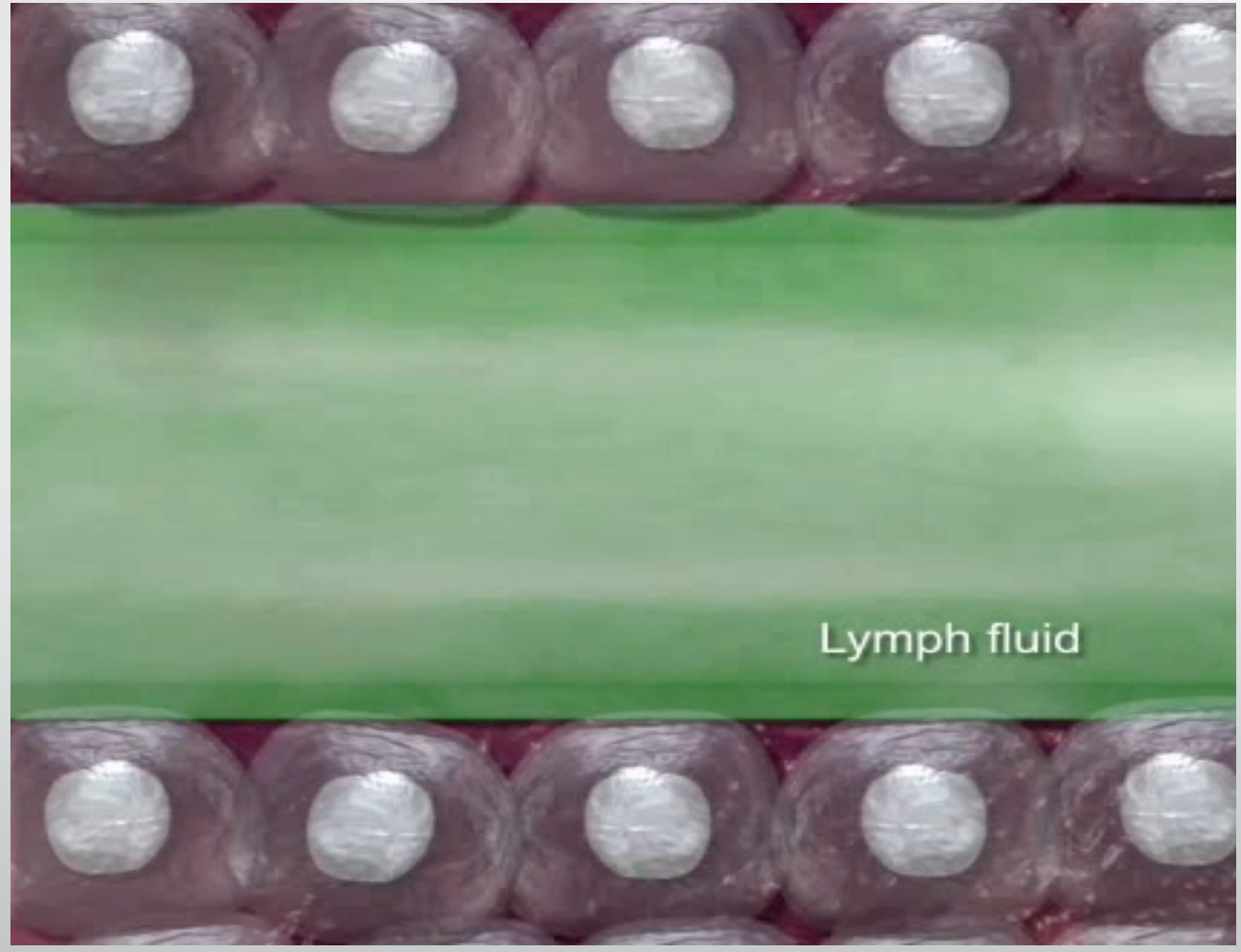
Consists of

- Lymph
- Lymph Vessels
- Lymphatic Trunks
- Lymphatic Ducts
- Bone Marrow
- Thymus
- Lymph Nodes
- Spleen
- Lymph Nodules

