



Done by:

HISTICS Team

Part Five:

Lymphoid & Circulatory Systems

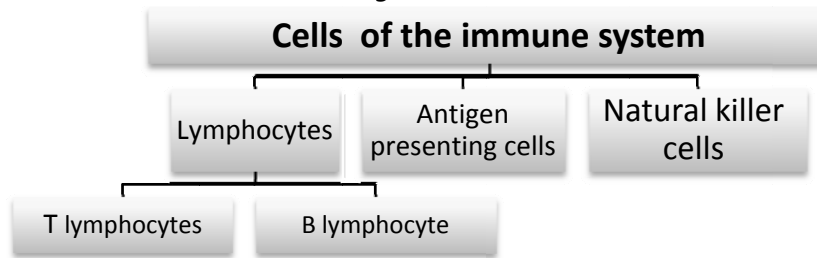
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1. Lymphoid System

- **Function:** immunological defense of the body.

1.1 Cells of the immune system



Lymphocytes

- round or pleomorphic cells (8-10 μm).
 - **Nucleus:** slightly indented, centrally located round, occupies most of the cytoplasm, dense heterochromatin.
1. **B- lymphocytes:**
 - small lymphocytes
 - Originate and develop into immunocompetent in the bone marrow.
 - The activated B cell undergoes mitosis, forming antibody-producing plasma cells (humorally mediated immune response) and B-memory cells.
 2. **T-lymphocytes:**
 - histologically identical to B- lymphocytes.
 - Formed in bone marrow but develop into immunocompetent in the thymic cortex.
 - Their plasmalemma has:
 - T cell receptors (TCRs).
 - CD molecules or markers (cluster of differentiation proteins).
 - several subtypes:
 - Memory cells.
 - T helper cells (CD4^+), divided into $\text{T}_\text{H}1$ & $\text{T}_\text{H}2$ cells
 - T cytotoxic cells (Tc cells) (T killer cells)
 - T suppressor cells (Ts cells).

(N.B. Both Tc & Ts cells are CD8^+)

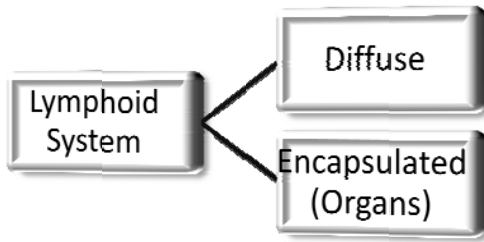
Antigen-Presenting cells (APCs):

- **Function:** Phagocytosis, catabolising and processing antigens and presenting them to T-cells.
- Can be:
 - Derived from monocytes: *e.g.* macrophages, dendritic cells
 - non-monocyte-derived cells: *e.g.* B cells and epithelial reticular cells of the thymus.
- They have class II MHC molecules (MHC II) but other cells have only MHC I.

Natural killer cells:

- similar to cytotoxic T cells, but don't have to mature in thymus gland.
- cytotoxic cells.
- antibody-dependent cell-mediated cytotoxicity.
- formed in red bone marrow
- kill some viral and tumor-altered cells in non-specific manner.

Stem cells.



1.2 Diffuse Lymphoid System :

- Not encapsulated

1.2.1 Mucosa-associated Lymphoid tissue (MALT):

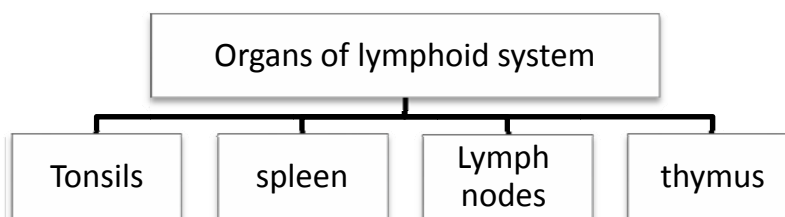
- localized lymphocytes infiltration and lymphoid nodules (solitary & aggregated) in the mucosa of gastrointestinal , respiratory, and urinary tract.
- For example: **gut-associated lymphoid tissue (GALT)**.

1.2.1.1 GALT:

- Lymphoid follicles along the GIT tract.
- Most of the lymphoid follicles are isolated from each other.
- **However**, they aggregate to form what is called **Peyer's patches**.
- Peyer's patches composed of : B lymphocytes, surrounded by T cells and APC.
- The most prominent accumulation of GALT is located in the ileum