Lymph

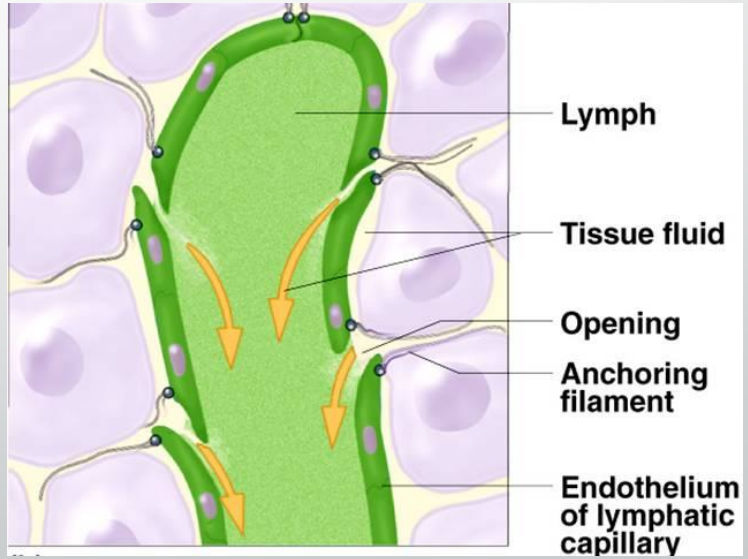
- Lymph derives from the Roman word ***Lympha*** that means clear fluid
- Lymph is very similar to blood plasma, it contains lymphocytes and other white blood cells. It also contains waste products, debris of cells, bacteria and protein
- Enters nodes through ***afferent*** lymphatic vessels
- Flows in one direction towards the heart
- Leave nodes through ***efferent*** lymphatic vessels

Lymph



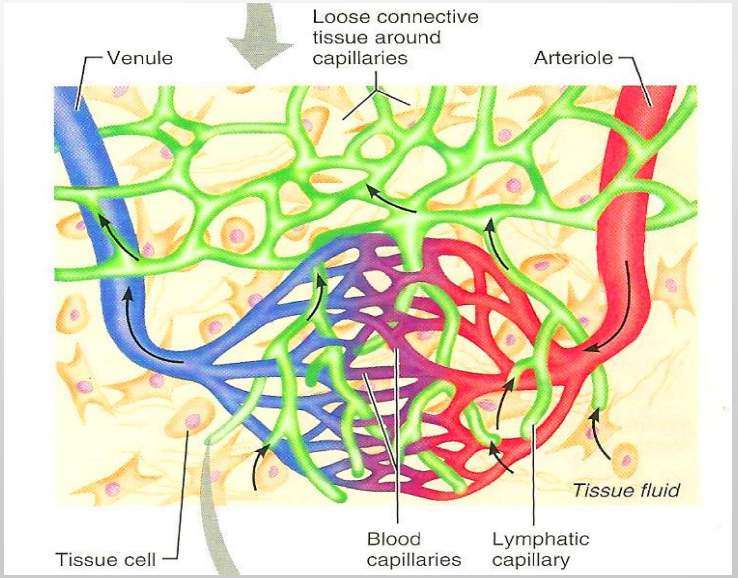
Lymphatic Capillaries

- Interlace between tissue cells and blood capillaries in loose connective tissues of the body.
- Larger in diameter than blood capillaries and have a one-way structure
- This is allowed by the endothelial cells of the lymphatic capillaries overlapping creating a microscopic closed-ended vessels
- Anchoring Filaments – Increase S.A