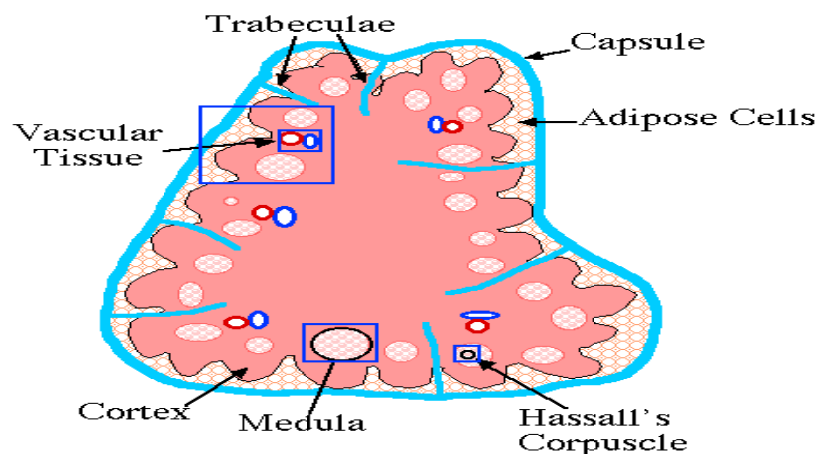
1.3 Lymphoid Organs

- They are classified into:
 1. **Primary (central)** lymphoid organs:
 - responsible for development and maturation of lymphocytes into immunocompetent cells
 - **examples:** fetal liver, bone marrow and thymus.
 2. **Secondary (peripheral)** lymphoid organs:
 - responsible for the proper environment in which the immunocompetent cells can react with each other as well as with antigens.
 - **Examples:** Lymph nodes, spleen, and mucosa-associated lymphoid tissues.



1.3.1 Thymus

- Primary lymphoid organ (the site of maturation of **T lymphocytes**)
- **Encapsulated**
- Composed of **two lobes**
- Originates early in the embryo and grow until puberty
- After few years of life it begins to **involute (atrophy)** and becomes infiltrated by **adipose cells**
- The capsule sends septa into the lobes dividing them into **lobules**.
- Each lobules composed of a **cortex** and **medulla**



Thymic Cortex:

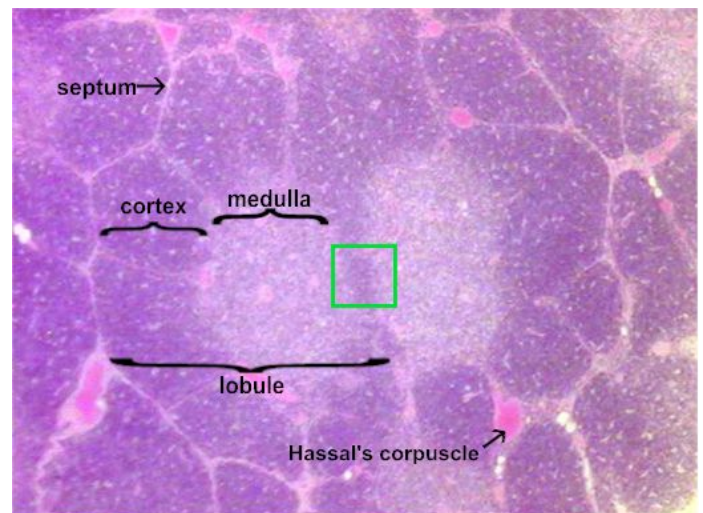
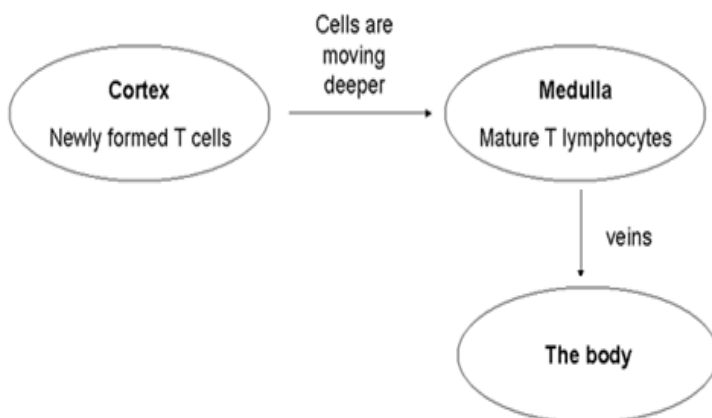
- **Much darker** than medulla because the large number of **T lymphocytes**
- The cortex houses **macrophages** and **epithelial reticular cells**
- immature T cells undergo proliferation and instruction to become immunocompetent.

Medulla:

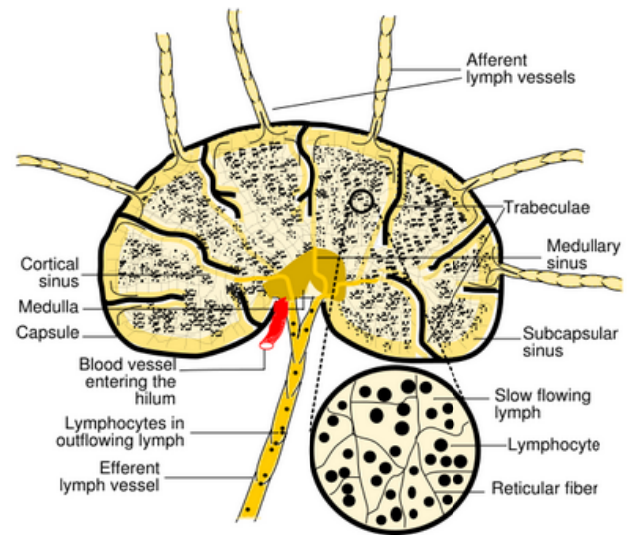
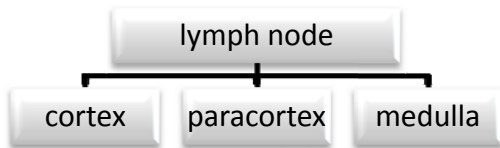
- The thymic medulla is lighter than cortex, it houses few immunocompetent T lymphocytes, and **epithelial reticular cells** and Hassall's corpuscles.
- **Epithelial reticular cells:**
 - Separate the cortex from the CT. capsule and trabecula.
 - surround vascular elements in the cortex.
 - form occluding junctions to isolate the cortex from the medulla and the cortex from the remainder of the body.
 - They produce hormones necessary for the maturation of T lymphocytes.
 - They form **thymic** or **Hassall's corpuscles**, which are formed of reticular cells coalescing around each other. Their number increases with a person's age.

Vascular Supply:

- The capillaries of the thymus are **continuous** in type
- They have thick **basal lamina** and invested by reticular epithelial cells that form **blood-thymus barrier**.
- This barrier protect the T lymphocytes from the blood-borne macromolecule
- **However**, these macromolecule can cross this barrier to eliminate T cells that are programmed against self-antigen (**if these T cells were released, they will attack the body itself**)
- Immunologically incompetent T cells leave the vascular supply at the corticomedullary junction, migrating to the periphery of the cortex to be mature, then deeper in the cortex and enter the medulla.

**1.3.2 Lymph Nodes:**

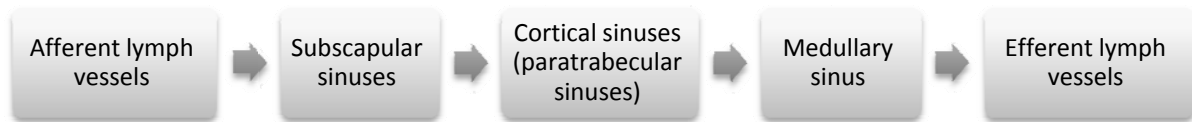
- **Function:** filtration of lymph and production of immunocompetent cells.
- **Main cells of lymph node:** T and B lymphocytes, APC, macrophages.
- **Location:** in various regions of the body but are more prevalent in the neck, axilla, groin.
- **Appearance:**
 - Small, soft, has a fibrous CT capsule, and surrounded by adipose tissue.
 - It has a convex surface that is perforated by **afferent lymph vessels**.
 - It has a concave surface that is called **hilum**, where arteries, veins enter and exit the node.
 - It has also a site for **efferent lymph vessels** (having valves) to leave the node.



Lymph node Cortex:

- Contain lymphatic nodules (follicles) and Subcapsular & Cortical (paratrabeular) lymph sinuses.
- The **capsule** sends **trabeculae** into the substance of the lymph node, subdividing the outer region of the cortex into incomplete compartments.
- The capsule thickens at the **hilum**
- **Reticular connective tissue** is suspended from the trabeculae to form the framework of the entire lymph node.

Route of the afferent lymph vessels:



- The lymph passes from the afferent vessels to the subcapsular sinuses which are continuous with the cortical (paracortical) sinuses, that deliver the lymph into the medullary sinuses to enter the efferent lymphatic vessels.

Paracortex:

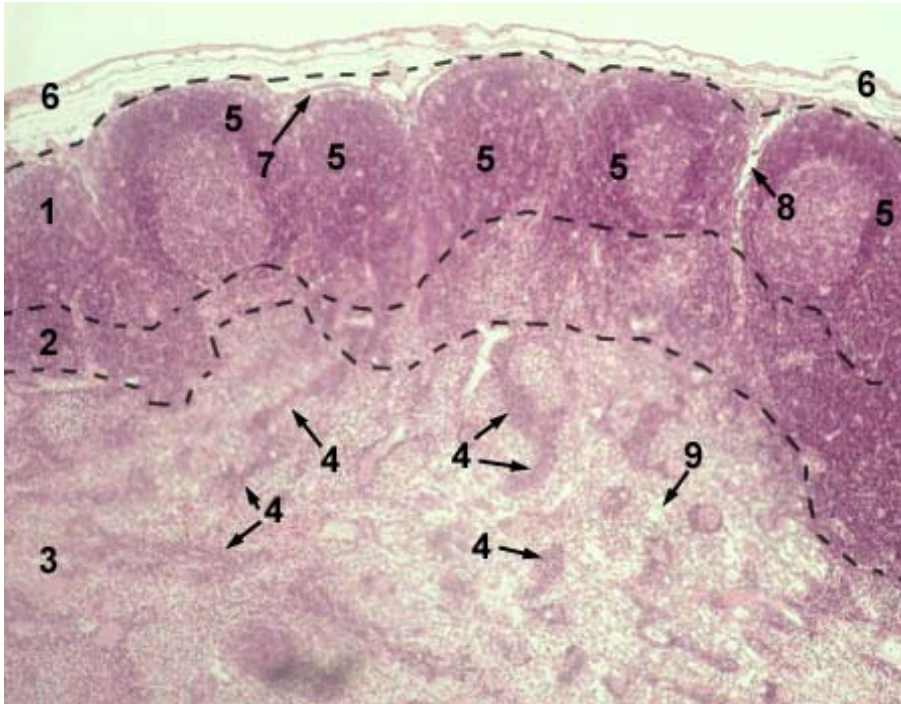
- The region between the cortex and the medulla housing **T lymphocytes**.
- **Thymus-dependent zone of the lymph node**.
- it's the site for APC to present antigen to T helper cells.
- Contains **High endothelial venules (HEV)** (postcapillary venules) which have unusual endothelium (have **cuboidal cells** instead of **squamous cells**).
 - HEV are the sites where lymphocytes enter the lymph node

Medulla:

- Composed of twisted **lymph sinuses** surrounded by clusters called **medullary cords** composed of (**lymphocytes, plasma cells, macrophages**) enmeshed in a network of reticular fibers and reticular cells
- There are trabeculae arised from the capsule of the hilum, conveying blood vessels.
- N.B. Efferent lymphatic vessels drain lymph with B & T lymphocytes.

Vascularization of the lymph node:





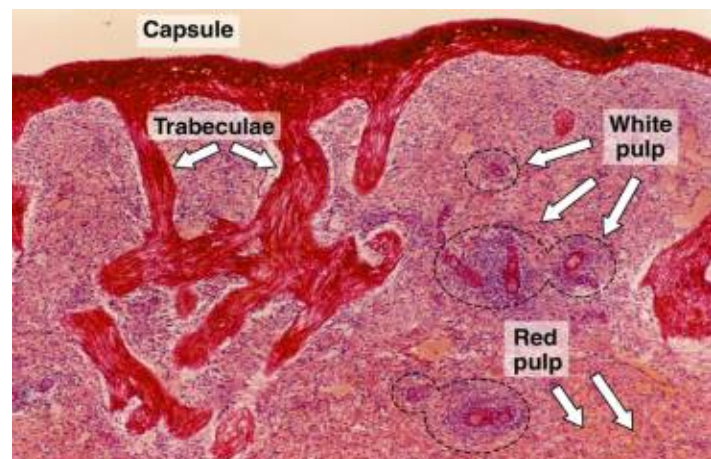
1. cortex 2. paracortical zone 3. Medulla 4. medullary cords 5. lymphoid follicle of the cortex 6. capsule
7. subcapsular sinus 8. cortical sinus 9. medullary sinus

Lymphoid nodules (follicles):

- Aggregates of B lymphocytes.
- Spherical in shape.
- May be:
 - **primary lymphoid nodules:** formed of virgin and memory B cells (without germinal centers)
 - **Secondary lymphoid nodules:**
 - have a pale center called **germinal center**.
 - Mostly activated B-lymphoblasts with macrophages & dendritic reticular cells.
 - They are sites of B memory cells and plasma cell regeneration.
 - the peripheral region, called **corona (mantle)** is **dark** because of accumulation of small lymphocytes that are migrating away .

1.3.3 Spleen:

- Largest lymphoid organ
- Has a capsule (irregular fibroelastic CT) that houses **smooth muscle**
- Has a convex surface as well as a concave aspect known as **hilum**
- functions:
 1. immunological
 2. filtration of blood
 3. antibody formation
 4. T- & B-lymphocyte proliferation
 5. it can release blood when needed
- The trabeculae arisen from the capsule carry vessels into and out of the parenchyma of spleen.
- has network of reticular fibers and reticular cells
 - The small areas within the network are occupied by venous sinuses.
- it has 2 regions, collectively called **parenchyma**:
 1. **white pulp:** gray area
 2. **red pulp:** surrounds the white pulp



White pulp and marginal zone:

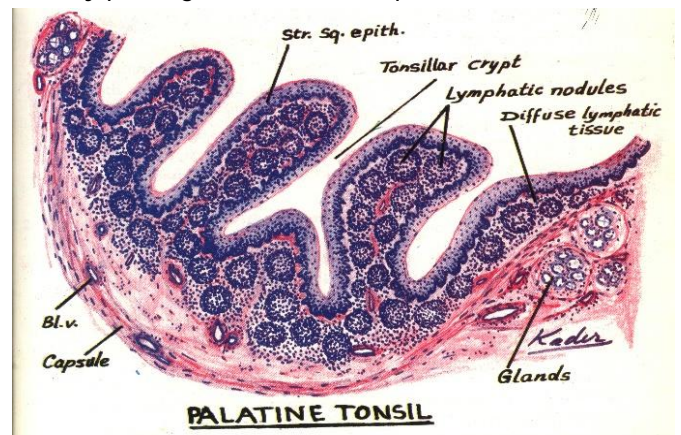
- structure closely associated with central arteriole (arteriole actually peripheral or eccentric)
- surrounding the central arteriole is periarterial lymphatic sheath (PALS) which houses T lymphocytes.
- Also, closed to PALS are lymphoid nodules of B cells that displace the central arteriole to the periphery
 - The lymphoid nodules have germinal centers
- **Marginal zone:** area surround and separate the white pulp from the red pulp.
 - it's composed of plasma cells, T and B lymphocytes , macrophages and APC
 - it has marginal sinuses surrounding lymph nodules .

Red Pulp:

- composed of **splenic sinuses** and **splenic cords (of billroth)**.. *arranged like a sponge, where the spaces represent the sinuses and the sponge material represents the splenic cords*
- the endothelial lining of splenic sinuses is unusual:
 1. cell are fusiform
 2. it has spaces between cells
 3. surrounded by reticular fibers coated by basal lamina
 4. splenic sinuses have **discontinuous** basal lamina
- **Macrophages** are numerous in the sinusoids.
- The splenic cords are composed of a loose network of reticular fibers, enveloped by reticular cells.
- **Stellate reticular cells function:** contact other cells with the endothelium-like simple squamous epithelium.
 1. **Macrophages:** phagocytose foreign matter. (numerous in the sinusoids)
 2. **Lymphoid cells** can enter or leave the sinusoids by passing between their squamous cell lining (**without the need of vessels**)

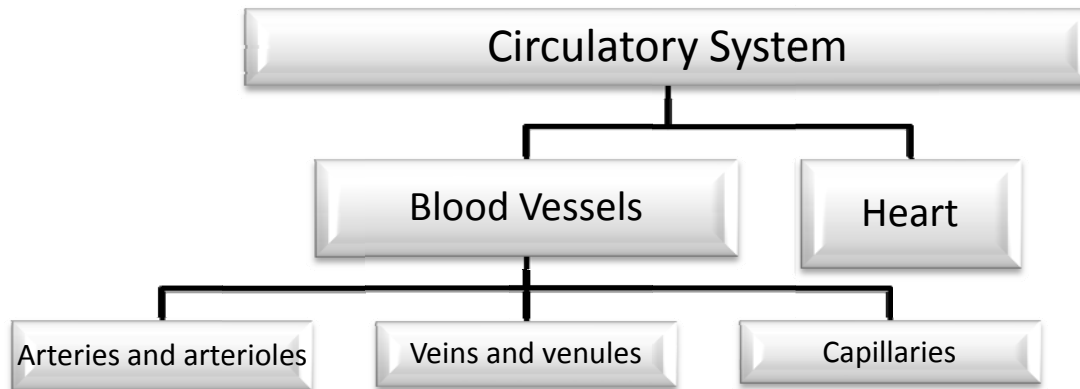
1.3.4 Tonsils:

- Aggregates of lymphoid nodules.
- Divides to :
 1. **palatine**
 2. **pharyngeal**
 3. **lingual**
- **incompletely encapsulated**
- it's interposed between airborne and ingested antigens
- They guard the entrance of the oral pharynx.



	Palatine tonsils	Pharyngeal tonsils	Lingual tonsils
Location	Boundary of the oral cavity and the oral pharynx	Roof of the nasal pharynx	Dorsal surface of the posterior one third of the tongue
Superficial aspect	Covered by stratified squamous nonkeratinized epithelium	Covered by pseudostratified ciliated columnar epithelium and patches of stratified squamous epithelium	Covered by stratified squamous nonkeratinized epithelium
Characteristics	Bilateral It has deep crypts invaginate the tonsillar parenchyma and contain food debris, bacteria, and dead leukocyte	single Has shallow longitudinal infoldings called pleats they have openings of seromucous glands	Several Each has a single crypt whose bases receives the ducts of mucous minor salivary glands
parenchyma	Have lymphoid nodules which have germinal centers	same	Same
Capsule	Isolated from the connective tissue by a dense fibrous capsule	Thin capsule	Flimsy capsule that separates it from connective tissue