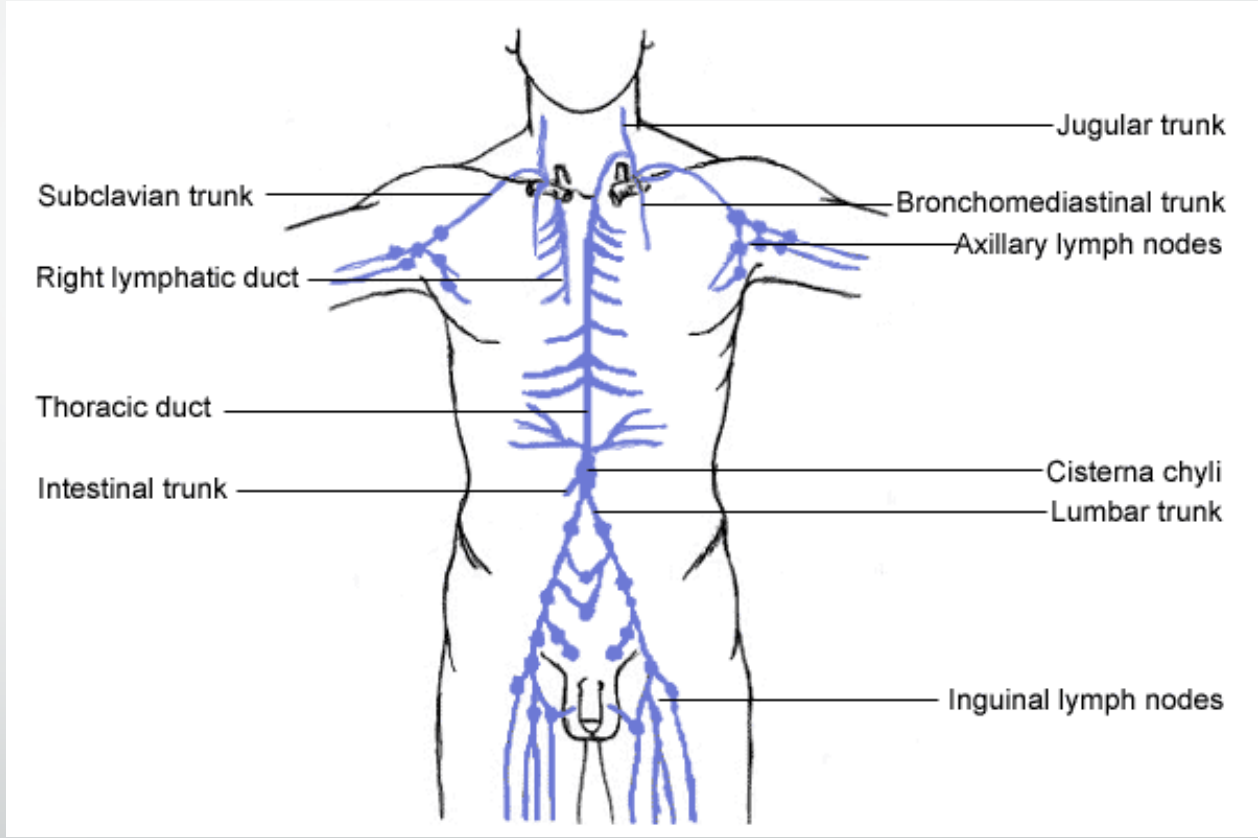
Lymphatic Vessels

- Lymphatic vessels form a one-way system flowing towards the heart, passing from lymphatic capillaries into lymphatic vessels and then through lymph nodes
- They are very similar to veins in structure but have thinner walls and more valves
- They are situated in the subcutaneous tissue of the skin and usually follow the same course as veins



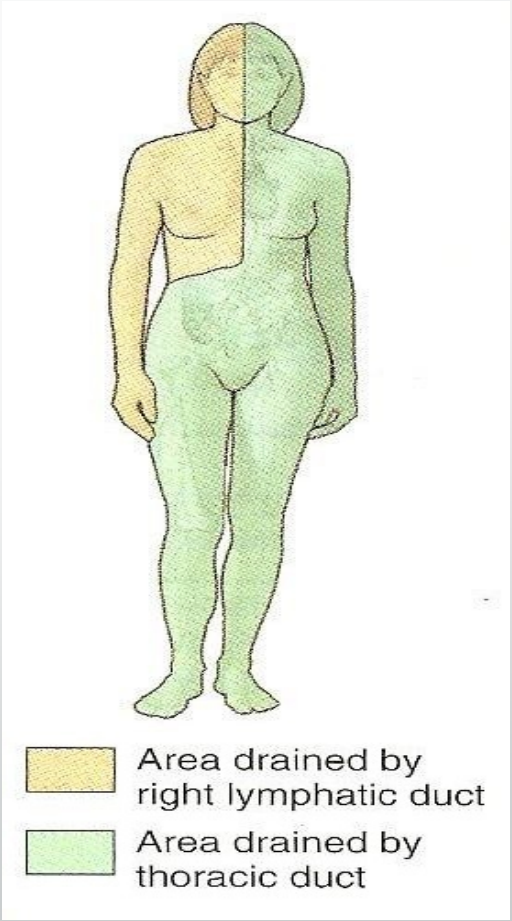
Lymphatic Trunks

- When lymphatic vessels exit lymph nodes they merge to form lymph trunks



Lymphatic Ducts

- Lymph trunks return lymph into two main channels, the thoracic and right lymphatic ducts. These then drain the fluid back into venous blood
- Right lymphatic duct drains the upper right side of the body,
- Thoracic lymphatic duct drains the rest of the body



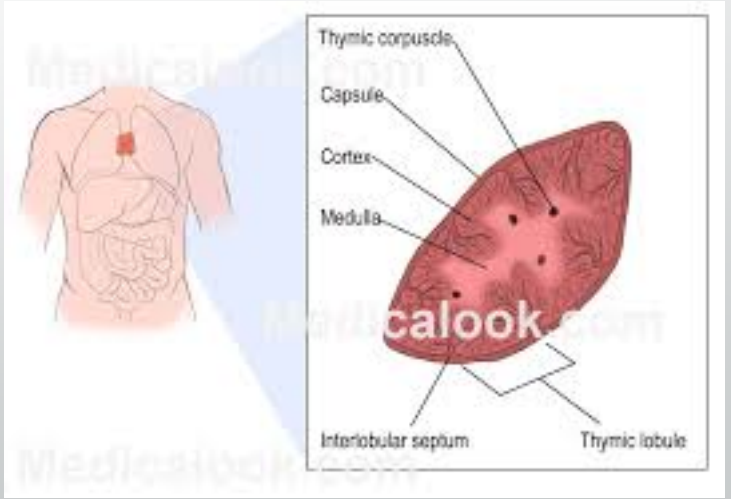
Red Bone Marrow

- Bone marrow contains two types of stem cells, hemopoietic which produce blood cells and stromal which produce fat, cartilage and bone
- Platelets, red blood cells and most white blood cells develop in red marrow, it additionally contains numerous blood vessels and capillaries.
- Red bone marrow's main function is to produce new blood cells and prevention of lymph backflow

Thymus

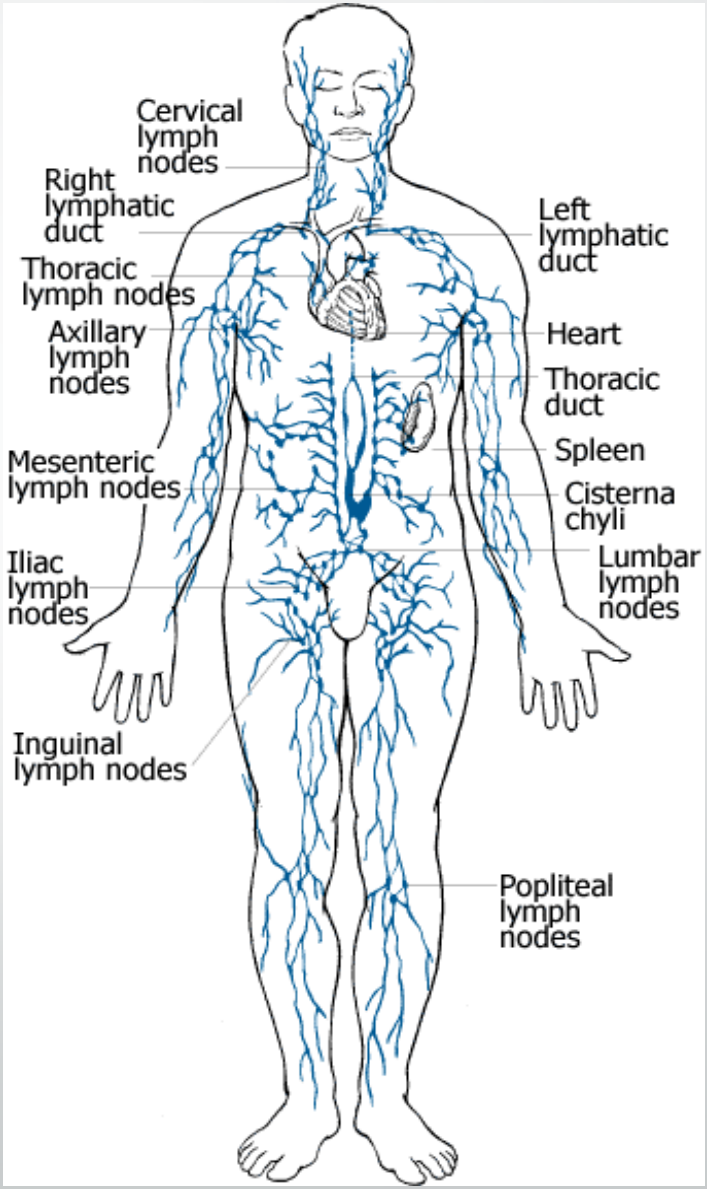
- The thymus is situated between the sternum and the aorta
- The thymus secretes the hormones thymosin and thymopoietin which cause T lymphocytes to become immunocompetent
- In childhood the thymus is large with the mass of around 70g, but after maturity the gland starts to atrophy so in old age it may only have the mass of 3g

- It is difficult to recognize from surrounding connective tissues as it is almost entirely made up of fibrous and fatty tissue