2. Circulatory System

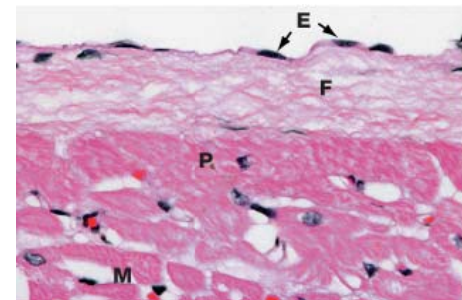
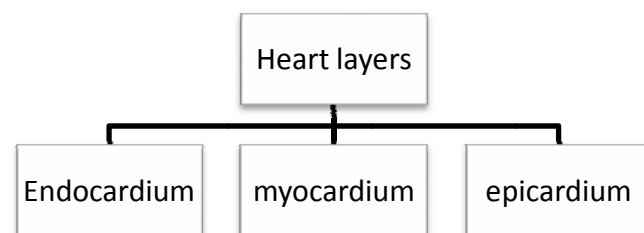


2.1 Heart

Made up of three layers

2.1.1 Endocardium

- Continuous with tunica intima of blood vessels (see 2.2).
- Composed of:
 1. **Endothelium:** simple squamous epithelium
 2. A deeper layer of fibro-elastic connective tissue
 3. deeper is a layer of dense connective tissue
- Deep to the endothelium is a **subendocardial layer:** a loose connective tissue forming the boundary between endocardium and myocardium, containing small blood vessels, nerves and Purkinje fibers.



2.1.2 Myocardium:

- Thickest layer in the middle containing cardiac muscle cells.
- Certain cardiac muscle cells attach the myocardium to the fibrous cardiac skeleton, others are specialized for endocrine secretions, and still others are specialized for impulse generation or impulse conduction.

2.1.3 Epicardium:

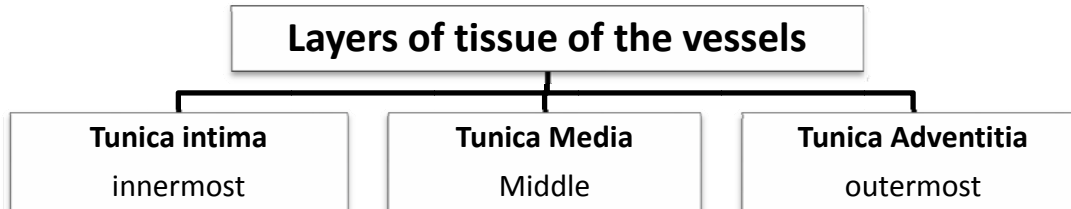
- It is the visceral layer of the pericardium forming the outermost layer of the heart.
- Composed of simple squamous epithelium known as **mesothelium**
- **Subepicardial layer:** composed of loose C.T., coronary vessels, nerves, region where fat stored.
- The epicardium (visceral layer of pericardium) is continuous with the parietal layer enclosing the pericardial cavity, which is filled with fluid.

Blood Vessels

2.2 General structure of blood vessels

- Generally, arteries have thicker walls and smaller lumens than veins.
- Arteries are round and usually have no blood in their lumina.

Vessels Tunics :



Tunica Intima:

- Composed of :
 1. **Endothelium** (simple squamous epithelium) rest on basal lamina. functions :
 - a) Provide smooth surface
 - b) Secretion.
 2. **subendothelial layer:** loose connective tissue and scattered smooth muscle cells, both arranged longitudinally
 3. **internal elastic lamina:** composed of elastin. It separates tunica intima from tunica media.

Tunica Media:

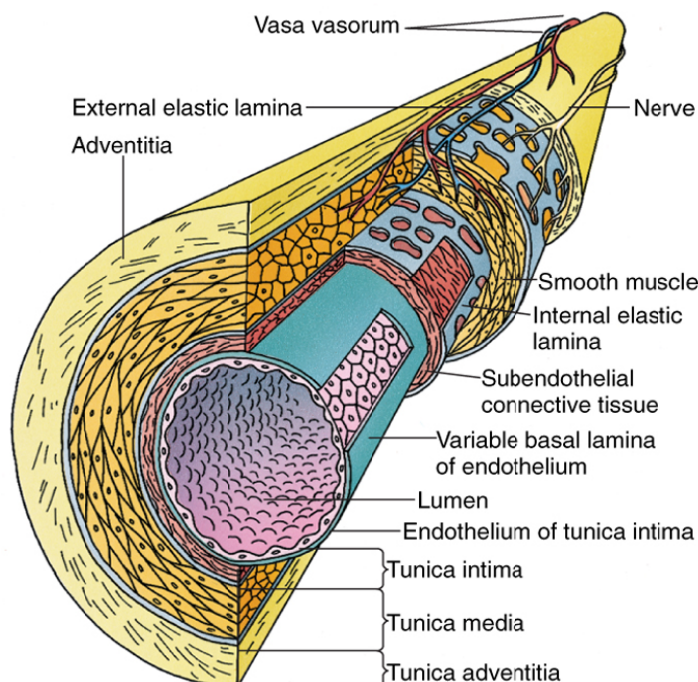
- **Thickest**, intermediate layer
- Composed of smooth **muscle cells**, **elastic fibers**, **type III collagen (reticular)**, **proteoglycans**.
- **Muscular arteries** have **external elastic lamina** separating tunica media from tunica adventitia.
- **Capillaries** and **post capillary venules** do not have tunica media. (**pericytes** replace it)

Tunica Adventitia:

- Composed of **fibroblasts**, **type I collagen**, **longitudinal elastic fibers**.
- Continues with the connective tissue surrounding the vessel.