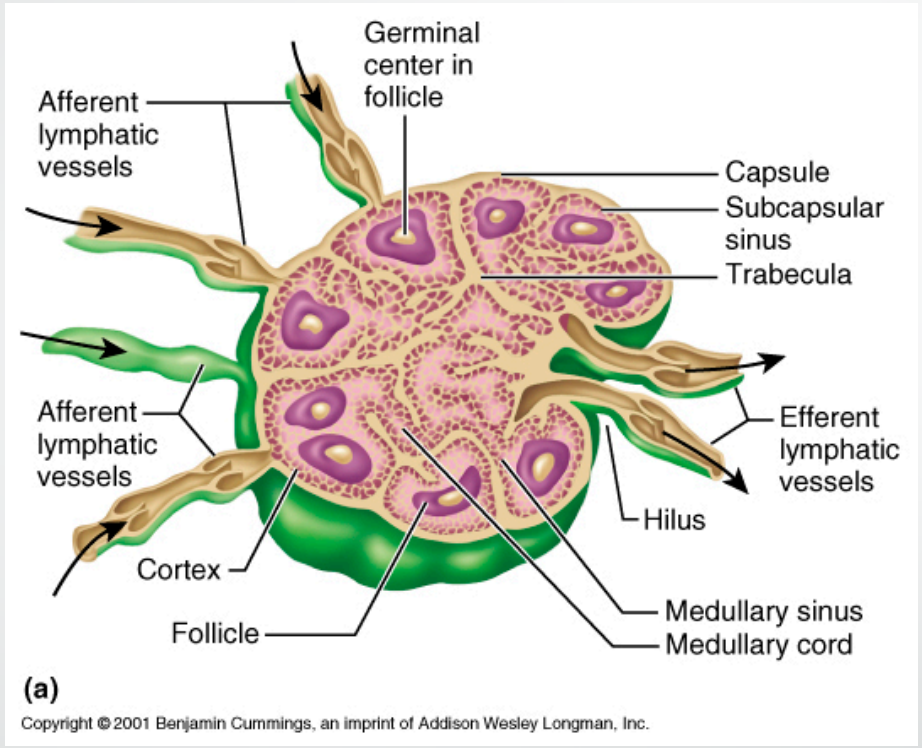


Lymph Node

- Lymph nodes are bean-shaped and vary in size from 1mm to 25mm
- There are 600 nodes that are found all over the body, deep and superficially and are typically found in groups
- 5 main locations are the cervical, axillary, intestinal also known as mesenteric, inguinal and popliteal nodes
- Nodes are divided into the deep medulla and the superficial cortex which is split into the inner and outer cortex