Vasa Vasorum:

- Tunica media and adventitia of large arteries and veins Can't get nutrients by diffusion and are nourished by the vasa vasorum, which are small arteries that enter the walls of blood vessels.
- **Because** venous blood is less i n oxygen, **vasa vasorum** are **more prevalent than artery**.



2.3 Arteries and arterioles



2.3.1 Elastic arteries

- **Examples:** aorta and branches of the aortic arch (subclavian, common carotid) & pulmonary trunk.
- **T. intima**
 1. Subendothelial thin laminae of elastic fibers in addition to the elastic lamina.
 2. Endothelium supported by connective tissue, connected by occluding junctions. Also, they form gap junction with smooth muscle cells from tunica media.
 3. Smooth muscle cells, collagen fibers.
 4. **Weible-palade bodies** : inclusions housing **von willebrand factor**
- **T. media**
 1. Have elastin (elastic membrane) known as **fenestrated membranes**
 2. Smooth muscle cells are less abundant. (circular)
 3. External elastic lamnae are also present
 4. Collagen, elastic fibers and reticular fibers
- **T. adventitia** has loose CT (with some fibroblasts) & abundant vasa vasorum.

2.3.2 Muscular arteries

- **Examples:** Most arteries. Brachial, ulnar, radial
- **T. intima**
 1. **Thinner** than in elastic arteries,
 2. but internal elastic laminae is more **prominent** and it sometimes duplicate to be called **bifid internal elastic laminae**
 3. Endothelium cells have processes to form gap junction with smooth muscle cells
- **T. media**
 1. Predominant circular smooth muscle
 2. Small arteries have 3 or 4 layers of smooth muscle cells. Large arteries have up to 40
 3. Smooth muscle cells are enveloped in **external lamina**
 4. Elastic fibers, Type III collagen (located in bundles)
 5. External elastic lamina is present only in large muscular arteries & absent in small arteries.
- **T. adventitia**
 1. contains vasa vasorum and unmyelinated nerve fibers.
 2. Elastic fibers, collagen fibers, ground substance.

2.3.3 Arterioles

- Arise from muscular arteries, having a diameter of less than 0.1 mm.
- **Tunica Intima**
 1. Endothelium supported by connective tissue
 2. Type III collagen fibers, elastic fibers
 3. Internal elastic lamina **absent** in small and terminal arterioles but **present** in large arterioles
- **T. media** has 1-2 smooth muscle layers and no external elastic lamina.
- **T. adventitia** is thin represented by fibroelastic connective tissue housing fibroblasts.

Metarterioles : arteries that supply blood to capillary beds, where smooth muscle layer is not continuous

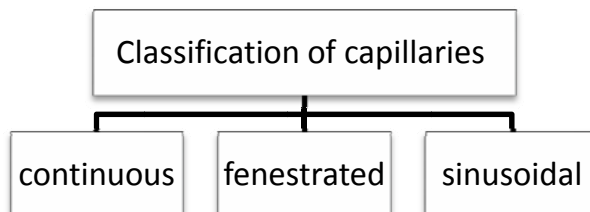
Precapillary sphinctors: a layer of smooth muscle just before the capillary to limit blood flow to capillaries.

2.4 Capillaries :

- Between arterioles and venules.
- Smallest blood vessels (diameter 10 μm)

2.4.1 General structure :

- Single layer of squamous endothelial cells
- Intermediate filaments (**desmin, vimentin**)
- **Pinocytotic vesicles** are characteristics of capillary
- **Constant diameter** throughout the entire length
- **Basal lamina**
- Endothelial cells joined by **fasciae occludents or tight junctions**
- **Pericytes** outside the capillaries
- they have processes which form gap junction with endothelium
- after injury, they may undergo **differentiation** to become smooth muscle cells or endothelium.



2.4.2 Continuous capillaries:

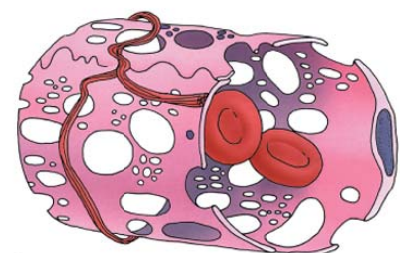
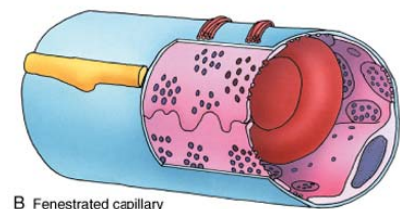
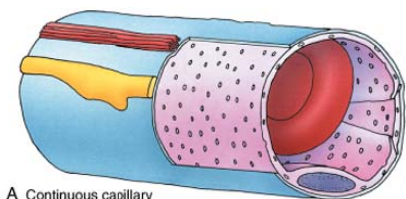
- present in muscles, nerves, connective tissues
- the junctions between endothelial cells are **fasciae occludents** which prevent passage of many molecules so they have to move through carrier-mediated transport. (They don't have pores)

2.4.3 Fenestrated capillaries:

- they have pores (fenestrae) covered by pore diaphragm
- present in: pancreas, intestine, endocrine gland
- renal glomerules is an exception it have fenestrae that lack diaphragm.

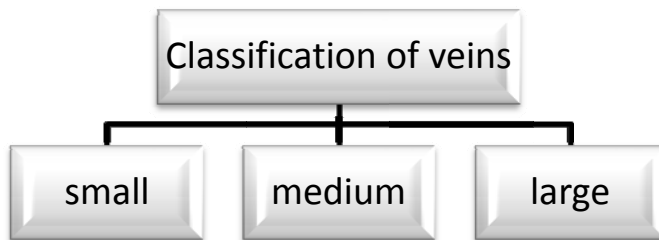
2.4.4 Sinusoidal capillaries:

- present in: bone marrow, liver, spleen, lymphoid organs
- they are called sinusoids
- enlarged diameter
- have fenestrae without diaphragm
- They form irregular large pools or channels.
- lack pinocytotic vesicles
- endothelium may be discontinuous
- in lymphoid organs it's continuous
- In endocrine glands it have continuous areas & discontinuous



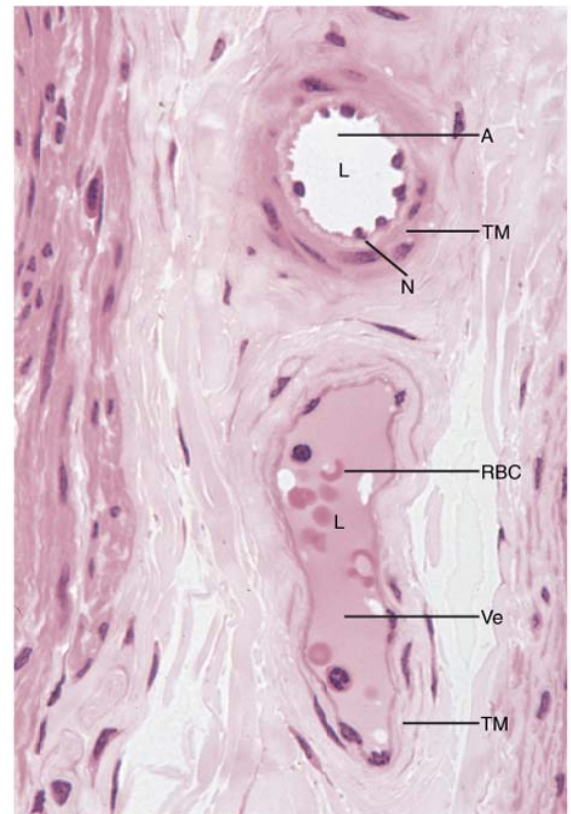
2.5 Veins:

- They have the same layers (tunica intima, media, adventitia)
- Musculature and elastic layers are not well developed
- Connective tissue is more pronounced
- Boundaries between tunica intima and media are not distinguishable
- Classification of veins is based on diameter & wall thickness



2.5.1 Venules and small veins:

- Thin endothelium
- Reticular fibers and pericytes (**no smooth muscles in venules**),
- But pericytes are replaced by smooth muscles in larger venules and small veins.
- More permeable than capillaries
- **High endothelial venules (HEV)**: venules in lymphoid organs that have cuboidal cells as endothelium instead of squamous cells.



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2.5.2 Medium Veins:

- **Tunica intima**: (thin) endothelium, basal lamina, reticular fibers, **No internal elastic lamina**
- **Tunica media**: (thin) smooth muscle cells, collagen fibers, fibroblasts.
- **Tunica adventitia**: (thickest), collagen and elastic fibers longitudinal with scattered smooth muscles.

2.5.3 Large Veins:

- **Examples**: vena cava, portal, renal, internal jugular, pulmonary
- **Tunica intima**: same as **medium veins**, but the subendothelial connective tissue layer is thicker.
- Most large veins do not have tunica media (except pulmonary veins and superficial veins of the leg)
- **Tunica adventitia**: well developed containing collagen and elastic fibers as well as vasa vasorum
- **Inferior vena cava** has a longitudinal smooth muscle cells in tunica adventitia.

2.5.4 Valves of veins:

- Function: prevent the backflow of the blood
- Abundant in the veins of the leg
- Valve is composed of two leaflets
- The leaflet is from tunica intima that jut into the lumen reinforced by collagen and elastic fibers.