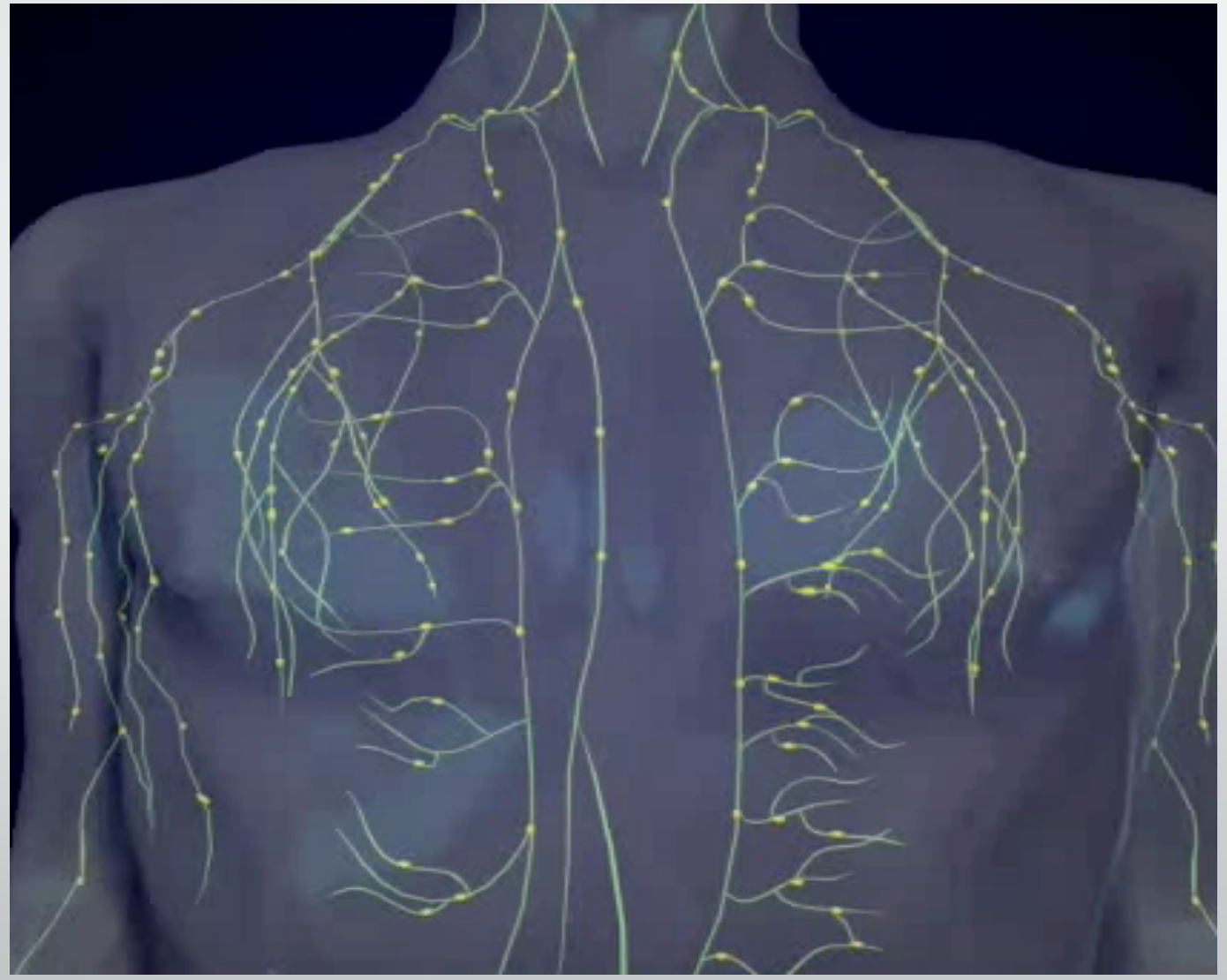
Lymph Node



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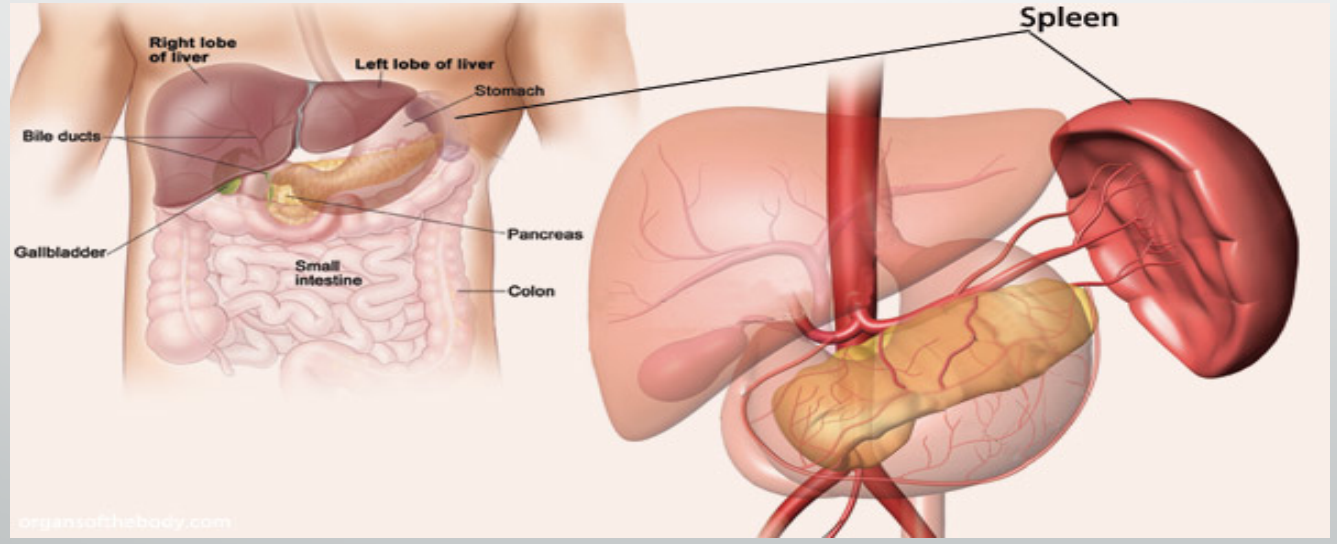
Medulla	Contains B cells, antibody producing plasma cells that have migrated out of the cortex into the medulla and macrophages.
Inner Cortex	Consists of T cells in transit which constantly flows between the blood, lymph nodes and lymph.
Outer Cortex	Contains oval shaped follicles containing densely packed B cells. Also dendritic cells encapsulate the follicles adjoining to the deeper region of the cortex.

Lymph Node



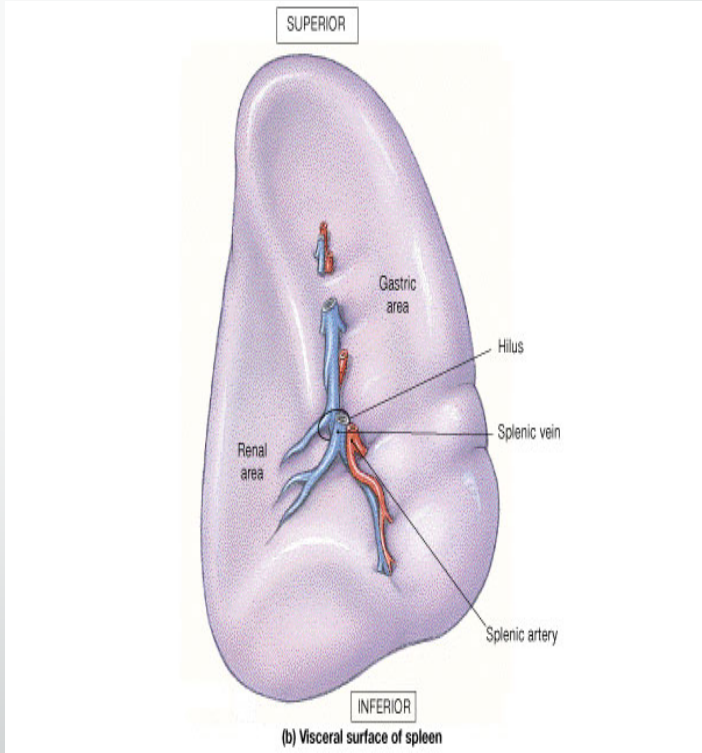
Spleen

- The largest single mass of lymphatic tissue in the body, measuring about 12cm
- Located in upper left abdominal quadrant between the stomach and diaphragm

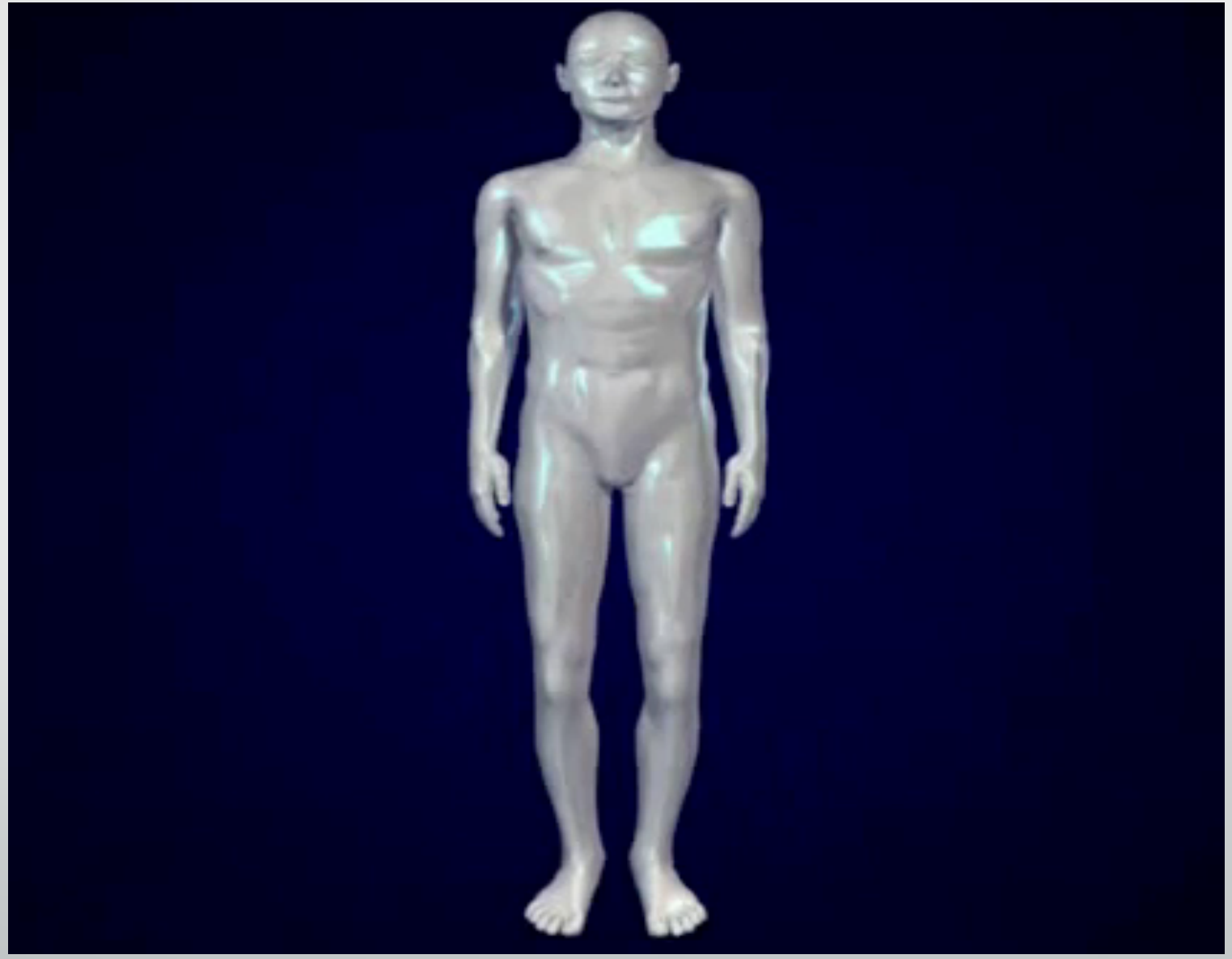


Spleen

	Description	Function
White pulp	Lymphatic tissue mostly comprising of lymphocytes and macrophages arranged around braches of the splenic artery called the central arteries.	B cells and T cells carry out immune functions. The macrophages destroy blood-borne pathogens via phagocytosis
Red pulp	Comprises of blood-filled venous sinuses and cords of splenic tissue called splenic or Billroth's cords. These cords are made up of red blood cells, macrophages, lymphocytes, plasma cells and granulocytes. Veins are also closely related to red pulp.	Three functions preformed in the red pulp: • Removal of ruptured, worn out, or defective blood cells and platelets by macrophages • Storage of platelets • Haemopoiesis in the foetus

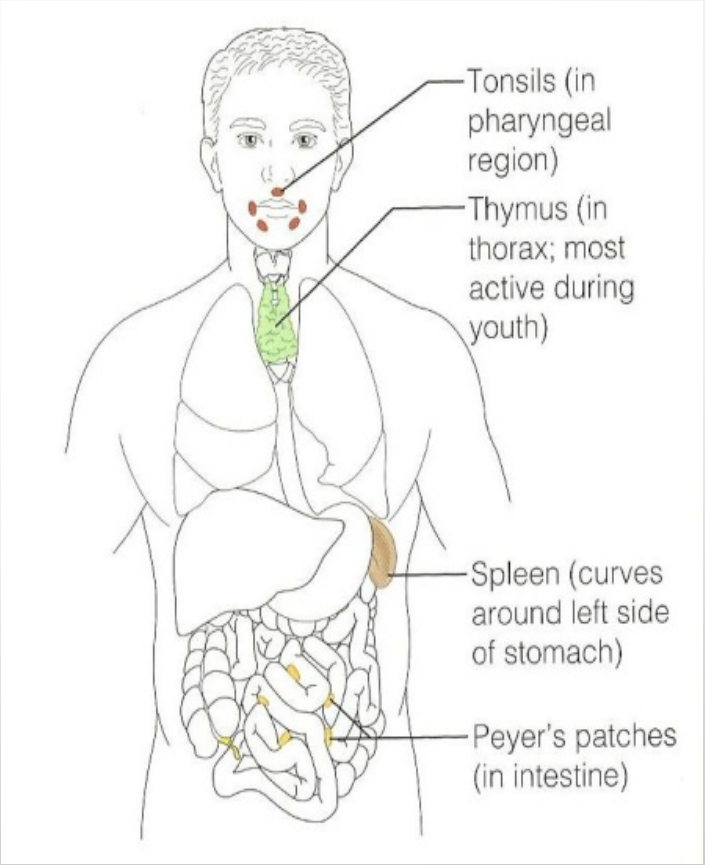


Spleen



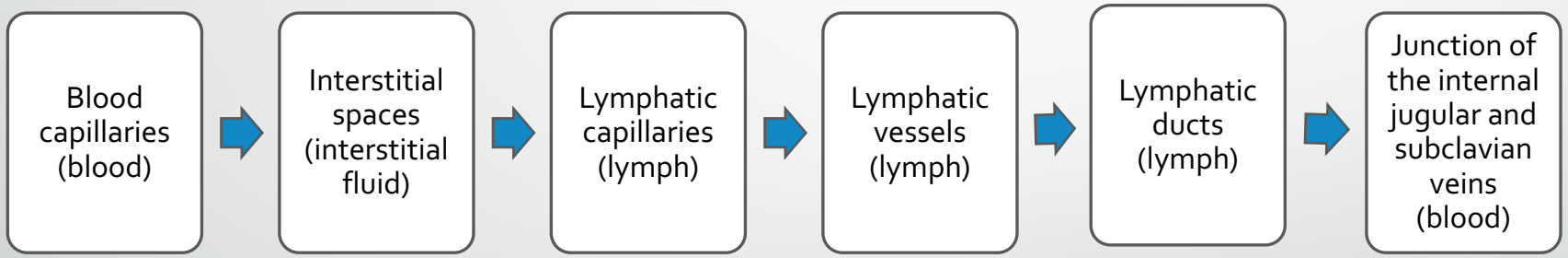
Lymphatic Nodules

- There are five groups of tonsils that surround the junctions of the oral cavity and nasal cavity
  - Nasopharyngeal tonsils
  - Palatine tonsils
  - Lingual tonsils



Pumping Mechanism

- The lymphatic vessels contain valves to prevent back flow and ensure the one-way flow of the lymph through the system



- As the lymph system does not have a main pump like the heart of the circulatory system it relies on two main pumping mechanisms, the skeletal muscle pump and the respiratory pump.

If in the Blood. What then?

